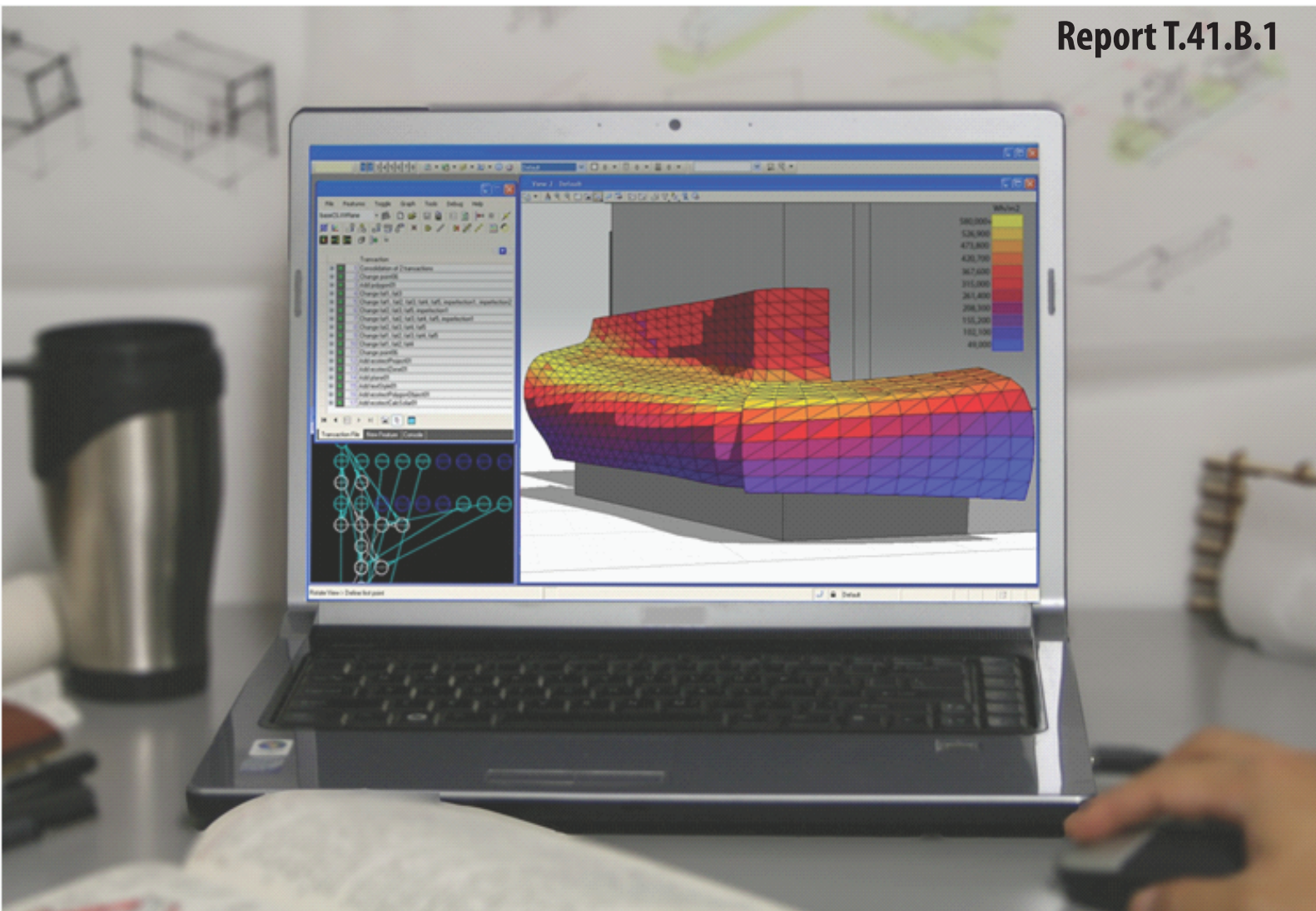


Task 41 - Solar Energy and Architecture

Subtask B - Methods and Tools for Solar Design

Report T.41.B.1



State-of-the-Art of Digital Tools Used by Architects for Solar Design



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State-of-the-art of digital tools used by architects for solar design

Editors

Marie-Claude Dubois (Université Laval)
Miljana Horvat (Ryerson University)

Contributors

Jochen Authenrieth, Pierre Côté, Doris Ehrbar, Erik Eriksson, Flavio Foradini, Francesco Frontini, Shirley Gagnon, John Grunewald, Rolf Hagen, Gustav Hillman, Tobias Koenig, Margarethe Korolkow, Annie Malouin-Bouchard, Catherine Massart, Laura Maturi, Kim Nagel, Andreas Obermüller, Élodie Simard, Maria Wall, Andreas Witzig, Isa Zanetti

Title image : Viktor Kuslikis & Michael Clesle © 2010
Title page : Alissa Laporte

CONTRIBUTORS (IN ALPHABETICAL ORDER)

Jochen Authenrieth
BKI GmbH
Bahnhofstraße 1
70372 Stuttgart
Germany
autenrieth@bki.de
autenrieth@baukosten.de

Pierre Côté
École d'architecture,
Université Laval
1, côte de la Fabrique
Québec, QC, G1R 3V6
Canada
pierre.cote@arc.ulaval.ca

Marie-Claude Dubois (Ed.)
Task 41, STB co-leader
École d'architecture,
Université Laval
1, côte de la Fabrique
Québec, QC, G1R 3V6
Canada
marie-claude.dubois@arc.ulaval.ca

Doris Ehrbar
Lucerne University of Applied
Sciences and Arts
Dept. of Engineering and
Architecture
Technikumstrasse 21
CH-6048 Horw
Switzerland
doris.ehrbar@hslu.ch

Erik Eriksson
White Arkitekter
P.O. Box 4700
Östgötagatan 100
SE-116 92 Stockholm
Sweden
erik.eriksson@white.se

Flavio Foradini
e4tech
E4TECH Sàrl
Av. Juste-Olivier 2
1006 Lausanne
Switzerland
flavio.foradini@e4tech.ch

Francesco Frontini
Fraunhofer Institut für Solare
Energiesysteme ISE
Heidenhofstr. 2, 79110
Freiburg,
Germany
francesco.frontini@ise.fraunhofer.de

Shirley Gagnon
École d'architecture,
Université Laval
1, côte de la Fabrique
Québec, QC, G1R 3V6
Canada
shirley.gagnon.1@ulaval.ca

John Grunewald
Inst. of Building Climatology
Faculty of Architecture
Dresden University of
Technology
Zellescher Weg 17
01062 Dresden,
Germany
john.grunewald@gmx.de

Rolf Hagen
Context AS
Langbrygga 5B
NO-3724 Skien
Norway
rolf@context.as

Gustav Hillmann
IBUS - Institut für Bau-,
Umwelt- und Solarforschung
GmbH
Caspar-Theyß-Str. 14a
14193 Berlin,
Germany
hillmann@ibus-berlin.de

Miljana Horvat (Ed.)
Task 41, STB co-leader
Department of Architectural
Science
Ryerson University
350 Victoria St.
Toronto, ON, M5B 2H3
Canada
mhorvat@ryerson.ca

Tobias Koenig
Data Design System GmbH
An der Hansalinie 48-50
59387 Ascheberg
Nordrhein-Westfalen
Germany

Margarethe Korolkow
IBUS – Institut für Bau-,
Umwelt- und Solarforschung
GmbH
Caspar-Theyß-Str. 14a
14193 Berlin, Germany
margarethe.korolkow@ibus-berlin.de

Annie Malouin-Bouchard
École d'architecture,
Université Laval
1, côte de la Fabrique
Québec, QC, G1R 3V6
Canada
annie.malouin-bouchard.1@ulaval.ca

Catherine Massart
Architecture et climat
Université Catholique de
Louvain, Place du levant, 1
1348 LLN
Belgium
**catherine.massart@
uclouvain.be**

Andreas Obermüller
Lieb Obermüller + Partner
Müllerstraße 43
80469 München
Germany
obermuller@lop.de

Andreas Witzig
Vela Solaris AG
Stadthausstrasse 125
CH-8400 Winterthur,
Switzerland
**Andreas.witzig@
velasolaris.com**

Laura Maturi
EURAC research, Institute for
Renewable Energy
Università degli Studi di
Trento
Viale Druso 1,
I-39100 Bolzano,
Italy
laura.maturi@eurac.edu

Élodie Simard
École d'architecture,
Université Laval
1, côte de la Fabrique
Québec, QC, G1R 3V6
Canada
elodie.simard.1@ulaval.ca

Isa Zanetti
SUPSI - DACD – ISAAC
Casella postale 105
Trevano
CH - 6952 Canobbio
Switzerland
isa.zanetti@supsi.ch

Kim Nagel
ISAAC-DACD-SUPSI
Swiss BiPV Centre of
competence
Casella postale 105, Trevano
CH - 6952 Canobbio
Switzerland
kim.nagel@supsi.ch

Maria Wall
Task 41, Operating Agent
Energy and Building Design
Lund University
P.O. Box 118
SE-221 00 Lund, Sweden
Maria.Wall@ebd.lth.se

ABSTRACT

This report presents a review of existing digital tools widely used today, as part of the Subtask B: Methods and Tools for Solar Design of the IEA SHC Task 41 “Solar Energy and Architecture”. The review covers a total of 56 computer programs, classified according to three categories: 1) CAAD (computer-aided architectural design), 2) visualization, 3) simulation tools. The aim of this review is to analyse the current software landscape for building projects with a focus on early design phase (EDP).

The review indicates that there are many CAAD software which today allow passive solar gains prediction (often via whole-building energy simulations): Allplan, ArchiCAD, DDS-CAD PV, MicroStation, Revit and Vectorworks. The review outlines that most CAAD programs are more suited for detailed design than EDP. The non-BIM application Google SketchUp now includes many plugins: IES VE-Ware, OpenStudio, and Google SketchUp Demeter, which allow performing thermal simulations based on IES, EnergyPlus and Green Building Studio. Google SketchUp is widely recognized for being used at EDP and is often used in the architect’s workflow as a predecessor software to other, more complex BIM or non-BIM applications (e.g. AutoCAD). Many CAAD software include algorithms for the prediction or visualization of daylighting, allowing photorealistic 3D rendering or using a visualization tool to perform photorealistic and even physically-accurate light rendering. Finally, amongst the CAAD tools reviewed, Allplan and DDS-CAD PV are explicitly developed for sizing photovoltaics (PV) and/or solar thermal (ST) systems and all CAAD programs linked to EnergyPlus through a plugin or export function (ArchiCAD, Google SketchUp, MicroStation, Revit, Vectorworks) allow active solar systems calculation.

All reviewed visualization software include advanced or very advanced algorithms for the simulation of light or daylight. In most software (Flamingo, Kerkythea, LuxRender, Maxwell Render, RenderZone, V-Ray, YafaRay), the approach to rendering is based on the physical laws of illumination. Only one program (LuxRender) explicitly allows choosing between biased and unbiased (physically accurate) rendering. Few visualization programs provide numerical output of light intensity results; the focus is clearly on visualization rather than numerical analysis. In most cases, 3D rendering does not support EDP design decisions; rendering is thought of as a post-design rather than a design tool. None of the visualization tools reviewed explicitly support the design and visualization of PV and/or ST (solar thermal) systems, which is identified as an area in urgent need of development. ISAAC recently developed a 3D CAD object (compatible with ArchiCAD and AutoCAD) to speed up the rendering procedure when integrating PV in architectural objects in order to facilitate and stimulate the use of BiPV (building integrated photovoltaic) systems by architects and designers and to improve the architectural quality of BiPV systems.

Many simulation software allow predicting passive solar gains: bSol, DesignBuilder, DPV (Design Performance Viewer), Ecotect, EDG II, ENERGIEplaner, eQUEST, IDA ICE, IES VE, LESOSAI, VisualDOE. bSol, EDG II and LESOSAI do not support a 3D environment and thus offer limited interest for architects. Many simulation software can be used for the estimation of daylighting and daylight availability (DAYSIM, DesignBuilder, Ecotect, eQUEST, IDA ICE, IES VE and Radiance) and only a few are really designed for the estimation of daylight utilization (replacement of electric lighting by daylighting). Also, many simulation software (Ecotect, ENERGIEplaner, eQUEST, IDA ICE, LESOSAI, Polysun, PV*SOL, PVSys, T*SOL, VisualDOE, etc.) allow sizing PV and ST systems. Apart from PVSys, which offers a preliminary design level, most stand-alone applications for active solar systems are more suited for detailed design than EDP.

In general, the review shows that most tools are more suited for detailed design than for EDP. The next step in this project should consist of actually testing the programs using a reference model and interview competent users to find out how to improve the actual tools.

EXECUTIVE SUMMARY

This report presents a review of existing computer tools widely used by architects today. This review was completed as part of the work plan of Subtask B on methods and tools of the IEA SHC (International Energy Agency-Solar Heating and Cooling Programme) Task 41 called “Solar Energy and Architecture”. This review covers a total of 56 computer programs, which were classified according to three categories:

1. CAAD (computer-aided architectural design) tools;
2. Visualization tools;
3. Simulation tools.

The aim of this review is to analyse the current software landscape available for architects, with a focus on early design phase (EDP) decisions of building projects, to identify missing software tools and/or missing functionalities required for encouraging and enhancing solar design of buildings and the integration of solar systems and technologies. The focus of this review is clearly on EDP, since EDP decisions have the greatest impact on the durability and performance of any project: approximately 80% of the design decisions that influence a building’s energy performance are made by the architect during the first weeks of design of a building project.

CAAD tools

Until recently, building information modeling (BIM) software such as Autodesk Revit, Bentley Architecture, Graphisoft ArchiCAD, and Vectorworks Architect focused primarily on modeling and refining building geometry. Users relied on third-party software such as Green Building Studio, Ecotect, Hevacomp and IES VE to analyze the energy consumption of a building. A series of developments in the past few years (since 2008) changed that: there are many CAAD software today which include some form of connection to an energy simulation program thereby allowing passive solar gains prediction. Amongst the CAAD tools reviewed, the following BIM applications offer the most interesting possibilities for energy simulations including passive solar gains predictions: Allplan, ArchiCAD, DDS-CAD PV, MicroStation, Revit and Vectorworks. Google SketchUp, which is not a BIM application, also integrates many plugins: IES VE-Ware, OpenStudio, and Google SketchUp Demeter, which allow performing thermal simulations based on IES VE, EnergyPlus and Green Building Studio. Google SketchUp is widely recognized for being used at EDP and is often used in the architect’s workflow as a predecessor software to another more complex BIM or non-BIM applications (e.g. AutoCAD).

None of the other CAAD software examined in this review allow passive solar gains prediction, either at EDP or at detailed design phase. Note that AutoCAD models (.dwg) can be exported to Ecotect or to other simulation software since the .dwg format is a widely accepted file format. A plugin called EnergyPlugged plugin is also available in beta version for running EnergyPlus from AutoCAD. Note however that AutoCAD is more suited for the detailed design phase.

Apart from perhaps ArchiCAD and Google SketchUp, which are convivial for EDP work, all the programs reviewed are more suited for detailed design than EDP. For EDP work, it is crucial for the architect to feel s/he has a “free” hand, i.e. having the capacity to easily modify a building’s overall volume, geometry and orientation. The changes made on these parameters (volume, geometry, orientation) should be connected to a direct, explicit feedback about passive solar gains. This review outlines the fact that this type of direct explicit feedback is still lacking in many CAAD-BIM programs but that the recent advances in this field are promising.

This review also indicated that most CAAD software include some features for the prediction or visualization of daylighting. Amongst the CAAD tools, the BIM applications offer many possibilities for daylight analyses. For example, MicroStation via the Bentley Hevacomp and Bentley Tas simulator make it possible to perform daylight analyses; Revit performs daylighting analyses using the IES VE-Ware plugin (which uses Radiance) and Revit is also compatible with Ecotect; Vectorworks is interoperable with IES VE and Ecotect, etc. Moreover, most of the non-BIM CAAD software reviewed also allow some form of daylight analysis and/or visualization. For example, AutoCAD creates .dwg files, which can be read by most lighting and simulation software, including Ecotect, Radiance, etc.; Blender allows adding a plugin called b/rad, which is a Blender-based user interface for Radiance; 3ds Max Design 2010 features the Exposure technology to conduct validation studies based on the Radiance engine; Google SketchUp performs daylighting analyses using the IES VE-Ware or OpenStudio plugin, etc.

Most CAAD software today allow the study of direct light patterns and the majority of CAAD software included in this review allow performing photorealistic 3D rendering or using a visualization tool to perform photorealistic and even physically-based light rendering. The 3D rendering provides qualitative daylight analysis. However, note that the estimation of real daylight utilization (energy savings by replacement of electric light by daylight, as performed with DAYSIM) is not explicit with most CAAD programs reviewed.

Amongst the CAAD tools reviewed, Allplan and DDS-CAD PV are explicitly developed for sizing PV and/or ST systems. Also, since EnergyPlus allows the simulation of active solar components for simulating PV and ST hot-water systems (e.g., solar collectors) all CAAD programs that are linked with EnergyPlus through a plugin or export functions (ArchiCAD, Google SketchUp, MicroStation, Revit, Vectorworks) allow active solar systems calculations. However, apart from Google SketchUp, which is often used at EDP, all the CAAD tools listed above are more suited for detailed design than EDP even if active solar features are linked to a 3D environment.

Visualization tools

None of the visualization software reviewed includes any form of algorithm for the prediction of passive solar gains, which was an expected outcome of this review. However, all the visualization software reviewed include advanced or very advanced algorithms for the simulation of light or daylight, which is not surprising since it is the main goal of these programs (i.e. to provide visualization for light-matter interactions). However, it is not always clear whether the calculations are “cosmetic” or governed by the natural laws of illumination. Only one program (LuxRender) explicitly allows choosing between biased and unbiased rendering: users can choose between physical accuracy (unbiased) and speed (biased). In many software (Flamingo, Kerkythea, LuxRender, Maxwell Render, RenderZone, V-Ray, YafaRay), the approach to rendering is based on the physical laws of illumination.

Generally, visualization software do not provide technical solar calculations but most of these programs can be used to study direct and/or diffuse light penetration patterns and shading effects on building facades and inside buildings, at one specific moment or for a sequence in time. Few visualization programs provide numerical output of light intensity results; the focus is clearly on visualization rather than numerical analysis. In most cases, 3D rendering does not support EDP design decisions; rendering is thought of as a post-design rather than a design tool. Many visualization software (LightWave, LuxRender) include detailed algorithms for the simulation of electric lighting effects by using .ies lighting files. Finally, most visualization software, except LuxRender, use limited color channels (e.g. RGB i.e. red, green, and blue) for the prediction of emitted and reflected surface colors. LuxRender uses full spectral colors, which is a promising development for future study of special coating and/or glazing materials widely used in solar architecture.

Finally, the review indicates that none of the visualization tools reviewed in this report explicitly supports the design of PV and/or ST (solar thermal) systems. This is certainly an area which needs much development in the future. However, a company called ISAAC recently developed a 3D CAD object to speed up the rendering procedure when integrating PV in architectural objects in order to facilitate and stimulate the use of BiPV (building integrated photovoltaic) systems by architects and designers and to improve the architectural quality of BiPV systems. The CAD object, which is still a prototype, can be used with both ArchiCAD and AutoCAD, two widely used modeling tools compatible with most of the visualization tools mentioned in this review.

Simulation tools

This review indicates that there are many simulation software which can be used for the prediction of passive solar gains. In most cases, the estimation of passive solar gains is considered in the calculation of the whole building thermal balance calculation. Simulation applications which include passive solar gains calculation are: bSol, DesignBuilder, DPV (Design Performance Viewer), Ecotect, EDGII, ENERGIEplaner, eQUEST, IDA ICE, IES VE, LESOSAI, VisualDOE. Note that bSol, EDG II and LESOSAI does not actually support a 3D environment and thus offers limited potential for the development of architectural design aspects. However, LESOSAI 7.0 will have a wizard 3D in September 2010 and allow import of 3D Google SketchUp before the end of 2010.

In addition, there are many software which can be used for the study of daylighting and only a few which are really designed for daylight utilization predictions. The simulation software with the most interesting daylight calculations are: DAYSIM, DesignBuilder, Ecotect, eQUEST, IDA ICE, IES VE and Radiance. Note that three of them, DAYSIM, Ecotect and IES VE, perform daylight analyses based on the Radiance algorithms. Radiance is probably the most advanced daylight simulation software, but it is not suitable for EDP, when much information about the building is missing. Other programs such as e.g. DesignBuilder, Ecotect and IES VE are probably more suitable for EDP work on daylighting aspects. Despite the fact that they support a 3D environment, DAYSIM, eQUEST, IDA-ICE are more suited for the detailed design phases.

Also, there are many software for sizing PV and ST systems. Note that two of them, ENERGIEplaner and LESOSAI, support active solar systems predictions based on the Polysun technology. Apart from PVsyst, which offers a preliminary design level, all the applications listed above are more suited for detailed design than EDP. However, the 3D environment is very simplistic in PVsyst, so this tool cannot really support the development of architectural design aspects. Additionally, the review indicates that most simulation software are not really suitable for the architectural integration of solar active systems because visualization capacities are not sufficiently developed.

This review shows that there are a very large amount of CAAD, visualization and simulation tools available today for architects. The review covers most of the tools widely known and used by the architectural community. However, a comprehensive review of all available tools in the world is nearly impossible due to the amount of information which must be collected. This review is thus wide but still incomplete. The next step in the present work should consist of actually testing the programs using a reference building and interview competent users to determine required improvements for the future success of solar design.

LIST OF ABBREVIATIONS

AEC:	Architecture, Engineering, and Construction
API:	Application Programming Interface
BIM:	Building Information Modeling
BiPV:	Building Integrated Photovoltaic
CAD:	Computer Aided Drawing / Computer Aided Design
CAAD:	Computer Aided Architectural Design
EDP:	Early Design Phase
GI:	Graphical Interface
GIS:	Geographic Information System
GDL:	Geometric Description Language
GSM:	Global Shared Memory
HDR:	High Dynamic Range
HVAC:	Heating, Ventilation and Air Conditioning
IAI:	International Alliance for Interoperability
ICT:	Information and Communication Technology
IDM:	Information Delivery Manual
IES:	Illuminating Engineering Society
IES:	Integrated Environmental Solutions
IFC:	Industry Foundation Classes
ISO:	International Organization for Standardization
LHS :	Left Hand System of coordinates
MAC:	Macintosh
MEP :	Mechanical, Electrical and Plumbing
NURBS:	Non-Uniform Rational Basis Spline
OOP:	Object Oriented Programming
PBRT:	Physically Based Rendering Technique
PC:	Portable Computer
PV:	Photovoltaic
RHS :	Right Hand System of coordinates
ST:	Solar thermal
TIN:	Triangulated Irregular Network
UCS:	User Coordinate System
UI:	User Interface
VBE:	Virtual Building Explorer
VRML:	Virtual Reality Modeling Language
WCS:	World Coordinate System

LIST OF FILE FORMATS

3DS:	File extension used by 3ds Max.
BLEND:	All of Blender's ".blend" files are forward, backward, and cross-platform compatible with other versions of blender, and can be used as a library to borrow pre-made content.
DAE:	COLLADA (.dae) is a COLLABorative Design Activity for establishing an interchange file format for interactive 3D applications.

- DGN:** DGN (.dgn) (Design) is the name used for CAD file formats supported by Bentley Systems' MicroStation and Intergraph's Interactive Graphics Design System (IGDS) CAD programs
- DWF:** Design Web Format (.dwf) is a secure file format developed by Autodesk for the efficient distribution and communication of rich design data to anyone who needs to view, review, or print design files.
- DWG:** DWG or .dwg ("drawing") is a file format used for storing two and three dimensional design data and metadata. It is the native format for several CAD packages including AutoCAD, IntelliCAD (and its variants) and Caddie.
- DXF:** AutoCAD (.dxf, Drawing Interchange Format or Drawing Exchange Format) is a CAD data file format developed by Autodesk for enabling data interoperability between AutoCAD and other programs.
- EPS:** Encapsulated PostScript (.eps) is a DSC-conforming PostScript document with additional restrictions intended to make .eps files usable as a graphics file format.
- GIF:** The Graphics Interchange Format (.gif) is a bitmap image format that was introduced by CompuServe in 1987 and has since come into widespread usage on the World Wide Web due to its wide support and portability.
- gbXML:** Schema developed to facilitate a common interoperability model integrating a myriad of design and development tools used in the building industry. gbXML is being integrated into a range of software CAD and engineering tools. This interoperability standard reduces the time to develop a building and also assures that when the building is put into operation it can meet the design intent.
- IES:** File from the Illuminating Engineering Society of North America.
- IGES:** The Initial Graphics Exchange Specification (IGES or .igs) (pronounced eye-jess) defines a neutral data format that allows the digital exchange of information among Computer-aided design (CAD) systems. Using IGES, a CAD user can exchange product data models in the form of circuit diagrams, wireframe, freeform surface or solid modeling representations. Applications supported by IGES include traditional engineering drawings, models for analysis, and other manufacturing functions.
- JPEG:** Pronounced "JAY-peg" (.jpg or .jpeg), named after the Joint Photographic Experts Group (who created the standard) is a commonly used method of lossy compression for photographic images.
- OBJ:** OBJ (.obj) is a geometry definition file format first developed by Wavefront Technologies for its Advanced Visualizer animation package. The file format is open and has been adopted by other 3D graphics application vendors. For the most part it is a universally accepted format.
- PNG:** Portable Network Graphics (.png) is a bitmapped image format that employs lossless data compression. The format .png was created to improve upon and replace .gif as an image-file format not requiring a patent license.
- PSD:** Photoshop's native format (.psd) stores an image with support for most imaging options available in Photoshop.

- SAT:** ACIS (.sat), the 3D ACIS Modeler (ACIS) is 3D modeling kernel (or engine) owned by Spatial Corporation (formerly Spatial Technology). ACIS is used by many software developers industries such as computer-aided design (CAD).
- STEP:** The STEP (.stp) (ISO 10303) Product Data Representation and Exchange standardization initiative covers computer-interpretable representation of product data, and its exchange. STEP-File is the most widely used data exchange form of STEP. Due to its ASCII structure, it is easy to read with typically one instance per line. The format of a .stp file is defined in ISO 10303-21 Clear Text Encoding of the Exchange Structure.
- TIFF:** Tagged Image File Format (abbreviated .tif) is a file format for storing images, including photographs and line art.
- WMF:** Windows Media Format (.wmf).
- VRML:** VRML, Virtual Reality Modeling Language (.wrl) is a text file format where, e.g., vertices and edges for a 3D polygon can be specified along with the surface color, UV mapped textures, shininess, transparency, and so on.
- X3D:** X3D, Extensible 3D (.x3d) is the ISO standard XML-based file format for representing 3D computer graphics, the successor to the VRML (.wrl).

LIST OF SCRIPTING AND LANGUAGES USED IN CAD

- C++:** C++ (pronounced "See plus plus") is a statically typed, free-form, multi-paradigm, compiled, general-purpose programming language. It is regarded as a middle-level language, as it comprises a combination of both high-level and low-level language features (form•Z, Maya, Rhino, etc.).
- EXPRESS:** EXPRESS is a standard data modeling language for product data. EXPRESS is formalized in the ISO Standard for the Exchange of Product model STEP (ISO 10303)
- JAVA2D:** Java 2D is an API for drawing two-dimensional graphics using the Java programming language. Every Java 2D drawing operation can ultimately be treated as filling a shape using a paint and compositing the result onto the screen.
- JAVA3D:** Java 3D is a scene graph-based 3D application programming interface (API) for the Java platform. It runs on top of either OpenGL or Direct3D.
- LScript:** LScript is LightWave's scripting language.
- MAXScript:** MAXScript is a built-in scripting language, and can be used to automate repetitive tasks, to combine existing functionality in new ways, and to develop new tools and user interfaces and much more. Plugin modules can be created entirely in MAXscript.
- MEL:** The Maya Embedded Language (MEL) is a scripting language used to simplify tasks in Autodesk's 3D Graphics Software Maya.
- OpenGL:** (Open Graphics Library) is a standard specification defining a cross-language, cross-platform API for writing applications that produce 2D and 3D computer graphics.

- Python:** Python is a general-purpose high-level programming language. Like other dynamic languages, Python is often used as a scripting language (Blender, Houdini, Maya, Rhino, Softimage, etc.).
- RSL:** RenderMan Shading Language (abbreviated RSL) is a component of the RenderMan Interface Specification, and is used to define shaders. The language syntax is C-like.
- Visual Basics:** Visual Basic (VB) is the third-generation event-driven programming language and integrated development environment (IDE) from Microsoft for its COM programming model. VB is also considered a relatively easy to learn and use programming language, because of its graphical development features and BASIC heritage.
- VRML:** VRML (Virtual Reality Modelling Language, pronounced vermal or by its initials, originally — before 1995 — known as the Virtual Reality Markup Language) is a standard file format for representing 3-dimensional (3D) interactive vector graphics, designed particularly with the World Wide Web in mind. It has been superseded by X3D.
- X3D:** X3D is the ISO standard .xml-based file format for representing 3D computer graphics, the successor to the Virtual Reality Modeling Language (VRML). X3D features extensions to .wrl (e.g. Humanoid Animation, NURBS, GeoVRML etc.), the ability to encode the scene using an .xml syntax as well as the Open Inventor-like syntax of VRML97, or binary formatting, and enhanced application programming interfaces (APIs).

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1. INTRODUCTION

Buildings today account for 40% of the world's energy use and the resulting carbon emissions are substantially more than those in the transportation sector [WBCSD, 2009]. To achieve an energy-efficient world, governments, businesses and individuals must transform the building sector through a multitude of actions, which include increasing energy awareness globally, and improving building energy codes, labelling and reporting mechanisms, appropriate energy prices and carbon costs, investment subsidies, increased and trained workforce capacity, and evolving energy-efficient designs and technologies that use passive and active approaches [WBCSD, 2009].

- Passive approaches include the use of daylight, passive solar heat gains optimized through the building's shape and orientation, daylight utilization, use of solar shading, etc.
- Active approaches include the use of thermal collectors for the production of hot water or air, building integrated photovoltaics (BiPVs) and building integrated thermal photovoltaics (BiTPVs) for the production of electricity and heat.

The amount of solar energy reaching the surface of the Earth is so vast that in one year, it is about twice as much as will ever be obtained from all of the Earth's non-renewable resources of coal, oil, natural gas, and mined uranium combined [Stanford University, 2010]. Also, according to Suzuki & Boyd [2008], more solar energy reaches the surface of the Earth in one hour than the total amount of energy used by humans in one year. Looking at the building sector, it is obvious that the surface of buildings offers a great opportunity for producing large amounts of energy closely located to end-use. In many locations, the solar energy incident on the roof of a typical home far exceeds its energy consumption; there is, therefore, the potential for a building to achieve, on average, net zero energy consumption if the utilization of solar energy to produce electricity, useful heat and daylight is optimized [SBRN, 2010].

In spite of these facts, a large portion of the potential to utilize solar energy still remains unused [Devin 2006]. According to the International Energy Agency [IEA 2009], this is caused by several factors:

- economical factors;
- lack of technical knowledge;
- reluctance to use “new” technologies; and
- architectural (aesthetic) factors.

While the economic factors are gradually losing grounds as the cost of solar energy systems is decreasing [Net Zero Energy Home Coalition, 2005], it is essential to address the last three factors, which are related to workforce capacity. In relation to this issue, it is interesting to mention that in a study about the weaknesses and barriers of the market as a basis for renewable energy use policies, Brown [2001] concluded that the main actors of the construction sector lack sufficient knowledge in terms of energy efficiency. Another, more recent, study [Maciela et al, 2006] underlined that there are great gaps in education related to the integration of bioclimatic strategies in architectural design; students of architecture generally learn highly technical stuff about the energy but they are not educated about the way to *integrate* the systems into *high quality* architecture. Also, in a study about design methods for highly efficient buildings, Larsson [2004] observed that the tools available at early design phase (EDP) are inadequate to evaluate the impact of early design choices on the building's efficiency.

The integration of solar energy systems and technologies in existing and new buildings will be greatly facilitated in the future if architects are informed, aware and engaged in the development of solar energy in buildings. Architects should also be aware of the potential, limitations and characteristics of

solar energy systems. Architects have a significant role to play in the development of solar energy systems and technologies in buildings because:

1. Early design phase (EDP) decisions (such as orientation, shape, size of openings) are primarily the responsibility of the architect;
2. EDP decisions have the greatest impact on the durability and performance of any project [Potvin 2005].

Larsson (2004), in a study about the design method used in highly efficient buildings, concluded that the greatest advantages in terms of energy use depended on decisions taken and verified at the very first phase of design. During the first few weeks of design, fundamental decisions are made that have an enormous impact on the energy consumption of the building and therefore the lifecycle cost [Livingston, 2007]. The truth of sustainable design is that approximately 80% of the design decisions that influence a building's energy performance are made by the architect in the EDP; the remaining 20% are made by engineers at the later phases of design. Therefore it is crucially important for architects to be able to utilise a quick and reliable energy performance evaluation at the very early stage of the building design process [GRAPHISOFT, 2009h].

1.1 Task 41: Solar Energy and Architecture

Task 41 - Solar Energy and Architecture is gathering researchers and practitioners from 14 countries in a significant project, which will identify obstacles for solar design while providing recommendations and support for the implementation of solar technologies and strategies in buildings. The ultimate goal of Task 41 is to instigate the development of high quality solar architecture. This task is focused mainly on the architectural profession, as a key factor in the future evolution and implementation of solar building design in existing as well as new buildings.

The main objectives of Task 41 are stated below:

- To support the development of high quality architecture for buildings integrating solar energy systems and technologies;
- To improve the qualifications of the architects and the communications skills and interactions between engineers, manufacturers, clients and architects.

The overall benefit will be an increased use of passive and active solar energy in buildings, thus reducing the non-renewable energy demand and greenhouse gas emissions. The objectives of this task are thus closely linked to the actions identified by the World Business Council for Sustainable Development i.e. to increase and train workforce capacity, and to evolve energy-efficient designs and technologies that use passive and active approaches [WBCSD 2009].

To achieve these goals, the work plan of Task 41 is organised according to three main subtasks:

Subtask A: Architectural quality criteria; guidelines for architects and product developers by technology and application for new product development.

Subtask B: Guidelines for the development of methods and tools focusing on tools for EDP and tools for the evaluation of integration quality of various solar technologies.

Subtask C: Integration concepts and examples, and derived guidelines for architects.

1.2 Subtask B - Description and objectives

Subtask B deals with methods and tools for solar design that architects use at early design phase (EDP). Whilst the term “early design phase” is very commonly used in discussing the building design process, it invariably refers to the stage of work where initial design ideas are being conceptualized in tandem with the formulation of the building project requirements [Lam, Chun Huang & Zhai, 2004]. It is generally recognized that this is an adaptive-iterative process [Mahdavi & Lam, 1993 via Lam, Chun Huang & Zhai, 2004]. However, it is often not clear in practice when this phase ends and the next begins [Lam, Chun Huang & Zhai, 2004]. According to Pfitzner et al [2007], the “Early Design Phase” (EDP) starts with the first client contact and ends with a design with recognisable functions, visualised for easy understanding and with a cost calculation to support the client’s “go/no-go” decisions. This is illustrated in figure 1.



Figure 1: Construction process for a building (source: Pfitzner et al., 2007).

The two main phases in EDP are: Brief Design and Concept Design. In Brief Design end-user needs, wishes, and limitations (like the available total budget) are translated into a building requirement specification, especially taking the client’s processes into account. Based on these requirement specifications, the Concept Design is started resulting in a design of the building that is sufficiently detailed to predict (within margins) performance, cost, and time aspects. In the concept design phase discipline-oriented concept partial designs are integrated into a ‘total concept design’. The subsequent, beyond ‘Early Design’, ‘Construction Design’ fixes all details and ‘how to construct’ issues resulting in a complete and fully detailed enough design to actually construct the building [Pfitzner et al., 2007].

Methods and tools used at EDP should support decisions and allow further development of the project at construction design as well as the evaluation of various solar technologies integration with architecture. At EDP, the architect may explore various building geometries, orientations and fenestration configurations, and be provided with recommended input parameters derived from an extensive contextual-based library support in terms of materials, construction, performance targets, etc. The output required at this phase may just be building loads without detailed considerations of mechanical systems and actual energy consumption [Lam, Chun Huang & Zhai, 2004]. However, the use of the building envelope to achieve a good balance of both active and passive solar utilization is a central concern in IEA Task 41 Subtask B and in the development of methods and tools.

The specific objectives of Subtask B are stated below:

1. To achieve an exhaustive review of existing methods and tools (state-of-the-art) that architects currently use at EDP when designing buildings which integrate active and/or

passive solar components. (This review will be carried as a supplement to work achieved within IEA Task 40 – Net Zero Energy Buildings).

