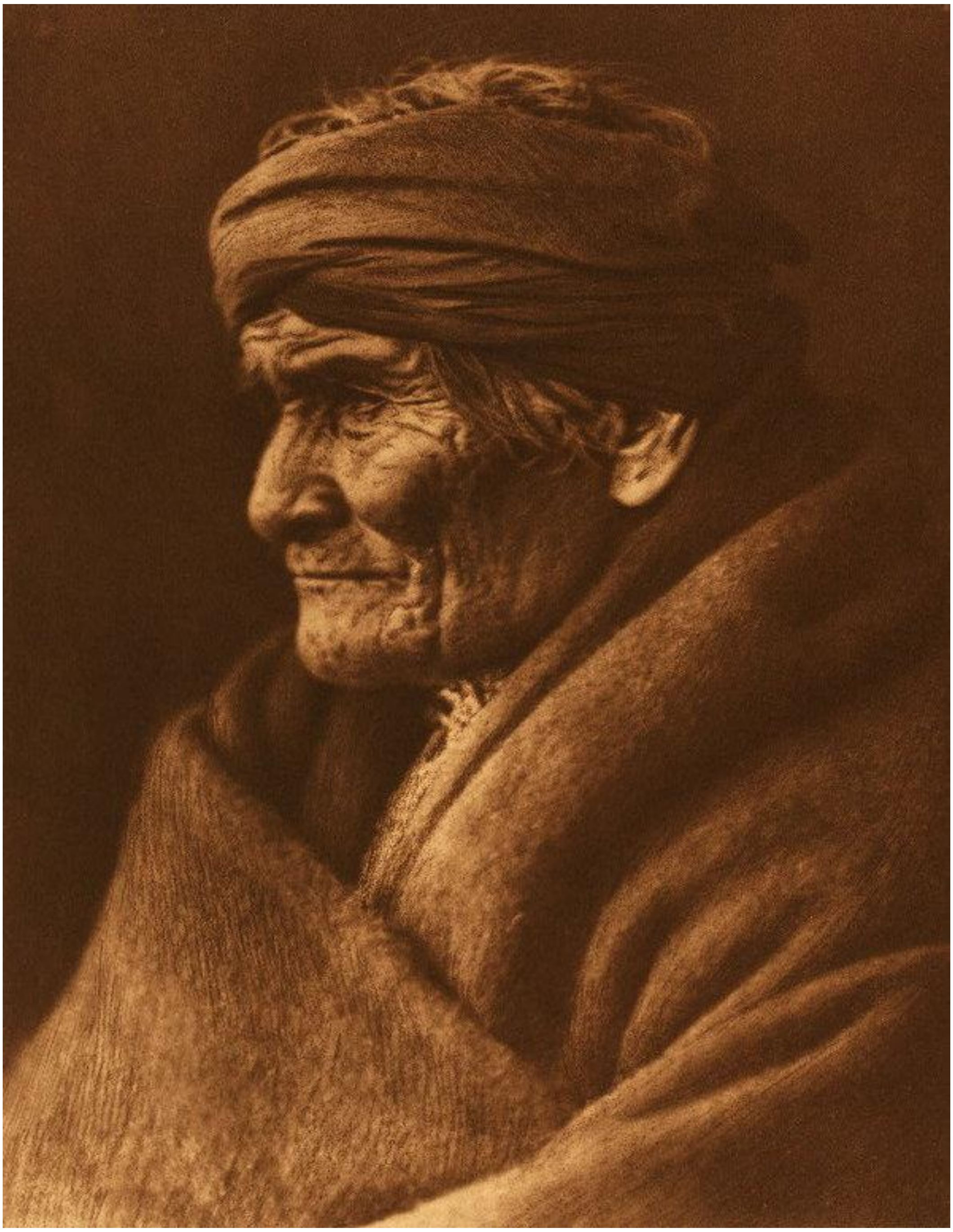

Edward S. Curtis, 1905.

GERONIMO

The CFS Daylighting Wizard

***

GERONIMO is a computer graphical tool based on the RADIANCE ray tracing software for the visualization of the impact of complex fenestration systems within buildings.

GERONIMO
Users Manual

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CONTENT

1. SOFTWARE INSTALLATION

GERONIMO can be downloaded from an FTP server located at EPFL. In any internet browser, one can type the address: ftp://lesoftp.epfl.ch/download/geronimo/Geronimo_v1.0.zip and download a ZIP archive containing the programme for Microsoft Windows. For the installation, the archive can be uncompressed in the directory "Program Files". The newly created folder "Geronimo" contains the executable "Geronimo.exe" that can be launched from Windows Explorer. The folder also contains the Radiance executable compiled for Windows using the Open-Source compiler MinGW. The Radiance program is described in the following section.

2. RADIANCE PROGRAMME

2.1 What is Radiance?

Radiance is a professional lighting simulation programme providing visualizations of virtual scenes. A lighting visualization is needed when the rendering of a given scene must also match real physical conditions. Radiance is capable of producing synthetic images of 3D computer models, which are often generated using CAD programs and describes each surface's vertices and material of a lighting environment.

The programme can be used to assist lighting designers and architects in predicting the illuminance and appearance of an architectural space prior to its construction or refurbishment. Its primary advantage over simpler lighting calculation and rendering software available on the market is that it has almost no limitations on the geometry or the materials that can be simulated [1].

Figure 1: Radiance lighting simulation of a Light Shelf day lit office space (Greg Ward 1994).

Radiance includes many of the features of popular computer graphics rendering programs together with the physical accuracy of an advanced lighting simulation software [2].

The programme has been thorough fully described in many publications and show the following specific features [1]:

- It uses a backwards ray-tracing technique for scenes rendering which includes both specular and diffuse samplings, unlike lighting visualizations programs based on the radiosity method. See Figure 2.
- Endeavours to produce accurate luminance predictions of lighting environments.
- Allows the calculation of other derived metrics as well as synthetic imaging (renderings).
- Is appropriate for daylight and electric lighting simulations. See Figure 3 and 4.
- Supports a variety of reflectance models including some 25 different types of surface materials.
- Supports complicated geometry and photometry.

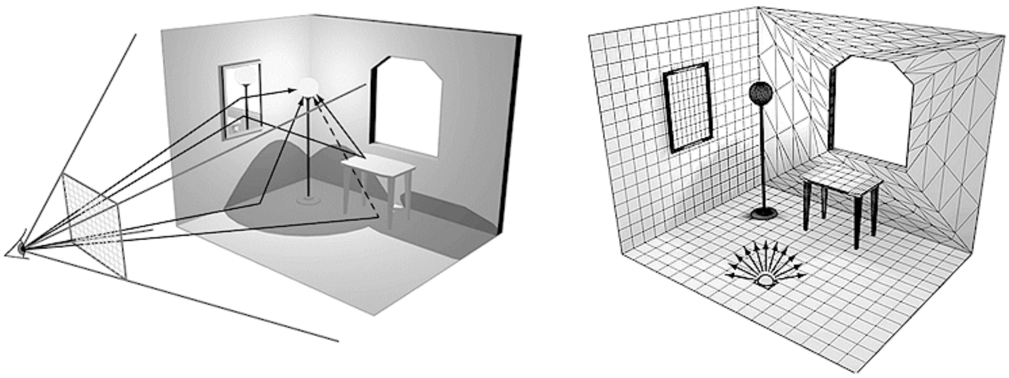

Figure 2: Computer rendering methods based on ray tracing (left) and radiosity (right).