2. To identify current obstacles preventing architects from using existing methods and tools for solar building design.
3. To identify important needs and criteria for new or adapted methods and tools to support architectural design and integration of solar components at EDP.
4. To provide clear guidelines for developers of digital tools for architects designing solar buildings, with focus on EDP.
5. To initiate communication with tool developers (industry) in order to stimulate the development of adequate and improved digital tools.
6. In collaboration with Subtask C, to collect output data, 3D models, figures, illustrations and facts produced by various tools in demonstration projects, to be included in the Communication Guidelines.
7. To disseminate the results of this research through publications in scientific and professional journals, as well as through seminars to practitioners (e.g. architects).

This report seeks to meet the first specific objective stated above by presenting a thorough review or “State-of-the-art” of existing computer tools that architects currently use at EDP or other phases. The aim of this review is to analyse the current software landscape for EDP of building projects, to identify missing software tools and/or missing functionalities required for encouraging and enhancing solar design of buildings and integration of solar systems and technologies. This review focuses primarily on computer tools rather than analytical or graphical tools, which are still used by some senior architects.

1.3 Objectives and scope of this review

This review focuses on computer tools used for the design of buildings, with a special emphasis on tools used by architects at EDP. A report by Pfitzner et al [2007] revealed that most of the software for design and analysis are mainly developed for the detailed design phase where extensive information is available and most design decisions already have been taken. An industry survey by Wong et al. [2000, via Lam, Chun Huang & Zhai, 2004] indicated that most energy modeling software tools are developed for the purpose of design verification and to meet building code requirements at the end of the design phase; the tools do not necessarily provide “active support” particularly for the “early” design process. This only emphasizes the importance of considering the EDP as a departure point for Subtask B and studying which tools are available for this phase, which is a crucial one in the initial definition of the building project.

The review covers a total of 56 computer software, which have been selected on the basis of their popularity amongst architects, and which have been classified according to three categories: Computer-aided architectural design (CAAD) tools, visualization tools and simulation tools. The review thus presents 23 well-known and popular CAAD programs, 13 visualization tools and 20 simulation tools used by architects today (see Table 1 on the next page).

Table 1: Overview of the computer programs presented in this report.

	CAAD tools	Visualization tools	Simulation tools
1	Allplan	Artlantis	bSol
2	ArchiCAD	Flamingo	DAYSIM
3	AutoCAD	Kerkythea	DesignBuilder
4	Blender	LightWave	Design Performance Viewer (DPV)
5	Bricscad	LuxRender	Ecotect
6	Caddie	Maxwell Render	EDG II
7	CATIA	mental ray [®]	EliteCAD
8	CINEMA 4D	POV-Ray	ENERGIEplaner
9	DDS-CAD	RenderMan	eQUEST
10	Digital Project	RenderWorks	Green Building Studio
11	form•Z	RenderZone	IDA ICE
12	Google SketchUp	V-Ray	IES VE
13	Houdini	YafaRay	LESOSAI
14	IntelliPlus Architecturals		Polysun
15	Lightworks		PVsyst
16	Maya		PV*SOL
17	MicroStation		Radiance
18	Revit		RETScreen
19	Rhinoceros 3D		T*Sol
20	SolidWorks		VisualDOE
21	Spirit		
22	Vectorworks		
23	3ds Max		

1.4 Method for collection of information

The programs listed in the previous section were selected by the group of architects, engineers, consultants and researchers involved in IEA Task 41– Subtask B. This group comprises, among others, architects active in European offices [White architects (Sweden), Context AS (Norway), DARK Arkitekter AS (Norway), etc.], consultants in the building industry [Esbensen consulting engineers (Denmark), IBUS Architekten und Ingenieure GbR (Germany)], researchers [Fraunhofer Institut für Solare Energiesysteme (Germany), Austrian Energy Agency (Austria), etc.] and university professors [Lucerne University of Applied Sciences and Arts (Switzerland), NTNU (Norway), School of Architecture - Université Laval (Canada) and Ryerson University (Canada), Lund University (Sweden), etc.]. The review has also benefited from assistance of a few software developers [Vela Solaris (Switzerland), Data Design System (Germany), e4tech (Switzerland), etc.].

Once a preliminary list of computer programs was determined, the websites of each program were visited and a database with key information was selectively built during the summer 2009. Also, scientific articles about the selected programs were consulted when necessary. Subsequently, this information was translated into short structured texts describing each program with key features and information regarding e.g. interoperability, import-export functions, modeling and rendering capabilities, actual solar calculations, etc. Modeling capabilities were reported because, as established by Bazjanac [2001, via Lam, Chun Huang & Zhai, 2004], up to 80% of the effort in preparing a simulation input file goes into the geometric description of building geometry.

Also, as the energy simulation tool is used within a design process that involves other software (e.g. CAD, spreadsheets, presentation, etc.), and assessment of the compatibility and interoperability of each of the selected tools with other typical software used in the industry had to be conducted. Interoperability in terms of import/export of files between CAD and simulation tools is seen to be an important feature in the tool specification [Lam, Chun Huang & Zhai, 2004]. A report by Pfitzner et al [2007] outlined that import and export functionalities belong to the most important missing functionalities, especially the interface between several project phases and project parties was identified as a missing key feature. The same report also revealed that collaboration tools were not used comprehensively and not implemented in projects successfully due to different barriers like complexity or people not being aware of the functionalities. Finally, this report outlined that possibilities of software tools were not well known in general and that there is a big gap between the users' requirements and the available software facilities. All these elements are important to consider in view of the present objectives of Subtask B i.e. to encourage and support the design of high quality solar building design and to provide appropriate tools and methods to succeed in this endeavour.

1.5 Important definitions

Some technical terms used throughout this report are defined below. This list is by no means exhaustive: it only seeks to bring clarifications to readers not directly involved in computer research or software development. Unless stated otherwise, the following definitions have been retrieved from Wikipedia (online version 2010).

Building Information Modeling (BIM)

Building Information Modeling (BIM) is the process of generating and managing building data during its life cycle [Lee, Sacks & Eastman, 2006]. Typically it uses three-dimensional, real-time, dynamic building modeling software to increase productivity in building design and construction [Holness, 2008]. The process produces the Building Information Model (also abbreviated BIM), which encompasses building geometry, spatial relationships, geographic information, and quantities and properties of building components. The American Institute of Architects has further defined BIM as "a model-based technology linked with a database of project information"[Lee, Sacks & Eastman, 2006], and this reflects the general reliance on database technology as the foundation. In the future, structured text documents such as specifications may be able to be searched and linked to regional, national, and international standards. Nevertheless, it is agreed upon that the term was popularized as a common name for a digital representation of the building process to facilitate exchange and interoperability of information in digital format. According to Eastman et al [2008], BIMs are characterised by:

- Building components (or intelligent objects);
- Components including data describing how they behave;
- Consistent and non-redundant data (automatic update);
- Coordinated data.

BuildingSMART

BuildingSMART is an initiative to obtain better quality for a lower cost in the building industry. An important technology, which is used for reaching this goal is the Industry Foundation Classes (IFC).

Computer-aided design (CAD)

Computer-aided design (CAD) is the use of computer technology for the design of objects, real or virtual. CAD often involves more than just shapes. As in the manual drafting of technical and engineering drawings, the output of CAD often must convey also symbolic information such as materials, processes, dimensions, and tolerances, according to application-specific conventions. CAD may be used to design curves and figures in two-dimensional ("2D") space; or curves, surfaces, and solids in three-dimensional ("3D") objects [Farin, Hoschek & Kim 2002]. CAD is an important industrial art extensively used in many applications, including automotive, shipbuilding, and aerospace industries, industrial and architectural design, prosthetics, and many more. CAD is also widely used to produce computer animation for special effects in movies, advertising and technical manuals.

Computer-aided architectural design (CAAD)

Computer-aided architectural design (CAAD) software programs are the repository of accurate and comprehensive records of buildings and are used by architects and architectural companies. Computer-aided design also known as CAD was originally the type of program that architects used, but since CAD could not offer all the tools that architects needed to complete a project, CAAD developed as a distinct class of software. All CAD and CAAD systems employ a database with geometric and other properties of objects; they all have some kind of graphic user interface to manipulate a visual representation rather than the database; and they are all more or less concerned with assembling designs from standard and non-standard pieces. Currently, the main distinction which causes one to speak of CAAD rather than CAD lies in the domain knowledge (architecture-specific objects, techniques, data, and process support) embedded in the system. A CAAD system differs from other CAD systems in two respects: 1) it has an explicit object database of building parts and construction knowledge; 2) it explicitly supports the creation of architectural objects.

Geometric Description Language (GDL)

In computer-aided design, Geometric Description Language (GDL) is the programming language of ArchiCAD library parts. GSM is the file format of these CAD objects. These objects are similar to blocks in AutoCAD, but unlike blocks, these are parametric, and the 2D and 3D features are connected, so in any view one can get the correct visualization (for example a side view on the section, top view on plan, and perspective in the 3D view). GDL scripts define an ArchiCAD library part in its main roles, these are 3D model, 3D model projected to section/elevation or to 2D plan, 2D plan view, user interface display and behaviour and listing quantities.

GNU

GNU is a computer operating system composed entirely of free software. Its name is a recursive acronym for "GNU's Not Unix!" This name was chosen because GNU's design is Unix-like, but differs from Unix by being free software and containing no Unix code.

Industry Foundation Classes (IFC)

The Industry Foundation Classes (IFC) data model is a neutral and open specification that is not controlled by a single vendor or group of vendors. It is an object oriented file format with a data model developed by buildingSMART (International Alliance for Interoperability, IAI) to facilitate interoperability in the building industry, and is a commonly used format for Building Information Modeling (BIM). The IFC model specification is open and available. It is registered by ISO as ISO/PAS 16739 and is currently in the process of becoming the official International Standard ISO/IS 16739.

Interoperability

With respect to software, the term interoperability is used to describe the capability of different programs to exchange data via a common set of exchange formats, to read and write the same file formats, and to use the same protocols. (The ability to execute the same binary code on different processor platforms is 'not' contemplated by the definition of interoperability.)

NURBS

Non-uniform rational basis spline (NURBS) is a mathematical model commonly used in computer graphics for generating and representing curves and surfaces, which offers great flexibility and precision for handling both analytic and freeform shape.

Object-oriented programming (OOP)

Object-oriented programming (OOP) is a programming paradigm that uses "objects" – data structures consisting of data fields and methods together with their interactions – to design applications and computer programs. Programming techniques may include features such as information hiding, data abstraction, encapsulation, modularity, polymorphism, and inheritance.

OpenGL

OpenGL (Open Graphics Library) is a standard specification defining a cross-language, cross-platform API for writing applications that produce 2D and 3D computer graphics. The interface consists of over 250 different function calls which can be used to draw complex three-dimensional scenes from simple primitives. OpenGL was developed by Silicon Graphics Inc. (.sgi) in 1992 and is widely used in CAD, virtual reality, scientific visualization, information visualization, and flight simulation. It is also used in video games, where it competes with Direct3D on Microsoft Windows platforms. OpenGL is managed by a non-profit technology consortium, the Khronos Group.

STEP

STEP, ISO 10303 is an ISO standard for the computer-interpretable representation and exchange of product manufacturing information. Its official title is "Industrial automation systems and integration - Product data representation and exchange", known as "STEP" or "Standard for the Exchange of Product model data". The International standard's objective is to provide a mechanism that is capable of describing product data throughout the life cycle of a product, independent from any particular system. The nature of this description makes it suitable not only for neutral file exchange, but also as a basis for implementing and sharing product databases and archiving. Typically, STEP can be used to exchange data between CAD, Computer-aided manufacturing, Computer-aided engineering, Product Data Management/EDM and other CAx systems. STEP is addressing product data from mechanical and electrical design, Geometric dimensioning and tolerancing, analysis and manufacturing, with additional information specific to various industries such as automotive, aerospace, building construction, ship, oil and gas, process plants and others.

VRML

VRML (Virtual Reality Modeling Language, pronounced vermal or by its initials, originally — before 1995 — known as the Virtual Reality Markup Language) is a standard file format for representing three-dimensional (3D) interactive vector graphics, designed particularly with the World Wide Web in mind. It has been superseded by X3D.

2. DIGITAL TOOLS USED BY ARCHITECTS TODAY

2.1 Office tools

A research by Pfitzner et al [2007] showed that in the very early phase of construction projects, in the brief design phase, mostly administrative and informal software tools like e.g. Microsoft Word and

Excel, are used. Most of these tools are office handling unstructured data. It is only later in the concept phase that more technical tools handling structured data start to be used. From client brief to concept design, there is thus a window of opportunity for introducing specific functionalities for solar design, which have certainly not been explored yet.

2.2 CAAD tools

The CAAD tools reviewed are presented in alphabetic order in the following sections. The tools, which were placed within the category “CAAD tools”, all include modeling features. Some of these tools like (e.g. CINEMA 4D and Lightworks) are often used as visualization tools rather than CAAD tools but since they do include some modeling capabilities, they are presented in the CAAD tools section below.

2.2.1 Allplan

Supplier, site, contact, last version, cost

Allplan is an object-oriented planning and design software developed by the Nemetschek Group. The last version is Allplan 2009. The cost of this program is 1433-4329 USD (990-2990 €), depending on the package bought, for one license of the 2009 version. It is possible to order a trial version, available for 30 days, on the official Nemetschek Allplan website [www.allplan2009.com]. Allplan works on the Microsoft Windows operating system only

Functions

Unlike other types of CAAD software, Allplan promotes interdisciplinary working in the areas of architecture, interior architecture, urban and landscape planning, structural planning, civil engineering, road construction, pre-cast factories and building services.

Allplan is used for 2D drawing and 3D modeling. With Allplan, it is possible to switch between 2D and 3D as needed. A large suite of basic geometric entities such as lines and circles is available in 2D drawings, in the same way as in any other CAAD software. Allplan offers advantages when working in 2D with architectural elements such as walls and openings. For example, it is not necessary to draw two parallel lines to define a wall. The 3D model serves as the basis for different analyses, quantity takeoffs, design checks and visualizations [Nemetschek Allplan GmbH, 2009].

Allplan 2009 includes new energy consulting tools. There is also an energy indicator for a precise analysis of renovation measures [CIMdata Inc., 2009]. In the Energy Performance Certificate, which is an optional module, users may estimate buildings according to energy and environmental criteria. These assessments are based on some European standards [Nemetschek Allplan GmbH, 2009].

Design stage, users

Allplan is a software for architects, drafters, engineers and contractors. There are five different products of Allplan. All of them are developed from the same Allplan platform, but each one offers specific tools for different types of use. The Allplan product line includes: Allplan Architecture, Allplan Engineering, Allplan BCM (building construction management), Allplan CAD Planning Data and Allplan Allfa. An Allplan model can be reused and edited in the Allplan product family. These software are used from the initial to the preliminary drawings, detailed design and construction cost planning. Moreover, Allplan Engineering provides structural analysis and calculations. Allplan BCM is used for estimating quantities and calculating costs [Nemetschek Allplan GmbH, 2009].

3D modeling

Allplan includes different tools to convert 2D drawings to 3D architectural elements, more or less automatically. Moreover, when using 2D architectural elements, a preview of the element, in isometric view, is available and allows verifying the design in many different ways.

Rendering

It is possible to create rendered images by using other software such as CINEMA 4D or Maxwell Render. In the last version, the interface to CINEMA 4D has been optimized, and it is now possible to choose cameras, lighting settings and background and transfer them as scene objects [Nemetschek Allplan GmbH, 2009].

Allplan does not provide an integrated animation model. Files can be exported to a capable animation software.

Coordinates

Allplan 2D drawing is performed according to x and y axes and 3D modeling is related to x, y and z axes. The coordinate system uses the RHS.

Import/export

There are many import/export options in Allplan. The general import formats are AutoCAD data (.dxf, .dwg, .dwt, .dxb) up to version 2009, MicroStation data (.dgn) up to version 8, .pdf, .ifc, CINEMA 4D files (.c4d), Google SketchUp (.skp) version 3 to 6, Rhino format (.3dm), VRML (.wrl), HPgl/2 plot files (.plt, .hp, .hpg, .hpl, .prn) and Step CDS (.stp). Some engineering import formats are also available such as FEM data (.asf) and CEDRUS elements (.sin). It is possible to import coordinate data, axis and curve trace data (.re1, .reb, .re2, .asc, .lin) and terrain model including longitudinal and transverse profiles (.lpr, .qpr). Moreover, via CINEMA 4D, a 3D computer graphics software, it is possible to import files from 3ds Max (.3ds), Adobe Illustrator (.ai), .stl, ACIS SAT (.sat), Parasolid (.xmt) and more [Nemetschek Allplan GmbH, 2009].

The export formats are generally the same as import, but it is possible to export to Google Earth (.kml), Universal 3d (.u3d) and 3ds Max (.3ds). It is also possible to export quantity data for Allplan BCM (.xac), Excel (.xls) and into .xml attribute format (.xml). Via CINEMA 4D, Direct 3D/ DirectX (.x), QuickDraw 3D, .stl, Shockwave (.w3d) and Wavefront (.obj) formats are available. Moreover, many image formats are supported in Allplan (import and export) such as .jpg, .png, Mac PICT (.pct), .psd, .tif or .bmp [Nemetschek Allplan GmbH, 2009].

Predecessor software, successor software

Since the .dwg format is almost universal in design and modeling software, all CAD packages can be predecessor software to Allplan. Moreover, any software that exports in the file formats listed above can be used before Allplan. .ifc data exchange allows access to many external applications or analysis programs. It is also possible to use Allplan's project data in spreadsheet programs, such as Microsoft Excel. CINEMA 4D and Maxwell Render can be used before and after Allplan, for rendering.

BIM

Allplan is the open platform for interdisciplinary working. Allplan is .ifc compatible and thus uses BIM technology by creating architectural models and also by allowing the calculation of quantities and costs. All partners benefit from up-to-date and accessible information about the respective design, implementation or current status. For example, the software can generate structural models that can be converted into structural analysis models. The calculation results then flow back into the structural model. Professionals can also update the model for heating, ventilation, sanitation and electrical systems [Nemetschek Allplan GmbH, 2009]. This makes it possible to identify conflicts between different designs early in the process [CIMdata Inc., 2009].

Actual solar calculation

Allplan 2009 Architecture provides a wide range of tools for energy consulting - from the sizing and installation of photovoltaic and solar thermal systems to energy indicators allowing rapid analysis of energy-related building re-development work. The calculations are based on climate file data available mostly for European locations. The optional energy performance certificate module allows energy and environmental appraisals based on the specific regional standards in Germany, Austria, Italy and France to be derived directly from the program and legally-required energy performance certificates to be created. Allplan Building Simulation completes the range of functions of Allplan with dynamic calculations of heating and cooling loads. It includes tools for setting up photovoltaic and solar-thermal installations [CIMdata Inc., 2009].

2.2.2 ArchiCAD*Supplier, site, contact, last version, cost*

ArchiCAD is an architectural BIM/CAD software supplied by Graphisoft, a Hungarian company which has developed virtual building solutions for 25 years. Graphisoft works with a large community of architects to bring forth projects that are better designed, more predictable to build and less expensive [GRAPHISOFT, 2009a]. The cost of the last version, ArchiCAD 13, available for Microsoft Windows (Mac and Wintel), is 4250 USD (2928 €) for one license. It is also possible to buy an upgrade of the program for 895 USD (618 €) and a free educational version is available [Khemlani, 2009a]. Moreover, on the Graphisoft web site, it is possible to register and receive a free 30 days trial version including interactive learning, which is called the BIM Learning Studio [GRAPHISOFT, 2009b].

Functions

ArchiCAD is a BIM application, which means that the software may be used to design and document a project, but also to enhance communication among all the project partners. The project is generally first built in 3D, and this virtual building generates 2D drawings and various calculations. This model also makes it possible to perform 3D rendering. It is possible to assign geometric 2D hatching named *fills* to the project to distinguish construction elements or to represent some areas that have specific characteristics. Although most parts of the modeling are built using virtual building elements, many 2D line commands are also available.

Design stage, users

ArchiCAD is mostly used by architects but, as a BIM technology, it allows easy exchanges with engineers. Architects start to build their BIM model at EDP and therefore use this ArchiCAD model in design, design evaluation, workview and modeling stages.

3D modeling

In ArchiCAD, the user builds a Virtual Building by using virtual building elements such as walls, slabs, columns, and more. ArchiCAD virtual building elements are entities with many editable parameters. A correctly modeled virtual building with minimal adjustments may be used to generate 2D drawings, 3D renderings and many different types of calculations [GRAPHISOFT, 2008c].

ArchiCAD 13 provides some new features for a more efficient design environment such as the oriented view. With this function, model elements appear perpendicular when working on them, and then restore the original orientation when done. Annotations are also fitted automatically to the final layout orientation angle [MacKenzie, 2009].

Rendering

The main focus of this software is not photo realistic imaging. However, two principal rendering tools are developed by Graphisoft and may be easily used with ArchiCAD: Virtual Building Explorer and

Artlantis. When these functions are installed, a new command *Export for [name of the tool]* appears in the ArchiCAD File menu, which allows different rendering options.

With Virtual Building Explorer, many view styles, such as Open-GL, shaded or Global Illumination may be combined with greyscale, hidden-line or edge-outlined presentation modes. A radiosity rendering engine is also available in order to produce more realistic visualization [GRAPHISOFT, 2009d]. Artlantis is a rendering application that is developed specifically for architects and designers. Artlantis Render generates high quality rendering and Artlantis Studio provides high quality rendering for QuickTime VR Panorama or animations. A large number of materials, parametric textures and 3D objects collections are available online for both Artlantis main versions [GRAPHISOFT, 2009e]. ArchiCAD also provides an integrated animation module.

Coordinates

ArchiCAD 2D drawing is performed according to x and y axes and 3D modeling is related to x, y and z axes. ArchiCAD uses the RHS.

Import/export

ArchiCAD supports up to AutoCAD 2009 files by using the .dxf/.dwg translator. Maps, layers, pen colors, fonts and blocks are preserved [GRAPHISOFT, 2009f]. With ArchiCAD 13, it is now possible to import viewport as embedded drawing and partial opening is enabled [MacKenzie, 2009]. Another new feature is the ability to merge all layout items and the model into a single .dwg file [Khemlani, 2009a]. The .pdf format is also supported to input as well as output. Many image formats are also supported such as .jpg, .psd or .tif.

Predecessor software, successor software

Since the .dwg format is universal in design and modeling, many CAD programs can be predecessor software to ArchiCAD. Graphisoft products are also successors or parallel software to ArchiCAD. For example, MEP Modeler is an extension to import, create and edit mechanical, electrical and plumbing networks, which can be coordinated with the ArchiCAD Virtual Building by using BIM technology [GRAPHISOFT, 2009g]; EcoDesigner works inside ArchiCAD to analyse the building's energy performance [GRAPHISOFT, 2009h]; Virtual Building Explorer and Artlantis may be used to achieve 3D rendering.

Moreover, ArchiCAD has a great interoperability due to the BIM technology and .ifc support. Via .ifc, many energy and structural applications may be successor software to ArchiCAD. For example, Scia Engineer, Tekla Structures, SAP2000, etc. are structural solutions software and Green building Studio, Energy Plus, ArchiPhysik, etc. are energy analysis programs that may be used with an ArchiCAD model.

BIM

ArchiCAD is the pioneer of BIM technology software. The last version has the potential to revolutionize collaboration based on BIM by allowing users to work together easily and quickly from anywhere where an Internet connection is available [Khemlani, 2009a]. ArchiCAD 13 is based on Graphisoft's new Delta Server synchronization. When a change is made to the model, only the changes are sent back to the shared file and forwarded to other users. This innovation seems to be very useful for design teams [MacKenzie, 2009]. ArchiCAD is the first BIM software to have this capability and the process is very fast because it is only the changes that are shared and not the entire model [Khemlani, 2009a]. This new file-sharing environment is called Teamwork 2.0. In this sharing system, each user has specific rights and these different permission levels can be customized. This level of control seems to be appreciated by model managers who work with a wide project team. Moreover, ArchiCAD 13 includes a new instant-messaging application [MacKenzie, 2009].

Actual solar calculation

In May 2009, Graphisoft unveiled its own analysis module, called EcoDesigner. Built into the ArchiCAD user interface and accessible through a single button, it quite literally is a single-click analysis program. Although not as comprehensive as Ecotect or IES, EcoDesigner provides ArchiCAD users with basic energy- and carbon-checking functions [Wong, 2010]. With Virtual Building Explorer, VBE, it is possible to set the sun altitude and azimuth. VBE provides different presentation modes such as shaded or global illumination. The function global illumination is produced by a radiosity rendering engine that calculates diffuse inter-reflections [GRAPHISOFT, 2009i].

With EcoDesigner, which works inside of ArchiCAD, architects can analyse the energy efficiency, energy balance, passive solar gains of their design at EDP [Khemlani, 2009b]. These energy analyses are performed based on location sensitive climate data and material thermal properties. This tool evaluates energy consumption as well as monthly energy balance based on the influence of the relationship between building volumes, orientation and dimensions of glazed surfaces and shading properties of the building. Geographical coordinates provided to EcoDesigner weather data, such as air temperature, solar radiance or wind speed, from an online database. The calculation is also based on some data that are defined by the user such as sun reflection, building type, internal heat gain profiles and openings [GRAPHISOFT, 2009h].

ArchiCAD BIM program also links with EnergyPlus, Green Building Studio, Ecotect, ArchiPhysik, and Riuska. Within ArchiCAD, it is possible to create zones and then export the simplified energy model into Ecotect using Green Building Studio's .gbXML format, where the energy analysis and solar design can be completed. From Ecotect, designers connect to other products like DOE-2, EnergyPlus, or other applications. ArchiCAD is referencing between objects within ArchiCAD to the objects within Ecotect, which means that the properties of a window or door have the same name in both applications.

2.2.3 AutoCAD*Supplier, site, contact, last version, cost*

AutoCAD is widely used software supplied by Autodesk running on Microsoft Windows. The last version is the AutoCAD 2010. The price is 3866 USD (2663 €) for one license of the 2010 version, but an upgrade from AutoCAD 2007, AutoCAD 2008 or AutoCAD 2009 can be bought from 461 USD (318 €) to 1389 USD (957 €). A trial version is also available for 30 days on the official Autodesk AutoCAD website [www.autodesk.com].

Functions

AutoCAD is a software for computer assisted drawing. Its principal functions are 2D and 3D drawing as well as 3D rendering. All 2D drawing commands such as line, circle, offset, etc., are available. AutoCAD also executes many measuring commands such as e.g. distance, area, scale or angle. Since the version AutoCAD Architecture 2009, the software can generate 2D sections and elevations directly from floor plans. These drawings maintain color, layers and all other properties attributed in the floor plans. If the original design changes, all generated sections and elevations are fully updated [Autodesk, 2008].

Design stage, users

AutoCAD is present along the whole design process. Architects, engineers and technical drawers use AutoCAD for concept design, construction design and also for the design of HVAC systems (MEP design). Building professionals may also use visualization since the software performs realistic 3D rendering.

3D modeling

There are three ways to model in AutoCAD. The first one is to create basic 3D shapes, also called solid primitives, such as boxes, cones, cylinders, spheres, wedges, pyramids and donuts. These shapes can be combined to create more complex solids by use of Boolean operations. The second way is to create 3D solids and surfaces from existing objects by employing different methods such as extruding objects, sweeping objects along a path, revolving objects around an axis, slicing a solid, lofting through a set of curves or converting planar objects with thickness into solids and surfaces. Moreover, it is now possible to simply push or pull faces, edges and vertices to model complex shapes. A function to smooth surfaces is also available. AutoCAD therefore allows creating and editing 3D shapes with the familiarity of 2D tools.

There are also many tools to navigate in the 3D model. For example, there are four different kinds of orbit tools: 3D Orbit, to move around a target, Constrained Orbit that constrains 3D orbit along a specific plane, Free Orbit, to move in any directions without references to the planes and Continuous Orbit. It is also possible to adjust the distance of the object, zoom and drag the view horizontally and vertically like in 2D view and simulate panning with a camera in a specific direction along the xy plane or z axis. The Steering Wheel, a tracking menu, combines many of the common navigation tools into a single interface.

The View Cube, which appears when the 3D graphic system is enabled, may also be used to navigate in the 3D model. The View Cube provides visual feedback of the current orientation of the model. When a point is moved or adjusted on the View Cube, the viewpoint of the model is automatically updated.

Rendering

With AutoCAD, it is possible to create realistic 2D images based on a 3D scene. Shades are calculated depending on lighting, materials and environmental settings. For example, it is possible to set a specific background, fog, to add a light and to set the surface's reflection. The renderer generates physically correct simulations of lighting effects, including ray-traced reflections and refractions, and global illumination. Some rendering presets are available and they are customizable. It is possible to create an animation with the ShowMotion module.

Coordinates

An AutoCAD 2D drawing is built according to x and y axes and 3D modeling is related to x, y and z axes. AutoCAD uses the RHS. In 2D drawings, there are two coordinate systems. The first one is a fixed system called the world coordinate system (WCS). The second one is a movable system called the user coordinate system (UCS). By default, both systems are coincident in the drawing. All objects are defined by their WCS coordinates, but it is usually more convenient to create an object based on the UCS. With the UCS, the user decides in which direction the different axes are. Usually, the user defines the UCS to make an intervention easier on the drawing.

Import/export

The principal import/export formats used with AutoCAD are .pdf documents and .jpg images. For example, it is possible to insert in the drawing any reference image. Metafile (.wmf) image format can also be imported in AutoCAD. It is also possible to import 2D/3D formats from other software such as MicroStation (.dgn), ACIS SAT (.sat) and 3ds Max (.3ds).

AutoCAD files may be exported in different file formats but the AutoCAD file extension (.dwg) is compatible with most other design and modeling software. With AutoCAD, it is possible to create a virtual EPS plotter to export the drawings in EPS file format (.eps).

Predecessor software, successor software

All Autodesk software may be used before and after AutoCAD, depending on their functions. The Autodesk family includes, for instance, Revit, 3ds Max and NavisWorks. Since the .dwg format is

almost universal in design and modeling software, all CAD packages may be predecessor software to AutoCAD. Moreover, any software that exports in .dwg, .dxf, .dwf or ACIS SAT (.sat) may be used before AutoCAD.

AutoCAD drawings may be used in conjunction with many calculation, simulation and estimation software because most of them support .dwg files. Other CAD applications or any graphic programs are successor software to AutoCAD.

BIM

Since AutoCAD 2009, it is possible to draw and document typical building elements such as walls, doors and windows. These components may be inserted and placed in the drawing with complete position control. For example, if a wall is moved, all connected walls and spaces are automatically updated [Autodesk, 2008]. This function is thus approaching BIM's definition but AutoCAD is not compatible with .ifc. Usually, this software is not used as a BIM application.

Actual solar calculation

In the rendering tools, there is a special light called “sun”, which simulates the effect of sunlight. This light source is similar to a distant light: the rays of the sun are parallel and have the same intensity at any distance. As default, this light has a yellowish hue. The angle of the sun is defined by the geographic location, which is specified and by the date and time of day. It is also possible to modify the intensity of the sun and the color of its light. In photometric mode, the sun color is disabled and the color is defined automatically based on the time, date, and location specified in the drawing.

The “sky” properties also influence light calculations. The option “sky illumination” adds extra light to the scene, simulating the effect of light through the atmosphere. The light cast from the atmosphere comes from all directions and, as default, this light has a bluish color.

2.2.4 Blender

Supplier, site, contact, last version, cost

Blender is a 3D graphics application developed by the Blender Foundation. The latest version is Blender 2.49a. Blender is a free software under the GNU General Public License, which means that users are free to share and modify the software (Free Software Foundation Inc., 1991). Blender can be downloaded on the official Blender web site [www.blender.org].

Functions

Blender's principal functions consist of 3D drawing and 3D rendering. Blender is also used to create animations, 3D video games and to perform video editing [Soler, 2009].

Design stage, users

Blender was first designed for infography. Main users are computer graphic specialists, but some architects, drafters and designers use Blender to create visualizations and animations. Some users may use the application for design work, but the primary use of Blender is at the modeling stage. Blender can be used for modeling, UV unwrapping, texturing, rigging, water simulations, skinning, animating, rendering, particle and other simulations, non-linear editing, compositing, and creating interactive 3D applications, including games.

3D modeling

3D modeling is one of the principal and most developed functions of Blender, and the application contains many 3D tools. It is possible to work with objects, meshes, curves, NURBS surfaces, text and meta objects which can be influenced by other objects. It is also possible to duplicate objects and use modeling scripts. The blender particle system can be used to simulate hair, grass, smoke and more. Moreover, two types of modifiers are available in Blender: deform modifiers, that only change

the shape of objects, and constructive modifiers that change mesh typology [BlenderWiki, 2009]. There are also smooth and soft selection editing tools for organic modeling.

Rendering

Many 3D rendering options related to lighting, material and texture settings are available in Blender. These various settings influence the renderings globally. With the use of a radiosity engine, the color of one object radiates onto another. Blender has an internal rendering engine, which is faster due to the use of many simplifying hypotheses. It is also possible to use an external rendering engine such as YafaRay. YafaRay is a free raytracer render engine which simulates the physical behaviour of light, instead of the Blender internal engine [BlenderWiki, 2009].

Coordinates

In Blender, 3D modeling is related to x, y and z axes. The RHS is used.

Import/export

There are many import/export options in Blender. The 2D formats supported are .tga, .jpg, .png, OpenEXR, .dpx, Cineon, Radiance .HDR, Iris, .sgi Movie, .iff, .avi and Quicktime .gif, .tif, .psd, .mov (Windows and Mac OS X). Blender can also read and write 3D formats such as .3ds, AC3D, COLLADA, .fbx Export, .dxf, Wavefront .obj, DEC Object File Format, DirectX, LightWave, .md2, Motion Capture, Nendo, OpenFlight, .ply, Pro Engineer, Radiosity, Raw Triangle, Softimage, .stl, TrueSpace, VideoScape, .wrl, .wrl97, .x3d Extensible 3D, xfig export [Blender Foundation, 2008].

Predecessor software, successor software

No information about software used prior to Blender is available, but we can suppose that every application that exports to one of the supported file formats may function as a predecessor software to Blender. Software that provide more rendering options than Blender may be used as successor software. Main successor software to Blender are: 3ds Max, V-Ray and YafaRay.

BIM

Blender does not provide direct BIM support.

Actual solar calculation

In the shading panel, there is a special lamp called “sun”. This lamp provides light of constant intensity emitted in a single direction. The direction can be changed by rotating the lamp. The intensity (energy) and the colors’ settings of the light source may be modified in the lamp panel [BlenderWiki, 2009]. Moreover, various settings for the appearance of the sun in the sky, and the atmosphere through which it shines, are available. For example, when the sun is high, the sky is blue, and when the sun is near the horizon, the sky is darker. These settings affect the model color and shading. However, these options are mainly focused on landscapes and not on buildings [BlenderWiki, 2009].

It is also possible to add a plugin named b/rad, which is a Blender based user interface for Radiance, a suite of programs for the analysis and visualization of lighting in design. This plugin is able to export Blender models to Radiance, both static models and animations, to make it easier to setup the simulation parameters, to calculate luminance/illuminance values on arbitrary grids, etc.

2.2.5 Bricscad

Supplier, site, contact, last version, cost

Bricscad is software supplied by Bricsys. It is a .dwg alternative CAD program that enables .dwg-based applications to serve markets of GIS, AEC, mechanical CAD, and civil engineering [Bricsys NV 2001-2010]. The last version is the Bricscad V10 Pro. The cost is 665 USD (463 €) for one

license (2010 version). An upgrade from Bricscad V10 Classic is available at the cost of 185 USD (129 €) and the price for an upgrade from the 2008 version is 125 USD (87 €). A trial version is also available on the official Bricsys website [www.bricsys.com].

Functions

Bricscad is software for computer assisted drawing which has the same interface as AutoCAD. Its principal function is 2D drawing but it also includes full ACIS modeling (3D) and rendering. All 2D-drawing commands such as line, circle, offset, etc., are available. Bricscad also executes many other commands such as e.g. distance, area, scale, offset, fillet, and trim. The Pro version includes eBridge now connecting to Vondle. eBridge and Vondle allow to manage, view, share, log all file versions of a CAD project. eBridge connects automatically with the Vondle servers and uploads the selected files. Files already on the server are checked automatically for modifications. Bricscad can be customized by adding custom programs written in any of several programming languages that run within Bricscad, including LISP, C/C++, VB/VBA/VB.NET.

Design stage, users

Similar to AutoCAD, Bricscad may be used through the whole design process. Architects, engineers, drafters, landscape architects, designers and manufacturers use it for EDP, architectural and structural design, product and part design and implementation design.

3D modeling

It is not possible to edit the model in the 3D view like in AutoCAD. There is no information available about 3D modeling in Bricscad.

Rendering

There is no information available about rendering in Bricscad.

Coordinates

The software drawing is performed according to x and y axes and 3D modeling is related to x, y and z axes.

Import/export

The principal output formats used with Bricscad are .pdf documents and .jpg images. It is also possible to export files in CAD format (.dwg, .dwt, .dxf), in vector format (.wmf, .emf) and in a raster format (.bmp). It is also possible to import 2D/3D formats from other software such as MicroStation (.dgn), ACIS SAT (.sat) and 3DStudio (.3ds) and all the AutoCAD formats. Bricscad is compatible with .dwg 2007 file format and supports .dwg versions 2.5 to 2009. Bricscad is also compatible ADS/SDS API and COM API.

Predecessor software, successor software

Since the .dwg format is universal in design and modeling software, all CAD packages can be predecessor software to Bricscad.

BIM

Bricscad does provide BIM support, but its compatibility with .ifc is unknown.

Actual solar calculation

There is no information about an actual solar calculation function in Bricscad. However, we can suppose that a kind of solar calculation is available because 3D rendering provides lighting and shading. However, nothing indicates that this calculation is based on physical laws. There are preset ambiances, so it is possible that the user may not be able to define parameters such as solar description, geographical location, date or time of the day.

2.2.6 Caddie

Supplier, site, contact, last version, cost

Caddie is a software supplied by the English company Advanced Computer Solutions (Europe) Limited. Originally designed by an architect, Caddie was initiated in 1985 as one of the first Computer Aided Design packages. The last version is the Caddie 10.1 build 6. Caddie is available in three versions. The full Professional version costs £1845 (2767 USD, 2040 €). The Budget version, which has limited functionality, costs £695 (1042 USD, 768 €). The Student version costs £85 (127 USD, 94 €). In addition to these, there is a photo-realistic rendering add-on package that costs £500 (750 USD, 553 €).

Functions

Caddie drawing uses the .dwg format for a seamless interface with other leading CAD systems, retaining drawings in their original form to make hassle-free collaborative working a reality. It is used for 2D drawings and 3D modeling. Caddie makes it possible to create a 3D building model, viewing the design from every angle and produce a set of plans, sections and elevations. The software also offers the possibility to create stairs, doors, windows and pre-calculated roofs [Caddiesoftware, 2008].

Design stage, users

Caddie provides users with multiple applications for architecture, civil engineering, surveying, digital terrain modeling, mechanical and steelwork. This software is used in concept design, architectural design, structural design, and modeling stages.

3D modeling

In Caddie, there are two ways to model. The first one consists of letting the user build a virtual building by using elements such as walls, roofs, floors, openings, ramps, curtain elements, columns, and more. These building elements are entities with editable parameters. The second way is to create 3D solids and surfaces from existing objects by employing different methods such as extruding objects, sweeping objects along a path, revolving objects around an axis, slicing a solid, lofting through a set of curves or converting planar objects with thickness into solids and surfaces.

Rendering

The rendering system of Caddie is named Caddie Vio. Caddie Vio provides architects and designers with the ideal way of creating high quality photorealistic renderings from the .dwg and .dxf models created in Caddie or other .dwg based CAD or modeling application. It is possible to create 2D images based on a 3D scene. Shades are calculated depending on lighting, materials and environmental settings. Caddie Vio offers a large library of pre-configured materials and textures including bricks, tiles, woods, glazing, textiles, stones and slates. It is also possible to use pre-configured and user-defined backgrounds and foregrounds [Caddiesoftware, 2008].

Import/export

Caddie supports .dxf and .dwf formats as well as it allows creating .pdf files.

Coordinates

Caddie 2D drawing is performed according to x and y axes and 3D modeling is related to x, y and z axes.

Predecessor software, successor software

There is no information available about system requirements in Caddie but any .dwg software may be predecessor software to Caddie.

BIM

Caddie BIM support is unknown. There is no information available about this feature on the official website. However, with applications for architecture, surveying, civil, terrain modeling, mechanical

and landscaping, Caddie Professional offers a one stop solution for multidisciplinary practices without the need to spend thousands on additional modules or extra software.

Actual solar calculation

Based upon the market leading “Lightworks” rendering engine which boasts over 2.5 million users worldwide, Caddie Vio provides even novice users with the means to produce stunning quality images of their designs. Caddie uses pre-configured artificial and natural lighting. The user has to choose whether, it is day or night, cloudy or clear; and if the lamp to use is a 60W bulb. The software also allows real time, real world sun and shadow studies to help with regard to sustainable development, impact under planning on surrounding properties and under the Right of Light Act. Other types of solar calculations e.g. passive solar gains, daylight utilization and PV and solar thermal installations are not possible with this program.

2.2.7 CATIA

Supplier, site, contact, last version, cost

CATIA is software supplied by the French company Dassault Systèmes. CATIA means Computer-Aided Three-dimensional Interactive Application. The last version is the CATIA V6R2010x. Users may choose the features they need and thus, the price depends on the chosen functional components. An educational license may be bought for 110 USD (81 €).

Functions

CATIA is a 3D application. Its principal functions are 2D sketching, 3D sketching, 3D modeling, 3D rendering and 3D animation. The last version allows multiple users to work on the same assembly simultaneously in the database. It is also possible to generate 2D drawings based on the 3D model. Drawing views can be created based on saved searches. This means that drawings could be made of parts containing, for example, a specified attribute or a certain size [Albert-Battaglin Consulting Group, 2008].

Design stage, users

CATIA supports multiple stages of product development, from conceptualization, design, manufacturing and engineering. This software is used mostly by engineers in many different areas, especially in the automotive and aerospace sector. It is also used in ship building, life sciences and construction fields.

3D modeling

3D modeling with CATIA is very intuitive. The users have the possibility to start modeling from scratch as well as from 2D sketching. It is also possible to sketch in 3D [Dassault systems, 2009]. CATIA V6 includes a new 3D modeling tool called CATIA Live Shape. CATIA Live Shape uses the 3D robot to easily create and modify complex geometries. The 3D robot looks like a coordinate system, which makes it possible to change its position and orientation. The CATIA Live Shape provides real-time feedback. Faces can be pushed and pulled, cut-outs or bosses and changes occur in real-time. A ruler can also be used to accurately locate and measure relative to desired geometric features [Albert-Battaglin Consulting Group, 2008].

Rendering

The standard rendering option included in CATIA V6 is a basic photo realistic rendering. CATIA includes three ambiances and a library of 209 materials. A total of 73 of these materials exhibit effects such as glass or car paint, which are linked to the material properties [Albert-Battaglin Consulting Group, 2008].

Coordinates

In CATIA, 3D modeling is related to the three Cartesian planes (xy, yz and xz).

Import/export

There is no information available about supported files in CATIA. However, it seems to support AutoCAD data (.dwg, .dxf).

Predecessor software, successor software

Since the .dwg format is universal in design and modeling, all CAD packages can be predecessor software to CATIA. Moreover, all Dassault Systèmes brands use a common database. This means that CATIA V6, DELMIA and SIMULIA all share the same V6 database. So, there is a great interoperability between all Dassault Systèmes products because the data created, for example, with CATIA, may be reused with other Dassault Systèmes software [Albert-Battaglin Consulting Group, 2008]. However, these software are more useful for industrial designers than architects because they provide information about the manufacturing process.

BIM

CATIA has support for BIM, and there is a great interoperability between all Dassault Systèmes products.

Actual solar calculation

There is no information about an actual solar calculation function in CATIA. However, we can assume that some kind of solar calculation is available because 3D rendering provides lighting and shading effects. However, nothing indicates that this calculation is based on physical laws. There are preset ambiances, so it is possible that the user may not be able to define parameters such as solar description, geographical location, date or time of the day. Other types of solar calculations e.g. passive solar gains, daylight utilization and PV and solar thermal installations are not possible with this program.

2.2.8 CINEMA 4D*Supplier, site, contact, last version, cost*

CINEMA 4D is software supplied by Maxon, part of the Nemetschek Group. The latest version is CINEMA 4D R11.5. The software is offered in various editions (architectural, broadcast, engineering edition) adapted to the user's work. The price is 2495 USD (2010 €) for the architectural edition, with an upgrade from CINEMA 4D R11 also available for 395 USD (318 €). The license includes CINEMA 4D, the advanced render and sketch and toon. It is also possible to download a 30 day trial version online [www.maxonshop.com].

Functions

CINEMA 4D is primarily used for its professional 3D animation tools. Its principal functions are 3D drawing, 3D rendering and animation. The software offers control over the textures with layers, filters and tablet support optimized for working in 3D. The material system provides control over the properties of the 3D objects. The software allows the user to define an object's color, diffusion, luminance, transparency, reflection, environment, fog, bump, alpha, specular, glow, displacement and illumination properties. It is also possible to paint on up to ten channels with a single stroke and customize almost every aspect of the interface. The following functions are also available: 3D painting, UV editing, animation, custom scripts and plugins [MAXON, 2010].

Design stage, users

CINEMA 4D is a design software for architects, products designers, mechanical engineers, illustrators and animators. CINEMA 4D is thus used at design, modeling and visualization stages.

3D modeling

The most basic shapes are provided as parametric primitives whose parameters like size, fillet and orientation are adjustable. Parametric objects can be used as they are or they can be converted to polygons to serve as a basis for more complex objects. A number of deformers and other generators can be used in conjunction with objects. Their non-linear construction history makes it easy to adjust items as the scene progresses. Splines can be used as the basis for extrudes, lofts, lathes and sweeps, all of which can be adjusted dynamically in real-time and even animated [MAXON, 2010].

Rendering

CINEMA 4D supports almost any broadcast or film application, with a maximum image size of 16,000 pixels square, and includes support for QuickTime, .psd, .tif and many other commonly used formats. CINEMA 4D's raytracer computes reflection, refraction and other high quality shading effects with ease. Adaptive and object-based antialiasing options save render time and eliminate artifacts. A variety of modes let the user adjust the antialiasing for broadcast, print or other mediums. CINEMA 4D also supports rendering in 32-bit per color channel, for HDR images in HDRI or OpenEXR format, with support for multiple processors, HyperThreading and Multicore technology. It is also possible to use CINEMA 4D's Multi-Pass rendering to increase control over the renders. This application lets the user render color, shadow, reflection and other effects to individual files for tweaking using the best compositing application [MAXON, 2010].

Coordinates

CINEMA 4D 3D modeling is performed according to x, y and z axes. The RHS is used.

Import/export

CINEMA 4D includes support for a host of industry-standard file formats. Images and movies in .psd, .tif, Targa, .jpg, QuickTime, .avi and other commonly used formats can be imported as textures or modeling templates, or used for final output. Support for vector formats extends to Illustrator import as well as Flash and EPS export. Assets can be exchanged with other 3D applications in .dxf, .3ds, .obj and other formats and entire scenes can be imported using LightWave 3D and .fbx formats.

Predecessor software, successor software

It is possible to import scenes from Allplan, Vectorworks and ArchiCAD by purchasing additional plugins. Windows users can even populate their scenes using Archvision's RPC format and extensive libraries of real people and objects. Scenes can be exported to the web using Macromedia's SW3D format and final renders can be exported directly to Adobe After Effects, Combustion, Final Cut Pro, Shake and NxN Alienbrain [MAXON, 2010].

BIM

CINEMA 4D does not provide direct support for BIM technology.

Actual solar calculation

Lighting in CINEMA 4D offers different types of light and shadow calculations. Parameters allow the user to adjust color, brightness, falloff and other properties. It is also possible to adjust the density and color of each light source's shadows and create visible or volumetric lights with noise patterns that appear in the light cone. A wide variety of options allow the user to create different lens flare effects. The sky in CINEMA 4D is rendered by using the luminance channel, which turns the material into a light source. The sky object encloses the entire scene spherically, and acts as a huge lamp which lights the torus from all sides [MAXON, 2010].

2.2.9 DDS-CAD

Supplier, site, contact, last version, cost

The DDS-CAD BIM/CAD-Software is supplied by Data Design System (DDS), a Norwegian company with German and Austrian subsidiaries. DDS has been developing software since 1984. DDS-CAD offers a range of products such as e.g. DDS-CAD MEP, DDS-CAD HVAC, DDS-CAD Electrical, DDS-CAD Plumbing, DDS-CAD PV. For example, the product DDS-CAD MEP is an advanced Building Information Modeling (BIM) tool for the design and documentation of electrical, HVAC and plumbing systems for buildings. The latest version of the stand-alone tool is DDS-CAD MEP 6.5. It is available in many different configurations. Users may choose the features they need and thus, the price depends on the chosen functional components. Therefore, the purchase price ranges between 2682 USD (1900 €) and 13 976 USD (9900 €). A free “DDS-CAD viewer” is available on the DDS web site [www.dds-cad.com].

Functions

As mentioned above, DDS-CAD is a BIM application for the design and documentation of architecture, electrical, HVAC and plumbing systems. With DDS-CAD MEP, users can work on their own, creating building models directly in the software, or work with 2D floor plans or 3D models imported from an architect or building designer. The software supports 2D floor plan imports in .dwg and .dxf formats, and is also certified for import and export of buildingSMART/.ifc data, either file based, or through direct connection to a Model Server.

DDS-CAD is a modeling system rather than just a 2D drafting package. Therefore, the model of the MEP systems created by the user drives the documentation output. As a result, there is no need to manually create individual drawings, schematics and other project documents. It is possible to generate multiple views from the model which form the exported drawings, schematics, schedules, visualizations and bills of quantity. Changes made in the model are automatically updated in all the documentation output. 3D rendering of the model design is possible in different ways; photo-realistic, hidden line view, semi-transparent walls, etc. In addition, multi-discipline collision detection and additional calculation and control functions make the designer’s work easier and quicker.

Design stage, users

DDS-CAD is used by planning offices, tradesmen, contractors, building managers, industrial enterprises and educational establishments. Being a BIM software, it may be used during the whole design process in the field of electrical, HVAC and plumbing design. It supports the user from the first concept design stage until the invoice is issued, in interaction with architectural BIM tools and back-office software applications.

3D modeling

The DDS-CAD user builds a 3D building model including all electrical, HVAC and plumbing components at a scale of 1:1. This model can be built by use of 3D building construction and installation elements such as walls, windows, cable containment, pipes, boilers, etc. The relevant parameters of these elements can be edited and adapted to suit the project. Once created, the building model is used as a basis for the various calculations such as heating loads, room volumes, bills of quantities, and many more. Furthermore, 2D drawings may be generated directly from the model.

Rendering

DDS-CAD offers a wide range of 3D rendering options and visualization modes. Lighting, textures and materials are editable and users may select their preferred presentation mode such as wireframe, greyscale, hidden-line, photo-realistic, isometric and more.

Coordinates

3D modeling is related to x, y and z axes. 2D drawing is related to x and y axes.

Import/export

DDS-CAD supports the following import/export formats:

- Import formats: .dxf, .dwg, .ifc (= .ifc 2x, 2x2 and 2x3), .bmp, .tif, .jpg, .gif, .png, .3ds, .pdf (external converter), .vdi 3805 format, .bdh format, DATANORM format.
- Export formats: .dxf, .dwg, .ifc (= .ifc 2x, 2x2 and 2x3), .dwf, .bmp, .tif, .wmf, .jpg, .3ds, .pdf, .wrl 2.0, and TrueSpace.

Predecessor software, successor software

The range of predecessor software results from the import options DDS-CAD provides. All applications which support an export in one of the DDS-CAD import formats may be used prior to DDS-CAD.

Main successor applications to DDS-CAD are back-office software applications to most of which DDS-CAD provides an interface. Furthermore, interfaces are available for the applications WSCAD (Electrical Automation CAD Software), Riuska (building energy simulation tool by O. Granlund), and the energy analysis software of ETU/Hottgenroth. Additionally, interoperability is ensured through supporting the .ifc format and by the dynamic implementation of BIM technology.

BIM

Data Design System used the phrase Building Information Model in printed brochures as early as 1985. The company has been closely involved in the buildingSMART organisation and development of the buildingSMART standards such as IDM (Information Delivery Manual) and Industry Foundation Classes (.ifc). As a corollary to this commitment, DDS consistently advocates the BIM technology.

Design with DDS-CAD means creating and dealing with realistic data models (i.e. information models) of buildings. All essential elements of the model (building components as well as included electrical, HVAC and plumbing systems) are equipped with additional data which are potentially valuable for the next design steps - either using DDS-CAD or a successor software application. DDS-CAD products have been certified by buildingSMART for the following versions of the Industry Foundation Class (.ifc): .ifc 2x, .ifc 2x2, .ifc 2x3.

Actual solar calculation

In DDS-CAD PV, it is possible to initiate comprehensive calculations and simulations at once, resulting in significant time savings. With help from various additional calculation modules, U-Value, energy calculations, energy simulations, cooling loads and ventilation can be efficiently calculated with a few mouse clicks. There are also, of course, specialized modules for electrical, plumbing and HVAC available. The results can be simply, comprehensively and graphically simulated and validated, before work starts on site. Moreover, solar and photovoltaic equipment can be efficiently planned, modelled and calculated. With DDS-CAD PV, the user can also photo-realistically represent the solar energy incident on the building, including the shadows cast by shading objects. In EDP, it can quickly be established whether a proposed solar energy system can be practically realized. The solar shading analysis can be run as a single static image or animated as a movie sequence. There are two animated versions available: one can simulate Sun/Shading at different times during the year as an aligned sequence of images. However, the software can also simulate the course of continuous sun in any arbitrary selectable period.

The design possibilities are almost unlimited: roof areas can be freely drawn in DDS-CAD PV, allowing all roof shapes to be planned. DDS-CAD PV is also suitable for the placement of solar energy systems in open spaces. The location of the solar plant on the latitude and longitude of the site is the basis for the exact sun position information in the project. The solar modules can be placed in any position on the site or attached to the building structure. The mountings for the solar modules can

also be created. For the preparation of plant layouts, and schematic diagrams for photovoltaic projects, a separate work area is available in DDS-CAD PV.

Since mid-2009, DDS has partnered with Vela Solaris in the solar energy calculation sector. The company makes the Polysun functionality available through the interface of DDS-CAD PV, thus providing a one-tool combination. The Polysun plugin by Vela Solaris provides the following main functionality: photovoltaic calculation, automatic inverter assignment, comprehensive module and inverter database (see also the description of Polysun).

2.2.10 Digital Project

Supplier, site, contact, last version, cost

Digital Project is software supplied by Gehry Technologies, which is owned by the architect Frank Gehry. Digital Project is based on CATIA V.5, which means that Gehry Technology made changes to CATIA to create a new visual interface suitable for architectural work. So, Digital Project uses CATIA as a core engine. The last version is the Digital Project V1 R4. There is no information about the price of a professional license of this last version, but the cost for an academic license is 200 USD (142 €) per year.

Functions

Digital Project products are used for 3D modeling and 3D rendering. Digital Project allows teams to design complex projects in a single 3D environment, and produce documents, such as plans, elevations, sections, detail drawings, notes, bills of materials and spreadsheets for quantity take-offs, directly from the 3D model. It is possible to add dimensions and annotations to the generated drawings.

Design stage, users

Digital Project is a high-performance modeling tool for architects, designers, engineers and contractors. Architects start to build their BIM model at EDP. So, they use this software in early design, architectural design, structural design, and modeling stage.

3D modeling

There are many modeling tools available in Digital Project. It is possible to create free-style surface modeling (NURBS), geometric modeling from wireframe, surface modeling based on solid geometry and parametric 3D surface and solids modeling [Gehry Technologies, 2009].

Rendering

Gehry Technologies offer two advanced rendering add-on products for Digital Project: Photo Studio and Photo Studio Optimizer. Photo Studio generates high-quality, photo-realistic images and movies of projects in 3D. Its ray-tracing technology provides real shadow calculation and reflection effects. Photo Studio Optimizer extends Photo Studio capabilities with 3D advanced rendering technologies such as global illumination and caustics which produce more accurate reflections and refractions. Photo Studio Optimizer improves realism with advanced material definitions [Gehry Technologies, 2009].

Coordinates

Digital Project 2D drawing is performed according to x and y axes and 3D modeling is related to x, y and z axes.

Import/export

They are many import/export options in Digital Project. General import/export formats are AutoCAD data (.dxf, .dwg), Steel Detailing Neutral Format (.sdnf), Initial Graphic Exchange Standard format (.igs), HOOPS Stream Files (.hsf), Industry Foundation Classes (.ifc), and the 3D .xml Format.

Predecessor software, successor software

Since the .dwg format is universal in design and modeling, all CAD packages can be predecessor software to Digital Project. Because it supports industry-standard formats, such as .ifc, this software has a great interoperability with other applications.

BIM

In Digital Project, any information required for the project has a place in the 3D environment, from geometric definitions to installation methods. Drawings produced in Digital Project are a snapshot of the model, like a report that is automatically updated when the design changes, reducing the risk of uncoordinated design information. Digital Project introduces the concept of Dictionaries and Attributes to assign non-geometric information to the 3D model such as material finish, cost codes, resources, schedule information and more [gtwiki, 2006]. Digital Project supports .ifc, which makes communication easier with partners.

Actual solar calculation

The Solar Render Tool allows easily investigating the impacts of sunlight on the project. This tool uses the Digital Project Photo Studio work bench and rendering tools. Users have to select a view which will be rendered, run the tool and enter the appropriate information in Longitude, Latitude, Year, Month, Day, Hour and Minutes boxes. It is also possible to render scenes using the same tool. When users ask to render a scene, a new default blue spherical environment is created, and then a directional light is placed where the sun would be and a new shooting is set up [gtwiki, 2006].

2.2.11 form•Z*Supplier, site, contact, last version, cost*

form•Z is a software supplied by AutoDesSys. The last version is form•Z 6.6, which is available at the cost of 1295 USD (1056 €) for one license (Version 6.6). A demo version is also available on the official form•Z website [www.formz.com]. This demo version does not support printing, saving and exporting.

Functions

form•Z is a computer-aided design tool. Its principal functions are 3D drawing, 3D rendering and animation. The 2D drafting module is an integral part of the whole system. Even though form•Z offers drafting tools to work directly in 2D, it is also possible to extract accurate reference drawings, such as plans, elevations, sections, isometric or perspective views, from the 3D model. These drawings may be refined in the drafting module, by changing the weights and the styles of the lines, by annotating them and by dimensioning and hatching them. form•Z also features unlimited layers that can be hierarchically structured in both modeling and drafting, using imperial or metric units [Yessios et al, 2008].

Design stage, users

form•Z is a design software for architects, products designers, mechanical engineers, illustrators and animators. form•Z is thus used at design, modeling and visualization stages.

3D modeling

As well as extracting 2D drawings from the 3D model, form•Z allows 2D drawings created in the drafting module to be transported into the modeling environment to become the basis of the 3D models. Moreover, it is possible to generate primitive forms, such as cubes, spheres or cones. Users can also create 2D surfaces and 3D solids by drawing shapes such as rectangles, polygons, circles, ellipses, points, segments, arcs or vector lines. form•Z allows the creation of 3D solids from existing objects by employing different tools such as parallel extrusions, extrusions to point (convergences), revolutions, multi-path skins, etc. Users can apply Boolean operations, including union, intersection

and difference. It is also possible to generate 3D terrain model from 2D contour lines and sites [Yessios et al, 2008].

Rendering

form•Z offers many rendering modes such as smooth shaded surfaces, shadows, transparency and more. In addition, form•Z RenderZone Plus offers advanced rendering and lighting effects and photorealistic rendering. This is based on advanced Global Illumination techniques such as final gather, ambient occlusion and radiosity [Yessios et al, 2008]. form•Z also provides an integrated animation module.

Coordinates

In form•Z, 3D modeling is performed according to x, y and z axes and the RHS is used. form•Z also provides a 2D module for drawings.

Import/export

There are many import/export options in form•Z. Supported formats are .sat, Artlantis, .bmp, DAE, DEM Data, .dwg, .dxf, .eps, FACT, .gif, HPGL, .igs, Illustrator, .jpg, .kmz, LightWave, Lightscape, .obj, .pdf, PICT, Piranesi, .png, QTVR, RIB, .sgi, .skp, .stp, .stl, .tga, .tif, .zpr.

Predecessor software, successor software

Since the .dwg format is universal in design and modeling, all CAD packages can be predecessor software to form•Z. Moreover, any software that exports in the file formats listed above can be used before form•Z.

BIM

form•Z does provide BIM support. It has .stp (step) import/export capability but not for .ifc format.

Actual solar calculation

form•Z automatically creates one distant light which is designated as the sun. Distant light emits parallel rays from an infinitely distant light source. It is possible to define the position of the sun by specifying the sun's altitude and azimuth or by selecting the geographic position of the site and the month, day and time of the desired solar position [Yessios et al, 2008].

2.2.12 Google SketchUp

Supplier, site, contact, last version, cost

Google SketchUp is a software supplied by Google. The last version is the Google SketchUp Pro 7. The price is 495 USD (399 €) for one license of Google SketchUp Pro 7. A trial version of Google SketchUp Pro 7 is available for eight hours on the official Google SketchUp website [sketchup.google.com]. A free version, which includes fewer functions than the Pro version, is also available on the website.

Functions

Google SketchUp Pro is a modeling software. Its principal functions are 3D modeling, 3D rendering and animation. It also includes several functions for 2D drawing. In addition to major drawing tools available, Google SketchUp offers some construction tools such as a tape measure tool, guide lines, dimension tool and section plane tool [Google, 2009a]. Moreover, Google offers a suite of applications related to Google SketchUp to increase its functionality, such as LayOut, to create documents and presentations, and Style Builder, to create custom and sketchy-edges styles for SketchUp [Google, 2009b].

Design stage, users

Google SketchUp Pro 7 is suitable for architects, civil engineers, and drafters. Google SketchUp Pro is generally used at early design, modeling and visualization stages.

3D modeling

In Google SketchUp Pro 7, the main way to model is to create 3D solids and surfaces from existing 2D objects by employing different tools such as Push/Pull tool, Offset Tool, and methods such as extruding a face along a single path or intersecting with the model. The principal drawing tools are line, arc, freehand (to create curves), rectangle, circle and polygon. Moreover, the Sandbox tool allows the creation of a triangulated surface (i.e. a site model) from contour lines. With SketchUp Pro 7, users can add intelligent attributes, relationships and behaviors to any component. These are called Dynamic Components, and Google SketchUp Pro 7 offers pre-defined Dynamic Components. It is also possible to download free models and Dynamic Components from a huge online library of models called the Google 3D Warehouse [Google, 2009a].

Rendering

Google SketchUp makes it possible to build “rendered” images, apply materials and create custom styles and add shadows, but the software cannot generate a photorealistic effect. However, many photorealistic rendering engines are compatible with SketchUp, such as V-Ray, Podium, LightUp for SketchUp, Indigo Renderer, Twilight Render and more [Google, 2009a].

Coordinates

Google SketchUp Pro 7 2D drawing is performed according to x and y axes and 3D modeling is related to x, y and z axes. Google SketchUp Pro 7 uses the RHS.

Import/export

Google SketchUp Pro 7 can import 2D files as well as 3D files. Supported 2D formats for importing are .jpg, Portable Network Graphics (.png), Tagged Image File (.tif) and Targa File (.tga). Supported 3D formats for importing are Google Earth terrain, 3ds Max files (.3ds), AutoCAD files (.dwg, .dxf) and DEM files (.dem, .ddf).

The available export 2D formats are .jpg, Portable Network Graphics (.png), Tagged Image File (.tif), Windows Bitmap (.bmp), .pdf files (.pdf), Encapsulated PostScript Format (.eps), Epix files (.epx) and AutoCAD files (.dwg, .dxf). It is also possible to export 3D files in those following formats: Google Earth format (.kmz), 3ds Max files (.3ds), AutoCAD files (.dwg, .dxf), COLLADA format (.dae), .fbx format (.fbx), OBJ format (.obj), XSI format (.xsi) and .wrl format (.vrm). Users may also export animations and walkthroughs as .mov with the Mac version, or export .avi files from the Windows version [Google, 2009a].

Predecessor software, successor software

Since the .dwg format is almost universal in design and modeling software, all CAD packages can be predecessor software to Google SketchUp. Moreover, any software that exports in the file formats listed above can be used before Google SketchUp.

Google SketchUp models may be rendered with an external rendering engine such as 3DPaintBrush, Artlantis, Maxwell Render, and SU2KT. These are successor software to Google SketchUp. Some plugins are also available for analysis tools such as IES VE, EnergyPlus OpenStudio and Greenspace Research’s Demeter [Google, 2009b]. IES remains an independent analysis software provider, operating under the guidance of its founder, Don McLean. His desire to make analysis software that is easier to learn and use led to the distribution of IES VE-Ware, a free analysis module compatible with Google SketchUp, and Autodesk Revit. Using Google SketchUp and IES VE-Ware, users can conduct basic building energy analyses — carbon emissions, energy consumption, and regulatory compliance — at no cost [Wong, 2010].

BIM

Google SketchUp Pro 7 does not offer direct support for BIM.

Actual solar calculation

The Google SketchUp shadows' feature is designed to give the user a general idea of how the sun and shadows affect the model during a day and throughout the year. The calculations are based on the location (latitude and longitude), directional orientation of the model, and an associated time zone. It is possible to use Google Earth to manually set the location and the directional orientation of the model. It is also possible to select the appropriate country and city directly in Google SketchUp [Google, 2009a]. In addition, Google SketchUp provides basic animation capabilities, such as travelling and solar animation.

Google SketchUp recently integrated a plugin called IES VE-Ware, which is a powerful simulation engine. Using Google SketchUp and IES VE-Ware, users can conduct basic building energy analyses- carbon emissions, energy consumption, and regulatory compliances-at no cost [Wong, 2010]. The IES VE-Ware plugin is also compatible with Autodesk Revit.

Google SketchUp also integrates OpenStudio, a free plugin for the Google SketchUp 3D drawing program. This plugin makes it easy to create and edit the building geometry in the EnergyPlus input files. The plugin also allows launching EnergyPlus simulations and viewing the results without leaving SketchUp. OpenStudio was created by the National Renewable Energy Laboratory for the U.S. Department of Energy.

Google SketchUp also integrates a Demeter, a plugin for SketchUp developed by Greenspace Research, a commercial division of Lews Castle College in Scotland. The plugin allows performing an energy analysis on a SketchUp design by adding attributes to the geometry and then connecting it to Green Building Studio's web service, or other analysis applications that import .gbXML. With the plugin, SketchUp is able to both import and export .gbXML files [Google SketchUp, 2010 <http://sketchup.google.com/green/analysis.html>].

2.2.13 Houdini*Supplier, site, contact, last version, cost*

Houdini is supplied by Side Effects Software (Toronto, Ontario). The program's website is [www.sidefx.com]. The last version is called Houdini 10. This version is available for Mac OS X, Windows and Linux and a trial version can be downloaded for free as part of the Houdini Apprentice Program. Artists who want to work on personal projects without render watermarks can also purchase Houdini Apprentice HD for 99 USD (78 €). The cost of the programs Houdini Escape and Houdini Master ranges from around 1995 USD (1580 €) to 7995 USD (6333 €) for a workstation license only.

Functions

Houdini is used for visual effects and character animation. Houdini 10 is the first commercially available software to slice up and distribute fluid simulations over a network of computers. 3D artists benefit from faster simulation times and the ability to create super-sized and scaled simulations.

Houdini uses a non-standard interface called a "NODE system". It has a hybrid micropolygon-raytracer renderer, Mantra, but it also has built-in support for commercial renderers like Pixar's RenderMan and mental ray®.

Design stage, users

Although it may be used by architects to create special shapes or effects, Houdini is developed especially for 3D artists, visual effect artists and the film industry.

3D modeling

Houdini's modeling tools can be used by modelers to create characters, sets and props or by visual effects artists to give particles and fluids shape and form. For traditional modelers, Houdini provides a robust set of tools that work with a wide variety of geometry types. For visual effects artists, Houdini's node-based workflow makes it easy to set up surfaces that are generated on the fly based on an underlying effect.

Rendering

Houdini is bundled with a production-class renderer, Mantra, which has many similarities to photorealistic RenderMan in its scope and application. Micropolygon rendering is supported, allowing high-quality displacement operations as well as traditional scan-line and raytracing modes. Shaders are scriptable and composed in their VEX language, or by using VOPs; their node-based interface to programming VEX. Mantra (as does Houdini itself) also supports point-clouds, which can be similar in application as brickmaps in RenderMan. This allows more complicated light interactions, such as sub-surface scattering and ambient occlusion, to be produced with lower computational overhead. Mantra can perform extremely fast volume rendering, and also physically based rendering - a technique which attempts to more accurately model the interactions of light.

Coordinates

Houdini is a 3D program. In Houdini, each of decision is recorded as a node that is wired up to other nodes. The resulting network provides a blueprint of the creative process and a framework for making revisions.

Import/export

There are four categories of available file formats in Houdini: Image formats, Geometry formats, Scene description formats (for renderers) and Chanel/audio formats. In Houdini, there are *External* formats that are supported via a standalone converter links to Houdini, and *Internal* that are built into Houdini. As an open-environment, Houdini also allows writing a custom importer/exporter. Many *Internal* images file formats are supported, such as the Houdin picture format (.pic), Random Access Texture maps (.rat), JPEG images (.jpg), TIFF images (.tif), and more. Main geometry *Internal* file formats supported are the Houdini ASCII geometry format (.geo), Houdini binary geometry format (.bgeo), Renderman geometry (.rib), PRISMSASCII format, binary format and move/draw format (.poly, bpoly, .d). For rendering, Houdini can export in Mantra Instantaneous Frame Description format(.ifd), and into Pixar's RenderMan byte stream format (.rib).

Houdini also imports the Autodesk FBX open-standard 3D file format, Collada files, and many files from the Torque Game Engine. These formats work directly inside Houdini via a plug-in.

Scripting

Houdini is an open environment, which supports a variety of scripting APIs. Python is increasingly the scripting language of choice for the package, and is intended to substitute its original CShell-like scripting language, Hscript. However, any major scripting language which support socket communication can interface with Houdini.

Predecessor software, successor software

Since Houdini allows reading and writing a wide range of files format, any software that exports in the file formats listed above can be used as predecessor or successor software to Houdini. Moreover, since Houdini is an open environment which allows creating customs importer/exporter, almost every file format may be supported by Houdini.

Houdini supports many renderers such as RenderMan, mental ray[®], Maxwell Render, AIR, 3Delight, and Sunflow. So, all these software may be used as successor software to Houdini.

BIM

Houdini is not a BIM application.

Actual solar calculation

Houdini allows performing physically based rendering - a technique which attempts to more accurately model the interactions of light so natural lighting effects can be modeled. However, the program does not allow to calculate passive solar gains or to size active solar systems.

2.2.14 IntelliPlus Architecturals

Supplier, site, contact, last version, cost

IntelliPlus Architecturals is software supplied by Data Prompt Technologies (DP Tech). This software is based on IntelliCAD technology, which emulates the basic interface and functions of AutoCAD. The last version is called IntelliPlus Architecturals V7, which is available at a cost of 2101 USD (1490 €). A trial version is also available on the official IntelliPlus Architecturals website [www.dp-cad.com].

Functions

IntelliPlus Architecturals is software for computer assisted drawing. Its principal functions are 2D and 3D drawing as well as 3D rendering. This software has a lot of commands similar to AutoCAD. All 2D-drawing commands such as line, circle, offset, polyline, and more are available. Many dimension tools are also available such as automatic dimension which automatically updates dimensions when the drawing is modified. The software can generate 2D plans, sections and elevations directly from the 3D model of the project. The interface of IntelliPlus Architecturals is similar to that of AutoCAD.

Design stage, users

Similar to AutoCAD, IntelliPlus Architecturals may be used through the whole design process. Architects, engineers, drafters and designers use IntelliPlus Architecturals for early design, architectural and structural design and implementation design.

3D modeling

In IntelliPlus Architecturals, the work in 3D is easier than in AutoCAD. It offers almost all the possibilities of Google SketchUp, while being better adapted to .dwg format. The software allows to work simultaneously in 2D and in 3D. There is also a large objects library which contains 3D objects such as windows, doors, stairs, roofs and more. These objects are “parametrics”, which means they have their own characteristics. When they are moved or stretched, these objects are adjusted automatically together with objects that are linked to them.

Rendering

The Photoidea menu allows creating photorealistic 2D images based on a 3D scene. It is possible to set a specific background, e.g. to add textures and lights and to determine the reflection of surfaces. There is also the possibility of inserting pictures of the site.

Coordinates

IntelliPlus Architecturals 2D drawing is performed according to x and y axes and 3D modeling is related to x, y and z axes. The RHS is used in this program.

Import/export

IntelliPlus Architecturals uses the .dwg format as native file format, which means that it reads and writes any files in this format without import or export conversion, and so, without lost data. Similar to AutoCAD, IntelliPlus Architecturals is friendly with .dxf files, .dwf files and .dwt files.

Predecessor software, successor software

Since the .dwg format is universal in design and modeling, all CAD packages may be predecessor software to IntelliPlus Architecturals. Moreover, there is a great interoperability with other Intelli Plus software such as Intelli Plus Electricity, Intelli Plus Pro Simulation (for structural calculations), Intelli Plus Premium and more.

BIM

IntelliPlus Architecturals has support for BIM, but its compatibility with .ifc is unknown.