The backward ray tracing technique produces a rendering of a synthetic image by emitting of thousands of light rays from the current viewpoint towards intersecting surfaces. From each surface intersection more rays are emitted until the completion of the image. See Figure 2 (left).

The radiosity method assumes that the surfaces are ideal lambertian diffusers [1]. It simulates the forward diffuse propagation of light rays starting at the light source without accounting for specular reflections. See Figure 2 (right). [3-5]

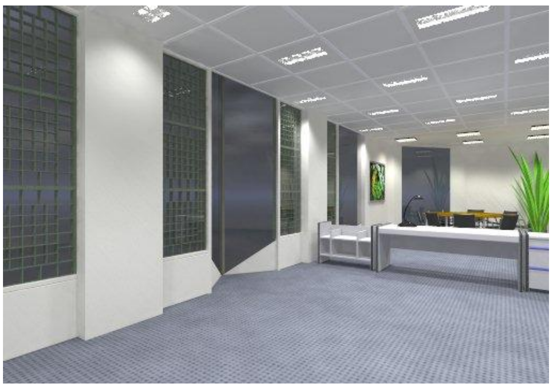

Figure 3: Radiance rendering of a space illuminated by electric light (John Mardaljevic, 1994).

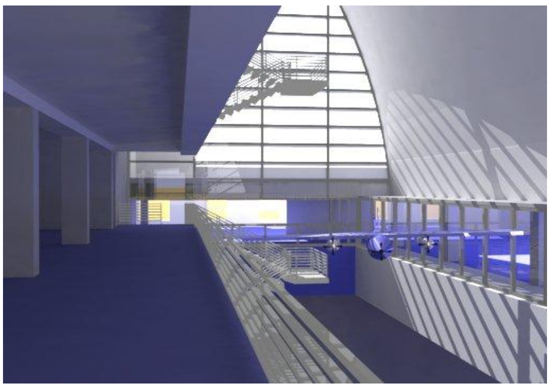

Figure 4: Radiance rendering of a space primarily illuminated by daylight - Inventure Place, August 5th, 8 AM (Charles Ehrlich, Greg Ward, 1994).

2.2 How does Radiance work?

The main input required to run lighting simulations of a project is a description of the three-dimensional surface geometry, surface materials and light sources gathered in a scene. From the latter and given a specified view point, a two-dimensional image is rendered with the *rpict* programme [2].

The first step consists of a creation of the **scene geometry**. Radiance can model arbitrary (but planar) polygons, spheres and cones as basic surfaces. It is also possible to create more complex shapes (boxes, prisms, surfaces of revolution) from surface primitives by using the adequate generators, such as: *xform, genbox, genrev, gensurf, gensky*. Although it is possible to create highly sophisticated scene geometries in the Radiance's text file format, it is more convenient to use a CAD programme - and more recently Google Sketchup™ - to create the scenes and export them to Radiance.

The second step is the **characterization of materials** in a geometrical model, which is required to determine how light rays interact in the scene. Radiance offers 25 material types and 12 other modifier types, such as: *light, illum, plastic, metal, dialectric, trans, BRTDfunc*. Most other materials are variations of them. All material types accept zero or more patterns or textures, which locally modify the colour or surface orientation according to user-definable procedures or data [1]. The light sources are defined by the way of *light* and *illum* materials, the difference residing in the "absorption" of light rays. Indeed, the light materials "absorb" rays, which is not the case for the *illum* material, which is randomly hit.

The third step is to **compile the file in an octree**. This procedure is realised by the *oconv* programme, which reads the scene file and converts it to a special Radiance octree format.

Last step is the **lighting calculation and rendering**. Radiance employs a backwards ray-tracing method, which means that light rays are traced along straight lines from the starting point (the viewpoint or a virtual photometer) into the scene and back to the light sources [1]. The main rendering programmes used by Radiance for that purpose are *rview*, *rpict* and *rtrace*:

- *rview* is an interactive program for scene viewing, which is meant primarily as a quick way to preview a scene, check for inconsistencies and light sources placement and select views for final high-quality rendering with *rpict*.

- *rpict* produces the raw (unfiltered) images. A Radiance picture is a 2D collection of red, green and blue colour radiance values, which is valuable for lighting visualization and analysis.

- *rtrace* computes individual radiance or irradiance values for lighting analysis. The input is a scene *octree* as well as the positions of the desired calculation points.

3. GERONIMO PROGRAMME

3.1 What is GERONIMO?

GERONIMO is user-friendly software for architects and lighting designers conceived to perform daylighting calculations. It allows visualizing the impact of Complex Fenestration Systems (CFS) in office buildings for different sky types (overcast and clear skies). The rendering engine of GERONIMO is the backward ray-tracing software Radiance. GERONIMO avoids the classical command-line usage of Radiance offering the use of a simple interface, which can be adapted to the users skills [6].

3.2 What is GERONIMO made for?

The main purpose of GERONIMO is to facilitate the implementation of Complex Fenestration Systems (CFS), as part of daylighting strategies in buildings. This is at the present a difficult task for architects and lighting designers, given the complexity of simulating the daylight flux propagation through a CFS and to the unavailability of simple tools to perform such tasks.

CFS are of special interest nowadays; they are based on the common principles of an efficient collection of the daylight flux, the blocking of sun rays and the spreading of the daylight flux on the work plane. They improve the light distribution in the room, while removing the potential excess of solar heat gains and contribute in that way to a displacement of electric lighting and a reduction of the fossil fuels demand [6].

The light transmission properties of CFS are measured using bidirectional goniophotometers, which were developed to characterize the bidirectional transmission distribution function (BTDF) of Complex Fenestration Systems [6].

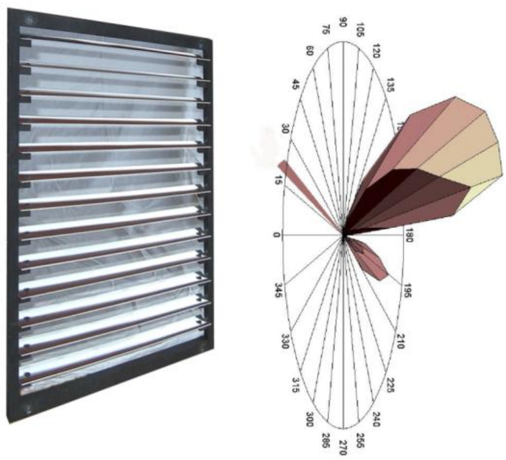

Figure 5: Photometric characteristics (BTDF Data) of mirrored venetian blinds measured using a CCD image based bidirectional goniophotometer [6].

The bidirectional transmission properties of a CFS (BTDF data) indicate how much and in what direction the daylight flux is redirected by the device [6]. GERONIMO facilitates the implementation of CFS in architectural projects by allowing the simulation of the daylight flux distribution by the CFS in a room using the corresponding BTDF Data in a virtual model. See paragraph 4.2.3

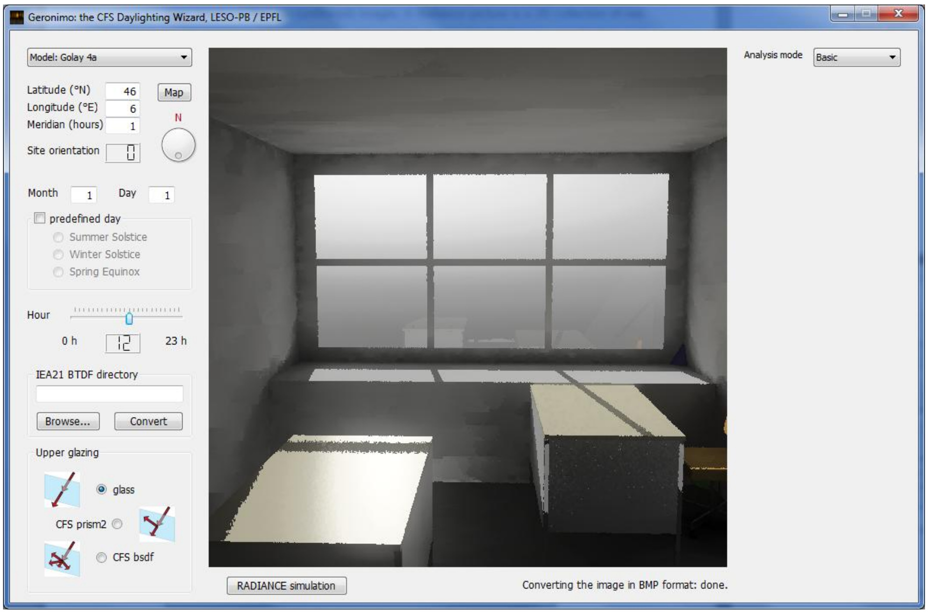

Figure 6: Simulation of an office room using a standard glazing for the upper window; the option *glass* was selected in the 'upper glazing' section, no BTDF data was selected in the BTDF directory.

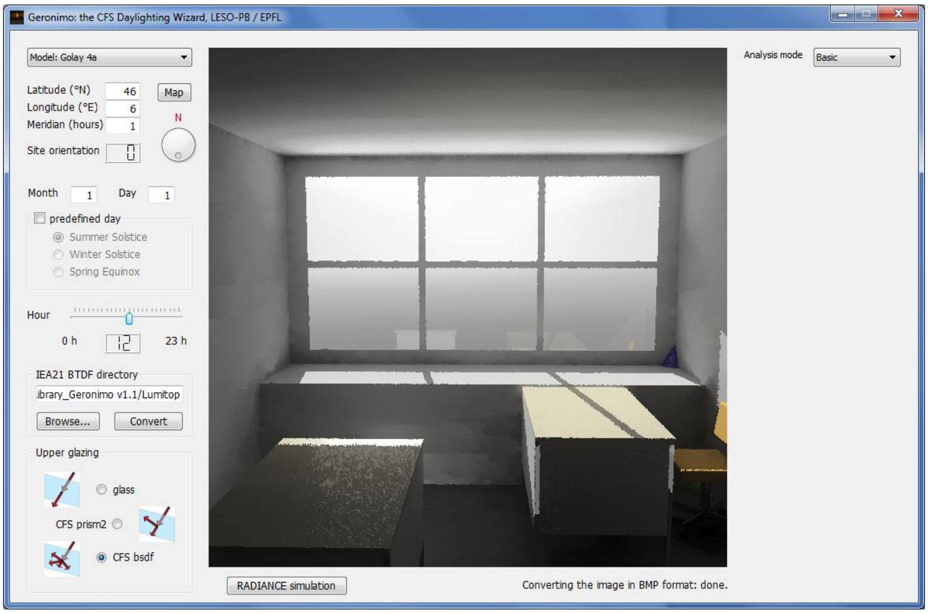

Figure 7: Simulation of an office room using BTDF data of a CFS (SSG Lumitop™) set-up as upper window; the CFS redirects the daylight flux to the ceiling, which is spreading it in a diffuse way into of the room.

3.3 Main Assets of GERONIMO

GERONIMO is a simplified lighting calculation tool aiming mainly at professionals of the building construction sector, such as architects and lighting designers. It however implies that the latter are familiar with computer design tools based on CAD software.

The main advantage of GERONIMO is that it offers an easy way to use Radiance without going through the sophistication of its command lines. When using GERONIMO, users have the opportunity to approach daylighting strategies and technologies available today by implementing Complex Fenestration Systems using the corresponding BTDF Data.

The use of GERONIMO facilitates the daylighting calculations without reducing its accuracy; a generalized use of the programme therefore would spread the knowledge and advantages of daylighting strategies both in new and retrofitted buildings; this represents important benefits in terms of energy savings and improvement of human visual comfort and health [7-9].

3.4 Calculation Features

With GERONIMO it is possible to proceed to three different types of analysis of the luminous performance of buildings, related to the following photometrical variables:

- Surface illuminance within the rendered scene
- Daylight factor mapping on horizontal surfaces
- Assessment of glare risks

This allows not only to account for electricity savings for lighting: it also includes the visual comfort and amenity of the occupants [6].

4. How to use GERONIMO?

4.1 Selection of Users Mode

Within GERONIMO it is possible to run simulations into the following three different users modes from which are depending the analysis of the buildings luminous performance:

- Basic Mode
- Medium Mode
- Advanced Mode

In the BASIC Mode the simulation will result in a rendering of the Radiance scene, according to the human vision (log scale sensitivity); no additional information about photometric variables, such as work plane illuminance and luminance distribution in the view field of the scene are provided to the users. A simulation run in the Basic Mode is presented at Figure 8.