Actual solar calculation

With IntelliPlus Architecturals, 3D rendered images are created according to the position of the sun, based on the time of day and geographic location of the project.

2.2.15 Lightworks*Supplier, site, contact, last version, cost*

Lightworks is software supplied and developed by LightWork Design. The last version is the Lightworks author 8.2. This software toolkit for producing advanced photorealistic images from 3D geometry is now integrated in over 80 Computer Graphics applications.

Functions

Lightworks is a high-performance rendering tool to Computer Graphics applications. This software is designed from the start to be integrated into many modeling systems. It lets users render images quickly and accurately, even during the design process.

Design stage, users

Lightworks provides photorealistic rendered images for the architectural, industrial and interior design markets. Lightworks can be used by architects, designers, engineers and visualization specialists. Lightworks is mainly used to generate photorealistic 2D images. It may be used at modeling and rendering stages, but because it is fully integrated into many software and it offers real-time rendering, it is used at EDP.

3D modeling

Lightworks is not a modeling tool. It only allows applying real-world materials on existing models. However, because Lightworks is totally integrated into the modeling application workflow, it provides the ability to make quick and easy revisions.

Rendering

Lightworks provides a wide range of high-end rendering functionalities. This software includes the ability to create a photorealistic or a sketch style image. It contains the latest technology in rendering techniques and algorithms, including radiosity, global illumination, ambient occlusion, final gather and ray tracing. The last release provides new developments for real-time rendering. For example, it includes a new progressive photorealistic rendering style which provides an early preview of materials and lighting.

Coordinates

Lightworks is created to be fully integrated into many modeling applications. Therefore, this software uses the coordinate system of the software in which it is integrated.

Import/export

There is no information about import/export functionalities in Lightworks. However, since this software is fully integrated into other computer applications, we can suppose that it has the same import/export possibilities that the software in which it is installed.

Predecessor software, successor software

Since Lightworks is designed to be a part of other software, we can suppose that most CAD or modeling applications can be predecessor software to Lightworks.

BIM

Lightworks is not compatible with .ifc. Consequently, this software is not used as BIM. However, because it is integrated in over 80 computer applications, it is possible that Lightworks be included into a BIM application.

Actual solar calculation

Lightworks rendering engine is based on algorithms which simulates the real behavior of natural light. However, there is no information about other specific functionalities related to solar calculation.

2.2.16 Maya*Supplier, site, contact, version, cost*

Maya is a 3D graphics application developed by Autodesk. The latest version is Maya 2010. The cost is 3495 USD (2817 €) for one license (2010 version). A trial version is available for 30 days on the official Autodesk Maya website [www.autodesk.com].

Functions

Maya's principal functions are 3D modeling and 3D rendering. The software can also be used to create animations, and television visual effects [Autodesk, 2009a].

Design stage, users

The main users of Maya are computer graphics specialists and designers in the film, TV and computer and video games industries. Some architects use Maya to explore, validate and convey their design. Some users may use it for design, but generally Maya is used at the modeling, visualization and animation stages [Autodesk, 2009a].

3D modeling

There are three main ways to model a project in Maya: NURBS, polygons and subdivision surfaces. Polygons are widely used due to their stability and functionality. Polygons also form the bridge between NURBS and subdivision surfaces. The polygon modeling includes a complete set of editing tools such as cut, bevel, extrude, extrude along a curve, and more. NURBS are used mainly for their ready-smooth appearance. NURBS construction tools include lofting, extrusion, trim, offset, Boolean operations and more. They can also be used to create polygon meshes. Subdivision surfaces are a combination of NURBS and polygons. They are smooth and can be manipulated like polygons [Autodesk, 2009a].

Rendering

Maya uses a rendering engine called mental ray[®] 3.7+. The engine provides photorealistic lighting features, such as global illumination, caustic, ambient occlusion, blurry reflections and refraction and motion-blurred particles. Image-based lighting is also available. There are some rendering presets, including physically accurate sun and sky, a set of architectural shades for hard-to-realize materials, and more [Autodesk, 2009a].

Many popular computer-animated films have been made with Maya software, including Ice Age (film series), its sequel Ice Age: The Meltdown, Geng: The Adventure Begins, Monsters vs. Aliens, James Cameron's Avatar, and others.

Coordinates

Maya 2D drawing is performed according to x and y axes and 3D modeling is related to x, y and z axes. Maya uses the RHS.

Import/export

Maya supports many geometry and scene formats such as AliasWire files, .igs files, .dxf format, .obj file, .wrl2 file, QuickTime format (.mov), GE2, Maya 3D Scene date (.rtg), OpenFlight format, RIB format and Open Inventor 2 files. Maya can also export to the rendering software mental ray[®]. Moreover, Maya supports the Autodesk .fbx data exchange technology which provides a great interoperability with 3D Studio MAX and MotionBuilder.

Predecessor software, successor software

Maya is designed for a great interoperability with many software used by designers and computer specialists. For example, Maya helps to minimize errors and reduce iterations when users paint textures in Photoshop, compose a shot with Maya Composite or Autodesk Flame, or animate characters in Autodesk MotionBuilder. Moreover, some users use 3ds Max to render Maya models [Autodesk, 2009e].

BIM

Autodesk Maya do not provide direct support for BIM technology. However, Maya, with its powerful modeling tool sets is often used as a complement of the building information modeling workflow during conceptualization [Autodesk, 2009a].

Actual solar calculation

In Maya, a directional light is used to emulate the sun because the sun is infinitely far away and its scale and translation are irrelevant. Only the direction in which the light is pointing is important [Autodesk, 2010].

2.2.17 MicroStation*Supplier, site, contact, last version, cost*

MicroStation is a software supplied by Bentley Systems, Incorporated. It is an advanced, yet intuitive and easy-to-use architectural building information modeling (BIM) application that empowers architects and designers to create with unlimited freedom. The last version is the MicroStation V8i, which is part of the large V8i Bentley's software suite. The V8i software suite includes 148 products. The price is 3800 USD (2696 €) for one license (2009 version). The last version of this software is available for Windows operating systems only.

Functions

MicroStation is a CAD software for 2D and 3D design and drafting and 3D rendering. MicroStation provides CAD standard drawing and management functions [Bentley Systems Incorporated, 2009a].

Some applications such as MicroStation Development Language or Visual Basic for Applications may be used to create extensions that can be used with MicroStation to add to its functionality. For example, some extensions allow obtaining accurate material lists for every item in the design, to sequence schedule for construction or check for interference between objects [Wikipedia, 2009a].

Design stage, users

As a BIM technology, MicroStation is used along the whole design process, from EDP to structural design. It is mostly used by architects and engineers but also by town planners, contractors and GIS professionals.

3D modeling

MicroStation allows creating curves, surface, mesh and more in 3D. Many tools are available to create and modify 3D geometry. For example, users can push, pull, drag, cut and extrude 3D geometries. When the model is created, it is possible to define relationships between geometries and create parametric forms by using the Generative Components. Generative Components allow a quick exploration of different alternatives for complex building by capturing and exploiting the critical relationship between design intent and geometry [Bentley Systems Incorporated, 2009b].

Rendering

MicroStation V8i includes the Luxology rendering engine to provide fast photo-realistic design visualizations. The rendering process is near real-time. Luxology allows delivering TV and film quality renderings and animations from 3D models. The rendering engine uses pre-configured settings for lighting and textures [Bentley Systems Incorporated, 2009a].

Coordinates

A MicroStation 2D drawing is built according to x and y axes and 3D modeling is related to x, y and z axes. MicroStation uses the RHS. The last version has an intrinsic geo-coordination that lets users coordinate information spatially from many sources using common coordinate systems. The geo-coordination approach fully embraces all types of GIS information. This function reduces the risk of errors on a site caused by poorly coordinated data and save time when coordinating data from various sources [Bentley Systems Incorporated, 2009b].

Import/export

MicroStation supports (input and output) a variety of standard CAD formats such as AutoCAD files (.dwg, .dxf). Google SketchUp data (.skp), Google Earth data (.kml), Rhino format (.3dm), .pdf, .ifc and Revit data (.rvt, .rft, .rfa) may also be imported in MicroStation. The export formats are generally the same as import, but it is also possible to export images (.jpg, .bmp), animations (.avi), 3D web pages in Virtual Reality Modeling Language (.vrm).

Predecessor software, successor software

MicroStation has a great interoperability with all the 148 software in the V8i suite. So, all V8i software may be used before and after MicroStation, depending on their functions. Moreover, since the .dwg format is universal in design and modeling, many CAD programs can be predecessor software to MicroStation. Any software that exports in a supported format (see Import/export section) may be used before MicroStation.

BIM

As a BIM technology, MicroStation supports collaboration and communication between design partners. The information about the building is shared by using the .ifc format.

Actual solar calculation

When rendering a view, users can use the Light Manager tool to define settings for Global Lighting. There are four different types of light: ambient, flashbulb, solar and sky light. Solar light simulates light from the sun. Users can define the direction of North in the model as well as specify a location and a time for solar lighting. The sky light is a directional light coming from each direction of an imaginary sky hemisphere. This light is used to add atmospheric lighting from the sky. Moreover, the Solar Study utility is used to create a sequence of images which shows the location of shadows cast by the sun over a period of time.

In June 2008, MicroStation struck an agreement with Environment Design Solutions Ltd (EDSL) securing exclusive worldwide rights to distribute EDSL's Tas, a full-featured analysis software suite intended for complex building systems and large projects [Wong, 2010]. Bentley Tas Simulator V8i, included in the Bentley V8i suite, is a simulation tool that provides dynamic thermal simulations. This software provides information about energy consumption, CO2 emissions, operating costs and

occupant comfort. It can also evaluate a wide range of passive design features. Bentley Tas Simulator V8i is based on a custom-designed simulation engine and is the high-speed performer for complex buildings. Bentley Tas Simulator V8i also shines at evaluating a wide range of passive design features such as operable windows and other types of passive ventilation. Bentley Tas Simulator V8i is used extensively in the United Kingdom for compliance checking with Part L of the building code, and can also be used with ASHRAE 90.1 and LEED in the US. Bentley Tas Simulator V8i is targeted at engineers, architects, and energy assessors who want a tool that is robust and productive. Bentley Tas Simulator V8i gives building professionals three tools in one package: a design tool, a compliance tool, an FM tool, as well as the ability to import .gbXML from Bentley Architecture, Bentley Building Mechanical Systems and Bentley speedikon Architectural. In addition, the software's direct data exchange between Bentley Tas Simulator V8i and Hevacomp Mechanical Designer V8i is possible, and it has a robust and comprehensive passive design capability.

In January 2008, Bentley Systems acquired energy-analysis software maker Hevacomp Ltd. Bentley Hevacomp offers a software for building performance design, simulation, and energy certification based on the EnergyPlus analysis engine. Supporting ISO, IEE, CIBSE, and ASHRAE standards, these industry-leading tools are used around the world to help predict a building's real-world performance and provide required compliance checking and documentation, such as those mandated by U.K. Part L2, Australia Section J, and the U.S. Green Building Council's LEED program.

To run sustainability analyses, Bentley ties into EnergyPlus, Trace700, and IES. They also are working on Green Building Studio, .gbXML, the system includes analysis capability for things like solar load, sun penetration, natural daylighting, in conjunction with electrical lighting.

2.2.18 Revit

Supplier, site, contact, last version, cost

Revit is software supplied by Autodesk. The last version is Revit 2010. Purposely built for building information modeling (BIM), Autodesk Revit Architecture provides superior support for sustainable design, clash detection, construction planning, and fabrication, while supporting collaborative work with engineers, contractors, and owners. The price is 5494 USD (3899 €) for a single license (2010 version). A trial version is also available for 30 days on the official Autodesk Revit website [www.autodesk.com].

Functions

Revit is a BIM application, which means that the software may be used to design and document a project, but also to enhance communication among all the project partners. The project is generally first built in 3D, and this virtual building generates 2D drawings and various calculations. This model also makes it possible to perform 3D rendering. Revit includes a conceptual design environment to express ideas and create a massing model without the constraints of building elements.

Design stage, users

There are three different products of Revit. All of them are developed from the same core technology, but each one offers specific tools for different types of use. The Revit product line includes: Revit Architecture, Revit MEP and Revit Structure. Architects and drafters use Revit architecture at all phases of the design process. Mechanical, electrical, and plumbing engineers use Revit MEP and structural engineers use Revit Structure at structural design phase. Revit supports early analysis of building forms so the design team can make better informed decisions at the earliest stages of the project. This capability allows to comprehensively clarify areas and volumes, to perform daylighting and energy analyses, and to gain insight into manufacturing viability and early construction material takeoffs.

3D modeling

In Revit, the user builds a Virtual Building by using elements such as walls, roofs, floors, openings, ramps, curtain elements, columns, and more. These building elements are entities with editable parameters. Another way to model is by creating conceptual massive forms, and then turn them into building elements. These conceptual forms may be created in Revit by using the conceptual design environment or in another software such as Google SketchUp.

Rendering

With Revit, it is possible to create realistic 2D images based on a 3D scene. Shades are calculated depending on lighting, materials and environmental settings. The rendering interface uses intelligent defaults to easily generate a quality rendered image. Advanced settings are also available for users with more rendering experience. For example, it is possible to adjust the exposure of the rendered image. The render engine performs some functions automatically such as radiosity, raytracing and daylighting [Autodesk, 2009b]

Coordinates

Revit 2D drawing is performed according to x and y axes and 3D modeling is related to x, y and z axes. Revit uses the RHS.

Import/export

In Revit, general import formats are AutoCAD files (.dwg, .dxf), DNG files (.dng), ACIS SAT files (.sat), Google SketchUp files (.skp) and Autodesk exchange files format (.adsk). It is also possible to import images such as .jpg, .png, .tif or .bmp. The export formats are generally the same as import, but it is possible to export into Industries Foundation Classes format (.ifc) and gbWLM format. The project data may be exported into ODBC database file, Excel files (.xls) and Lotus 1-2-3 files (.wk1). It is also possible to export Walkthroughs and solar studies into .avi files [Autodesk, 2009b].

Predecessor software, successor software

Since the .dwg format is universal in design and modeling, all CAD packages can be predecessor software to Revit. Moreover, any software that exports in the file formats listed above can be used before Revit. For example, it is possible to use Google SketchUp before Revit, but it seems that this method is not currently used. .ifc data exchange allows access to many other external applications or analysis programs. The Autodesk Exchange format allows exporting the building and site into a civil engineering application. It is also possible to use Revit's project data in spreadsheet programs, such as Microsoft Excel or Lotus 1-2-3.

With Globe Link, users can publish 3D building information models directly from Revit® Architecture software into Google Earth™ mapping service. Users can also obtain site information from Google Earthmapping service and import it into Revit 2010 applications for building and site layout purposes. Globe Link is optimized for Google Earth version 4 mapping service.

BIM

As a building information modeling environment, Revit is the mirror of the real world of buildings. Integrated bidirectional associativity helps to ensure that any change to project information is reflected throughout the model. BIM allows more precise conceptual design, which better informs design decision making and enhances client understanding, while supporting more efficient and sustainable production, construction, and fabrication [Autodesk, 2008a].

Actual solar calculation

In Revit Architecture, it is possible to create a solar study as an animation or as an image. There are three types of solar studies available. The “still” study creates a single frame showing shadow patterns for a specific location and time. The “single-day” study produces an animation which shows the impact of shadows at the project location during a defined range of time on a specific day. Finally, the

“multi-day” study produces an animation which shows the impact of shadows at the project location at a specific time of the day over a defined range of days [Autodesk, 2009b].

In July 2008, Autodesk acquired Green Building Studio and Ecotect, which are now integrated with Revit [Wong, 2010]. Revit thus makes it possible to perform energy analysis using Autodesk Green Building Studio web-based services, and study building performance employing Autodesk Ecotect software. Autodesk 3ds Max Design software can also be used to evaluate indoor environmental quality in support of LEED 8.1 certification. A new plugin called IES VE-Ware has also recently been made compatible with Autodesk Revit [Wong, 2010].

2.2.19 Rhinoceros 3D

Supplier, site, contact, last version, cost

Rhinoceros 3D is a software supplied by McNeel. The last version is called Rhino 4.0. The price is 995 USD (706 €) for one license (4.0 version). This version is also available, only for teachers and students, for 195 USD (143 €). The price for a lab kit, for schools only, which includes a license for each computer in a classroom, is 975 USD (716 €). A trial version is also available on the official Rhinoceros 3D website [www.rhino3d.com/index.htm]. This fully functional version will allow saving the project only 25 times.

Functions

Rhinoceros 3D is a NURBS-based modeling tool. In addition to all the modeling tools, Rhino includes many annotation tools such as text, arrows, and dimensions. Dimensions in perspective view are supported. Some analysis tools are also available in Rhino, such as area, volume, hydrostatic calculations and more.

Design stage, users

Rhinoceros 3D is commonly used by industrial designers, architects, marine designers, jewelry designers, automotive designers, as well as multimedia and graphic designers [Wikipedia, 2009b]. Rhinoceros 3D is used for modeling as well as visualization.

3D modeling

Rhino includes different tools to create curves from a point, line, polyline, mesh, rectangle, helix and more. It is also possible to create curves from other objects, for example, through points, polylines or from two views. Users can create surfaces from three to four points, from three to four curves, from planar curves, by sweep along a path with edge matching and more. Solids can be created by using a box, sphere, cylinder, tube, cone, extruded surfaces. Boolean operations are available to edit solids [Mc Neel, 2007].

Rendering

The Rhino rendering engine provides render preview in Open GL, shadows, raytrace render with textures, bumps and transparency. Many types of light sources are available, such as point light sources, directional lights, rectangular lights, linear lights and spotlights with hotspots. Rhino 3D allows saving render settings in a file and customizing the resolution of the rendered image. Options to generate a rendered preview of selected objects and to shade only selected objects are also available.

Rhinoceros 3D supports some rendering plugins, such as Maxwell Render or V-Ray, and other plugins developed by McNeel (Flamingo and Penguin). Flamingo is a rendering engine which brings the raytrace and radiosity rendering inside Rhino. This plugin includes photometrically rendered images with reflection, refraction, diffusion, translucency, depth of field and more, a wide material library with user controllable properties, and many lighting options including sun, sky and global

illumination. Penguin brings freehand sketching, watercolor painting, cartoon-like rendering and technical illustration to Rhino. It is a non-photorealistic renderer which uses Open GL rendering for fast results.

Coordinates

Rhinoceros 3D and 2D drawing is performed according to x and y axes and 3D modeling is related to x, y and z axes. The RHS is used in this program.

Import/export

There are many import/export options in Rhinoceros 3D. Mainly supported file formats are AutoCAD files (.dwg/.dxf), .dgn, .fbx, Autodesk 3D StudioMax files (.3ds), LightWave 3D files (LWO), .stl, SLC, .obj, RIB, POV, UDO, .wrl, , .stp, VDA, GHS, GTS, .kml, PLY, Google SketchUp (.skp), SolidWorks and 2D graphics formats such as .bmp, .tga, uncompressed .tif, illustrator files (.ai). The .igs neutral data format, which allows a digital exchange of information among CAD systems, is also supported. Moreover, Rhino can export in several formats: ACIS SAT files (.sat), Parasolid files (X_T), CSV (to export properties and hydrostatics) [Mc Neel, 2007].

Predecessor software, successor software

Since the .dwg format is universal in design and modeling, all CAD packages can be predecessor software to Rhinoceros 3D. All software that support the .igs data format, such as AutoFORM, AutoShip, Breault, CADCEUS, CAMSoft, CATIA, Integrity Ware, IronCAD, LUSAS, Maya, MAX 3.0, Mechanical Desktop or MicroStation, can be used before or after Rhino. Moreover, any software that exports in the file formats listed above can be used before Rhino. Rhinoceros 3D model may be rendered with an external render engine such as Maxwell Render, V-Ray and more [Wikipedia, 2009b].

BIM

Rhinoceros 3D does not provide direct support for BIM technology.

Actual solar calculation

Solar calculation is available because 3D rendering provides lighting and shading. The Flamingo plugin includes a sun lighting option which seems to simulate the effect of the sun in rendering. However, Rhinoceros 3D does not generate technical solar calculations (solar gains and sizing of active solar systems).

2.2.20 SolidWorks

Supplier, site, contact, last version, cost

SolidWorks is developed by Dassault Systèmes. The last version is SolidWorks Premium 2010. The price is 10 995 USD (8083 €) for SolidWorks premium or 6995 USD (5143 €) for SolidWorks pro. This version does not include design validation capabilities. A trial version is also available on the official Dassault website [www.solidworks.com].

Function

SolidWorks is a 2D and 3D CAD design software. In SolidWorks, a 3D environment is designed, 2D drawings based on the 3D model are created afterwards. The 2D drawing lets the user sketch entities such as lines, rectangles, circles and splines. It is also possible to add dimensions, relation and annotated SolidWorks sketch entities that can snap to points (endpoint, midpoints, intersections, and so on), drawings with tables, symbols and automatic balloon notes. It compares drawings automatically and highlights differences between versions.

The 3D application includes a multiple validation tool that allows the user to design to the same conditions that will be experienced in the real world. It is possible to study the interactions of

assembly components, simulate static or dynamic loads and evaluate the design performance under stress, strain, and displacement. The user can also apply a wide variety of physically-based models and ensure welded structures perform at peak operating conditions in applying pressure, forces, and bearing loads. These applications are few examples of validation tools included in SolidWorks:

- Structural validation – Enhance product quality by identifying areas prone to weakness and failure with simulation and validation tools built for designers and engineers. Provide on-screen feedback when critical design goals are violated to allow for earlier optimization of product designs.
- Environmental impact evaluation – Provide feedback about the environmental impact of the parts designed to optimize material, part geometry, and sources for manufacturing.
- Design for manufacturability – Leverage this upfront design validation tool to identify geometry that is difficult, expensive, or impossible to manufacture by conventional machining operations, such as milling, drilling, and turning.
- Fluid flow simulation – Use a wizard-based tool for fluid flow simulation that displays results as slice planes or flow trajectories.
- Stack-up analysis – Perform tolerance stack-up analysis and determine the effects that tolerances have on parts and assemblies, including maximum/minimum worst-case tolerance stack-up analysis. Validate tolerances and make necessary tolerance changes until the desired tolerance stack-up results are reached [Dassault Systèmes, 2009].

Design stage, users

SolidWorks offers an optimized user experience for engineers and drafters in medical, aerospace, mechanical, structural and electrical industry. SolidWorks is used at modeling and rendering stages as well as for validation of the project.

3D modeling

The 3D shapes are created by “push and pull” control points to create stylish, curve-continuous surfaces. The first feature created in a part is the base. This feature is the basis on which other features are created. The base feature can be an extrusion, a revolve, a sweep, a loft, thickening of a surface, or a sheet metal flange. However, most base features are extrusions. It is also possible to scan concept sketches or data into SolidWorks using ScanTo3D and complete the product design in SolidWorks [Dassault Systèmes, 2009].

Rendering

SolidWorks creates photorealistic rendering images from 3D CAD models and allows the user to make animations of 3D CAD models.

Coordinates

SolidWorks 2D drawings are performed according to x and y axes and 3D modeling is related to x, y and z axes.

Import/export

SolidWorks built-in translators let the user exchange CAD data created in a variety of software applications and file formats, including: 3D .xml, .ai, CADKEY, CGR, .dwg, .dxf, HCG (CATIA highly compressed graphics), .hsf (Hoops), IAM (Autodesk Inventor), IDF, .igs, IPT (Autodesk Inventor), .jpg, Mechanical Desktop, PAR (Solid Edge), Parasolid, .pdf, Pro/ENGINEER, .psd (Adobe Photoshop), Rhino, .sat, .stp, .stl, .tif, Unigraphics, U3D, VDA-FS, .wrl.

Predecessor software, successor software

Besides supporting the export of data to several 2D formats, SolidWorks software supports the import of data in the .dxf and .dwg formats as well as AutoCAD blocks, allowing the creation of 3D models

directly from 2D data. Also, SolidWorks supports the import of 2D “blocks” from AutoCAD as the basis for sketching a new 3D feature in SolidWorks. CircuitWorks is designed to bridge the gap between SolidWorks and Electrical Computer-Aided Design (ECAD) systems by providing tool that allows users to import and export printed circuit board (PCB) designs between SolidWorks and ECAD systems. Integrated within SolidWorks, CircuitWorks reads the industry standard IDF 2.0, IDF 3.0, and PADS file formats.

BIM

SolidWorks is not BIM compatible.

Actual solar calculation

There is no information about an actual solar calculation function in SolidWorks. However, we can suppose that a kind of light calculation is available because 3D rendering allows lighting and shading analysis.

2.2.21 Spirit 2009

Supplier, site, contact, last version, cost

Spirit is software supplied by STI/Softtech, a software company specialized in software for the building industry. Softtech, which is based in Germany, was incorporated in 1985. The last version of Spirit is called Spirit 16 and it is possible to obtain a trial version for 10 days on the company’s website [www.softtech.com].

Functions

Spirit is 2D and 3D software that allows the user to sketch, model, visualize, document and estimate. It is possible to orbit the model, apply procedural textures via drag and drop and edit applied materials. The user can download and utilize a variety of free textures from the Spirit website. The software offers a comprehensive suite of tools that include color transparency, color fill with manufacture based special color palettes, including Sherwin Williams, bitmap transparency, bitmap background transparency, and gradient color fills as well as bitmap tiling. Softtech developers have integrated Google SketchUp directly into the building information network of the software, allowing Spirit users an integration with Google SketchUp without the need for any plugins [STI International Inc., 2006].

Design stage, users

As a BIM technology, Spirit is used along the whole design process, from early stages to structural design. It is mostly used by architects and engineers but also by town planners and contractors.

3D modeling

In Spirit, the user builds a virtual building by using elements such as walls, roofs, floors, openings, ramps, curtain elements, columns, and more. Another way to model is by creating conceptual massive forms and then, turn them into building elements. Spirit offers 3D modeling tools such as the polyslab with push/pull technology, sweepbody, comprehensive Boolean operations, 3D knife with trim and break options, terrain modeling with TIN, drop mesh and rule surface which now encompasses the 3D mesh object with appropriate automatic smoothing in Fresco II rendering [STI International Inc., 2006].

Rendering

With FrescoII II, the integrated rendering solution, Spirit offers the possibility to generate compelling visuals and panoramas. Shades are calculated depending on lighting, materials and environmental settings.

Coordinates

Spirit 2D drawing is performed according to x and y axes and 3D modeling is related to x, y and z axes.

Import/export

Spirit offers output of the visualization or CAAD data to any Windows based plotting device. It also has built in support for direct output to .pdf and .dwt with advanced support for dynamic links. It is also possible to obtain an output directly on the Windows clipboard or to a bitmap image at virtually any supported resolution. Multi-Scale plotting allows layouts of details at varying scales on any number of plot sheets. Batch plotting internally or externally speeds the process of creating plotting sets. Spirit can import and reference a variety of standard industry data formats including the following: SketchUp .skp, AutoCAD dwg/dxf (including support for paper space and ACIS solid models), Microsoft Word .doc, Microsoft Excel .xls, Rich Text format .rtf, html, txt. Spirit can export the BIM data directly to dwg format [STI International Inc., 2006].

Predecessor software, successor software

All CAD packages can be predecessor software to Spirit. Moreover, any software that exports in the file formats listed above can be used before Spirit. For example, it is possible to use Google SketchUp before Spirit.

BIM

Spirit supports the modern BIM concept. It offers an array of BIM based modeling tools, including walls, doors, windows, niches, recesses, floors, columns, stairs, rooms, roofs, dimensions as well as new view dependent fixtures and furnishing components, all accessible via drag and drop technology from the resource browser. Windows and doors are parametric and editable as embedded or exterior components. The integration of the bi-directional ProntoReporting utility in Spirit completes the picture by providing accurate quantity estimates from the BIM model [STI International Inc., 2006].

Actual solar calculation

In the software, the user can change the sun position to calculate shadows any time of day or year for any location on Earth. No other types of solar calculations are available in this program.

2.2.22 Vectorworks*Supplier, site, contact, last version, cost*

Conscious of the building's importance in the discussion about climate change, Nemetschek developed some software solutions to ease the work of designers: Vectorworks is one of them. The last PC version (Vectorworks 2010) including Renderworks is available at the cost of 2395 USD (1699 €) for one license. It is possible to buy an upgrade from Vectorworks 2009 to the last version for 480 USD (341 €). This software is available for MAC and PC.

Functions

Vectorworks is CAD software used for 2D drawings (including technical drawings), 3D drawings and 3D renderings. A large suite of 2D drawing tools is available such as rectangle, circle, free hand, arc, polygon, etc. Many commands, such as connect/combine, tangents, 2D Reshape, rotate mirror, offset or fillet, helps to design with precision and intelligence. The detailing suite in Vectorworks Architect allows annotating and detailing drawings. This option includes constrained, angular, radial and chain dimensions, exterior wall dimensioner, note manager, and more. An important details library is also available from CAD details website. Vectorworks Architect allows creating presentations by using gradients, images fills, hand sketch styling or hatches. An unlimited color choice is also available, including palettes from Pantone, Benjamin Moore, Sherwin-Williams, Resene, Pittsburgh Paints, etc.

Design stage, users

There are seven different products of Vectorworks. All of them are developed from the same core technology (Vectorworks Fundamentals), but each one offers specific tools for different types of use. The Vectorworks product line includes: Vectorworks Architect, Vectorworks Landmark, Vectorworks Machine Design, Vectorworks Spotlight, Vectorworks Designer and RenderWorks. Architects, designers, landscape architects and engineers generally use Vectorworks for design, modeling and rendering. Vectorworks Architect is the only product of the line that includes BIM technology. This product also offers drawing organization, project management, drawing notes management and more than 100 architecture-specific tools, object and commands. Vectorworks allows 2D and 3D drawing, production management and presentation capabilities for all phases of the design process.

3D modeling

The simple way to model with Vectorworks is by using basic modeling operations. This software allows extruding shapes from 2D forms or using 3D primitives. Many free-form modeling tools are also available in Vectorworks. For example, it is possible to extrude along a path, to perform multiple extrude commands, to create a 3D form that changes shape from one end to the other. Basic shapes can be combined to create more complex solids by use of Boolean operations. Other different functions are also available in 3D modeling such as loft surface, unfolding surfaces, shells or extraction. Many NURBS surface modeling tools are now available, which allows creating any shape, such as organic shapes, by blending, twisting, deforming and sculpting.

Rendering

Vectorworks' 3D rendering is possible by using Renderworks. Renderworks is integrated to Vectorworks and provides realistic rendering by using radiosity algorithms, final gather and HDR imaging. Renderworks may also produce artistically styled presentation drawings such a freehand effects. Renderworks comes with hundreds of textures, and makes it possible to apply a 2D image to a 3D surface. With Renderworks, it is also possible to use .ies light distribution files to render physical light. These files are created by many major lighting manufacturers and can be downloaded for free from the Internet sites.

Coordinates

Vectorworks 2D drawing is performed according to x and y axes and 3D modeling is related to x, y and z axes and the RHS is used.

Import/export

There are many import/export options in Vectorworks. Vectorworks is Autodesk (.dxf, .dwg, .3ds) and Google SketchUp (.skp, .kml) friendly. Many image formats are also supported such as .jpg images, .tif and photoshop formats (.psd) and .eps files. Vectorworks supports many types of 3D files such as .igs file to be easy transferred with other CAD programs, ACIS SAT files (.sat) and Parasolid X_T files. Exporting in .stl format allows sending Vectorworks models to 3D printers and rapid prototyping machines.

Vectorworks can import a variety of worksheet formats. It is also possible to export in Database format, to use it in a database program, such as Microsoft Access or FileMaker.

Predecessor software, successor software

Since the .dwg format is almost universal in design and modeling, all CAD packages can be predecessor software to Vectorworks. Moreover, any software that exports in the file formats listed above can be used before Vectorworks. For example, it is possible to use a Google SketchUp file in Vectorworks, and it is also possible to export a Vectorworks 3D model to Google Earth. .ifc data exchange allows access to many external applications or analysis programs. It is also possible to use Vectorwork's project data in spreadsheet programs, such as Microsoft Excel, or in a database program, such as Microsoft Access or FileMaker.

BIM

BIM in Vectorworks includes 2D drawings linked with 3D model and project data. If a change is made into one of these views, it is automatically updated in all others. The BIM functionality is available in 2D and 3D workflows. Some parametric architectural objects such as columns, desk, custom stairs, custom cabinet or chairs, with valuable linked information, are available in 2D and 3D. There are some intelligent building shell tools to ensure the transition into a BIM workflow. These functionalities are customizable doors and windows tools, wall and roof framer and more.

Vectorworks supports the .ifc format, which makes communication easier with partners. This software provides a lot of information on the building project. For example, it is possible to perform an energy analysis or a lighting calculation. The BIM technology in Vectorworks allows simulating fire or a natural disaster. In Vectorworks' libraries, the user may also find many calculation sheets, for instance to size ventilation systems.

Actual solar calculation

Nemetschek, which develops and markets the Vectorworks BIM software and also owns Graphisoft, has made a considerable effort to ensure its modeling platforms are interoperable with IES (IES stands for Integrated Environmental Solutions and VE stands for virtual environment) and Autodesk Ecotect Analysis (which, even under Autodesk's ownership, remains available for use with competitors' BIM software) [Wong, 2010]. The BIM technology allows the users to simulate different sun positions with the Solar Animation Command. The building project is viewed, with the sun in different positions in short films generated by this function. Light intensity calculation is also available. With RenderWorks, some atmospheric effects can be simulated.

2.2.23 3ds Max

Supplier, site, contact, last version, cost

3ds Max is software supplied by Autodesk. The last version is the 3ds Max 2010. The price is 3 495 USD (2856 €) for one license (2010 version). An upgrade from 3ds 2009 is available at the price of 895 USD (732 €) and the price for an upgrade from the 2008 version is 1795 USD (1469 €). A trial version is also available on the official 3ds Max website [www.autodesk.com].

Functions

Autodesk 3ds Max 2010 is full-featured 3D modeling, animation, rendering and visualization effect software. There is a customized installation of 3ds Max 2010 called 3ds Max Design 2010. 3ds Max Design has the same functionality as 3ds Max, with the addition of the Exposure lighting analysis technology. The Software Development Kit (SDK) is not available in 3ds Max Design instead of 3ds Max. Both products offer a new referencing workflow to organize complex scenes.

Design stage, users

3ds Max Design offers an optimized user experience for architects, designers, engineers and visualization specialists. 3ds Max is used in the creation of games, movies and television content. Both 3ds Max and 3ds Max Design are used at modeling and rendering stages as well as for animations. However, 3ds Max Design may be used at early design stages to validate the design since it offers the Exposure technology.

3d modeling

In both products, 2D shapes serve as starting point for creating editable forms, lines, splines and spline cages to convert to any 3D geometry type. There are a many construction tools such as loft, one- and two-rail sweep, beveling, extrude, fillet, cap, offset, lathe, ruled, mirror and multisided blend. The Modeler has a high degree of control with tools such as attach, detach, align, stitch together,

extend, fillet, or rebuild surfaces. The last version includes the new Graphite modeling tools, which provides over 100 new modeling tools unified in a unique user interface [Autodesk, 2009c].

Rendering

Both 3ds Max and 3ds Max Design include a fast scanline rendering which provides realistic image creation. Raytrace materials and maps produce realistic reflections and refractions. Moreover, a full range of depth of field, motion blur, film grain, hair, fur, and lens-based effects are available. The 2010 version features a new Material Explorer for navigating or modifying all rendering-related assets in a scene. Many plugins are available to render 3ds models, such as V-ray. There are also many plugins for volumetric light, fog, and fire creating atmospheric effects [Autodesk, 2009c].

Objects can be animated along curves with controls for alignment, banking, velocity, smoothness, and looping, and along surfaces with controls for alignment. Weight path-controlled animation between multiple curves, and animate the weight. Objects can be constrained to animate with other objects in many ways — including look at, orientation in different coordinate spaces, and linking at different points in time. These constraints also support animated weighting between more than one target. All resulting constrained animation can be collapsed into standard keyframes for further editing.

Coordinates

3ds Max and 3ds Max Design 2D drawings are performed according to x and y axes and 3D modeling is related to x, y and z axes. The RHS is used.

Import/export

In 3ds Max and 3ds Max Design, main import and export file formats are AutoCAD files (.dwg, .dxf), motion analysis software tool (HTR), Autodesk Alias files (MTL), Landscape view format (VW), .obj format and more. The .igs neutral data format, which allows a digital exchange of information among CAD systems, is also supported as well as the file interchange format (.fbx). 3ds Max also supports Plain text .wrl file (WRL). The export formats are generally the same as import, but it is possible to export into datafile format (DF), Atari image format (ATR), .dwf files, m3g format and more.

Predecessor software, successor software

Since the .dwg format is universal in design and modeling, all CAD packages can be predecessor software to 3ds Max. Moreover, any software that exports in the file formats listed above can be used before 3ds Max. All Autodesk products such as Motion Builder, Maya, Mudbox and AutoCAD may be used before or after 3ds Max. 3ds Max is often successor software to Revit. In these cases, 3ds is used to render a Revit model. 3ds Max and Design now recognize and improve inter-application workflows with Revit through accurate import of lights, materials and cameras [Autodesk, 2009d].