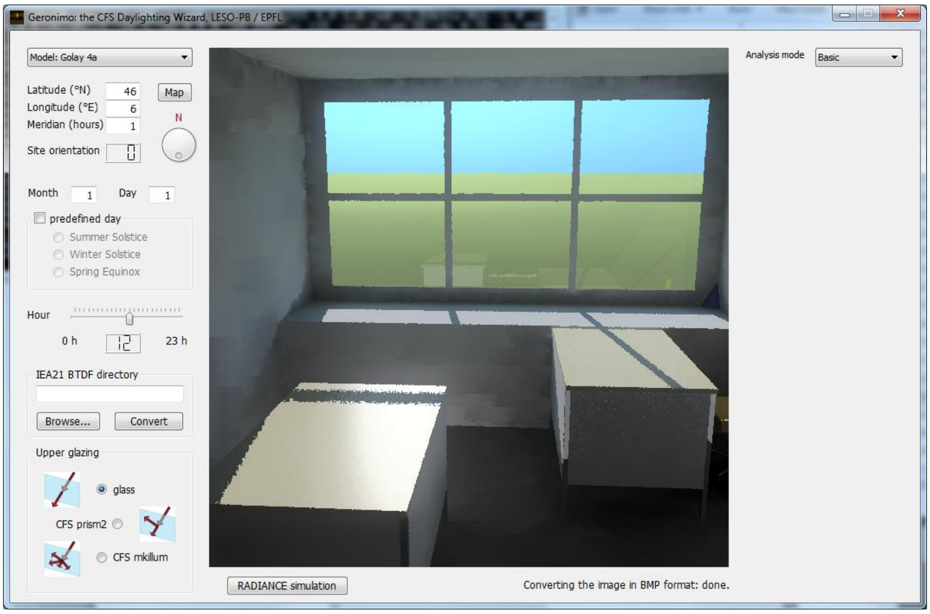

Figure 8: Rendering of an office room according to human vision simulated in the Basic Mode of GERONIMO.

In the MEDIUM Mode, computer simulations can be run to assess the three photometric variables presented in the paragraph 3.4:

- Work Plane Illuminance
- Daylight Factor Mapping
- Glare Indexes

The first and the second variables are thoroughly described in several well-known publications of the Commission Internationale de l'Eclairage (CIE), as well as in the IESNA Lighting Handbook [10]. Glare risks are assessed using the most common and used glare indexes, which are:

- CIE Glare Index (CGI)
- Daylight Glare Index (DGI)
- Unified Glare rating (UGR)
- Visual Comfort Probability (VCP)
- Discomfort Glare Probability (DGP)

The simulation of an office room fitted with standard double-glazing is presented at Figure 9. Paragraph 4 will gives an overview of the different commands and buttons of the visual interface used for that purpose.

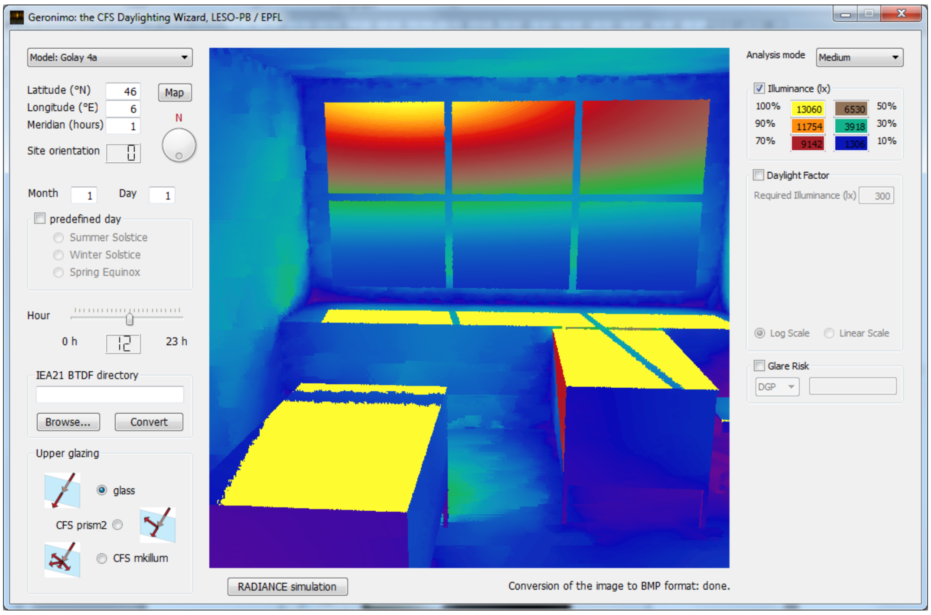

Figure 9: Simulation of an office room in the Medium Mode with activation of the 'Illuminance' checkbox for visualization in 'false colours'.

The ADVANCED Mode was conceived for users having excellent skills in the utilization of Radiance and familiar with the programme *rtrace/rpict* as well as the definition of the different simulation parameters. When selected the Advanced Mode displays a box where modifications of *mkillum* parameters are possible; a selecting bar controlling the parameters that drive the accuracy of the rendering is also displayed. An example of this feature is given at Figure 10.

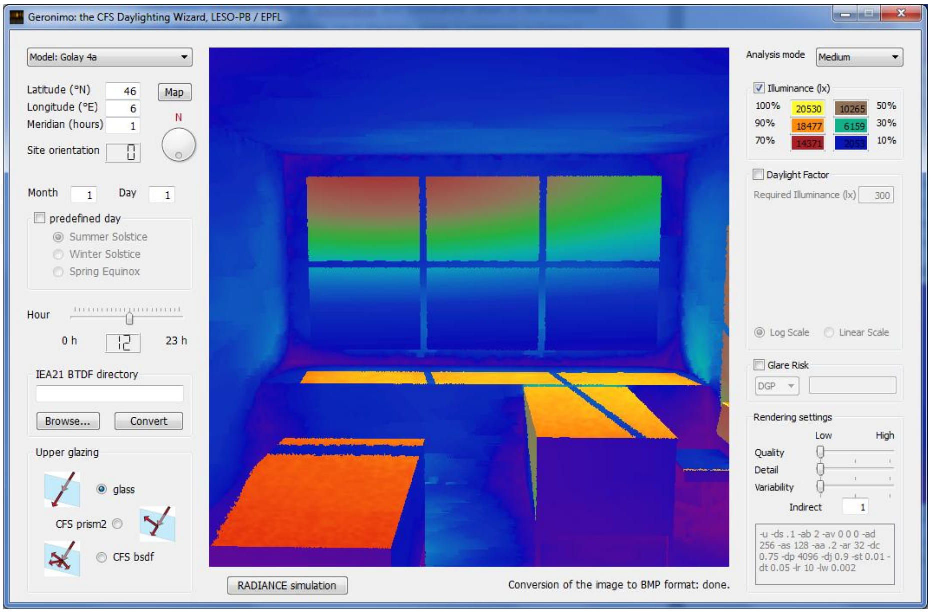

Figure 10: Simulation of an office room in the Advanced Mode with setting of the different variables of *mkillum* and *rendering* programmes.

4.2 Getting started with the Interface

The GERONIMO interface consists of a single window subdivided in three main sections. The left-hand section contains the pre-requisite for the simulation runs, such as:

- The model selection
- The model location and orientation
- The date and hour of simulation
- The type of conversion of BTDF Data to Radiance (*mkillum* or *prism2*)
- The BTDF Data directory name (IEA Task 21 format or standard gltzing)

The middle section of the interface is a rendering of the scene made by the way of OpenGL. By using mouse-clicks and mouse-movements in this section, the user can navigate in the scene and select a viewpoint.

The right-hand section of the interface displays different analysis modes, described in paragraph 4.1 (Basic, Medium and Advanced Mode), which can be selected.

4.2.1 Room Selection

In the upper part of the left-hand section, a display menu with different selectable room options for simulation runs is shown. The room description file must be keyed into GERONIMO as a 3D virtual model and was previously set-up using a CAD programme. See Figure 11.

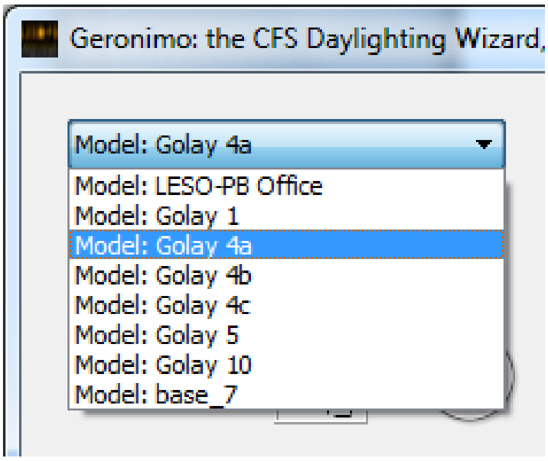

Figure 11: Display menu showing the different 'Room options' for GERONIMO simulations.

Notes for Advanced Users	Models are stored in the Radiance text file format in the files base_*i*.rad (where *i* is the room index).

4.2.2 Geographical Location

Different functions can be selected in the upper part of the left-hand section defining the geographical parameters of the room to be simulated, including:

- The location of the building (latitude, longitude and meridian)
- The orientation of the room (geographical azimuth)
- The moment of the simulation (date and hour or predefined dates)

Predefined dates of simulation are provided in the programme; they include the winter and summer solstices at noontime, as well the spring and autumn equinoxes. See Figure 12.

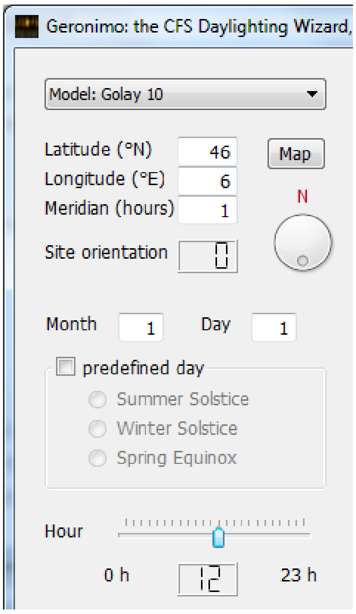

Figure 12: Upper part of the left-hand section of GERONIMO interface with geographical parameters selection

4.2.3 Standard Glazing or Complex Fenestration Systems Simulations

The downer part of the left-hand section of GERONIMO interface is related to CFS simulations. A browser bar can be used to select a CFS among the BTDF Data available for different Complex Fenestration Systems. The data directory is a result of the IEA Task 21 research programme during which a full analysis of the luminous characteristics and performance of different Advanced Daylighting Systems (including CFS) was carried out [11, 12]. The display menu shows the BTDF Data available for simulation runs.

As these systems are often made of highly reflective materials or materials with angular selective properties, which can limit the visibility of the occupants toward outside, they must be placed in the upper window location. Such an example is presented at Figure 13.

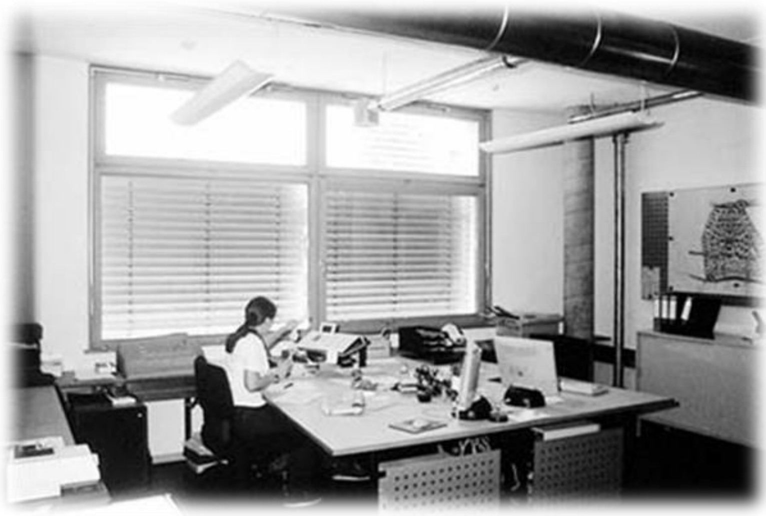

Figure 13: View of an office room fitted with prismatic-panels on the upper window [11, 12].

The downer part of the left-hand section of GERONIMO interface refers to the 'Upper glazing' selection previously mentioned. It allows defining the Complex Fenestration System, which is fitted to the upper window in order to improve the daylight distribution in the room. For the simulation of standard glazing (double insulated glazing), the option to be selected is *glass* shown as a "button" in the 'Upper glazing' window. See Figure 14.

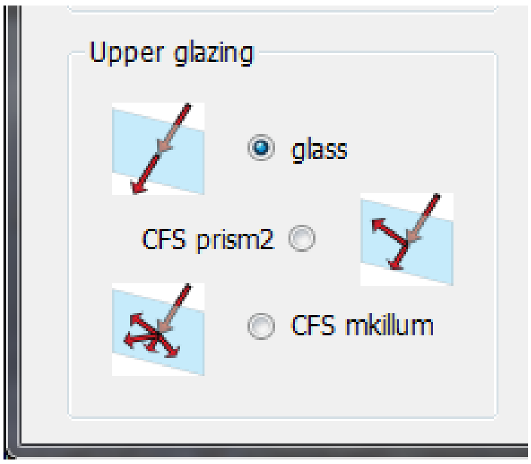

Figure 14: Left-lower part of GERONIMO interface including the selection of the 'Upper glazing'; the 'glass' option must be chosen to simulate a standard double-glazing.

In order to simulate Complex Fenestration Systems using GERONIMO, BTDF Data files issued from the previous IEA Task 21 research programme must be converted. The two alternative 'CFS prism2' and 'CFS mkillum' options, corresponding to different physical approximations of the photometric features of the BTDF Data, can be used to run simulations. They correspond to Radiance programmes, which can be described as follows:

- *CFS prism2* was designed for prismatic glazing and prismatic films; it models the transmitted daylight flux by the way of two main redirections typical for this kind of daylight redirecting device (rather than only one light ray used for the 'glass' option)
- *mkillum* computes the distribution of the daylight flux passing through window glazing, skylights and other 'secondary light sources'.