BIM

3ds Max and 3ds Max Design do not provide direct support for BIM technology.

Actual solar calculation

3ds Max Design 2010 features the Exposure technology for simulating and analyzing sun, sky and artificial lighting. Exposure enables users to analyse how the sun, sky and artificial lighting interact with the design and to explore lighting effects right in the viewport. Exposure conducts validation studies based on Radiance engine. There are settings for sun and sky. It is also possible to load weather data for a specific location and date. It is easy-to-use at early design stage. It is possible to run a real-time shadow analysis at a specific time, or to produce an animation for a day. The daylight simulation considers materials at a reflecting level. To generate a daylight simulation, the user selects a view with the camera, and chooses how much lighting he wants in the scene. Exposure may generate a visualization of results directly on the scene, for example, by creating a gradient representing the distribution of light. It may also produce graphical and Microsoft Excel output of results [Autodesk, 2009c]. The reliability of daylight simulation with Exposure is comparable to results obtained with DAYSIM, simulation software developed by Reinhart (2006). When it does not

include the Exposure technology, 3ds Max 2010 may assist sustainable design with its simulation features like advanced photometric lighting, which allows users to reduce overall energy requirements by seeing how natural and artificial light is distributed in a space [Autodesk, 2009c].

2.3 VISUALIZATION TOOLS

2.3.1 Artlantis

Supplier, site, contact, version, cost

Artlantis is supplied by Abvent. The last version is Artlantis R / Artlantis Studio, but the Alpha version of Artlantis 3 has just been announced and the new version can be expected relatively soon. The price is 1530 USD (1271 €) for one license. A free 30-day trial version is available on the Artlantis website [www.artlantis.com]. There are two different Artlantis products: Artlantis Render and Artlantis Studio. Artlantis Render mainly generates fixed images while Artlantis Studio produces QuickTime VR Panorama, QuickTime VR Objects and animations.

Functions

Artlantis is a pure rendering program, based on imported 3D models. Its principal functions are 3D rendering (Artlantis R) and animation (Artlantis Studio). The application allows the user to create, edit and apply materials, set up lights and cameras, and render the resulting scene according to a number of individually adjustable parameters. The model can also be supplemented with imported objects such as vegetation.

Design stage, users

Artlantis is a high-end rendering program for visualization purposes, both architectural and other. Generally used at the visualization stages, this software may be used at EDP to validate the design and see how natural and artificial light will affect the project. Since Artlantis is a 3D rendering software which produces photorealistic images and animations, it is mainly used at advanced design stages, when users have to produce images for presentations to clients.

3D modeling

Artlantis uses imported object files from other software, and allows the placement of supplementary objects such as vegetation, viewports, lights, sky and clouds to support photorealistic representations. Materials are assigned to objects using the layer structure of the original object file. It is also possible to apply textures by dragging and dropping from the built in material libraries, and scenes can be edited using special materials such as neon shaders, adjustable transparent bodies and coloured reflectors. Artlantis is a pure rendering engine and does not allow the editing of the 3D model itself.

3D rendering

The renderings performed in Artlantis are based on the physical properties of light and can be used to generate an accurate simulation of real world behaviour. Storing multiple perspective configurations enables the user to completely analyze lighting variants, seasonal variations or environmental configurations. Artlantis focuses on high-speed generation of 3D-renderings, and the workspace includes a preview window giving a simplified representation of the final image, allowing rapid adjustment of lights, shaders and materials without going through the entire rendering process [Abvent, 2009].

Coordinates

Artlantis uses conventional x, y and z axes.

Import/export

Artlantis supports the import of a number of file formats, including .dxf, .dwg, .dwt, .obj, .fbx and .3ds. Rendered images can be exported in .jpg, .bmp, .tif, .tga and .png formats.

Predecessor software, successor software

Abvent offers Artlantis plugins for ArchiCAD, Vectorworks, SketchUp Pro and Revit. In addition, the import/export options allow most common CAD software to function as predecessor software for Artlantis. Principal predecessor software are Image modeler, VIZ, Revit, AutoCAD Architecture, AutoCAD, Vectorworks, SketchUp, ArchiCAD, 3DS Max, Cinema 4D, Maya, Rhinoceros, Lightwave, Poser, Modo, and Amapi. Successor software for further editing of generated renders includes all applications capable of importing the exported image formats (.jpg, .tif, etc). Artlantis is compatible with Apple and Windows-based platforms.

BIM

Artlantis is not compatible with IFC. So, this software is not used as BIM.

Actual solar calculation

Artlantis provides light from sun and sky. The “sun” light is based on geographic location and time of the year and day. Intensity of these lights may also be adjusted manually. These two lights allow illuminating exterior and interior scenes easily. Artlantis rendering provides lighting and shading based on ray-tracing, and rendering presets include physically accurate sun and sky models. However the software does not supply actual solar calculations other than the resulting rendered image so solar calculation is limited to qualitative lighting and daylighting studies through images.

2.3.2 Flamingo*Supplier, site, contact, last version, cost*

Flamingo is a plugin for the Rhinoceros 3D modeling software. It is developed by the creators of Rhinoceros, supplied by McNeel and sold both separately (although it requires Rhinoceros to work) and as a bundle with the Rhinoceros software. The last version is called Flamingo 2.0. The price for Flamingo is 495 USD (495 €) for one license. The global price for Rhino 4.0, Flamingo, Penguin and Bongo is 1695 USD (1695 €) for one license. The price is reduced for schools, teachers and students. An evaluation version is also available on the official Flamingo 3D website [www.flamingo3d.com/download.htm]

This is a fully functional version with limited material, light fixture, and plant libraries. The evaluation version also draws thin black lines across the final rendered image.

Functions

Used inside Rhinoceros 3D, Flamingo provides a host of features that speed up and simplify image rendering. It uses both raytracing and radiosity to create sophisticated single-frame images and animations and automatically calculates indirect light, hard and soft shadows, color bleeding, reflections, translucency, transparency, refraction, highlight, depth of field, and depth attenuation. Rendering changes are immediately applied to the Rhino model and there is no need to export a model or start over.

Design stage, users

Flamingo is commonly used by industrial designers, marine designers, jewelry designers, automotive designers, architects, as well as multimedia and graphic designers.

Rendering

Flamingo combines raytracing and radiosity to create high quality images. It calculates light, shadows, materials, transparency, diffusion, reflection, refraction, highlight, angular blend, and

ClearFinish™ from surface properties. Flamingo's accurate lighting model produces sophisticated effects and high-quality images. Flamingo also provides an extensive material library. Properties of materials are physically-based and include reflectivity, transparency, highlight, and index of refraction. Lighting simulation is provided for an unlimited number of lights (directional, point, spot, linear, rectangular and goniometric lights, sun, ground and sky). Simulations are physically-based and light intensity is specified in Watt. Global illumination can be simulated with light dome or HDR image.

Import/export

Flamingo needs Rhinoceros 3D to be used. Rhino supports many import formats. Refer to the specific section of this report for more information.

Predecessor software, successor software

Refer to the section about Rhinoceros 3D of this report for more information.

BIM

Flamingo does not provide direct support for BIM technology.

Actual solar calculation

Flamingo does not generate technical solar calculations (solar gains and sizing of active solar systems).

Flamingo provides accurate daylight simulation (sun, sky, ground and cloud cover components), based on geographical location, month and time of a day (an exact solar time calculator is used).

2.3.3 Kerkythea

Supplier, site, contact, last version, cost

Kerkythea is a standalone freeware/open source renderer developed by Ioannis Pantazopoulos. The latest release for Kerkythea is Kerkythea Rendering System 2008 Echo Edition v.2.0.5. This version is available for free online at [www.kerkythea.net].

Functions

Kerkythea's principal function is 3D rendering but it can also be used to create walkthrough animations. The software is used as a plugin of multiple software like e.g. Google SketchUp, 3ds Max and Blender. The user can easily navigate in the model by using action tools such as rotate, pan, roll and dolly [Kerkythea, 2005].

Design stage, users

Kerkythea offers an optimized user experience for architects, designers, engineers and visualization specialists. Kerkythea is specially developed for the rendering stage. However, Kerkythea may be used at EDP to validate the design.

3D modeling

First created as a rendering tool, Kerkythea does not offer the possibility to model a complete project. However, it supports all triangulated planes, meshes and spheres shapes previously built in other software. Kerkythea also allows modifying basic settings of the model like point of view, sun, sky and materials. Kerkythea also makes it possible to place light to brighten the model. A wide range of light sources are available such as omni light, spot light, IES light, projector light, point diffuse, area diffuse. Kerkythea supports many material libraries: matte, blurry, translucent, dielectric, glass, and phong materials are easy to create and modify.

Rendering

Kerkythea provides photorealistic rendering and uses lighting features, such as global illumination, caustic, ambient occlusion, blurry reflections and refraction and motion-blurred particles. It supports various rendering techniques such as classic ray tracing, path tracing, photon mapping, depth rendering, mask rendering and clay rendering. The program also allows setting render channels like alpha channel, shadow, roughness and Fresnel for compositing tasks. Three camera projections are available: planar, cylindrical and spherical [Kerkythea, 2005].

Coordinates

Kerkythea 3D modeling is related to x, y and z axes.

Import/export

Scenes exported in Kerkythea can be saved as xml or .kzx (kerkythea scene) format. The main import files are .3ds, .obj, .sia, .kzx and .xml format. The user can also export the rendered image as .jpg, .png, .bmp, .gif, .hdr format.

Predecessor/successor software

As a plugin, Google SketchUp, 3ds Max and Blender are the main software used prior to Kerkythea.

BIM

Kerkythea is not BIM compatible.

Actual solar calculation

The Kerkythea sun feature is designed to give the user a general idea of how the sun and shadows affect the model during a day and throughout the year. The calculations are based on the location (latitude and longitude), directional orientation of the model, and an associated time zone.

2.3.4 LightWave*Supplier, site, contact, last version, cost*

LightWave 3D is an application developed by NewTek. The last version (LightWave v9) is available at the cost of 995 USD (725 €) for one license. It is possible to buy an upgrade for 495 USD (360 €). This software is available for MAC and PC [www.newtek.com/lightwave].

Functions

LightWave 3D is a modeling, animation and rendering software. A large suite of 2D commands are available like e.g. flip, cut, swap, paste, copy, paste, mirror. LightWave modeler performs subdivision surface and polygonal modeling. LightWave also makes it possible to perform texturing and shading to create any design.

Design stage, users

LightWave's renderer and modeler are designed for visualization and design from early sketches to finished printed high resolution renderings. LightWave is used in broadcast television production, film visual effects, video game development, print graphics and visualization such as architectural design [NewTek, 2010].

3D modeling

The simple way to model with LightWave is by using basic modeling operations. The most basic shapes are provided as parametric primitives whose parameters like size, fillet and orientation are adjustable. Parametric objects can be used as they are or they can be converted to polygons to serve as a basis for more complex objects. A number of deformers and other generators can be used in conjunction with objects. LightWave allows extruding shapes from 2D forms or using 3D primitives.

Many surface modeling tools are also available, which allows creating any shape, such as organic shapes, by blending, twisting, deforming and sculpting.

The node editor in LightWave allows creating subsurface scattering materials and shaders. This editor can accurately simulate lighting and shading for materials such as marble, milk, etc., as well as a specific and easy to use material for skin shading. Commands like e.g. blinn, oren-nayar, ambient occlusion and other shading models, provide unlimited shading possibilities [NewTek, 2010].

Rendering

LightWave rendering uses IES (Illuminating Engineering Society) lighting that accurately duplicates physical light sources from manufacturers' datasheets. Implementation of state-of-the-art BSP/KD Tree Algorithm provides faster and more efficient raytracing. Functions like global illumination and radiosity create photorealistic scenes and products while simulating the effect of real-world lighting in photography. LightWave rendering technology produces scenes using arbitrary camera lenses and warps create fantastic effects such as: camera plane deformations, arbitrary projections, UV map generation, true orthographic rendering, space warp simulations, lens distortion duplicating real-world lenses or "imaginary" lenses and one-camera 360° panorama rendering [NewTek, 2010].

Coordinates

LightWave 3D modeling is related to x, y and z axes and uses the RHS.

Import/export

LightWave includes support for a host of industry-standard file formats. Images and movies in .psd, .tif, Targa, .jpg, QuickTime, .avi and other commonly used formats can be imported as textures or modeling templates, or used for final output. Support for vector formats extends to Illustrator import as well as Flash and .eps export. It also supports file formats like Collada, .fbx and .obj I/O.

Predecessor software, successor software

No information about software used prior to LightWave is available, but we can suppose that every application that exports to one of the supported file formats may function as predecessor software to LightWave.

BIM

LightWave is not BIM compatible.

Actual solar calculation

In LightWave, a distant light source is used as the sun. The user can set attributes to this light source like ambient color, intensity, light type and light intensity. It is also possible to set ray angles and to choose a diffuse or a specular light source. The lighting system is a plugin API, a new light plugin class header improves the sampling for the photometric, spherical and dome lights. The light properties offer the possibility to load IES light source files and display a thumbnail preview of the luminaire with other information and controls. In addition, there is an IES Info panel that shows the description from the IES file, a gonio photometric graph, and detailed text info on IES file [NewTek, 2010]. LightWave does not generate technical solar calculations (solar gains and sizing of active solar systems).

2.3.5 LuxRender

Supplier, site, contact, last version, cost

LuxRender is an open source software rendering system for physically correct image synthesis. LuxRender [www.luxrender.net] is based on PBRT, the unbiased raytracer developed by Matt Pharr and Greg Humphreys for academic use. The program was then modified and made suitable for artistic use by Terrence Vergauwen's programmers' team. The first official release for general public is

available since 2008. The last stable release is LuxRender 0.6.1 / 2009; the up-coming release is LuxRender v0.7RC1.

Functions

LuxRender is a rendering program and not a 3D modeling application. As such, content to be rendered must be created in another program.

Some of the main features of LuxRender are:

- biased and unbiased rendering: users can choose between physical accuracy (unbiased) and speed (biased).
- full spectral rendering: instead of the RGB color spectrum, full spectra are used for internal calculations.
- hierarchical procedural and image based texture system: procedural and image based textures can be mixed in various ways, making it possible to create complex materials.
- displacement mapping and subdivision: based on procedural or image textures, object surfaces can be transformed.
- network and co-operative rendering: rendering time can be reduced by combining the processing power of multiple computers.
- perspective (including shift lens), orthographic and environment cameras.
- HDR output: render output can be saved in various file formats, including .png, .tga and .exr.
- LuxRender features support for cooperative cross-platform network rendering. Whether it is on a local network or over the Internet, multiple computers can render together, both on animations and on single images, without limits on the number of computers that can work together.

Design stage, users

LuxRender is mainly used at the visualization stages, but it can also be used in EDP for visualizing the way light influences spaces. It is used in architectural visualization, object design visualization and generally in graphic design.

Rendering

LuxRender is built on physically based equations that model the transportation of light. This allows to accurately capture a wide range of phenomena, fully supporting high-dynamic range (HDR) rendering. The core of LuxRender is fully spectral: unlike traditional rendering software, which only operates on distinct colors (such as red, green and blue), it uses individual wavelengths. This allows LuxRender to correctly deal with wavelength dependent effects, such as dispersion, or accurately capture the color of incandescent lights, making the rendered images look more natural.

Photometric data in the form of IES (Illuminating Engineering Society) diagram can be used to accurately define the light distribution pattern of a light source. As environment light, it is possible to use a HDR image, a sun/sky system or a plain color. While the rendering is running, it is also possible to interactively adjust the color and intensity of any light source and add post process effects like bloom, glare, chromatic aberration and vignetting, giving the image a final touch of photorealism.

Coordinates

LuxRender is related to x, y and z axes.

Import/export

LuxRender relies on exporter scripts that export a scene from a 3D modeling program. Render output can be saved in various file formats, including .png, .tga and .exr.

Predecessor software, successor software

The program runs on Microsoft Windows and Mac OS X. It is an external rendering program and relies on exporter scripts that export a scene from a 3D modeling program. The primary exporter is LuxBlend, which tightly integrates LuxRender with Blender. It also features interactive material preview inside Blender, significantly reducing the time it takes to create complex, realistic materials. Exporters for major 3D packages like Maya, Cinema4D, XSI and 3ds Max are under development.

BIM

LightRender is not BIM compatible.

Actual solar calculation

LuxRender does not generate technical calculations for active solar systems, energy analyses or solar gains predictions. A model of sun lighting from NASA measurements is used for visualization reasons. The model includes atmospheric absorption adjustable through the turbidity parameter and the size of the sun can be tweaked from its reference size with the relsize (relative size) parameter.

2.3.6 Maxwell Render

Supplier, site, contact, version, cost

Maxwell Render is a software supplied by Next Limit Technologies. The last version is the Maxwell Render V2. The price is 995 USD (731 €) for one license. An upgrade from Maxwell Render v1.x is available at the price of 395 USD (290 €). A trial version is also available on the official Maxwell Render website [www.maxwellrender.com].

Functions

Maxwell Render is rendering software. Its principal functions are 3D rendering and animation. This software includes an independent application named Maxwell Studio. This is a scene editor with a full 3D environment. This application allows the user to save the scene in 3D or CAD applications and import it into Maxwell Studio, where it is possible to create, edit and apply materials, set up lights and cameras, and send to the Maxwell Render. It is also possible to edit the scene and import objects.

Design stage, users

Maxwell Render is used in architectural visualization, product design, jewelry, film production, scientific research and other high-end rendering markets. Generally used at the visualization stages, this software may be used at EDP to validate the design and see how natural and artificial light will affect the project.

3D modeling

This software allows the user to import object files from other software and set attributes like position, rotation, scale, pivot, smoothing, and normals. It is also possible to apply textures using UV projectors and physical materials and lights. The user can create multiple cameras, adjust their position and parameters, set sky options and see an interactive representation of the sky settings. Maxwell Render offers a customizable layout with the ability to save layouts [Next Limit Technologies, 2009].

Rendering

Maxwell Render is a rendering engine based on the mathematical equations governing light transport, meaning that all elements, such as emitters, materials and cameras, are derived from physically accurate models. It is possible to choose between three main render types. The application offers features needed to prepare, edit and render perfect such as multilight, sub-surface scattering, stacked materials and displacement. The program also allows setting render channels like alpha channel, shadow, roughness and Fresnel for compositing tasks [Next Limit Technologies, 2009].

Coordinates

Maxwell Render 3D modeling and rendering is performed according to x, y and z axes.

Import/export

Maxwell Render supports many geometry and scene formats such as .mxs, .obj, .stl, .ply, .lwo, .xc2, .3ds, .dxf, .fbx, .dae. Maxwell Render can also export the rendered image as jpg, .bmp, .tif, .tga, .png, .jp2 format.

Predecessor software, successor software

The software supports platforms through many plugins like 3ds Max, VIZ, Maya, LightWave, Rhino, CINEMA 4D, SolidWorks, form•Z, Google SketchUp, ArchiCAD, XSi and Modo.

BIM

Maxwell Render is not BIM compatible.

Actual solar calculation

There is no information about an actual solar calculation function in Maxwell Render. However, we can suppose that a kind of solar calculation is available because Maxwell's approach to rendering is based on real-world units, settings and physical laws. 3D rendering provides lighting and shading, and rendering presets include physically accurate sun and sky models.

2.3.7 mental ray®*Supplier, site, contact, last version, cost*

mental ray® was developed by company called mental images GmbH, Berlin, Germany [www.mentalimages.com]. Version 3.8 (released January 2010) will be available within several OEM (Original Equipment Manufacturers) products throughout 2010. Pricing information is available at mental images' OEM partners, who also distribute the software. mental ray® is available in integrated version or in standalone version.

Functions

mental ray® is a programmable, high-performance rendering software for a wide range of applications, such as the creation of visual effects for movies and contents for games, the visualization of cars and other virtual models or simulation of architectural design with accurate lighting. It generates multifaceted imagery of exceptional quality, ranging from stylised to photorealistic images. mental ray® can be embedded into other front-end applications or used as a standalone rendering software.

mental ray® offers various rendering features, such as 'ray tracing', 'rasterizer', 'global illumination', 'iray rendering mode', 'image-based lighting', 'tile-based and progressive rendering', and 'light mapping'. In general, geometry shaders allow for customizing the tessellation or subdivision of objects. Material and texture shaders take control over every aspect of surfaces; photon shaders control global illumination effects; camera shaders simulate different lens types and output shaders control post-processing effects. The flexible shader interface allows the use of the predefined, essential shading and illumination functions provided by the software as well as the extension and customisation of the shader library according to the individual needs.

mental ray® generates architectural visualizations with high quality and realism, whereas the physically accurate simulation of light includes direct and indirect illumination conditions as well as light emission properties of existing lamps. The optimized environment lighting mode (IBL) and global rendering features not only provide a physically correct lighting environment, but - in combination with other front-end applications - also enable the measurement of actual indoor lighting intensities.

Design stage, users

mental ray[®] supports photorealistic visualization of architectural design and illumination scenes at any design stage, whenever product data in CAD or other styling systems is available. It provides photorealistic rendered images and animations and has a wide range of applications: CAD visualization, feature animation, game creation, architectural design, product prototyping and design lighting design and visualization. Therefore, it can be used by architects, designers, engineers, game creators and other visualization specialists.

3d modeling

mental ray[®] is not a 3D modeling software, but a 3D rendering software. Used in conjunction with other front-end applications, such as a CAD program, it allows for 3D modeling. Examples of these applications are AutoCAD, Autodesk 3ds Max, Autodesk Image Studio, Autodesk Inventor Series, Autodesk Maya, Autodesk Revit, Autodesk Softimage, Autodesk VIZ, Bunkspeed SHOT, CATIA V.4 / Visualization Studio, CATIA V.5 / Photostudion2 and Photo Studio Optimizer and V.6, Maticad Domus 3D, Pro/ENGINEER, RTT DeltaGen, RTT PowerHouse, SensAble FreeForm, SolidWorks, Visoft or Side Effects Houdini (via mental ray[®] standalone). User-supplied functions allow the creation of textures, materials, new lighting models, volume and lens effects, as well as geometry and displacement.

Coordinates

mental ray[®] does not work with coordinates. The rendering software works with geometric primitives (.mi scene description language files) consisting of triangles, arbitrary polygon meshes and trimmed free-form surfaces as well as hierarchical subdivision surfaces, fast subdivision meshes and specialised hair geometry. Translators and translator plugins allow mental ray[®] to be used in conjunction with various 3D modeling and front-end systems.

Library

mental ray[®] provides the linked front-end applications and its libraries with a number of additional standard shader packages for basic illumination tasks and comprehensive packages for typical materials used in architecture and design, as well as subsurface scattering or physical sun and sky lighting. For example, photometric data of light sources (IES data, provided by product producers) can be imported to simulate a realistic idea of the illumination scenery.

Import/export

A number of translators and translator plugins allow mental ray[®] to be used in conjunction with various 3D modeling and front-end systems. For renderings in the standalone version of mental ray[®], a translator plugin exports the various file formats, such as .dwg, .dxf, .3ds, etc. of scene databases in mental images' .mi scene file format (ASCII or mixed ASCII/binary form). Where mental ray[®] is embedded into a front-end application, such as a CAD program, it shares the data with the application.

mental ray[®] generates various output formats, such as picture file formats or specific formats for depth maps or label channels. It supports alpha channels, 8 and 16 bits per component, 32-bit floating-point component mode or RGBE HDR images. mental ray[®] provides photorealistic visualizations for a wide range of applications, transferring abstract settings, such as difficult light conditions, materialisation or spatial arrangements, into well readable imagery. The ability of the software to efficiently use hardware memory as well as networks of machines allows for efficient and fast outputs.

Method of calculation

The architecture of mental ray[®] is founded on a network transparent scene and rendering database. User-supplied C or C++ shaders can be used within mental ray[®] to create geometric elements at runtime of the renderer, procedural textures, materials, etc. Advanced rendering acceleration techniques are used for primary visible surface determination and BSP algorithm for secondary rays. The exploitation of parallelism on both multiprocessor machines and across network of machines leads to most efficient memory usage. Together with built-in disk caching and garbage collection, it

allows mental ray[®] to render scenes with great complexity even on machines with a small amount of memory. Advanced rendering acceleration techniques are used to achieve even higher performance than achieved by built-in automatic scene cost analysis.

Predecessor software, successor software

mental ray[®] can be combined with any suitable modeling or animation system. The rendering software provides three levels of integration into digital content or design and engineering tools:

1. Integration: mental ray[®] is available in a C++ library version for direct integration into front-end applications. It allows full scene database sharing across the application. This tight integration has many advantages, such as fast scene preparation, interactive change of scene elements between frames or even during rendering of a frame, and direct access between application and rendering data. mental ray[®] rendering technology is available or already integrated in applications such as Autodesk Maya, Autodesk 3ds Max, 3ds Max Design, Autodesk Softimage, and Autodesk software.
2. Translator application: mental ray[®] relays on a translator application that reads the data of the content creation system and passes it on to the database of the mental ray[®] library.
3. Translator plug-in: mental ray[®] relays on a translator plug-in that exports scene databases into mental images' .mi scene file formats. As no application data needs to be loaded into memory, the standalone version is best suited for large volume rendering projects. It is available for 3ds Max, 3ds Max Design, Maya and Softimage.

BIM

mental ray[®] is not compatible with IFC. So, this software is not used as BIM. However, it may be integrated into BIM application such as Autodesk Revit.

Actual solar calculation

mental ray[®] itself does not support the calculation of active or passive solar strategies. If required, this function could be included into the respective CAD-environment. Nonetheless, mental ray[®] provides a physically correct lighting environment required for quantitative indoor lighting evaluations. However, it is a qualitative calculation because it does not provide numerical data. Images may be also inaccurate because 3D rendering combines physically correct simulation and the creation of visual phenomena. mental ray[®] includes a wide range of functionality for creation and editing of visual phenomena. mental ray[®] also supports HDR environment lighting, area light sources, and lights with IES profiles. mental ray[®] performs image-based lighting and image mapping. Image mapping is a method for sampling an object before rendering, and storing the results for later use. The result is used as a texture.

Comments

Integrated into the CAD-environment, planners can use mental ray[®] within their well known interface without a need for importing or exporting data. Photorealistic imagery assists architects in analysing and discussing difficult arrangements of light, materials, and spaces. mental ray[®]'s rendering engine provides the base for lighting analyses in Autodesk 3ds Max Design 2009, an application that can be used to support daylight related design decisions for scenes with complexities comparable to the five NRC (National Research Council Canada) daylighting test cases [Reinhart & Breton, 2009].

2.3.7 POV-Ray

Supplier, site, contact, last version, cost

POV-Ray is supplied by Persistence of Vision Raytracer. The last version is POV-Ray version 3.6.2, available for free at [www.povray.org].

Functions

The Persistence of Vision Ray-Tracer creates 3D photo-realistic images using a rendering technique called ray-tracing. It reads in a text file containing information describing the objects and lighting in a scene and generates an image of that scene from the view point of a camera also described in the text file.

The POV-Ray package includes detailed instructions on using the ray-tracer and creating scenes. Many scenes are pre-defined in POV-Ray so images can be created immediately. These scenes can be modified so the user does not have to start from scratch. In addition to the pre-defined scenes, a large library of pre-defined shapes and materials is provided. The user can include these shapes and materials in the scenes by just including the library file name at the top of the scene file, and by using the shape or material name in the scene [2008, Persistence of Vision Raytracer].

Design stage, users

Main users of POV-Ray are computer graphic specialists, but some architects, drafters and designers use POV-Ray to create visualizations. Some users may use the application for design work, but the primary use of POV-Ray is at the visualization stage.

3D modeling

POV-Ray scenes are described in a special text language called a "scene description language". The user types commands into a plain text file and POV-Ray will read it to create the image. The process of running POV-Ray is a little different on each platform or operating system. The user must read the platform-specific documentation, which will provide instructions about how to command POV-Ray to turn the text scene description into an image.

By entering command in the text editor, the user can create basic shape primitives such as spheres, boxes, quadrics, cylinders, cones, triangle and planes. Advanced shapes are also available. Shapes can easily be combined to create new complex shapes. Textures can be assigned to objects and a lot of properties can be modified. Users can create their own textures or use pre-defined textures such as e.g. brass, chrome, copper, gold, silver, stone, wood, etc. [Persistence of Vision Raytracer, 2008].

Rendering

Many 3D rendering options related to lighting, camera and atmospheric effects are available. Camera types include perspective, orthographic, fisheye. Lighting parameters offer the possibility to create spotlights, cylindrical lights and area lights. Other textures settings like e.g. phong and specular highlighting let the user create more realistic-looking surfaces.

Coordinates

POV-Ray 3D modeling is related to x, y and z axes.

Import/export

The images created with POV-Ray are automatically saved on disk usually in .tga, .png or .bmp format.

Predecessor/successor software

There is no information about software used prior or after POV-Ray.

BIM

POV-Ray is not BIM compatible.

Actual solar calculation

There is no information about an actual solar calculation functions in POV-Ray. However, POV-Ray's radiosity system is based on a method developed by the author of Radiance (Greg Ward), which provides a way to replace the constant ambient light value with a light level which is based on what surfaces are nearby and how bright in turn they are [POV-Ray, 2010].

2.3.8 RenderMan

Supplier, site, contact, last version, cost

RenderMan is a registered trademark of Pixar. RenderMan is threefold: 1) As the RenderMan Interface Specification, or RISpec in short, which is an open API developed by Pixar Animation Studios to describe three dimensional scenes and turn them into digital photorealistic images [Pixar, 2005]. This API includes the RenderMan Shading Language. 2) Renderman Shading Language (abbreviated RSL) is a component of the RenderMan Interface Specification, and is used to define shaders. The language syntax is C-like. A shader written in RSL can be used without changes on any RenderMan-compliant renderer, such as Pixar's PhotoRealistic RenderMan, DNA Research's 3Delight, Sitexgraphics' Air or an open source solution such as Pixie or Aqsis. And 3) PhotoRealistic RenderMan, or PRMan for short, is a proprietary photorealistic RenderMan-compliant renderer. It primarily uses the REYES algorithm but is also fully capable of doing ray tracing and global illumination [RenderMan, 2009].

Two examples of PRMan implementation by Pixar are RenderMan Studio and Renderman for Maya. Render Man Studio is a collection of independent software tools that together provide an advanced render pipeline that takes data from Maya (or other software applications) and send it to a render farm using the RenderMan Pro Server renderer. RenderMan Studio also has the option of an Embedded RenderMan Renderer that enables to render locally as a standalone workstation seat. The standard RenderMan Studio costs 2000 USD (1659 €) per license. RenderMan for Maya costs 995 USD (825 €) per license and is available for purchase online from Pixar's web site [Pixar, 2010].

Functions

Pixar's RenderMan has advanced features for creating visual effects, and because Pixar is also a movie studio, the core rendering technology has been proven on some of the most demanding 3D productions ever realized: Memory efficiency (see REYES algorithm), Camera Controls [Fast 3D motion blur, Shutter Timing, True 3D depth-of-field, Bokeh controls], Particles [Points (riPoints), Spheres (riSphere), Implicit surfaces (riBlobby)], Hierarchical subdivision surfaces, Curve rendering (riCurve primitive)

Hair and fur (riCurve primitive), High quality displacements (8, 16, and 32 bit), Deep shadows (Transparent and filtered), Subsurface Scattering (Point based), Global Illumination [Ambient Occlusion (ray traced & point based), Color Bleeding (ray traced & point based), Image Based Lighting (HDRI), Caustics (photon based), Ray traced area lights], Pixar's Organized Point Clouds (with API), Pixar's Brick, Maps (with API), Ray Tracing, Hybrid system (sub-system of RSL), Programmable ray tracing, Ray tracing groups, CSG (Booleans in the renderer), Secondary Outputs (AOVs), OpenEXR (reading and writing) [Pixar, 2010].

Design stage, users

Renderers using Renderman standard are using numeral applications for visualization and animation purposes such as film production, design of products, architectural visualization, scientific research and other high-end rendering activities. As for other high end renderer, Renderman is used for visualization purposes (3D and animation), softwares from RenderMan could be used at EDP to validate the design and study how natural and artificial light will affect the project.

3D modeling

Essentially used as rendering software, some software implementation include 3D modeling capabilities such CSG (Booleans operations).

Rendering

Essentially designed for rendering applications, Renderman is used for 3D and animation renderings. Refer to the Functions section above for more details.

Coordinates

RenderMan uses a LHS by default. The image plane is perpendicular to the Z axis at $Z = 0.0$. The camera is located at the origin (0.0, 0.0, 0.0) and points toward the +Z direction.

Import/export

RenderMan being an interface and rendering standard does not provide import/export by itself. However, it has a dedicated file format RIB (RenderMan Interface Bytestream), which is of ASCII format and contains the whole description of the scene to be rendered.

Predecessor software, successor software

RenderMan is integrated as "successor" to some CAD software, as plugin such as Maya, and "predecessor" to many more that provide RIB file format export, such as K-3D, Blender, LightWave, Rhino, CINEMA 4D, SolidWorks, form•Z, Google SketchUp, ArchiCAD.

BIM

RenderMan is not a BIM application.

Actual solar calculation

RenderMan provides ray-tracing and global illumination; many papers have been published on design illumination based on RenderMan [Millard Ragan-Kelley, 2004].

2.3.9 Renderworks*Supplier, site, contact, last version, cost*

Renderworks is a software supplied by Nemetschek. The last version is Renderworks 2010. Renderworks is included in Vectorworks 2010 at the cost of 2395 USD (1943 €) for one license. The software package is available for MAC and PC.

Functions

Renderworks is the rendering engine of Vectorworks. Renderworks is integrated to this BIM application and provides photorealistic rendering for the BIM models created in Vectorworks.

Design stage, users

Renderworks provides photorealistic as well as sketchy rendered images of Vectorworks' BIM model. Moreover, since there are different releases of Vectorworks, for each category of users, Renderworks can be used by architects, engineers, lighting specialists, landmark architects, designers and computer specialists. It can be used at modeling and rendering stages, but because it is fully integrated into Vectorworks, it seems to be used earlier in the design process.

3D modeling

Renderworks software is not a modeling tool. It only allows applying real-world materials on existing models created in Vectorworks. However, because Renderworks is totally integrated into Vectorworks, it provides the ability to make quick and easy revisions. Moreover, Renderworks allows placing some shrubs and plants into scenes that are rendered quickly and look great.

Rendering

Renderworks is integrated into Vectorworks and provides realistic rendering by using radiosity, final gather and HDR imaging. Renderworks can also produce artistically styled presentation drawings such as drawings with freehand effects. Renderworks comes with hundreds of textures, and it is also possible to apply a 2D image to a 3D surface and it is possible to use .ies light distribution files to render physical light. These files are created by many major lighting manufacturers and can be downloaded for free from their Internet sites.

Renderworks developers merged all mapping controls into a single tool. It is possible to use 2D and 3D texture mapping in this software. It is also possible to add a blur factor to the simple glass and mirror reflectivity shaders. In the last release, some contents have been added, such as HDRI backgrounds, including exteriors, interiors, and studio backgrounds.

Coordinates

Renderworks is created to be fully integrated into Vectorworks. So, this software uses the coordinate system of Vectorworks. Renderworks and Vectorworks 2D drawing is achieved according to x and y axes and 3D modeling is related to x, y and z axes. The RHS is used in both programs.

Import/export

Since Renderworks is integrated into Vectorworks, it has the same import/export functionalities as Vectorworks. Both programs are compatible with Autodesk (.dxf, .dwg, .3ds) and Google SketchUp (.skp, .kml). Many image formats are also supported such as .jpg images, .tif format, photoshop format (.psd) and .eps files. Vectorworks supports many types of 3D files such as IGES files to be easily transferred with other CAD programs, ACIS files (.sat) and Parasolid X_T files. Exporting in .stl format allows users to send Vectorworks models to 3D printers and rapid prototyping machines.

Predecessor software, successor software

Since Renderworks is designed to be a part of Vectorworks, it is successor software to this BIM application. All graphical applications, such as Photoshop, can be successor software to Renderworks, because these software are used by many architects or designers to retouch and adjust final images.

BIM

Renderworks is included into Vectorworks, and Vectorworks support is .ifc compatible. So, Renderworks is totally integrated into a BIM application.

Actual solar calculation

Renderworks offers a great flexibility for creating both hard and soft-edge shadows. Since Vectorworks produces solar animations, we can suppose that Renderworks, which is integrated into Vectorworks, is based on algorithms that simulate the real behaviour of light. Moreover, Renderworks performs intensive lighting calculations to represent reflection and transparencies, as well as the interplay between light and materials.

2.3.10 RenderZone

Supplier, site, contact, last version, cost

RenderZone is a rendering software supplied by AutoDesSys. Renderzone is available as a plugin for bonzai3d or integrated in form•Z. The cost of both versions is 399 USD (332 €). Trial versions of both software include trial versions of RenderZone. These free trial versions are available on the AutoDesSys official website [www.form•Z.com/index.html].

Functions

form•Z RenderZone allows the user to create photorealistic and sketchy renderings based on the LightWorks rendering engine.

Design stage, users

RenderZone is used by architects, designers and computer specialists to produce 3D renderings. Since RenderZone is a 3D rendering software which produces photorealistic images, it is mainly used at advanced design stages, when users have to produce images for presentations to their clients.

3D modeling

This software is not a modeling tool. It only allows rendering images from 3D models created in form•Z or bonzai3d.

Rendering

RenderZone offers three levels of rendering: simple, z-buffer, and raytrace. A user can start developing the image of a 3D model at the simple level and gradually turn on features and render the model at the most photorealistic level. RenderZone also includes the ability to produce images based on global illumination techniques, which create renderings with the highest degree of realism, since the illumination of a scene takes into account the accurate distribution of light in the environment. In RenderZone, global illumination includes final gather, ambient occlusion, and radiosity techniques, which can be applied separately or combined.

One or more light sources can be used in RenderZone, which can be ambient, distant (sun), cone, point, projector, area, custom, line, environment, and atmospheric lights. Light sources may appear to glow in images, simulating the reflection of lights off dust particles in the air. Environment and atmospheric lights are advanced lights, which are especially optimized for global illumination. Other light types produce soft (mapped) or hard (raytraced) shadows [AutoDesSys Inc., 2010].

Sketch rendering mode is also available. This feature produces non photorealistic images, which appear as if they were drawn by manual rendering techniques, such as oil painting, water color, or pencil hatches.

Coordinates

There is no information about a coordinate system used in RenderZone.

Import/export

There is no information about import and export functionalities into RenderZone. However, we can suppose that, as rendering software, RenderZone allows exporting into a wide range of image file formats as other rendering tools.

Predecessor software, successor software

Since RenderZone is a plugin to bonzai3d and/or integrated into from•Z, both software are predecessor software to RenderZone.

BIM

RenderZone is not compatible with IFC. So, this software is not used as BIM.

Actual solar calculation

RenderZone allows producing images based on global illumination techniques, which create renderings with the highest degree of realism, since the illumination of a scene takes into account the accurate distribution of light in the environment. In RenderZone, global illumination includes final gather, ambient occlusion, and radiosity techniques, which can be applied separately or combined. One or more light sources can be used in RenderZone, which can be ambient, distant (sun), cone, point, projector, area, custom, line, environment, and atmospheric lights [AutoDesSys Inc., 2010]. There is no information about other types of solar calculations included into RenderZone.

2.3.11 V-Ray

Supplier, site, contact, last version, cost

V-Ray is a software supplied by Chaos Software. Three products are available: V-Ray Max, V-Ray Maya and V-Ray Rt all adapted for a different software. The price is 299 USD (240 €) but a trial version is available on line at [www.chaosgroup.com].

Functions

V-Ray is a rendering solution allowing user's actions while working on the scene. The program automatically and progressively generates a photorealistic preview of the scene. It is designed to improve the artist's work on the texturing and lighting stage. A major feature of V-Ray is its ability to track changes to the scene performed by the user and automatically update the active shade preview. The following scene changes are supported: create/delete objects (geometry, lights, cameras, etc.), move/rotate/scale objects, apply/remove/edit object modifiers, apply materials on objects, modify material properties like textures, colors, etc., modify light properties (like position, color, etc.) [Chaos Software, 2010].

Design stage, users

V-Ray is a visualization software for the visual fx, film, media and entertainment, architecture, automotive design, product design, television, and other industries. It is thus used at design and visualization stages.

3D modeling

As a visualization tool, it is not possible to model a project in V-Ray. This software is used as a plugin as a part of other software like Autodesk 3ds Max or Maya. The user has to build his model in another software and export it in V-Ray to render the scene. However, it is possible to modify many parameters on materials, light sources, cameras, textures, inside the V-Ray platform.

Rendering

As explained before, to perform rendering, the user has to export the scene from the successor software or open the scene from V-Ray. Since the default V-Ray settings are not suited for a fast initial preview, it is necessary to make a few quick adjustments (global illumination, irradiance and noise) before the first rendering. V-Ray also supports and reacts to the following: animation types, camera animation, object animation (move/rotate/scale and deformations), material animation, and light animation. Other camera effects are available like perspective views, depth-of-field with broken effects and camera distortion [Chaos Software, 2010].

Coordinates

V-Ray does not relate the model to a coordinate system.

Import/export

V-Ray especially supports 3ds Max and Maya files and exports in many image file formats like .jpg, .png, .bmp, .tga, .hdr, .exr, .sgi.

Predecessor/successor software

V-Ray is first used for Autodesk 3ds Max and Maya but also supports distributed rendering across multiple machines in the local network like Google SketchUp and CINEMA 4D.

BIM

V-Ray is not a BIM application.

Actual solar calculation

V-Ray offers physically accurate full global illumination solutions and different GI algorithms (path tracing, irradiance cache, photon maps, light cache). The following methods for illumination are supported by V-Ray: Indirect (global) illumination - progressive path tracing as global illumination solution, direct illumination - standard lights, photometric lights, environment illumination and image-based lighting (ibl).

The VRaySun and VRaySky are special features which are provided by the V-Ray renderer. Developed to work together, the VRaySun and VRaySky reproduce the real-life sun and sky environment of the Earth. The following are few examples of parameters that can be modified:

turbidity, ozone - this parameter affects the color of the sun light, photon emit radius, indirect horizontal illumination - specifies the intensity (in lx) of the illumination on horizontal surfaces coming from the sky [Chaos Software, 2010].

2.3.12 YafaRay

Supplier, site, contact, last version, cost

The YafaRay software is an associated project placed under the Public Interest (SPI) umbrella. SPI is a non-profit organization which was founded to help projects developed and distributed as free open source software and hardware. The last software version is YafaRay 0.1.1 and it is free open source software. YafaRay can be downloaded for free from [www.yafaray.org].

Functions

YafaRay is a free open-source raytracing engine. Raytracing is a rendering technique for generating realistic images by tracing the path of light through a 3D scene. YafaRay works as an external render engine. An engine consists of a 'faceless' computer program that interacts with a host 3D application to provide very specific raytracing capabilities "on demand". Blender 3D is the host application of YafaRay. YafaRay works with any Blender official release from [www.blender.org]. This software simulates the physical behaviour of light, instead of the Blender internal engine [YafaRay, 2010].

YafaRay main features are similar to the other visualization tools. The user can add multiple types of light sources (point light, area light, mesh light, etc.), modify properties of background and mapping, add basic image textures (.tga, .jpg, .png, .exr, .hdr), different types of cameras (perspective camera, orthographic camera, angular camera). YafaRay also makes it possible to integrate volumes and apply multiple materials to them such as diffuse, glossy shaded, basic glass and emit material.

Design stage, users

Main users of YafaRay are computer graphic specialists, but some architects, drafters and designers use this program as a visualization tool. Some users may use the application for design work, but the primary use of YafaRay is at the rendering stage.

3D modeling

As an external rendering engine, YafaRay does not provide developed 3D modeling functions. The 3D model has to be built in Blender before being exported to YafaRay. The volume integrator is basically used to insert effects in the general model already built in Blender. For example, YafaRay's volumetric features provide a simulation of light interacting with particles suspended in a region of space. A common volumetric scenario is the "beam of light" effect, for example when light enters a dusty room through a window creating a visible shaft of light. YafaRay uses a realistic physically based model to render volumetric effects, and provides a basis for creating not just believable beams of light, but also smoke, clouds, fog, and other volumetric effects.

YafaRay also allows modifying existing objects previously built in Blender. The script takes the current Blender selected and active object and gives it custom YafaRay properties, depending on the object selected (camera, light or object) [YafaRay, 2010].

Rendering

YafaRay offers three renderings functions. The first one (Render) is handled in a separate window from Blender. This window appears when the rendering process is launched from the settings user interface (UI). It includes options and parameters to save renders. The second (Render anim) renders the frames set in Blender, using the Blender active camera. The third one (Render view) renders the Blender active 3DWindows.

These render parameters can be set by the user: ray depth, shadow depth, transparent shadows, output and input gamma, threads and anti-aliasing.

Coordinates

In YafaRay, 3D modeling is related to x, y and z axes.

Import/export

It is possible to load a YafaRay scene in .xml format. Scenes can be saved in the YafaRay .xml format. Final rendering images can be saved as .bmp, .png and .exr. Also, basic image textures (.tga, .jpg, .png, .exr, .hdr) can be imported.

Predecessor/successor software

Blender is the most common predecessor software used for YafaRay. There is no information about other software used prior to YafaRay, but we can suppose that every application that exports to one of the supported file formats may function as predecessor software to YafaRay.

BIM

YafaRay is not a BIM application.

Actual solar calculation

YafaRay uses a python-coded settings interface to set up most of lighting and shading parameters and all rendering settings. YafaRay has a traditional raytracing method which only renders light cast from light sources, called direct lighting. Additionally, YafaRay has three different global illumination models, which are path tracing, photon mapping and bidirectional path tracing. Raytracers like YafaRay try to reproduce global illumination (GI) by means of techniques that follow light's natural behaviour, such as casting samples of rays that bounce in the scene observing realistic rules. These samples are computed so a general result can be extrapolated from a limited amount of rays.

Light settings are mostly controlled by the YafaRay UI. In Blender, the only actions required are placing lights and choosing a Blender light type. Arealight size and spot beam parameters are controlled in Blender panels. In YafaRay, lighting power is controlled by a couple of settings (Color and Power) available in the python UI for every light type, therefore the Blender Distance and Energy buttons do not have any effect at all on YafaRay. It is possible to create Sun light in the Blender 3DWindows. The YafaRay UI allows choosing between two kinds of light sources: Directional and Sun. Directional light is a traditional sun light model which produces parallel rays and hard-edged shadows [YafaRay, 2010].

2.3.13 CAD object used with AutoCAD and ArchiCAD for visualization of active solar systems

The company ISAAC has developed a 3D CAD object to speed up the rendering procedure when integrating PV in architectural objects in order to facilitate and stimulate the use of BiPV systems by architects and designers and to improve the architectural quality of BiPV systems. GDL intelligent objects technology offers the optimal way of describing building components to use in construction design and facility management applications. The ability to select building components before and during the design phase will benefit both the designer, who can design using real objects, and the component manufacturers, who can successfully market their products at EDP.

The physical characteristics of a standard PV product (mono and multicrystalline, thin film, opaque surface, partially transparent) such as color (cells, background, frame), shape (cells and modules), typology of the electrical contacts (standard, back contact), transpance and reflection have been analysed. Each of these factors correspond to GDL information which carries 2D and 3D geometry, product logic and behaviors, parameters, material definitions and a specific user interface. These

features allow customizing the CAD object with little effort to the requirement of every user, reproducing most of the products currently on the market.

The CAD object can be used with both ArchiCAD and AutoCAD, all the information necessary to correctly download it can be found on the website [www.bipv.ch]. This tool is still a prototype and consequently during its utilization, it is possible to come across some anomalies.

2.4 SIMULATION TOOLS

The following section on simulation tools is by no means comprehensive. The programs presented below were selected on the basis of their popularity amongst architects and because they hold particular promise for use in schematic design. For a comprehensive list of all simulation programs available, the US Department of Energy (DOE) Building Energy Software Tools Directory should be consulted at the following address: [apps1.eere.energy.gov/buildings/tools_directory/].

2.4.1 bSol

Supplier, site, contact, last version, cost

bSol is developed by the University of Applied Sciences Western Switzerland (HEVs), competence group energy in Sitten [www.bsol.ch]. The cost of the program is 801 USD (590 €) for one license, 2010 USD (1480 €) for five (5) licenses and 2812 USD (2070 €) for ten (10) licenses. Academic licenses are available at reduced rates.

Functions

bSol is a program that simulates the thermal behaviour of a building over one year, considering its specific climate and the surrounding topography. It supports the optimal design of a building by defining the heating energy demand in relation to the architectural parameters, such as orientation of the building, thermal insulation, size of openings, choice of glazing, ventilation (with /without heat recovery) or thermal inertia.

Within a building, bSol supports two different climate zones (e.g. heated and unheated zones). These zones are defined by the enclosing areas (south-oriented façade, roof, slab on ground, etc.) with a certain heat transmission rate as well as the inherent thermal mass (floor slabs, subfloors, internal walls, load bearing walls, etc.) with the potential for heat storage. The enclosure consists of the (opaque) walls, windows, doors and thermal bridges. The simulation relies on climate data from METEONORM (air temperature, diffuse global radiation, elevation of the sun, azimuth, etc.).

The simulation is conducted in two steps. In a first step, a static calculation determines the different parameters of a building. It provides the heat capacity of the different materials, the heat capacity of a zone, the heat transfer of all areas, the equivalent collector area of the windows as well as the total of surfaces, volumes, thermal transfers and heat capacity. In a second step, dynamic calculations for each of the 8760 hours of a year determine the thermal behaviour of the building. The calculation algorithms allow identifying the solar radiation through windows as well as displaying the effects of varying building parameters. The dynamic calculation identifies the reaction of the building in relation to weather changes (air and ground temperature, solar radiation) as well as in relation to the prevalent internal energy sources (internal gains, heating, and cooling). Following the hourly calculation of the indoor air temperature, the contribution of the HVAC systems (supply and capacity) can be determined according to the requirements.

The results of the simulations provide:

- numeric data showing the potential for improving the project from an energetic point of view, the reference parameters of a building in relation to the specific heating and cooling energy / capacity over a year or a defined period of time;
- graphics presenting information about the indoor air temperature or the hourly heating and cooling capacity over the entire year;
- a display of the specific climate data, such as outdoor air temperature, global horizontal radiation, etc.

Design stage, users

bSol is designed for architects and engineers interested in optimizing the parameters of a building in terms of energy performance at the very early design stage and at subsequent stages.

3D modelling

bSol does not support a 3D-environment. The building model is set up through numeric inputs or predefined parameters.

Coordinates

bSol does not relate the building model to a coordinate system.

Import/export

Import is possible with the following file extensions: .bSol, .btm, .exp, .meteo, .hrz. Export is possible to the following extensions: .doc, .xls, .jpeg, .jpg, .png, .tiff, .bmp and clipboard.

Predecessor software, successor software

Building data is directly entered into bSol or imported from another project. It is not possible to import building data from other programs. However, the numeric or graphic results can be used in other programs. Building and climate data, the operational parameters and the horizon are entered by the user or imported from another project.

BIM

bSol is not BIM compatible.

Actual solar calculation

bSol does not calculate active solar systems but it considers passive solar gains in the thermal balance calculation. Passive solar gains are determined by calculating the incident solar radiation for each facade in consideration of climate data, orientation and horizon.

2.4.2 DAYSIM

Supplier, site, contact, last version, cost

DAYSIM is a Radiance-based daylighting analysis tool that has been developed at the National Research Council of Canada in collaboration with the Fraunhofer Institute for Solar Energy Systems in Germany. Windows tm and Linux versions of DAYSIM can be downloaded free-of-charge from [www.nrc-cnrc.gc.ca/eng/projects/irc/daysim/download.html]. The actual version of DAYSIM is called version number 3.

Functions

While Radiance has been initially developed to simulate luminances and illuminances under selected sky conditions or under artificial lighting systems, DAYSIM uses the Radiance simulation algorithms and the daylight coefficient method to efficiently calculate illuminance distributions under all appearing sky conditions in a year (dynamic simulation) [Reinhart, 2006]. The task of a daylight simulation algorithm is to predict indoor illuminances and luminances at a particular point (or at a

particular sensor) in time step, based on a 3D building model and the sky condition at this point in time.

Design stage, users

DAYSIM is a valuable software for architects, engineers and researchers with the aim to assess the daylight contribution in a particular building during the design stage. The combination of flexibility (due to the Radiance engine) and accuracy makes it a good tool for assessing the daylight autonomy, daylight level or annual irradiation on a defined sensor. For this reason, DAYSIM can also be used to predict the incident radiation on a PV panel or a thermal collector but the program is not suited for sizing these components taking into account the mechanical or electrical systems.

3D modeling

The input required for a simulation in DAYSIM is a description of the 3D surface geometry, materials (optical properties), and light sources in a scene. For carrying out a time-series simulation within DAYSIM, additional specifications for the sensors grid (x,y,z coordinates and x,y,z directions) are required.

Rendering

The main purpose of DAYSIM is not to produce rendering or photorealistic images but rather, to perform accurate calculations and predictions for daylight utilization potential (replacement of electric lighting by daylighting).

Coordinates

DAYSIM 3D model, as in Radiance, is performed according to x, y and z axes. The RHS is used for the surface orientation. The coordinates can be given in any unit of length.

Import/export

To perform a simulation with DAYSIM Radiance, two input files are required: the building geometrical model and the weather data file. The description of a building for a daylight simulation requires a 3D model of the building which contains information on the geometry of the building and its surroundings as well as optical properties of all material surfaces (e.g. RGB, red green blue, reflectance, specular reflectance, roughness, etc.). CAD modelers are used to create two or three dimensional virtual models of a building. Several tools exist to convert .dxf or .dwg files together with .3ds files into .rad description files [www.schorsch.com/download/radiance.html]. It is also possible to easily export Radiance or DAYSIM files using Ecotect.

A publicly available SketchUp plugin called su2rad, developed by Thomas Bleicher, can be used to export SketchUp scenes into the Radiance format [Bleicher, 2008]. To describe the annual amount of daylight available inside a building, the amount of solar radiation at the building site over the course of the year (weather file) must be known and entered in the program. This information is usually provided in the form of test reference year (TRY) files. TRY files provide typical annual profiles of exterior climate data such as ambient temperatures, wind direction and velocity, precipitations as well as direct and diffuse irradiances. The time step is usually one hour. An excellent free source of TRYs is the US Department of Energy's site at [www.eere.energy.gov/buildings/energyplus/weatherdata.html]. The site provides hourly climate data for many locations worldwide in the .epw format. DAYSIM directly imports .epw files and extracts the information required for an annual daylight simulation (global horizontal radiation and diffuse radiation or direct and diffuse radiation).

BIM

DAYSIM cannot be used as a BIM program.

Actual solar calculation

As mentioned above, DAYSIM is based on the Radiance engine. DAYSIM results tend to be very similar to Radiance classic results especially under overcast sky conditions. DAYSIM is a program specifically dedicated to daylight utilization studies i.e. estimate daylight autonomy and replacement potential of electric lighting by daylighting. It does not specifically calculate solar gains through windows or allow sizing PV and thermal installations although part of the results might be used with some creativity in the process of planning other solar aspects.

2.4.3 DesignBuilder*Supplier, site, contact, last version, cost*

DesignBuilder (DSB) [www.designbuilder.co.uk] has been developed by DesignBuilder Software Ltd. The last officially released version is Version 2.1.0.025. A Beta-version already accessible is called DesignBuilder 2.1.0.044. There are two different types of DesignBuilder 2.1 packages available: The Simulations Packages and, for the UK and Ireland, the Energy Assessor Packages. There are two further options for both of them. Buying the Simulations Packages, it is possible to choose the Design Simulation Package including a 3D Modeler, EnergyPlus Simulation and a Visualization tool for 1449 USD (1067 €) or the Advanced Design Simulation package containing CFD functions for 4199 USD (3091 €). The Energy Assessor Advanced Package includes not only 3D Modeler, Certification and a Visualization tool (Energy Assessor Package) but also the EnergyPlus Simulation for 1399 USD (1029 €).

Functions

DSB is the first comprehensive user interface to the EnergyPlus (E+) dynamic thermal simulation engine [apps1.eere.energy.gov/buildings/energyplus/]. DSB provides an easy-to-use yet powerful 3D modeler. DSB simplifies the data input for E+ and allows setting predefined parameters for easily checking building energy demand, CO₂ emissions as well as lighting and comfort performance. So DSB simplifies the whole process of building simulation and allows comparing the function and performance of buildings and its different design versions and delivering results in a short time.

DSB also includes the calculation of heating and cooling system sizes. For each of the building zones, the calculated loads can be obtained for heating and cooling the zone depending on lowest or highest outside dry bulb temperature from the input weather data. The CFD tool is a powerful yet easy to use 3D analysis tool for predicting airflow and temperature distribution in and around buildings. So it is possible to simulate e.g. wind conditions around the building as well as thermal behavior in larger rooms of the building design.

There are six language options, partially still under development: English, Italian, Spanish, German, French and Portuguese.

Design Stage, users

DSB has been developed for use at all stages of building design. Because DSB is a software tool for design, simulation and visualization of buildings, it is useful for architects, civil engineers, building equipment engineers and other designers participating in building design process or the optimization of energy flows in and outside existing buildings. With the help of DSB, architects and engineers are able to predict the effects of their decisions, which shall be realized at the building structure, the building envelope or the technical equipment.

3D Modeling

DSB includes 3D modeling functionality which is manageable and very easy. The way to deal with 3D Models in DSB is comparable to Google SketchUp. The definition of the building is first determined with its building blocks (floors). In a further step, these blocks can be divided into

different zones with own user profiles and technical equipment. These zones are built by elements like walls, ceilings or floors, which have their own defined properties (construction, adjacency). They contain other elements like windows, doors, holes.

Rendering

To control the consistence of the 3D building model, it is useful to use the existing visualization functionality. The results of the rendering can be exported as .jpg, .bmp, .png and other image files for external usage.

Coordinates

DSB uses the RHS to define surface orientation of all existing building elements. The positive y-axis defines the north direction. The zero point of the z-axis defines the surface of the Earth (ground), so that all elements under this level are by default adjacent to ground and can be changed in specific cases.

Import/export

The 2D drawing file import function of DSB contains the import of vector files like .dxf as well as images like .pdf, .bmp, .jpg, .png, .gif as well as .tiff files. For import of 3D model data from other CAD tools, see BIM. Weather data files also can be imported. Different formats are available like .epw, .csv, .tmy, .tmy2, .tm2, .iwecc, .iwecc, .wea and others. This weather file also contains data about direct and diffuse radiation.

After simulation, DSB displays the result output optionally as graph, grid or tables, which later can be exported to clip board or file as .csv or .bmp. The report generation with export functionality to MS Word (.doc) is still under development. The internal data management will be improved as well in the future. At the moment, it is possible to export a .csv report file containing all information about the building model (volume, areas, area of built envelope, and zone data like elements, constructions and users activity definitions). The simulation output data can be exported separately.

BIM

DesignBuilder v.2 provides interoperability with BIM models through its .gbXML import capability. This allows to import 3D architectural models created in Revit, ArchiCAD or MicroStation (and other 3D CAD systems supporting .gbXML data exchange) to provide heating and cooling system sizes and environmental performance data in the most efficient way possible. This standard has become the defacto industry standard scheme, which allows to import 3D architectural models created in Revit, ArchiCAD or MicroStation (and other 3D CAD systems supporting .gbXML data exchange) into the DSB data structure.

Actual solar calculation

Solar calculation functionality is included for passive solar gains prediction. Internal heat gains generated by solar radiation through windows and glass facade elements are calculated. DSB as well includes daylighting-models to simulate savings in electric lighting by the use of lighting control systems. Active solar systems like PV and ST are not available so far but a possible future tool option.

2.4.5 DPV (Design Performance Viewer)

Supplier, site, contact, last version, cost

Design Performance Viewer (DPV) is currently being developed by Keoto AG, c/o ETH Zurich, Institute for Technology in Architecture, www.keoto.net in Zurich, represented by Arno Schlueter and Frank Thesseling. The first publically available beta-version was supposed to be released at the end of January 2010. The prices are still not known at the time of writing this report.

Functions

Due to the underlying digital building model, the energy and exergy consumption as well as the resulting energy-dependent costs can be queried by the users at any time and at no additional costs. The relevant energy figures are calculated in real time; they can be saved and illustrated. This means that decisions taken on the building geometry, the construction system or the technical systems are instantly reflected by the expected energy and exergy consumption as well as the respective energy-dependent costs. Design decisions regarding the efficiency of a building may be taken at any time and promptly be included into the iterative design process. Thus, the use of this simulation program yields an optimised planning process to create more sustainable buildings in terms of energy, economy and architecture.

The building model is directly built in the CAAD-BIM environment. Parameters required for the energy calculations can be linked to the building components and modified at any time. The upcoming release already provides templates with the most commonly used construction systems.

DPV is directly linked to the library of the CAAD-BIM environment (parameterized building parts). Energy calculations for buildings in Switzerland use the climate data provided by SIA 380/1, a Swiss energy standard. The implementation of the METEONORM climate data in upcoming releases as well as the link with the CRB cost database are planned in coming development phases.

The annual heating energy demand is calculated according to SIA 380/1. The calculation results can be comprehensibly summarised and illustrated. It is also possible to evaluate and display the energy flows. Parameters and calculations are saved in a digital model. In this way, they can easily be exchanged among different users. Upcoming releases will be provided with a print function to create .pdf outputs of the results.

Design stage, users

DPV allows architects and planners to determine the energy and exergy consumption of a building already in the EDP. Thus, at a very early design stage, relevant energy figures can promptly be introduced into the design process. Additionally, it is possible to test energy and exergy strategies by using different combinations of technical and construction systems.

3D modeling

Data export or import to and from other programs is not necessary as DPV is directly embedded into the planning environment (Autodesk REVIT). An .ifc-interface will be implemented to make this energy and exergy calculation available for other design tools.

Coordinates

DPV 2D drawing is performed according to x and y axes and 3D modeling is related to x, y and z axes. It uses the RHS (depending on the CAAD environment).

Method of calculation (upcoming version)

The upcoming publically available release uses static calculations to determine the annual heat energy consumption according to SIA 380/1. Exergy flows are calculated with formulas developed at ETH. After mid 2010, an additional “physical calculation nucleus” will be available for dynamic calculations. Due to the modular design of the software, many different information and calculation models may be integrated into the program in the future.

Predecessor software, successor software

DPV is directly embedded into the planning environment (Autodesk REVIT), linking data export and import directly with the CAAD software.

Actual solar calculation

Active solar calculations are not available in DPV. In upcoming releases a simple implementation of PV or thermal collectors will be possible.

Comments

Contrary to conventional programs, DPV supports an instant evaluation of energy and exergy consumption as well as the respective energy-dependent costs. The manual entry of data is not necessary as the simulation program is embedded into the CAAD environment. And, starting from the EDP, information and calculations can be accessed and exchanged throughout the entire planning process. Instant feedbacks on design decisions, such as the form of the building or building elements, construction and technical systems, allow minimizing wrong planning decisions and eliminate unnecessary planning stages. Information on the relevant energy figures can be integrated promptly into the design of a building.

2.4.5 Ecotect*Supplier, site, contact, last version, cost*

Ecotect was developed by Dr. Andrew Marsh and Square One Research Limited. In June 2008, the rights of the program were acquired by Autodesk. The cost of a single user license is 2499 USD (1740 €). It is possible to register on the Ecotect website [www.ecotect.com] and receive a free 30 day trial version. The current version is V5.60 and the software runs on Windows.

Functions

Ecotect is a graphical building and environmental analysis tool. The program utilizes 3D models imported from CAAD-BIM predecessor software, but also allows for the direct creation of models with Ecotect's integrated drafting tools. Ecotect can perform a large number of different analyses within a 3D model, including shadows and reflection analysis, shading design, solar analysis, lighting design, analysis of views and light, acoustic analysis, thermal analysis and ventilation and air flow studies. The package can also create data concerning resource management and environmental impact of building materials.

Design stage, users

Ecotect can perform analyses of varying complexity based on simple or detailed CAAD-BIM models, and is therefore suitable for most design stages. The tool particularly focuses on supporting decision making at EDP.

Ecotect was written and developed by architects, with architecture and the design process firmly in mind. However, engineers, local authorities, environmental consultants and a wide variety of other users within the fields of building and environmental design also use the program.

3D Modeling

Ecotect can import CAAD-BIM models from most CAAD software through common file formats (ref. import/export section).

The modeling system in Ecotect is based on the principle of zones. Zones function much as layers in other CAD programs, but can also be taken to mean a space or volume of air within a building. The correct designation of zones is critical for many of the analyses performed by Ecotect, and imported 3D models will therefore require a certain amount of editing and supplementing before these analyses can be performed. The exception to this is shadow and lighting analyses, which can be performed on simple volumetric models without clearly designated zones. Zones can be created with the drafting tool in Ecotect, or by selecting individual objects in an imported model and designating the appropriate zone.

Coordinates

Ecotect uses the x, y and z axes, and the RHS. All objects are positioned in 3D space, even if drawn as 2D objects on the working plane.

Import/export

Ecotect supports direct import from many common rendering formats, including Imagine, Lightscape, Maya, Reanimation and Renderware, as well as import from CAAD software through the .dxf and .iff file formats.

Export is supported to Radiance (ray-traced rendering), POV-Ray and .wrl, .dxf (compatible with most CAAD software), EnergyPlus, DOE-2/eQUEST and SBEM for detailed energy simulations as well as AIOLOS and HTB2.

Ecotect also supports the export and import of data to several computational fluid dynamics (CFD) tools such as NIST-FDS, Fluent and WinAir4. Coupled with climate data files containing average wind data, this allows the program to analyse airflow both through and around buildings or complex urban environments.

Ecotect is intended as a conceptual design tool. The program therefore only requires a minimum of input data in order to perform initial sun shading studies and preliminary assessments. As the design process continues, the amount of data input into the model can be increased, allowing acoustic and thermal simulations and resource modeling.

Predecessor software, successor software

As the program supports .dxf and .iff import, most CAAD software can work as predecessor software to Ecotect, in addition to the supported rendering programs. The requirement for clearly defined zones for many calculations means that a moderate amount of editing will normally be required following an import. 3D models exported from Ecotect can be used by most CAAD software. In addition, several specialized software packages (see Import/export section) can be successor software to Ecotect.

BIM

At present .ifc format is not supported. However, work is underway to implement support for BIM in Ecotect. This could considerably simplify the import/export process, as individual building components (windows, walls etc) will maintain their object characteristics and identities after the transfer.

Actual solar calculation

Ecotect uses integrated climate data files to correctly calculate solar positions and incident radiation. The program uses this data to generate daily and yearly sun path diagrams and shading tables, shadows and shadow range diagrams for indoor and outdoor locations, reflection analysis and interactive visualization/ shadow generation. Shading design tools can generate the exact shading shape to perfectly shade a window for any specified period as well as modeling light redirection systems. Solar analysis diagrams can be generated to visualize incident solar radiation on all surfaces of the model, assisting in identifying optimum positions for solar collectors and other solar energy components. Solar availability can also be calculated at an urban level.

Using solar access analysis, the amount of solar radiation incident on any object can be calculated. Combined with total annual radiation, this can assist in determining the best position and orientation for active solar components. The tools also allow the calculation of the solar radiation incident on any solar collector, making it possible to estimate likely energy production through the year. As appliances and equipment can also be assigned within the model, it is possible to compare estimated electricity consumption with electricity production, simplifying demand matching and the sizing of active solar components.

2.4.6 EDG II

Supplier, site, contact, last version, cost

Energy Design Guide II (EDG II) is developed by the Institute for Building Technology at ETH Zurich, Prof. Dr. Bruno Keller and Stephan Rutz [www.energy-design-guide.ch]. The last version of this program is EDG II V. 20090409_1. The price for one license is 467 USD (341 €).

Functions

EDG II supports the design of a building with low heating and cooling demand at a very early design stage. As the building is meant to set the boundaries for sizing the HVAC system, only the heating and cooling demand of the building (and not the way it is covered) is calculated. This strategy requires to first minimize the demand of a building and second, to cover the needs using efficient heating and cooling systems.

EDG II relies on a completely dynamic and analytical calculation of the heat transmission as well as the charge and discharge processes in a room, whereas the thermal condition of the room is characterised by one single temperature (by virtue of simplification). The calculation relies on a model that considers the three relevant factors:

- loss factor K [W/m^2K](standardised on the outer surface),
- solar temperature-correction factor γ [m^2K/W], defined through the energy transmission of the opaque elements (in relation to the outer surface),
- time constant τ [s,h], defined through the dynamic storage capacity (in relation to the outer surface).

The program performs three basic steps in the calculation: pre-processing (input and transformation of data), processing (calculation of indoor temperature, cold and hot discomfort hours) and post-processing (output of data).

The data input consists of:

- environmental data: climate data in relation to the latitude, horizon, shadow through neighbouring buildings (graphic or numeric input) and reflection off the ground;
- operating data: internal heat sources, comfort limits, air exchange rates (only leakage and/or users, not building equipment) relying on weekly and annual timetables;
- control parameters: heating/cooling power, sunscreens (defined for every façade or the indoor temperature), night ventilation (high or low) and night setback;
- spatial parameters: orientation of primary façade (graphic or numeric input), U-value, construction (light, medium, heavy), detailed layering (calculation of thermal mass) and surrounding rooms (same temperature or unheated).

EDG II contains an individually upgradable library with predefined parameters including:

- weekly and annual timetables of operating data;
- list of sunscreens (transmission τ , reflexion ρ);
- list of glazing types (U-value, g-value);
- list of window frames (U-value);
- list of building materials (λ , c , ρ -values);
- climate data for 22 locations in Switzerland as well as some locations in Germany and Austria (DRY – values). Values for other locations in Europe, USA, Japan and China may be added.

The results can be printed as technical report consisting of:

- 3D graphics for overheating hours (Nw), cold discomfort hours (Nk) and 0-energy hours (N0);
- time dependant graphics for the annual run of the heating and cooling capacity, operation of sunscreens and night cooling;
- tables with sum of energy and peak capacity demand, overheating hours (Nw), cold discomfort hours (Nk) and 0-energy hours (N0).

Design stage, users

EDG II supports the outlay of a building with low heating and cooling demand in different planning phases, starting at the very early design stage. It is designed for architects, engineers and interested building professionals.

3D modeling

EDG II does not provide a 3D environment. The building model is defined through the input of numeric data, graphic inputs and predefined parameters.

Coordinates

EDG II does not relate the building model to the coordinate system.

Import/export

Import is possible from .klf, .helios, etc. and export to .doc, .xls, .jpeg, .jpg, .png, .tiff, .bmp and clipboard.

Predecessor software, successor software

It is not possible to import data from predecessor software. This means that all data has to be entered directly into the EDG II. However, all inputs of a specific simulation provide a model that can be exported to another user and be imported by another user. The numeric output tables can be used in other programs.

BIM

EDG II is not a BIM application.

Actual solar calculation

EDG II does not take active solar systems into account but it includes the passive solar potential into the calculations, considering the horizon, the shadow of neighbouring buildings as well as the reflection of the ground. Since the program only calculates the energy demand of the building and not how this energy demand is covered, it provides information on how the building works in terms of passive energy gains and heat losses. This information relays on dimensions and materialisation of the building as well as the building environment. Especially the 3D graphs of the results allow an easy interpretation and fast estimation of the parameters to be changed.

2.4.7 EliteCAD

Supplier, site, contact, last version, cost

EliteCAD is developed by Elite Software, a company offering more than 30 programs on the company's website [www.elitesoft.com]. The cost of these programs varies from 249 USD (196 €) to 1495 USD (1182 €).

Functions

Elite Software is a software developed for HVAC, electrical, plumbing, and fire protection design software. Over 30 programs are offered for such applications as HVAC load calculations, building energy analysis, HVAC duct and pipe sizing, plumbing and lighting design, fault current calculations, voltage drops, fuse and breaker coordination, etc.

Four software categories are available: HVAC, electrical, lighting, plumbing and fire protection. With EliteCAD, the user can calculate heating and cooling loads for commercial buildings, energy usage and operating costs for residential and light commercial buildings and graphically design various types of HVAC systems. Other software by Elite Software make it possible to draw printer-friendly psychrometric charts and analyse complex processes, perform common electrical calculation and data look-up tasks and design indoor lighting with point-by-point calculations or with zonal cavity calculations. The principal calculation method of all these software is based on reference books like the ASHRAE Handbook of Fundamentals and the Illuminating Engineering Society (IES) Reference Volume [Elite Software Development Inc, 2009].

Design stage, users

EliteCAD is used by engineers, architects and contractors at the design evaluation and validation stages.

Modeling

The major part of the programs proposed by Elite Software use full screen editing features that provide a simple "fill in the blank" input procedure. All input data is checked at the time of entry so that no improper data can be entered. The general project data needed includes the project name, location, client, designer, and other such items.

A modeling specific program is also available, which let the user switch to visual data entry. The Drawing Board program is used for drawing floor plans and ductwork. Drawings can be quickly created by dragging and dropping drawing objects from the built-in object catalogues onto the drawing window. The drawing objects in Drawing Board are pre-programmed shapes such as entire room shapes, walls, doors, windows, and ductwork. These are intelligent objects that contain data useful for the "Chvac", "Rhvac" and "Ductsize" programs.

Coordinates

EliteCAD 2D drawing is performed according to x and y axes.