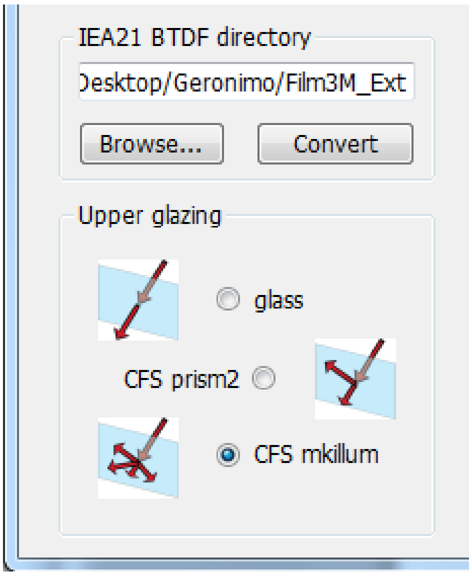

Figure 15: Left-lower part of GERONIMO interface including the selection of the 'Upper glazing'; 'CFS prism2' or 'CFS mkillum' options must be selected to simulate a CFS whose BTDF data is available in the BTDF directory.

Notes for Advanced Users

The Radiance files used for the simulations are:

- windowGLASS_*i*.rad
- windowPRISM2_*i*.rad
- windowMKILLUM_*i*.rad

The selection of the available 'Upper glazing' option is made according to the desired approximation depending from the specific Advanced Daylighting System to be simulated (standard double-glazing or CFS) as well as the required level of accuracy.

When clicking **BROWSE,** the folder containing all the available BTDF Data files of the different CFS is opened. It is necessary at this point to select one of them and click **CONVERT** in order to pinpoint the selected BTDF Data file to the CFS, which should be simulated. See Figure 16.

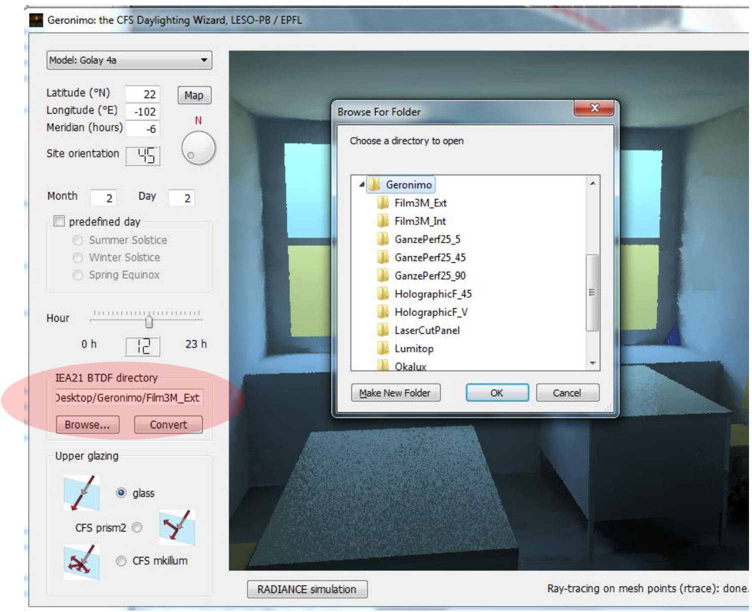

Figure 16: Display of the available BTDF Data files of CFS to be set on the upper window.

A message appears in the lowest part of the middle-section of the visualization area, informing the user that the conversion of the BTDF data is in progress. See Figure 17.

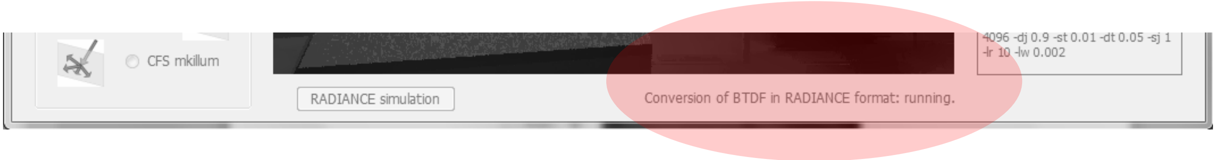

Figure 17: View of the information displayed in the lowest part of the middle section of the interface reporting about the progress of the simulation run.

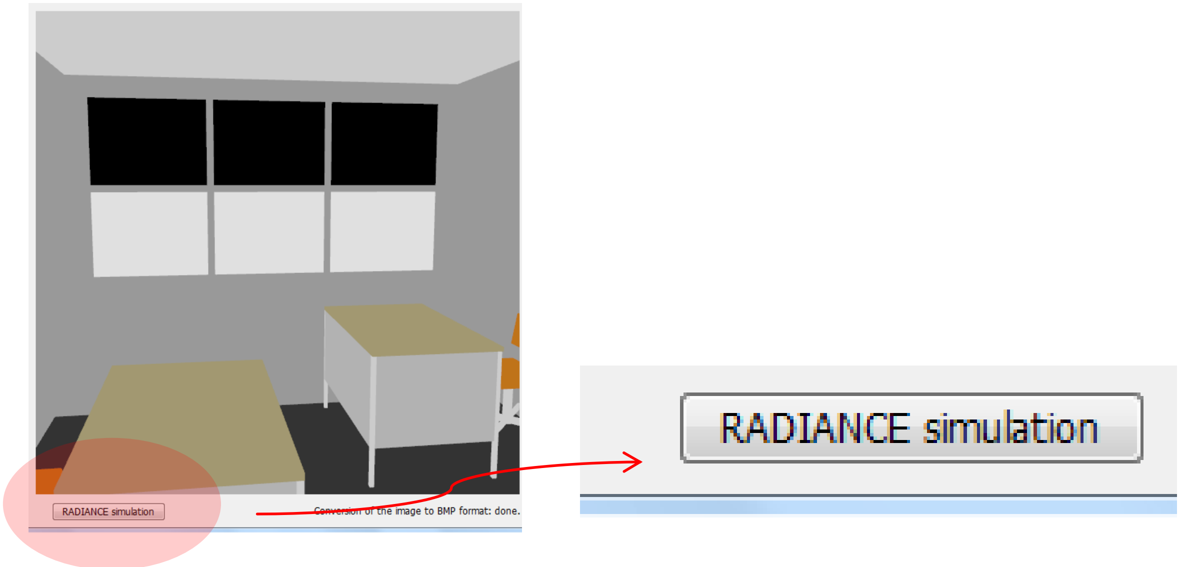

Figure 18: 'RADIANCE simulation' button located in the lower-left part of the visualization area.

Notes for Advanced Users	The image will be saved in BMP format in the file base_*i*.bmp (where *i* is the room index)

From that point on, it is possible to run a simulation by clicking **RADIANCE simulation;** the programme will display a view of the rendered scene in the middle-section of the interface showing the simulated model at a given location and moment. See Figure 18.

4.2.4 The Visualization Area

This paragraph is dedicated to the description of the simulation results. The main one is a Radiance picture, created using the *rpict* command and providing a rendering of the scene. Informations about the current status and progress of the simulation run are given at the bottom of the picture (lowest part of the middle section of the interface). Some indications regarding the success or possible failure of the simulation are also given at the same place. Figure 19 shows a Radiance picture of an office room created with the *rpict* command.

Figure 19: View of the visualization area of the GERONIMO interface (middle-section) showing a picture created using the *rpict* command.

4.2.5 Selection of the Analysis Mode

In the upper part of the right-hand section of GERONIMO interface is located a display menu from which three different users modes can be selected (see paragraph 4.1). As explained above, the Basic Mode allows simply achieving a room rendering according to the human vision (luminance log scale), the Medium Mode allows obtaining 'false-colour' illuminance rendering, daylight factor maps and assessment of glare risks. Some specific parameters can also be set to define the simulations accuracy in the Advanced Mode. See Figure 20.

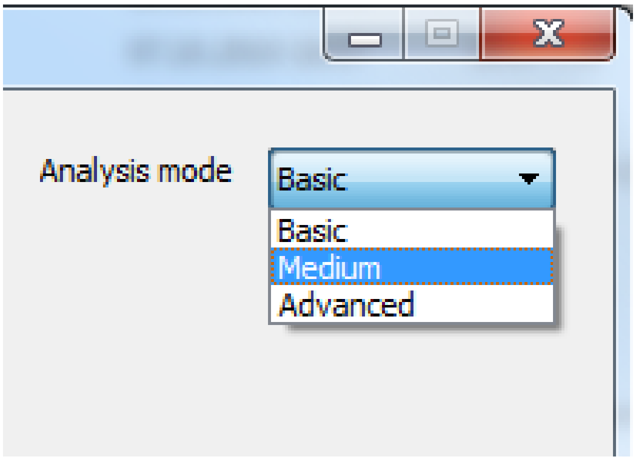

Figure 20: Right-upper parts of GERONIMO interface allowing a user selection of the simulation analysis mode.

Checkboxes must be activated in the Medium Mode to pinpoint the photometric variable to be considered for analysis; paragraph 4.1 thoroughly describes the three possible variables that can be selected in this case.

- **Workplane illuminance**

When the 'Illuminance' checkbox is activated, isolux contours are calculated and traced within the rendered scene shown in the visualization area. Surface illuminances are sorted from their minima to their maxima and displayed with the associated colour scale. False-colours are used to facilitate the users visualization according to the following rule:

- The blue colour corresponds to the areas of lower illuminance
- The yellow colour points out the areas of larger illuminance.

Figure 21 illustrates such a rendering in case of an office room fitted with different desks in the working environment.

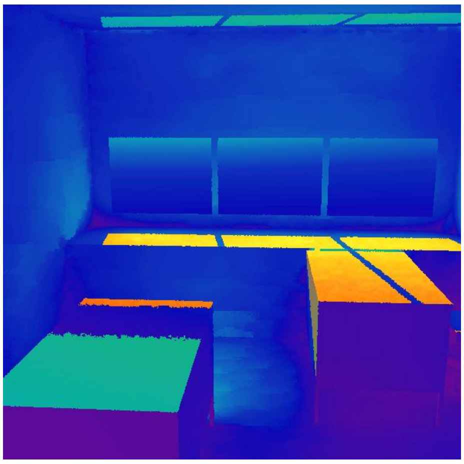

Figure 21: View of isolux contours in case of a work plane illuminance analysis (Medium Mode)

- **Daylight Factor Mapping**

The Daylight Factor (DF) is defined as the ratio of indoor illuminance on a given surface (E_i) and the simultaneously available outdoor horizontal illuminance (E_{hz}). It is given by the following formula:

$$DF = (E_i/E_{hz}) \times 100 \ [\%].$$

When the 'Daylight Factor' checkbox is activated, GERONIMO performs a calculation of Daylight Factors for a CIE overcast sky. The programme displays a DF top-view of the room for grid points represented as a grey-scale image. A little window placed in the right-hand section of the interface, just below the checkbox, shows the DF top-view. Daylight Factors are converted in an 8-bit grey level image (between 0 and 255 digits) according to a log (or linear) scale. A minimum illuminance value must be entered in order to define a minimal threshold for the grey-scale image; the latter is displayed as black colour in order to outline room spaces requiring electric lighting to complement an insufficient daylight contribution. Figures 22 and 23 show examples of a DF calculation in Log and Linear scales.

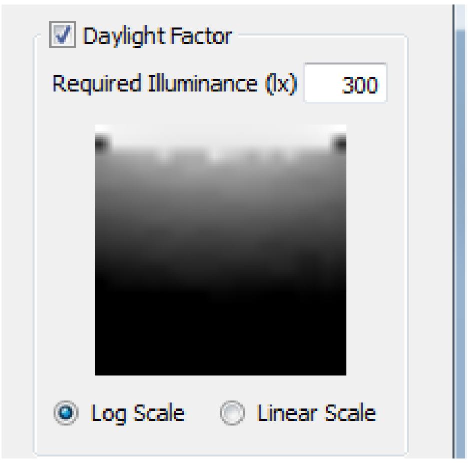

Figure 22: Daylight Factor Map presented according to a Log Scale.

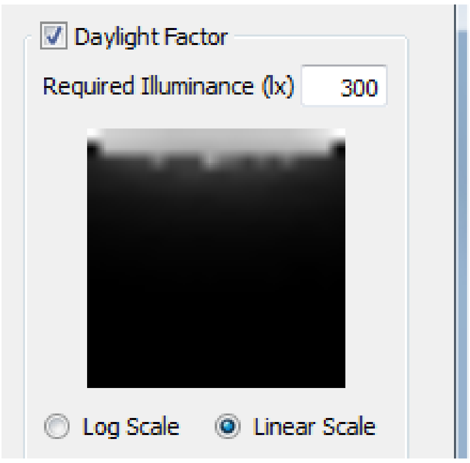

Figure 23: Daylight Factor Map presented according to a Linear Scale.

When clicking with the mouse on the iconic DF window, a text box is displayed. The latter informs the users about the maximum and minimum illuminance values as well as about their corresponding daylight factors. An illuminance threshold (minimum required workplane illuminance) together with the corresponding DF value is also given in the text box. See Figure 24.

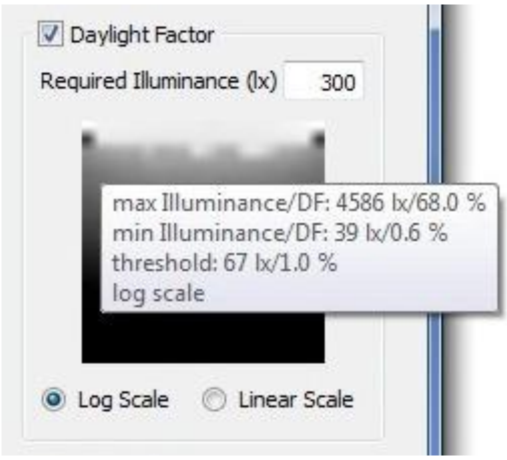

Figure 24: Text box displaying information about the maximum and minimum illuminance values, their corresponding DF as well as the specification of a threshold for electric lighting; it can be obtained by clicking with the mouse on the Daylight Factor (DF) iconic window,

- Glare Risks

In order to assess potential glare risks within the simulated room, the corresponding checkbox located in the middle of the right-hand section of the interface must be activated. A display menu will be shown allowing the selection of the Glare Index, which will be used for glare calculations during the simulation. See Figure 25.