Import/export

EliteCAD programs provide several different types of reports which can be selectively previewed on screen or printed. Virtually all calculated data can be exported to a comma delimited text file that can be imported into a spreadsheet program such as Excel. The reports can be previewed on screen, printed, or saved as a file. Any combination of detailed and summary reports can be selected for printing by the user. All reports reflect the input data that caused the calculated results. Many programs by Elite Software allow import .gbXML files from CAAD drawing software such as AutoCAD MEP and many other programs. [Elite Software Development Inc, 2009].

Predecessor/successor software

Project data from EliteCAD programs can be exported to Elite Software's Energy Audit program as well as to eQUEST and PowerDOE programs. Export is also possible to Energy Audit for analysis of residential and light commercial projects, or to any application which uses unitary HVAC equipment. Export to eQUEST or PowerDOE is suggested for a precise analysis of large commercial projects that require precise modeling of variable loads, equipment, operating schedules, and control schemes [Elite Software Development Inc, 2009].

BIM

EliteCAD is not a BIM application.

Actual solar calculation

EliteCAD does not calculate reduction in heating loads due to solar gains through windows. The load calculation programs thoroughly report the heating and cooling loads on the structure, but do not

specifically help with selecting active solar equipment to meet these loads. EliteCAD does not either calculate daylight utilization potential.

2.4.8 ENERGIEplaner

Supplier, site, contact, last version, cost

ENERGIEplaner is a software provided by BKI, which is a subsidiary of the architectural associations of Germany. Its primary task is to investigate and establish the costs of building projects as a basis for cost calculations. The main products of BKI are technical books with building costs and software for cost estimations and cost calculations (BKI KOSTENplaner). Beside these products, BKI offers a software for energy consulting and calculations according to the EnEV (for residential and non-residential buildings, for new and old buildings), called BKI ENERGIEplaner.

Functions

With BKI ENERGIEplaner the following net energy, final energy, auxiliary energy and primary energy is calculated:

- heating,
- domestic hot water,
- lighting,
- cooling,
- ventilation (air conditioning).

BKI ENERGIEplaner is based on the Energieeinsparverordnung (EnEV) 2009. The underlying engineer standards are mainly DIN V 18599 (Part 1-10) and, for residential buildings, DIN V 4108-6 with DIN V 4701-10. Additional calculations are moisture proofing and summer heat protection according to DIN 4108. For evaluation of economic efficiency, the BKI ENERGIEplaner offers a calculation of amortization on a straight-line-basis. Therefore the costs of a renovation are compared to the reduction of energy costs in the building in different variations. A rate of price increase and an interest rate are considered.

Design stage, users

The users of the BKI ENERGIEplaner are mostly architects and civil engineers working on new buildings or evaluating existing buildings with regard to energy consumption.

3D modeling

Modeling of 2D-polygons (rooms) is possible but 3D-modeling is not yet part of BKI ENERGIEplaner.

Coordinates

BKI ENERGIEplaner does not relate the building model to a coordinate system.

Import/export

Import and export of databases, calculation results and building model as .xml is possible.

Predecessor software, successor software

BKI Fotoaufmass can be used to measure surfaces and volumes of buildings from pictures. Results of BKI Fotoaufmass can be imported into BKI ENERGIEplaner as .xml-File.

BIM

BKI ENERGIEplaner is not BIM software.

Actual solar calculation

BKI ENERGIEplaner Polysun Inside is an additional module, which offers a state-of-the-art yet simple PV-Simulation for calculation according to the EnEV 2009. With the EnEV 2009 it is, for the first time in Germany, possible to charge the electrical gains of PV against primary energy consumed by the building.

2.4.9 eQUEST

Supplier, site, contact, last version, cost

eQUEST is a part of the DOE-2 software developed by James J. Hirsch & Associates in collaboration with Lawrence Berkeley National Laboratory, with LBNL DOE-2 work performed mostly under funding from the United States Department of Energy. eQUEST 3.63b is the most recent release. This freeware is available on the Energy Design Resources website, a Californian foundation that offers a palette of decision-making tools and resources to design, build and operate more energy-efficient buildings [www.energydesignresources.com, see Energy Design Resources, 2010].

Functions

eQUEST is a building energy simulation tool. This software combines a building creation wizard, an energy efficiency measure wizard, and a graphical reporting tool with a simulation "engine" derived from the latest version of DOE-2. (DOE-2, in its "raw" standard form is a command line, or "batch"-oriented program, for which the user creates input files, using a text editor, with the building description in DOE-2's building description language).

eQUEST features a building creation "wizard" that walks the user through the process of creating a building energy model. This involves following a series of steps that help him describe the features of his design that would impact energy use, such as:

- architectural design,
- HVAC equipment,
- building type and size,
- floor plan layout,
- construction materials,
- area usage and occupancy,
- lighting system.

The eQUEST building creation wizard first requests the most general information about the building design, and then pursues into progressively deeper details. In all, the building description process comprises 23 data-entry steps – each represented by a "wizard" screen. After compiling a building description, eQUEST produces a detailed simulation of the building, as well as an estimate of how much energy it would use. Within eQUEST, DOE-2 performs an hourly simulation of the building design for a one-year period. It calculates heating or cooling loads for each hour of the year, based on information about walls, windows, glass, people, plug loads, ventilation.

During the simulation, DOE-2 tabulates the building's projected energy use for various end uses such as lighting, plug loads (computers, appliances, copiers, etc.), heating, cooling, ventilation, pumping, shading, fenestration.

eQUEST offers several graphical formats for viewing simulation results. For instance, it is possible to display graphs of estimated overall building energy on an annual or monthly basis. The user can also compare the performance of alternative building designs.

In addition, eQUEST allows performing multiple simulations and view the alternative results in side-by-side graphics including energy cost estimation, daylighting and lighting system control, automatic implementation of common energy efficiency measures (by selecting preferred measures from a list). Advanced user can input additional building details to analyse complex buildings. A 3D view of the building geometry is available in this version, as well as HVAC system diagrams [Energy Design Resources, 2010].

Design stage, users

eQUEST is a software used by everyone in the construction industry. It could be used for non-residential new construction, home builders, design educators and the owners of existing buildings. eQUEST is designed to support all design phases, when information is most limited and until the completion of the project.

3D modeling

It is possible to create polygonal shapes as in many other software by using pick point in a grid. Building geometry relies on predefined generic shapes or user input via drawing tablet. The user can also import .dwg files and edit them in the Design Wizard. The most common way to use the software is by creating a building from the Design Wizard. These applications help the user to set all parameters needed to perform a simulation like footprint shape, ceiling height and envelope construction type.

Coordinates

eQUEST does not relate the building model to a coordinate system.

Import/export

The software provides users with the ability to import .dwg files. It is also possible to export analysis results in Excel (.xls) format. eQUEST also allows importing DOE-2 input files.

Predecessor software, successor software

It is possible to import .dwg files in eQUEST.

BIM

eQUEST is not a BIM application.

Actual solar calculation

eQUEST does provide a detailed calculation of passive solar heat gains. It offers multiple possibilities to interact with active and passive solar strategies. eQUEST includes a PV module that supports active solar design. This module makes it possible to determine voltage, angle, dimension and temperature between the cell and the back surface. However, it is important to note that there is no capability to model solar thermal systems in eQUEST.

eQUEST also allows predicting the performance of skylights, lighting system controls and effects of obstructions on daylight that can affect lighting system response. These calculations may be modified according to depth, width, length, window type, type of glass, etc. Another application allows the user to calculate the direction of occupant view, which is measured as a clockwise angle from the space y-axis. This angle is used to calculate daylight glare.

The design-day weather data and schedules of operations in eQUEST offer up to three 24 hour design day weather profiles. Thee 24 hour design weather sequences can be repeated for any number of days to include different solar angles. It is also possible to set many options of the building site characteristics like latitude, longitude.

eQUEST solar heat gain calculations do not provide a detailed calculation of solar *distribution* on interior surfaces: it relies on user-controlled assignment of the interior distribution of solar gain. By contrast, eQUEST daylighting prediction does provide detailed tracking of the “direct” daylight

component. The treatment of the “indirect” component uses the split-flux method, which predicts average reflected daylight levels and neglects internal obstructions of complex fenestration and spatial configurations [James J. Hirsch & Associates, 2009].

2.4.10 Green Building Studio

Supplier, site, contact, last version, cost

Green Building Studio (GBS) is a web-based energy analysis service supplied by Autodesk. An annual single-user subscription cost 745 USD (595 €) and a 10-users subscription cost 4995 USD (3989 €). These subscriptions provide an unlimited access to the web service including unlimited projects and unlimited runs. A limited access for a 30-days free trial is available on the official Autodesk Green Building Studio website [gbs.autodesk.com/gbs/account.mvc/login]. This free trial allows performing calculations for up to two building projects.

Functions

GBS is an analysis tool which performs whole building energy analysis. GBS is easy to use; the user only specifies the building type and geographical location as input and there are built-in libraries for various simulation parameters (building construction, shading, internal heat gain, infiltration, schedule, HVAC system and equipment and utility rates) based on statistical data [Lam, Chun Huang & Zhai, 2004]. Users can evaluate how the building components affect energy use. It allows optimizing energy efficiency and evaluating the carbon footprint of building projects. This software also performs LEED reporting for some credits about daylighting, water efficiency, energy and atmosphere. Moreover, the Design Alternative feature helps users determine the variations to a run that will improve energy efficiency. This feature allows significant design decisions to be made in little time. However, since GBS does not provide modeling tools, these design alternatives are made by choosing predefined alternatives with scroll down menus. One major limitation is the fact that the simulations are performed for the US territory only.

Design stage, users

GBS allows architects and designers to work with sustainability earlier in the design process. These creators can also share their GBS files with engineers. GBS is more suited for detailed design stage because main exterior walls, windows, roofs, floors and interior partitions separating the building's thermal zones are necessary.

3D modeling

GBS does not provide a 3D interface. The model has to be created in another software, which can export to the .gbXML format.

Rendering

Green Building Studio does not provide rendering functions.

Coordinates

Since GBS does not provide 3D interface, no coordinate system is used.

Import/export

GBS provides a great interoperability with BIM tools and others software. Various file formats are supported such as .gbXML, VRML, DOE-2, EnergyPlus, and some weather files (binary format or .csv files). The model in GBS can be exported as DOE-2 or .gbXML file format for detailed energy analysis using other simulation programs [Lam, Chun Huang & Zhai, 2004].

Predecessor software, successor software

GBS allows direct geometry capture from Autodesk Architectural desktop (ADT), ArchiCAD, Revit, Autodesk Building System CAD programs without a need for remodeling [Lam, Chun Huang & Zhai,

2004]. GBS also interoperates with other compatible energy-analysis software. An add-on, which can be downloaded from the official web service, allows to access to Autodesk GBS on web directly from the Revit BIM-platform. So, Revit is an important predecessor software to GBS. It is also possible to share GBS files between engineering software programs. However, this software is not designed for highly detailed simulations such as other engineering software.

BIM

Green Building Studio does not support the .ifc format. So, this software is not considered as a BIM application. However, it offers a great interoperability with Autodesk Revit, which is a BIM application.

Actual solar calculation

Since GBS performs whole building energy use analysis, we can suppose that it considers passive solar gain. Moreover, qualifications for LEED about daylighting credits are automatically provided for every analysis. This software performs glazing factor calculations for each room. These calculations allow users to determine the action required to improve this factor, and increase eligibility for these LEED credits. GBS also analyses every exterior surface of the building to determine the amount of electricity that could be generated with PV panels on these surfaces. A summary of this PV electricity potential is provided and these results are presented only as numerical data and for the entire building (not for each surface).

2.4.11 IDA ICE

Supplier, site, contact, last version, cost

IDA ICE is developed by the EQUA Simulation Technology Group in Stockholm [www.equa.se]. The last version is IDA ICE 4.0. The price for one license is 2464 USD (1800 €).

Functions

IDA ICE is based on the IDA Simulation environment, an object oriented and equation based modeling system developed by the same company. IDA ICE is building simulation software used for predicting and optimizing heating loads, cooling loads, energy consumption and thermal comfort in buildings. IDA ICE calculates the dynamic interaction between the ambient climate, the building, the building system and the building occupants. Calculated variables in IDA ICE are resource consumption (energy, CO₂) and comfort values (temperature, operative temperature, hours with high temperature, humidity, CO₂-concentration, Fanger comfort values, etc.).

Design stage, users

IDA ICE works at four different user levels: Wizard, Standard, Advanced and Developer. The wizards are easy to use and allow obtaining estimations for specific questions about the thermal behaviour of buildings in the design or planning stage. The standard level provides efficient model building with 2D and 3D GUI. It allows understanding the predicted dynamic behaviour of a building in different model precision levels: simple models for the design stage and detailed models for the planning or optimization phase. The advanced and developer level allow investigating the thermal behaviour of new non-standard systems in all planning phases. The two levels need expert knowledge. Any system and any physical phenomena can, when required, be taken into account.

3D modeling

The 3D geometry model describes the building and its thermal zones as well as the interzonal thermal connections through wall/floor/roof constructions, windows and openings. The geometry model can either be imported from an .ifc file or built up from scratch. For the latter, 2D CAD Import supports the working process. Any 3D CAD object can be imported as shading element.

Coordinates

IDA ICE 2D drawing is performed according to x and y axes and 3D modeling is related to x, y and z axes. The RHS is used.

Import/export

Import is possible from .ifc, .dxf, .dwf, .3ds, .cgm, .cmx, .dgn, .drw, .gbr, .svg, .pcl, .prn, .prt, .pct, .plt, .wpg, .vwpg, .bmp, .jpeg, .jpg, .png, .pcx, .tiff, .tif, .pcd, .tga, .emf, .wmf and export is possible to .html, .doc, .xls, .jpeg, .jpg, .png, .tiff, .bmp and clipboard.

Predecessor software, successor software

The normal work flow with IDA ICE can be described as follows: CAAD => IDA ICE => Results (Excel etc.)

BIM

IDA ICE imports all versions of .ifc so the program is .ifc compatible. The imported information from .ifc includes 3D models with walls, windows, glazing types, constructions and materials.

Actual solar calculation

Passive solar calculations are performed with IDA ICE. Solar loads and shading calculations are performed using ray tracing algorithms with consideration of surface reflection, venetian blinds, advanced shading control, including different optical parameters for different spectral bands. Active solar calculations are also performed. Component models for PV and solar thermal do exist. However, they are not available at the user levels for the early planning phase. This function is planned to be implemented in a near future.

2.4.12 IES VE*Supplier, site, contact, last version, cost*

VE (Virtual Environment) is developed by IES, Integrated Environmental Solutions in Scotland, [www.iesve.com]. The last version of the software to this date is version 6.0.3. The license fee depends on the number of modules one purchases and if the user wants a single user license, LAN and WAN license and if the user wants an annual or perpetual license. Therefore the cost varies from approx 274 USD (200 €) annually to tens of thousands of Euros.

Functions

Virtual Environment PRO is a bundle of modules that work with the same geometrical model within VE PRO. The modules can perform almost any aspect of building analysis spanning from energy simulation using the heat balance method, sophisticated lighting analysis using Radiance to a simplified CFD module. The amount of results that can be obtained from VE is vast; including comfort values, different radiant temperatures and so on. The complete list of modules and their uses can be seen in Table 2.

TABLE 2. Description of the modules in VE (from IES website).

Module	Description
ApacheCalc	Heat loss/gain calculations using CIBSE procedures to determine design heating/cooling loads
ApacheLoads	Design heating/cooling loads calculations using ASHRAE Heat Balance Method
ApacheHVAC	Works in conjunction with ApacheSim to provide effective modelling of conventional/advanced HVAC systems, operation and control

MacroFlo	Works in conjunction with ApacheSim to provide bulk airflow analysis for passive/hybrid ventilation system design and simulation
RadianceIES	Sophisticated 3D simulation of light levels using advanced ray-tracing techniques, covering luminance, illuminance, daylight factors, perceived impact, photorealistic visualization
FlucsPro	Daylight and electric lighting design analysis to calculate number of luminaires required and light levels for defined schemes/planes
FlucsDL	Daylight analysis capabilities of FlucsPro to calculate light level values and daylight factors
LightPro	Allows to place and edit luminaires within a room for subsequent analysis using FlucsPro, or a detailed simulation using RadianceIES
SunCast	Advanced 3D solar analysis for a building and its site; visual, graphical and numerical outputs
MicroFlo	CFD system for detailed predictions of airflow and heat transfer processes in and around building space
Simulex	Simulate occupant behaviour in the event of a building evacuation or other ingress/egress; identify potential problems and find solutions
Lisi	Powerful, easy to use lift design and simulation tool
ModelIT	VE-Pro module for 3D geometry creation, data assignment and import functions

Design stage, users

VE PRO uses different levels of complexity depending on which module the user chooses. Simple energy and lighting analyses can be performed with little experience with the software early in the design process and it is possible to perform more advanced analysis when needed. Many of the modules in the bundle can exchange results to provide more accurate and detailed analyses.

3D modeling

3D modeling in VE Pro is done in the ModelIT module. The module is capable of creating almost any geometry. This geometry is then used in all the other modules.

Material modeling

Please see the section about Radiance in this report.

Rendering

Please see the section about Radiance in this report.

Import/export

VE includes a plugin for Revit Architecture and MEP that can import the Revit model into VE, which has little or no losses in terms of information about the geometry if the Revit model is correctly defined. Furthermore .gbXML files (exported from ArchiCAD, for example) and .dxf files can be used to create geometry in ModelIT. The results can be exported to Microsoft Excel. A discussion has been going on in Sweden about creating an import plugin for Revit using the Revit API to import results from VE so that no relevant information is lost from the Revit model and to simplify the iterative design process.

BIM

The best way to use VE Pro is to use it in conjunction with Revit, which is a BIM application.

Actual solar calculation

VE Pro contains several modules for solar calculations. Among them is the Radiance module, which has been mentioned earlier and which is a very powerful tool. Furthermore, other modules (Flucs method and Suncast module) are powerful tools which do not only produce quantified information about solar irradiation both on interior and exterior surfaces, but can feed this information into the energy simulation modules to provide a more accurate solar load.

2.4.13 LESOSAI*Supplier, site, contact, last version, cost*

LESOSAI is developed by E4tech Software SA, a company that specializes in building physics and building energy analysis [www.e4tech.com/en/software-introduction.html]. LESOSAI 6.0 version costs 800 CHF (550€) for new version, and 480 CHF (330€) for upgrades from previous versions. Additional modules also need to be purchased depending on the users needs [www.lesosai.com/en/02_tarifs.html].

Functions

LESOSAI [www.lesosai.com] is software for thermal energy calculations and certifications of buildings comprising one or more heated or cooled zones. It is designed primarily for building and thermal engineers and architects. The simulations can be done month by month or hourly; the internal gains are defined by the SIA2024 (40 possible scenarios).

LESOSAI allows the calculation of environmental impacts of energy consumption, taking into account the energy used (heating, cooling, lighting, ventilation and internal gains) but also considering the construction materials of the building. The calculation is based on a life cycle analysis of a building and uses the list of impacts provided by the KBOB (extracted from the Ecoinvent database), and methodology consistent with the SIA 2032 Swiss technical specifications.

In order to simulate buildings in many places throughout the supported countries, LESOSAI integrates the official weather data and the generator METEONORM. To calculate the thermal conductance coefficient (U-value), LESOSAI includes USai [www.u-sai.com], which can also synchronize the databases of materials with several producers who participated in the [www.materialsdb.org] project. LESOSAI also supports the calculation of heating power according to EN 12831 and SIA 384.201 by zone or by room.

The graphical user interface is optimized to handle complex buildings in sufficient detail for the building certification. From this data, all required parameters for the dynamic simulation are extracted and passed to the Polysun simulation kernel by an internal software interface. The selection of system templates is based on the Polysun template database.

Design stage, users

The software supports several languages: English, French, German and Italian. Users can choose from several calculation methods. LESOSAI is certified for Switzerland, France and Luxembourg and can be used in other countries for thermal energy calculations.

3D modelling

Lesosai 7.0, Polysun inside will have a wizard 3D from September 2010 and import .nbdm format at the end of 2010 (export from Google Sketch Up is made possible).

Coordinates

Lesosai 7.0 classic version is performed using area, orientation and slope, without the need for the x,y,z position. The wizard gives the possibility to quickly build classical design of buildings and drawing will be an importation of the .nbdm format.

Import/export

Import in .nbdm will be possible at the end 2010. Export to .pdf, .bld, .txt files is possible.

Predecessor software, successor software

No predecessor software are relevant for LESOSAI, but all software including exportation in .nbdm format will be accepted. Successor software is generally not relevant, but Excel can be used to open the .txt files exported from Lesosai.

BIM

Lesosai does not support the .ifc format. So, this software is not considered as a BIM application.

Actual solar calculation

LESOSAI uses the Polysun inside calculation.

2.4.14 Polysun*Supplier, site, contact, last version, cost*

Polysun is developed and sold by Vela Solaris AG, a privately-held Swiss corporation, which has been founded in 2007 as a spin-off of the Institute for Solar Technology SPF at the University of Applied Science Rapperswil in Switzerland.

Polysun is sold according to three user levels. Designer, being the highest level with a price range between 1300 USD to 4200 USD (1000 to 3200 €) offers full flexibility in system design by its unique graphical editing capability. Polysun Professional ranging from 380 to 2000 USD (290 to 1600 €) offers a user friendly interface and targets solar energy professionals, who are mainly focusing on standardized systems [Vela Solaris, 2008]. Vela Solaris is engaged in several partnerships where the Polysun simulation kernel is made available for other software. With the label “Polysun Inside”, it is ensured that simulation results are consistent with the calculation of the standalone version of Polysun enabling a data exchange between the various programs.

Functions

The standalone version of Polysun is mainly used for the prediction of system profit ratio (early planning phase) and system optimization (detail planning). Calculations are based on a dynamic simulation model and statistical weather data. As a result, Polysun is not only a valuable tool for engineering work like optimization and design, but also for quality control and marketing support. With its solar thermal features, Polysun is widely used in retrofit applications due to its unequalled flexibility in the detailed system representation. In Solar Photovoltaics, Polysun offers an automatic inverter matching as well as an accurate yield prediction.

Polysun is shipped with a comprehensive component catalogue database ranging from photovoltaic modules, inverters, solar thermal collectors, heating units, etc. In these catalogues, commercially available components are stored with all necessary data characteristics. Updates are provided over the Internet by Vela Solaris. Furthermore, a large number of system templates are included with established heating and PV concepts. This allows a fast and efficient work.

Design stage, users

Polysun is mainly targeting at installers and planners of solar energy systems. Polysun offers a broad range of functionalities required for the analysis and design of domestic energy systems ranging from PV to ST, heat pump and cooling systems. With its physics-based simulation capability, it is a high quality basis for yield and economic viability calculations. It comprises the necessary calculations for amortization and the data required for subsidy applications.

With its user-friendly interface translated in ten different languages (including Chinese), Polysun has a broad world-wide customer database. While Vela Solaris is providing support in German and English, they have partners in many different countries providing local support and ensuring that the template and component database are relevant and up-to-date.

3D modeling

There is no 3D modeling capability in Polysun.

Coordinates

There is no 3D modeling capability in Polysun. Horizon data and position of the sun are visualized graphically.

Import/export

Polysun offers import for external weather data (hourly, monthly) and horizon data (plain data, HoriCatcher, SunEYE).

Predecessor software, successor software

Polysun has the METEONORM weather data kernel included. It uses OpenStreetMap for a detailed definition of the object location. Polysun offers a broad range of system components in its database (PV and inverter database of Photon, solar thermal collectors of SPF and other testing institutes, heat pump data from NTB).

The Polysun platform offers a universal software interface for other applications [Witzig, Foradini, Munari Probst, Roecker, 2009]. In these applications, the “Polysun Inside” DLL is fully integrated and users have access to the Polysun features through the host software. Examples are LESOSAI, ENERGIEplaner, DDS, plan4solar.

BIM

Polysun is not a BIM application. However, with the application DDS-CAD, it is closely linked to a BIM kernel in the DDS software.

Actual solar calculation

Polysun has a full featured solar simulation engine including in-depth representation of thermodynamic and photovoltaic physics. In particular, it offers the combination of solar thermal, photovoltaic and heat pump applications which is important because of their strong interdependence.

The program enables easy PV system sizing and delivers the most important results at an impressive speed. Shading analyses can be carried out, although in more complex shading situations PVsyst is more accurate.

2.4.15 PVsyst

Supplier, site, contact, version, cost

PVsyst is a software package for the study, sizing, simulation and data analysis of complete PV systems supplied by the Institute of Environmental Sciences (ISE) and the University of Geneva. The last version is the PVsyst 5.04. The price is 1000 CHF (984 USD, 676 €) for one license (5.04 version). A license for additional machines costs 200 CHF (197 USD, 135 €). The price for an educational license is 800 CHF (787 USD, 541 €). A trial version is also available for 15 days on the official PVsyst website [www.pvsyst.com/5.0/index.php]. After the evaluation period, PVsyst may run in Demo mode, with restricted capabilities.

Functions, design stage, users

PVsyst is used by architects, engineers and researchers at preliminary design and project design stages. At preliminary design, PVsyst is used to pre-size systems. It also evaluates the monthly production and performances and performs a preliminary economic evaluation of the PV system. At project design stage, the software generates detailed simulations computing hourly values and supports the user in the definition of the PV-field and the selection of the right components.

3D modeling

A 3D CAD tool is available to draw the geometry of the complete system. However, modeling tools are very simplistic in PVsyst.

Rendering

The modeling tool performs rendering in real-time. It is possible to generate animations over a whole period to study the impact of shading under specific conditions.

Coordinates

PVsyst 2D drawing is performed according to x and y axes and 3D modeling is related to x, y and z axes.

Import/export, predecessor software, successor software

With PVsyst, it is possible to import meteorological database from many sources on the web. Users have access to meteorological data as hourly values from Meteonorm, Satellites, US TMY2 and Helioclim-2. They also have access to meteorological data as monthly values such as Meteonorm, WRDC, NASA-SSE, PVGIS-ESRA and RETScreen. Custom meteorological files can be easily imported in any ASCII format.

PVsyst provides specific graphical or tabular tools, which can be exported to other software. This includes output of solar geometry (sun paths, incidence angles, etc.), various graphs of the components' behavior (PV modules, batteries, pumps), hourly meteorological plots, and calculations of irradiation on tilted planes, also with graphical comparisons with clear day model, transposition factor plots, for plane orientation optimization, and more [University of Geneva, 2010].

BIM

PVsyst is not compatible with .ifc so this software is not a BIM application.

Actual solar calculation

Solar calculation is the main function of PVsyst. This software works at two levels (preliminary and project level) by helping to pre-size and size different systems for a project. For grid-connection systems, and especially for building integration, the preliminary design level of PVsyst demands available areas, nominal power or energy yield desired. For stand-alone systems, the preliminary level calculates a size based on the required PV power and battery capacity. For pumping systems, the user may specify the water needs and pumping conditions. The preliminary level also estimates the required power of the pump and the PV array. At this level, evaluations are performed using monthly values [University of Geneva, 2010].

The project design level is mostly engineer-oriented compared to the preliminary level. This part performs through system design using hourly simulations. It offers the users a large database of PV components, and detailed parameters allowing fine effect analysis, including thermal behaviour, wiring and mismatch losses, real module quality loss and incidence angle losses. A 3D CAD tool is available for “near shading” detailed studies. This tool computes a shading factor for beam component as a function of the sun's position. The shading of diffuse radiation is taken into account using an integral of the shading factor over the sky portion "seen" by the array. It is also possible to partition the array in order to evaluate the electric losses due to the string layout. This level may define the horizon for “far shading” calculations. It provides condensed result forms, which summarize all

system parameters and the most significant result plots and tables for one given simulation. Other detailed results are available for several dozens of simulation variables. PVsyst includes an operating voltage optimization tool. The software performs close comparisons between measured and simulated values, allowing for detecting and analyzing even very little mistuning of real systems. [University of Geneva, 2010]

2.4.16 PV*SOL

Supplier, site, contact, last version, cost

PV*SOL is supplied by Valentin EnergieSoftware GmbH, Berlin, Germany [www.valentin.de]. The cost of this program is 476 USD (348 €) for Stand-Alone systems, 640 USD (468 €) for Grid-Connected systems and 955 USD (698 €) for both systems. The last version is PV*SOL 3.0.

Functions

PV*SOL is a program for the design and simulation of PV systems. It is possible to create a system using a wide range of modules and to determine the size of the system with the roof layout facility. After testing all relevant physical parameters, the program shows the right inverter and PV array configuration. The shading of the system due to horizon, trees or buildings can be taken into account in the simulation. In addition, it is possible to determine the capital value of the system, the electricity production costs and the amortization period.

The calculations are based on hourly balances. The output of a PV system, which is determined by simulation over a period of one year, is based on a mathematical model which allows the exact reproduction of the characteristic curve for each of the PV modules contained in the database. If different module types or differently oriented arrays are used within a PV system, the program simulates this by combining module groups into PV sub-arrays.

Climate data for irradiation and air temperature is delivered with the program for approximately 650 European locations. The integrated module MeteoSyn contains further international locations and can also generate hourly values from monthly data entered by the user. In addition, the German Weather Service's TRY format climate files can be imported into the program. And with the Swiss program METEONORM, worldwide climate data can be created and imported into PV*SOL. The results of the simulations (e.g. projected specific annual yield, system efficiency, solar fraction, economic efficiency, energy) can be produced in graphical format, in a comprehensive project report.

Design stage, users

This dynamic simulation program has been developed for engineers, planners, roofing specialists and electrical engineers or building technicians and can be used at every stage of the design: at the start for pre-sizing and then for the design and optimization of the PV system.

3D modelling

PV*SOL does not support a 3D-environment.

Coordinates

The calculation is performed according to x and y axes. In order to specify the system orientation, the Azimuth angle is used (negative for east oriented and positive for west oriented surfaces).

Import/export

Import is possible with the following file extensions: .prg, .pra, .prj, .wet, .wbv, .dat, .try, .emm, .eta, .tar, .sch. Export is possible with the following file extensions: .prg, .wbv, .dat, .try, .emm, .tar, .eta, .sch, .pdf, .doc and clipboard.

Predecessor software, successor software

Several meteorological databases can be imported in the program (e.g. METEONORM, PVGIS, NASA data). Every climate data, if available in hourly format (i.e. 8760 values for temperature, global radiation, wind and relative humidity), can be saved as an ASCII file (separating the data with a TAB and using the ending .dat) and imported in PV*SOL. As output, PV*SOL provides graphical and tabular tools, which can be exported to other programs and further elaborated.

BIM

PVSOL is not a BIM application.

Actual solar calculation

The program enables easy PV system sizing and delivers the most important results at an impressive speed. Shading analyses can be carried out, although in more complex shading situations PVsyst is more accurate.

Climate data for irradiation and air temperature in hourly intervals for a period of one year is delivered with the program for approximately 650 European locations. The integrated module MeteoSyn contains a further 2000 international locations and can also generate hourly values from monthly data entered by the user. By simply entering the monthly mean values for any new location, it is possible to extend the database. If the monthly values for a particular location are not available, they can be obtained from the NASA website.

2.4.17 Radiance*Supplier, site, contact, last version, cost*

Radiance is a suite of programs for the analysis and visualization of lighting in design. It is a physically based, backward ray tracing rendering tool that has been developed by Greg Ward at the Lawrence Berkeley National Laboratory. The last version is the Radiance v 3.9 but the v 4.0 will be available soon. Radiance can be downloaded for free from the Internet site [radsite.lbl.gov/radiance/].

Functions

Radiance is able to predict internal illuminance and luminance distributions in complex buildings or boundary spaces under arbitrary sky conditions or electrical lighting. Radiance uses ray tracing in a recursive evaluation of the luminance integral in a room. Input files specify the scene geometry, materials, luminaries, time, date and sky conditions (for daylight calculations). Calculated values include the radiance, luminance, irradiance, illuminance (in three color channels) and glare indices. Simulation results may be displayed as color images, numerical values and contour plots. It is also a valuable program for estimating the incoming or incident irradiation on a generic surface or volume.

Design stage, users

Radiance is software for architects, engineers and researchers wishing to carry advanced lighting simulations with high physical accuracy. The combination of flexibility and accuracy makes it unique in providing realistic images with predictive power for architects, engineers and lighting designers.

3D modeling

The input required for a simulation in Radiance is a description of the 3D surface geometry, materials, and light sources in a scene. Rendering an image requires additional specification for the view point, direction, and angles desired. Once a scene geometry has been described, it is compiled into an "octree" file that acts as an efficient data structure for the ray tracing process (by determining which surface is intersected by a ray). Without an octree or similar sorting method, ray tracing is not practical [Ward Larson & Shakespeare, 1998].

Geometric input to Radiance consists of a boundary representation using N-sided polygons (concave or convex, holes represented with seams), spheres, cones, cylinders and rings (i.e. circles with holes). Different modifiers for these primaries are also implemented in Radiance.

Material modeling

Radiance is capable to model complex materials as well as different types of light sources. The materials can be opaque, transparent or translucent. In contrast to a radiosity ray tracers, Radiance is capable to handle specular reflections. The reflection material models can be adapted to any stage from a perfect specular reflection (like mirror) to a perfect diffuse reflection (Lambertian). Similar possibilities are available for transparent or translucent materials.

Rendering

Radiance is based on a backward ray tracing algorithm. This means that light rays are traced in the opposite direction to that which they naturally follow. The process starts from the eye (the viewpoint) and then traces the rays up to the light sources taking into account all physical interactions (reflection, refraction) with the surfaces of the objects composing the scene. Wave optics (like polarization, interference and diffraction) of light rays is not taken into account. Radiance calculates only geometrical optical problems. The idea behind (backward) ray tracing is to simulate individual light rays in space to calculate the luminance distribution in a room from a given viewpoint. Therefore, rays are emitted from the point of interest and traced backwards until they either hit a light source or another object. In the former case, the luminance distribution function of the light source determines the luminance contribution at the viewpoint. If a ray hits an object other than a light source, the luminance of the object needs to be calculated by secondary rays which are emitted from the object. The angular distribution under which secondary rays are spawned depends on the optical properties of the object.

Coordinates

Radiance 3D-model is performed according to x, y and z axes. The RHS is used for the surface orientation. In Radiance, coordinates can be given in any unit of length. Of course, when a single scene is formed by more than one scene file, these must use the same unit of length. Each single ray "carries" a certain amount of radiance (hence the name of the software) expressed in (W/m^2sr). The radiance is divided into three "channels" corresponding to the red, green and blue primary colors (abbreviated as RGB).

Input/output

Translators for the .ies standard luminaire data format and AutoCAD .dxf format are included with the distribution. Additional translators from CAD formats and to/from other image formats are available.

Several CAD translators and image file converters for going to and from Radiance are available. Some examples are:

- dx2rad - An AutoLISP .dxf translator
- ra2pict - A translator from Radiance to Macintosh PICT
- ra_xim - A translator between Radiance pictures and Ximage format
- torad - An improved AutoLISP translator for Radiance

The complete list of available tools may be found on the following web sites:
[radsite.lbl.gov/radiance/pub/translators/index.html] and
[www.schorsch.com/download/radiance.html]

An interactive pre-viewer for the Radiance synthetic image system, written by Peter Apian-Bennwitz is also available. The name of this tool is RSHOW and can be downloaded for free under: [www.pab-opto.de/progs/rshow/].

BIM

Radiance is not a BIM application.

Actual solar calculation

Radiance has a very powerful and accurate engine for the calculation of solar irradiance on different surfaces (defined via a sensors matrix). The calculations are based on the site definition (latitude and longitude) and on the sky definition (different CIE sky models are implemented in Radiance). The simulations in Radiance can be performed hour by hour. If the users need annual simulations or long term estimations, it is possible to use the DAYSIM program. Radiance is a program primarily aimed at illumination studies and does not include algorithms for the calculation of passive solar heat gains or sizing active PV or ST systems.

2.4.18 RETScreen

Supplier, site, contact, last version, cost

RETScreen is a software developed by Natural Resource Canada. This Clean Energy Project software has been developed through the collaboration between many experts from industry, government and academia. The last version is called RETScreen 4. It may be downloaded for free on the official website [www.retscreen.net/ang/home.php]. RETScreen is available in many languages and it is used by over 250000 users in 222 countries.

Functions

RETScreen is a Microsoft Excel based application. This software evaluates the energy production and savings, costs, emission reductions, financial viability and risk for various types of Renewable-energy and Energy-efficient Technologies. The software also includes product, project, hydrology and climate databases, a detailed user manual, and a case study based college/university-level training course, including an engineering e-textbook.

Design stage, users

RETScreen may be used by architects and engineers to evaluate their projects. Since RETScreen requires a very good description and comprehension of the project, this software is more suitable for detailed design stages.

3D modeling

RETScreen does not provide a 3D interface. Simulations are based on numerical inputs in the Excel sheet.

Rendering

RETScreen does not provide rendering functions.

Coordinates

Since RETScreen does not provide 3D interface, no coordinate systems is used.

Import/export

Since RETScreen is a Microsoft Excel based application, its import and export options are the same as in Excel. However, in RETScreen, all data, which describe the building project, have to be entered by users. So, import and export functionalities are not really used in RETScreen.

Predecessor software, successor software

Since all data have to be entered by users, all software may be used before RETScreen to design the building project. Moreover, the user must have a very good understanding of the building project. So, the use of a CAD or BIM application as predecessor software to RETScreen is really essential.

BIM

RETScreen does not support the .ifc format. So, this software is not a BIM application.

Actual solar calculation

There is no information about consideration of passive solar gains in RETScreen. In the rendering production options, photovoltaic production is included. However, it is the user who has to define how photovoltaic modules contribute to electricity production. It is the same with ST systems for hot water. So, RETScreen considers active solar systems, but it does not provide solar calculations.

2.4.19 T*Sol*Supplier, site, contact, last version, cost*

The supplier of T*Sol is Valentin EnergieSoftware GmbH, Berlin, Germany [www.valentin.de]. There are differently detailed programs available: T*Sol Express (214 USD/160 €), T*Sol Professional (basic version: 774 USD/580 €, set: 1308 USD/980 €), T*Sol Expert (basic version: 1709 USD/1280 €; set: 2644 USD/1980 €). The set includes more modules for the simulation, which can also be bought separately. The last version of T*Sol is called T*Sol 4.5.

Functions

T*Sol is a simulation program for solar thermal heating systems including hot water preparation, space and swimming pool heating. It is possible to simulate different configurations consisting of components of a database. Starting from standard-components (i.e. 1200 different collectors) parameters can be changed according to the individual system. The influence of the system's parameters can be evaluated by easily testing different combinations. An automatic design assistant helps to optimize the design/dimensioning of collector area and storage tank volume.

There are functions in order to define consumption profiles and include the influence of partial shading by the horizon and other objects like trees or buildings.

Besides the standard evaluation values for solar thermal systems (produced energy (hot water and space heating) of the solar system, efficiency, solar fraction, etc.), the program also calculates economic efficiency. The evaluation of the results can be done graphically or in a table format. A comprehensive report of the solar thermal system can be produced.

The calculations are based on the investigation of energy flows. Yield prognoses are made based on hourly balances. As climate data, the same data as for PV*Sol can be used (See PV*Sol section).

Design stage, users

T*Sol is a dynamic simulation program that can be used at any design stage. It can be used for approximate evaluations of a solar thermal system and also for a detailed optimization including all components. T*Sol has been developed for engineers, planners, building technicians, etc. It is a program for planners (express), engineers (professional) and for researchers (expert). Its focus is the energy performance of a solar thermal system, so it does not support visualization of architectural design. The results of the simulation can only be communicated as e.g. suggestions for best slope, required space for collectors and other components of the system, such as storage tank, heat exchanger, etc. The program is available in different languages: English, Spanish, French, German, Italian, Portuguese, Polish, Slovakian, Slovenian, Czech, Hungarian, and Rumanian.

3D modeling

T*Sol does not support a 3D environment.

Coordinates

There are no axes according to visualization of the solar thermal system. The system is defined by orientation, slope and location. The results of the calculations are performed according to x and y axes.

Import/export

Import of measurement data into T*Sol-format is possible. This allows the evaluation of the measured data and a comparison to the simulation results. Import of weather data in the following formats is possible: .try, .dat, .wbv. Export is possible to .pdf, .rtf, e-mail, ASCII format. Import/export of files of/to word and spreadsheet processing programs is also possible.

Predecessor software, successor software

Predecessor and successor software are similar to the ones for PV*Sol (see PV*Sol section).

BIM

T*Sol is not a BIM application.

Actual solar calculation

Actual solar calculation is similar to PV*Sol (see PV*Sol section). The program enables to size solar thermal systems easily and delivers the most important results rapidly. Shading analyses can also be carried out.

2.4.20 VisualDOE

Supplier, site, contact, last version, cost

VisualDOE is supplied by Architectural Energy Corporation. The last version is VisualDOE 4.0 and the price is 1250 USD (1008 €) for a single license. It is also possible to download a trial version from the website [www.archenergy.com/products/visualdoe/].

Functions

VisualDOE is an energy simulation program used to accurately estimate the performance of building design alternatives. VisualDOE covers all major building systems including lighting, daylighting, HVAC, water heating, and the building envelope. Among the range of simulation results are electricity and gas consumption, electric demand and utility cost. Hourly results are available for a detailed analysis. The software also offers energy calculations for LEED certification [Architectural Energy Corporation, 2004-2009].

Design stage, users

The program is targeted for use by architects, engineers, MEP firms, energy consultants, utilities, national laboratories, universities, energy service companies, HVAC equipment manufacturers and building product manufacturers. VisualDOE is a building energy simulation program used to optimize the parameters of a building in terms of energy performance at EDP and at subsequent stages.

3D modeling

In VisualDOE, it is possible to import shapes from a CAAD (.dxf) file to create the custom block, choose a layer from the .dxf file and import closed polygons. The user can also create his model in the software. The user can drag and drop block shapes from the tool bar to up to ten levels or plan views, place multiple blocks on the same level, size each block and enter the number of stories, choose roof, ceiling, floor and interior floor construction from the library and move blocks by assigning x and y values.

In the simulations, the users can check whether a model is defined correctly before or after running simulations. If there are errors or warnings in the model, users will get alert messages identifying the sources. The software also provides the possibility to calculate surface temperature of building facades. Inside and outside surfaces temperatures can be produced in hourly reports. Hourly reports of mean radiant temperature (MRT) of a space can also be produced for further thermal comfort analysis.

It is also possible to calculate minimum air flow and minimum design airflow per floor area and to obtain cooling and heating availability schedule. Users can apply multipliers to adjust lighting power density, equipment power density, and occupant density for selected rooms. For example, a user may want to decrease the lighting power density by 20% for selected rooms, so the LPD adjustment factor of 0.8 can be entered and update the rooms [Architectural Energy Corporation, 2004-2009].

Rendering

VisualDOE cannot be used for rendering.

Coordinates

VisualDOE 2D drawing is performed according to x and y axes and 3D modeling is related to x, y and z axes.

Import/export

VisualDOE lets the user import shapes from all CAAD (.dxf) files to create the custom block. The simulation reports are exports in .txt files.

Predecessor software, successor software

Schedules of lighting, equipment, occupant, fan, air infiltration, cooling and heating temperature set points can be imported from input files for DOE-2 (created by VisualDOE, eQuest, EnergyPro, PowerDOE or even with a text editor) and EnergyPlus. Imported schedules can be further saved to the VisualDOE library or project template files for later use or sharing among users.

BIM

VisualDOE is not BIM compatible.

Actual solar calculation

VisualDOE lets the user control lighting systems and daylighting. It is also possible to conduct simulations and report on absorption of solar radiation by the roof and exterior walls transmission, absorption of solar radiation by windows and internal gains.

Since PV energy can be added or subtracted pretty much independently of the rest of the building energy use and loads, the total kWh contribution can be analysed using PVWATT. PVWATT only requires some very basic inputs such as sq.ft., AC-DC derating, location (latitude), and mounting declination angle. PVWATT is especially suitable for obtaining the full annual energy contribution, and not the hourly increments [Architectural Energy Corporation, 2004-2009].

3. CONCLUSIONS

As part of the work achieved within IEA Task 41 Solar Energy and Architecture, Subtask B: Methods and tools for solar design, this report presented a review of existing computer tools widely used by architects today. The review covered a total of 56 programs in three categories: CAAD, visualization and simulation software. A total of 23 CAAD tools, 13 visualization tools and 20 simulation tools were reviewed.

3.1 CAAD TOOLS

3.1.1 Overview of available CAAD software for the prediction of passive solar gains

Until recently, building information modeling (BIM) software such as Autodesk Revit, Bentley Architecture, Graphisoft ArchiCAD, and Vectorworks Architect focused primarily on modeling and refining building geometry. To analyze the energy consumption of a building, users relied on third-party software such as Green Building Studio, Ecotect, Hevacomp (an interface to EnergyPlus), and IES. A series of acquisitions in the past few years (since 2008) changed that, however [Wong, 2010]. This review has indicated that there are many CAAD software traditionally used by architects and which today include some form of algorithm for the prediction of solar gains in buildings (often in connection with energy simulations). Amongst the CAAD tools, the BIM applications offer the most interesting possibilities for energy simulations including passive solar gains predictions. These applications are: Allplan, ArchiCAD, DDS-CAD PV, Google SketchUp, MicroStation, Revit and Vectorworks, which are all BIM applications:

- Allplan allows carrying standard energy calculations and obtaining energy certification classes valid for most European locations. Although we may assume that, due to the energy calculation module, passive solar gains are calculated, it does not appear that the information about passive solar gains is explicit in Allplan or that it allows an explicit feedback to the designer in the EDP. Note that Allplan is a complex and advanced, .ifc compatible program, which may be used at concept design stage, but seems more suited for detailed and structural design and cost calculations.
- ArchiCAD, with the suit of .ifc compatible programs like EcoDesigner, Artlantis Render and Artlantis Studio, makes it possible to perform detailed and dynamic energy balance calculations. Built into the ArchiCAD user interface and accessible through a single button, EcoDesigner quite literally is a single-click analysis program. Although not as comprehensive as Ecotect or IES, EcoDesigner provides ArchiCAD users with basic energy- and carbon-checking functions. ArchiCAD BIM program also links with energy simulation programs like IES, EnergyPlus, Green Building Studio, Ecotect, ArchiPhysik, and Riuska.
- DDS-CAD PV allows comprehensive calculations of U-Values, heating/cooling loads, and ventilation. DDS-CAD is more suited for detailed design than EDP design.
- Google SketchUp with its compatible IES VE-Ware plugin allows users to conduct basic building energy analyses using IES VE: carbon emissions, energy consumption, and regulatory compliance. The IES VE plugin adds a toolbar in Google SketchUp, which provides direct access to all IES tools: VE-Ware, VE-Toolkits, VE-Gaia and the full VE-Pro suite. So, through this plugin, it is possible to produce numeric information about solar irradiation on surfaces and heat gains through windows. As Google SketchUp is used at EDP by many architects, this plugin allows performing solar design validations at EDP. Google SketchUp also integrates OpenStudio, a free plugin which makes it easy to create and edit

the building geometry in the EnergyPlus input files. EnergyPlus is a powerful energy simulation tool. Google SketchUp Demeter plugin allows performing an energy analysis on a SketchUp design by adding attributes to the geometry and then connecting it to Green Building Studio's web service. Google SketchUp also integrates Demeter, a plugin to perform an energy analysis on a SketchUp design by adding attributes to the geometry and then connecting it to Green Building Studio's web service, or other analysis applications that import .gbXML.

- MicroStation now includes the Bentley Tas Simulator V8i, which is a simulation tool that provides dynamic thermal simulations. This software provides information about energy consumption, CO₂ emissions, operating costs and occupant comfort. It can also evaluate a wide range of passive design features. In addition, the Bentley Hevacomp program offers possibilities for building performance design, simulation, and energy certification based on the EnergyPlus engine.
- Autodesk Revit also makes it possible to perform energy analyses using Autodesk Green Building Studio web-based services, or to study building performance employing Autodesk Ecotect software. However, many users have expressed problems with great information loss when exporting a Revit file to Ecotect or Green Building Studio. Only the geometry is retained and the I (information) in the BIM is apparently lost.
- Vectorworks BIM software is interoperable with IES VE and Autodesk Ecotect Analysis (which, even under Autodesk's ownership, remains available for use with competitors' BIM software).
- According to Wong (2010), solar study — or identifying heat gain, heat loss, and comfort levels at the target site based on annual sun path — has become an integral component of most leading building energy-analysis software packages. Most products mentioned previously — including Ecotect, Hevacomp, and IES — offer this capability. These tools allow calculating the anticipated solar radiation on a virtual buildings' windows, surfaces, rooms, and spaces; compare summer and winter heat patterns; and identify heating and cooling requirements to keep residents comfortable throughout the year. Depending on the outcome of this simulation exercise, shading devices, PV panels may be added to the design or the building may be reoriented.

None of the other CAAD software examined in this review allow passive solar gains prediction either at EDP or at detailed design phase. Note that AutoCAD, which is certainly one of the most widely used software in the world, does not directly support the calculation of passive solar gains through windows, but the .dwg files created with AutoCAD can be exported to Ecotect or to other simulation software since the .dwg format is a widely accepted file format worldwide. A plugin called EnergyPlugged plugin is also available in a beta version for running EnergyPlus from AutoCAD. Note however that AutoCAD may be used at concept design phase but is more suited for the detailed design phase.

Apart from perhaps ArchiCAD and Google SketchUp, which are convivial for EDP work, all the programs listed above are more suited for detailed design than EDP. For EDP work, it is crucial for the architect to feel s/he has a “free” hand, i.e. having the capacity to easily modify a building's overall volume, geometry and orientation. The changes made on these parameters (volume, geometry, orientation) should be connected to a direct, explicit feedback about passive solar gains. This review outlines the fact that this type of direct explicit feedback is still lacking in many CAAD-BIM programs but that the recent advances in this field are promising. The integration of analysis functions in BIM software such as ArchiCAD and Revit and the availability of free analysis tools such as IES VE-Ware foretell a future where most, if not all, BIM software will include entry-level sustainability tools [Wong, 2010].

3.1.2 Overview of available CAAD software for estimation of daylighting and daylight utilization

This review has also indicated that most CAAD software include some features for the prediction or visualization of daylighting. Amongst the CAAD tools, the BIM applications offer many possibilities for daylight analyses:

- Allplan allows exporting to CINEMA 4D and Maxwell Render, to produce photorealistic renderings and visualization of light behavior.
- In ArchiCAD, two principal rendering tools can be easily used: Virtual Building Explorer (VBE) and Artlantis. With VBE, it is possible to set the sun altitude and azimuth and obtain different presentation modes such as shaded or global illumination. Global illumination is produced by a radiosity rendering engine that calculates diffuse inter-reflections and may produce photo realistic visualization. Artlantis is a rendering application developed specifically for architects and designers. ArchiCAD BIM program also links with EnergyPlus, Green Building Studio, Ecotect, which allow daylight analyses.
- MicroStation via the Bentley Hevacomp and Bentley Tas simulator makes it possible to perform daylight analyses.
- Revit performs daylighting analyses using the IES VE-Ware plugin (which uses the Radiance engine). Revit also makes it possible to perform daylight analysis using Autodesk Ecotect.
- Vectorworks is interoperable with IES VE and Ecotect. IES VE performs daylight analyses based on the Radiance engine. Vectorworks can also produce high quality daylight renderings using RenderWorks, for a given location and time of the year. RenderWorks performs radiosity rendering which simulates the real-world light behaviour.
- Also, the review indicated that most of the non-BIM CAAD software allow some form of daylight analysis and/or visualization:
- AutoCAD creates .dwg files, which can be read by most lighting and simulation software, including Ecotect, Radiance, etc.
- Blender allows adding a plugin called b/rad, which is a Blender-based user interface for Radiance. It is able to export Blender models to Radiance, both static models and animations, to make it easier to setup the simulation parameters or to calculate luminance/illuminance values on arbitrary grids.
- Caddie Vio uses the Lightworks rendering engine, which simulates the real behavior of natural light.
- CINEMA 4D is an advanced rendering engine, which also accepts Allplan, Vectorworks, and ArchiCAD files. Lighting in CINEMA 4D offers different types of light and shadow calculations. The sky in CINEMA 4D is rendered by using the luminance channel, which turns the material into a light source. The sky object encloses the entire scene spherically, and acts as a huge lamp which lights the scene from all sides.
- In Digital Project, the Solar Render Tool allows to easily investigate the impacts of sunlight on the project. The Digital Project Photo Studio work bench and rendering tools make it possible to render scenes, adding a default blue spherical environment and a directional light (the sun).
- form•Z allows direct sunlight studies according to latitude, longitude, etc. In form•Z, the RenderZone Plus offers advanced rendering and lighting effects and photorealistic rendering, based on advanced Global Illumination techniques such as final gather, ambient occlusion and radiosity.
- Google SketchUp performs daylighting analyses using the IES VE-Ware plugin, which uses the the Radiance engine to simulate the physical behaviour of light. Google SketchUp also

allows adding daylighting controls and illuminance map through the OpenStudio plugin to EnergyPlus.

- Houdini allows performing physically based rendering.
- Lightworks simulates the real behavior of natural light.
- Maya uses the rendering engine mental ray[®], which provides a physically correct lighting environment required for quantitative indoor lighting evaluations. However, it is a qualitative calculation because it does not provide numerical data.
- Rhinoceros 3D allows setting many types of light sources and supports some rendering plugins, such as Maxwell Render, V-Ray, Flamingo and Penguin. The Flamingo plugin includes photometrically rendered images with reflection, refraction, diffusion, translucency, depth of field and more, a wide material library with user controllable properties, and many lighting options including sun, sky and global illumination.
- 3ds Max Design 2010 features the Exposure technology for simulating and analyzing sun, sky and artificial lighting. Exposure conducts validation studies based on the Radiance engine. Exposure may generate a visualization of results directly on the scene or produce graphical and Microsoft Excel output of results.

Some CAAD software include the Global Illumination algorithm in rendering options. Global Illumination allows performing more realistic lighting results. The principal characteristic of this algorithm is that it calculates diffuse inter-reflection of light onto and between objects. Two major Global Illumination algorithms are “Radiosity” and “Ambient occlusion”. Radiosity is the one which can be the most useful in qualitative evaluation of daylight because it mimics the real-world light behavior. The Radiosity feature is included in Blender, Cinema4D, form•Z, Rhinoceros 3D and 3ds Max Design.

Most other CAAD software allow the study of direct light patterns. The majority of CAAD software included in this review allow performing photorealistic 3D rendering. The 3D rendering provides qualitative daylight analysis but the estimation of real daylight utilization (energy savings by replacement of electric light by daylight, as performed with DAYSIM) is not explicit with most CAAD programs reviewed.

3.1.3 Overview of available CAAD software for sizing PV and ST systems

Amongst the CAAD tools reviewed, Allplan and DDS-CAD PV are explicitly developed for sizing PV and/or ST systems. Also, since EnergyPlus allows the simulation of active solar components for simulating PV and ST hot-water systems (e.g., solar collectors) [Griffith & Ellis, 2004], all CAAD programs that are linked with EnergyPlus allow active solar systems calculation. Note that Energyplus includes a detailed PV and Solar collector library. EnergyPlus also features on-site PV inverter and storage systems in addition to ST hot water systems.

- Allplan makes it clearly and explicitly possible to perform rather detailed sizing and design of PV and ST installations.
- DDS-CAD PV allows efficiently planning, modeling and calculating ST and PV equipment. In the early stages of design, it can quickly be established with DDS-CAD PV whether a proposed solar energy system can be practically realised.
- ArchiCAD allows exports in Green Building Studio (.gbXML) format into DesignBuilder, an interface to EnergyPlus.
- Google SketchUp, with the OpenStudio plugin, provides an interface to EnergyPlus to allow simulating active solar components.
- MicroStation includes the Hevacomp, which is a user interface of EnergyPlus.

- Revit allows exporting in .gbXML format to EnergyPlus via Ecotect.
- Vectorworks is interoperable with IES VE and Ecotect. From Ecotect, it is possible to export to EnergyPlus. As third-party tools emerge to translate between .ifc and .gbXML, Vectorworks will easily connect to MEP analysis tools such as EnergyPlus and IES/VE [Laiserin, 2010].

Note that, apart from Google SketchUp, which is often used at EDP, all the CAAD tools listed above are more suited for detailed design than EDP even if active solar features are linked to a 3D environment. Even the Google SketchUp active solar calculation environment is used more as a post-design rather than a design tool since the calculations are performed within OpenStudio (EnergyPlus interface).

3.2 Visualization tools

This review outlines the fact that few visualization tools include solar calculations in terms of passive solar gains prediction or design of active solar systems. Most visualization tools are focused only on visualization of electric light and/or daylight effects.

3.2.1 Overview of available visualization software for the prediction of passive solar gains

None of the visualization software reviewed includes any form of algorithm for the prediction of passive solar gains, which was an expected outcome of this review.

3.2.2 Overview of available visualization software for estimation of daylighting and daylight utilization

Most visualization software reviewed include advanced or very advanced algorithms for the simulation of light, which is not surprising since it is the main goal of these programs (i.e. to provide visualization for light-matter interactions). However, it is not always clear whether the calculations are “cosmetic” or governed by the natural laws of illumination. Only one program (LuxRender) explicitly allows choosing between biased and unbiased rendering: users can choose between physical accuracy (unbiased) and speed (biased). In many software such as Flamingo, Kerkythea, LuxRender, Maxwell Render, RenderZone, V-Ray, and YafaRay the approach to rendering is based on the physical laws of illumination.

Generally, visualization software do not provide technical solar calculations but most of these programs can be used to study direct and/or diffuse light penetration patterns and shading effects on building facades, at one moment or for a sequence in time. For example, Flamingo provides accurate daylight simulation (sun, sky, ground and cloud cover components), based on geographical location, month and time of a day (an exact solar time calculator is used). Kerkythea’s sun feature is designed to give the user a general idea of how the sun and shadows affect the model during a day and throughout the year. LuxRender uses a model of sunlighting from NASA measurements where parameters such as atmospheric absorption are adjustable from the turbidity parameter. In Maxwell Render, rendering presets include physically accurate sun and sky models. V-Ray, with V-RaySun and V-RaySky, reproduce the real-life sun and sky environments.

Few visualization programs provide numerical output of light intensity results. However, in Flamingo, simulations are physically-based and light intensity is specified in Watts.

In most cases, 3D rendering does not support EDP design decisions; rendering is thought of as a post-design rather than a design tool. However, Kerkythea, Maxwell Render and LuxRender may be used at EDP are mainly used at the visualization stage but they can also be used at EDP for visualizing the way light influences spaces.

Many visualization software include detailed algorithms for the simulation of electric lighting effects. LightWave rendering uses .ies lighting files that accurately duplicate physical light sources from manufacturers' datasheets. LuxRender allows using photometric data in the form of .ies files to accurately define the light distribution patterns of an electric light source.

Most visualization programs, except LuxRender, use limited color channels (e.g. RGB i.e. red, green, and blue) for the prediction of emitted and reflected surface colors. In LuxRender, full spectral rendering is used instead of the RGB color spectrum, which promises very interesting developments for the future study of special coatings and glazing materials, highly relevant for solar architecture.

3.2.3 Overview of available visualization software for sizing PV and solar thermal systems

This review indicates that none of the visualization tools allow sizing PV and/or solar thermal systems and visualizing the result of PV or solar thermal system integration.

The company ISAAC has developed a 3D CAD object to speed up the rendering procedure when integrating PV in architectural objects in order to facilitate and stimulate the use of BiPV systems by architects and designers and to improve the architectural quality of BiPV systems. The CAD object, which is still a prototype, can be used with both ArchiCAD and AutoCAD. The object is interesting for *visualization* of active solar systems.

3.3 SIMULATION TOOLS

3.3.1 Overview of available simulation software for the prediction of passive solar gains

This review indicates that there are many simulation software which are used for the prediction of passive solar gains. In most cases, the estimation of passive solar gains is considered in the calculation of the whole building thermal balance calculation. Simulation applications which include passive solar gains are: bSol, DesignBuilder, DPV (Design Performance Viewer), Ecotect, EDGII, ENERGIEplaner, eQUEST, IDA ICE, IES VE, LESOSAI, VisualDOE.

- bSol is a software which simulates the thermal behaviour of the building over one year. 3D environment is not available, so the user has to input numerical and parametric data to describe the architectural parameters. Architectural parameters include the orientation of the building, thermal insulation, size of openings, thermal inertia, heated/unheated zones, etc. The solar radiation through windows (passive solar gains) is determined by the calculation algorithm.
- DesignBuilder (DSB) is an interface to the Energy Plus dynamic thermal simulation engine, which is targeted at architects. DSB calculates internal heat gain generated by solar radiation through windows and glass facade elements. This 3D analysis tool is also BIM-compatible through .gbXML import capability. Imports from Revit, ArchiCAD and MicroStation are possible.
- As a Revit add-on, DPV provides an instant evaluation of the energy consumption of the CAAD-BIM model. The performance calculation is based on the parameters of the BIM

model. Imbedded in Revit, DPV allows architects and planners to determine the energy and exergy consumption of a building already as EDP. The upcoming publically available version uses static calculations for after mid 2010, an additional physical calculation nucleus will be available for dynamic calculations.

- Ecotect is a graphical building and environmental analysis tool, which performs, among others studies, thermal analysis based on climate data integrated files. The thermal analysis calculates heating and cooling loads for models with any number of zones and with any type of geometry. These files are also used to calculate solar positions and incident radiation. Ecotect allows visualizing incident solar radiation on all surfaces and windows over any period of time. It considers site overshadowing and shows variations in solar resources available to the building at times when heating or cooling is required. Ecotect also calculates solar availability on the spaces around buildings and can be used for solar studies at an urban level. A shading design tool can generate the exact shading shape to perfectly shade a window for any specified period as well as modeling light redirection. Ecotect is compatible with Revit but conversion from the BIM-CAAD to Ecotect is actually limited to the geometrical aspects (information in the BIM is lost).
- EDG II (Energy Design Guide II) supports the design of a building with low heating and cooling demand at EDP, including the passive solar potential, considering the horizon, shadow of neighbouring buildings and reflection of the ground. However, EDG II does not provide the building model with a 3D environment; the building model is defined through the input of numeric data, graphic inputs and predefined parameters.
- ENERGIEplaner calculates heating, lighting, cooling, which includes passive solar gains.
- eQUEST, which is based on well-known DOE-2 dynamic energy simulation software, calculates heating and cooling loads during a year based on a data-entry building description. eQUEST is a building energy simulation tool and as such, it allows the prediction of passive solar gains through windows. eQUEST is designed to support all design phases, when information is most limited and until the completion of the project.
- IDA ICE performs passive solar calculations at four user levels, related to the level of the design progress. Solar loads calculations are performed by using ray tracing algorithms. It considers shading devices and advanced shading control.
- IES VE contains a series of advanced modules and can perform almost any aspect of building analysis spanning from energy simulation using the heat balance method. VE Pro uses different levels of complexity; simple energy studies can be performed with little experience with the software at EDP. Different modules consider passive solar gains into their calculations. SunCast provides advanced solar analysis in 3D for a building and its site while Apache Calc predicts heat losses and gains. SunCast produces numeric output about solar irradiation both on interior and exterior surfaces.
- LESOSAI allows assessing the building energy performance according to six official weather data: Italy, France, Germany, Luxembourg, Romania and Switzerland. The graphical UI is optimized to handle complex buildings in sufficient details.
- VisualDOE is an energy simulation program used accurately estimate the performance of building design alternatives, covering major building systems including HVAC and building envelope. The program, which is targeted at architects and engineers, can be used to optimize the parameters of a building in terms of energy performance at EDP and at subsequent stages.

The programs bSol, EDG II and LESOSAI do not support a 3D environment and thus offer limited interest for architects. A higher understanding of the building is required for these software, because the user has to describe the configuration of the building in terms of data-entry and numerical input.

Note also that the program EliteCAD seems to be targeted at engineers rather than architects and is more suited for the detailed design phase.

3.3.2 Overview of available simulation software for estimation of daylight utilization

This review indicates that there are many software which are used for the estimation of daylighting and daylight availability and only a few which are really designed for the estimation of daylight utilization. The simulation software with the most interesting daylight calculations are: DAYSIM, DesignBuilder, Ecotect, eQUEST, IDA ICE, IES VE and Radiance. Note that three of them, DAYSIM, Ecotect and IES VE, perform daylight analysis based on the Radiance algorithms.

- DAYSIM is a Radiance-based daylighting analysis tool. In contrast to Radiance, it is designed to perform annual or long term analysis. DAYSIM is probably the best suited program for predicting daylight utilization potential (replacement of electric lighting by daylighting).
- DesignBuilder, an interface to EnergyPlus, provides a wide range of environmental performance simulation into a 3D interface, also performs daylight analysis. It produces simulation for buildings with daylight controls. Glazing and other openings in the fabric can either be defined parametrically by making simple model data settings or they can be drawn explicitly.
- Ecotect can perform lighting analysis and design, analysis of views and light. Ecotect is also supported by the Radiance engine for ray-tracing rendering.
- eQUEST also allows to simulate daylight controls. The software also calculates daylight control positioning. An important weakness of this simulation software is that daylight cannot be transmitted through interior glazed surfaces. For example, daylight in an atrium cannot be transmitted to adjacent rooms.
- IDA ICE calculates daylight levels at an arbitrary room location. It also performs natural light computation and evaluates the solar penetration.
- IES VE modules provide access to the Radiance calculation engine, and this advanced light/daylight calculations can be performed with IES VE. It allows calculating light levels, including luminance, illuminance, daylight factor, etc. Moreover, the FlucsPro module calculates the number of luminaires required based on daylight and electric lighting design. FlucsDL calculates light level and daylight factor.
- Radiance is a very powerful engine for the analysis and visualization of lighting in architectural space. Radiance has been the subject of a number of validation studies and is well recognized for the validity of the lighting results produced. It is able to predict internal illuminance and luminance distribution in complex buildings. Radiance is probably the most accurate light/daylight simulation engine and it is used by many other software: DAYSIM, Ecotect and IES VE, etc., as well as a large number of visualization tools (Blender via b/rad, etc.).

Radiance is probably the most efficient daylight simulation software, but it is not suitable for EDP, when much information about the building is missing. Other programs such as e.g. DesignBuilder, Ecotect and IES VE are probably more suitable for EDP work on daylighting aspects. Despite the fact that they support a 3D environment, DAYSIM, eQUEST, IDA-ICE are more suited for the detailed design phases.

3.3.3 Overview of available simulation software for sizing PV and ST systems

This review indicates that there are many software for sizing PV and ST systems. Note that two of them, ENERGIEplaner and LESOSAI, support active solar systems predictions based on the Polysun technology.

- DPV will include a simple implementation of PV and ST collectors in upcoming releases.
- Ecotect performs solar analysis diagrams that may be used to identify the optimum position and orientation for active solar components. This software also allows comparing estimated electricity consumption with electricity production by solar components. This function simplifies the sizing of components.
- ENERGIEplaner Polysun Inside is an additional module which offers state-of-the-art yet simple PV-simulation for calculation according to the EnEV 2009.
- eQUEST includes a PV module that supports active solar design. This module makes it possible to determine voltage, angle, dimension and temperature between the cell and the back surface. However, there is no capability to model solar thermal systems in eQUEST.
- IDA ICE allows performing active solar systems calculations with PV and ST components included in the model. However, they are not available at the user level for early planning phases. This function is planned to be implemented in a near future.
- In LESOSAI, the selection of system templates is based on the Polysun database. Parameters are transferred to the Polysun simulation engine by an internal software interface.
- Polysun offers a wide range of features for the design and simulation of domestic energy systems, including active solar components. It may be used at EDP for the prediction of system profit ratio and at detailed design stage to optimize the system. ST as well as PV are supported by Polysun.
- PV*SOL is a program used only for the design and simulation of PV systems. In addition to all modules which determine the size and configuration of the system, an economic module assesses the capital value of the system, the electricity production cost and the amortization period. Note however, that PV*SOL does not support a 3D-environment.
- PVsyst is used at preliminary design for pre-sizing systems. It evaluates the monthly production and performance of systems. It also performs a preliminary economic evaluation of the PV system at this design stage. At project design stage, which is more engineer-oriented, this application performs detailed simulations according to several dozens of variables. PVsyst considers shading of diffuse radiation.
- T*Sol is a simulation program specifically designed for the sizing of ST heating systems including hot water preparation, space and swimming pool heating. T*Sol is a dynamic simulation program that can be used at any design stage but it does not support a 3D environment.
- VisualDOE allows active solar systems calculations using PVWATT. PVWATT only requires some basic inputs such as sq. Ft., AC-DC derating, location (latitude) and mounting declination angle. PVWATT is especially suitable for obtaining the full annual energy contribution and not the hourly increments.

Apart from PVsyst, which offers a preliminary design level, all the applications listed above are more suited for detailed design than EDP. However, the 3D environment is very simplistic in PVsyst, so preliminary decisions cannot be visualized at the whole-building scale. Additionally, the review indicates that simulation software are not really suitable for the architectural integration of solar active systems because visualization is not sufficient.

3.4 Limitations and wild cards

This review shows that there is a very large amount of CAAD, visualization and simulation tools available today for architects. The review covers most of the tools widely known and used by the architectural community. However, a comprehensive review of all available tools in the world is nearly impossible due to the amount of information which must be collected. This review is thus wide but still incomplete.

Most of the information provided in this report has been retrieved from the Internet, from the official websites of each software provider. This information tends to be tendentious and ameliorates the performance, user-friendliness, compatibility or scope of application of the tools that each provider presents. A further step in the present work could be to test the programs using a reference model and/or ask users if they agree with the facts presented in this report.

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IEA Solar Heating and Cooling Programme

The International Energy Agency (IEA) is an autonomous body within the framework of the Organization for Economic Co-operation and Development (OECD) based in Paris. Established in 1974 after the first “oil shock,” the IEA is committed to carrying out a comprehensive program of energy cooperation among its members and the Commission of the European Communities.

The IEA provides a legal framework, through IEA Implementing Agreements such as the Solar Heating and Cooling Agreement, for international collaboration in energy technology research and development (R&D) and deployment. This IEA experience has proved that such collaboration contributes significantly to faster technological progress, while reducing costs; to eliminating technological risks and duplication of efforts; and to creating numerous other benefits, such as swifter expansion of the knowledge base and easier harmonization of standards.

The Solar Heating and Cooling Programme was one of the first IEA Implementing Agreements to be established. Since 1977, its members have been collaborating to advance active solar and passive solar and their application in buildings and other areas, such as agriculture and industry. Current members are:

Australia	Finland	Portugal
Austria	France	Spain
Belgium	Italy	Sweden
Canada	Mexico	Switzerland
Denmark	Netherlands	United States
European Commission	New Zealand	
Germany	Norway	

A total of 44 Tasks have been initiated, 33 of which have been completed. Each Task is managed by an Operating Agent from one of the participating countries. Overall control of the program rests with an Executive Committee comprised of one representative from each contracting party to the Implementing Agreement. In addition to the Task work, a number of special activities—Memorandum of Understanding with solar thermal trade organizations, statistics collection and analysis, conferences and workshops—have been undertaken.

To find Solar Heating and Cooling Programme publications and learn more about the Programme visit

www.iea-shc.org or contact the SHC Secretariat, Pamela Murphy, e-mail: pmurphy@kmgrp.net.

Current Tasks & Working Group:

Task 36	Solar Resource Knowledge Management
Task 38	Solar Thermal Cooling and Air Conditioning
Task 39	Polymeric Materials for Solar Thermal Applications
Task 40	Towards Net Zero Energy Solar Buildings
Task 41	Solar Energy and Architecture
Task 42	Compact Thermal Energy Storage
Task 43	Rating and Certification Procedures
Task 44	Solar and Heat Pump Systems

Completed Tasks:

Task 1	Investigation of the Performance of Solar Heating and Cooling Systems
Task 2	Coordination of Solar Heating and Cooling R&D
Task 3	Performance Testing of Solar Collectors
Task 4	Development of an Insolation Handbook and Instrument Package
Task 5	Use of Existing Meteorological Information for Solar Energy Application
Task 6	Performance of Solar Systems Using Evacuated Collectors
Task 7	Central Solar Heating Plants with Seasonal Storage
Task 8	Passive and Hybrid Solar Low Energy Buildings
Task 9	Solar Radiation and Pyranometry Studies
Task 10	Solar Materials R&D
Task 11	Passive and Hybrid Solar Commercial Buildings
Task 12	Building Energy Analysis and Design Tools for Solar Applications
Task 13	Advanced Solar Low Energy Buildings
Task 14	Advanced Active Solar Energy Systems
Task 16	Photovoltaics in Buildings
Task 17	Measuring and Modeling Spectral Radiation
Task 18	Advanced Glazing and Associated Materials for Solar and Building Applications
Task 19	Solar Air Systems
Task 20	Solar Energy in Building Renovation
Task 21	Daylight in Buildings
Task 22	Building Energy Analysis Tools
Task 23	Optimization of Solar Energy Use in Large Buildings
Task 24	Solar Procurement
Task 25	Solar Assisted Air Conditioning of Buildings
Task 26	Solar Combisystems
Task 27	Performance of Solar Facade Components
Task 28	Solar Sustainable Housing
Task 29	Solar Crop Drying
Task 31	Daylighting Buildings in the 21st Century
Task 32	Advanced Storage Concepts for Solar and Low Energy Buildings
Task 33	Solar Heat for Industrial Processes
Task 34	Testing and Validation of Building Energy Simulation Tools
Task 35	PV/Thermal Solar Systems
Task 37	Advanced Housing Renovation with Solar & Conservation

Completed Working Groups:

CSHPSS, ISOLDE, Materials in Solar Thermal Collectors, Evaluation of Task 13 Houses, and Daylight Research.