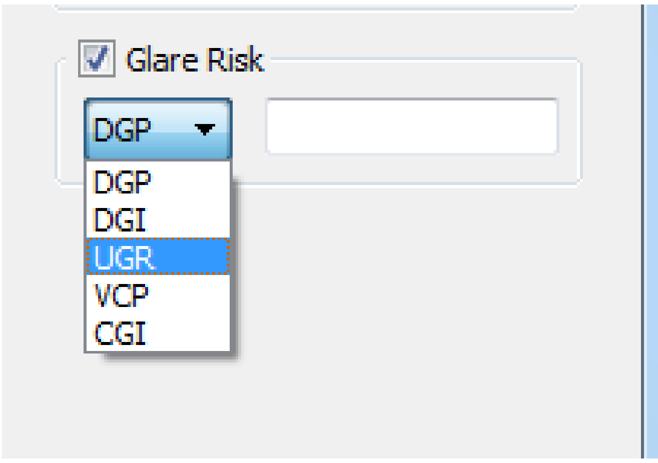

Figure 25: Display menu of the different possible options (Glare Indexes) for the assessment of glare risks with GERONIMO

The possible options for the assessment of glare risks through the use of Glare Indexes are the following:

Daylight Glare Probability (DGP)

The Daylight Glare Probability (DGP) represents the 'percentage of people disturbed' by discomfort glare. It is based on human reactions to daylight-based glare in a side-lit office environment with venetian blinds. It requires the relative size, the position and the luminance of the potential glaring source. The whole DGP formula includes the luminance (Ls), the solid angle (ωs) and the Guth position index of each potential glaring source (P). The sources must be previously identified as potentially glaring, a task which is currently solved by an appropriate Radiance programme [13].

Daylight Glare Index (DGI)

The Daylight Glare Index (DGI) is a modified version of the British Glare Index (BGI) suggested by Hopkinson. It is adapted to predict glare for large sources such as windows. Validation studies of the DGI formula have shown that the correlation between glare due to windows and the predicted DGI is weaker than for artificial lighting. There is apparently a greater tolerance of mild degrees of glare from windows than from a comparable artificial lighting situation; the tolerance does however not extend to severe degrees of glare [14].

Unified Glare Rating System (UGR)

The Unified Glare Rating (UGR) is commended by the CIE as a general formula for assessing glare. In order to apply the UGR formula, a prior knowledge of the position and brightness of each potential glare source is required. The UGR is quite accurate but relatively difficult to apply and require computer calculations. For artificial light sources, such software packages exist from most major producers of light fittings. They all require the modelling of the scene under investigation and produce a glare index for a defined position within the room [15].

Working area	Maximum allowed UGR
Drawing rooms	16
Offices	19
Industrial work, fine	22
Industrial work, medium	25
Industrial work, coarse	28

Visual Comfort Probability (VCP)

The Visual Comfort Probability (VCP) of a lighting system expresses the relative fraction of people who, when viewing from a specified location and in a specified direction, are expected to consider it acceptable in terms of discomfort glare. The VCP is related to Discomfort Glare Rating (DGR) by the way of an analytical equation [10].

CIE Glare Index (CGI)

The CIE adopted the following formula, defining the CIE Glare Index (CGI), suggested by Einhorn, as a unified glare assessment method:

$$\mathrm{CGI} = 8\log_{10} 2\frac{[1+(E_\mathrm{d}/500)]}{E_\mathrm{d}+E_i}\sum_{i=1}^{n}\frac{L_\mathrm{s}^2\omega_\mathrm{s}}{P^2}$$

where:

E_d (lx) is the direct vertical illuminance at the eye due to all sources

E_i (lx) is the indirect illuminance at the eye ($E_i = \pi \cdot L_b$)

4.2.6 Selection of *Mkillum* and *Rendering* Parameters

The Advanced Mode included for Advanced Radiance Users implies that the latter are familiar with the different rendering parameters of the programme. If the Advanced Mode is selected, a checkbox is displayed allowing adapting these parameters according to the quality requirements of the image rendering.

Because of the interrelated nature of the simulation variables and parameters, the recommended settings are given herein.

LOW DETAIL:

QUALITY =	Low	Med	High
-dr *-dp*	0 64	1 256	3 1024

MEDIUM DETAIL:

QUALITY =	Low	Med	High
-dr *-dp*	0 128	1 512	3 2048

HIGH DETAIL:

QUALITY =	Low	Med	High
-dr *-dp*	0 256	1 1024	3 4096

Figure 26: Recommended settings of Radiance parameters according to the quality requirements rendering details for a Direct Calculation [1].

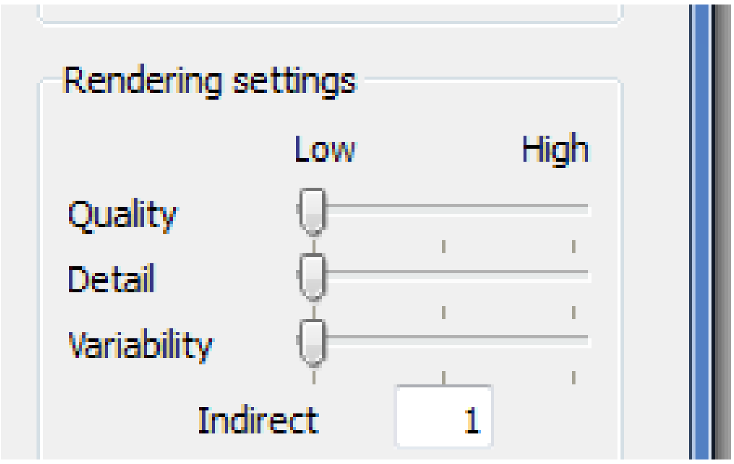

Figure 27: Selection bar used to modify the Radiance image rendering quality, detail and variability

A combination between Low and High rendering settings can be established regarding the quality, detail and variability of the rendered image. The 'Indirect' input accounts for the parameter -ab (ambient bounces), which indicates the number of diffuse inter-reflections that will be considered during the simulation. A setting of 0 turns the inter-reflection calculation off.

The *rad* input variables influencing the ambient parameter settings are QUALITY, INDIRECT, VARIABILITY, DETAIL, ZONE and EXPOSURE. The recommended settings for the interrelated variables and parameters are shown on Figure 28.

	Quality=Low -ab 0		Quality= Med -ab I		Quality= High -ab I+1	
DET= Low	-ar 4		-ar 8		-ar 16	
DET= Medium	-ar 8		-ar 16		-ar 32	
DET= High	-ar 16		-ar 32		-ar 64	
VAR= Low	-aa 0.4	-ad 64	-aa 0.3	-ad 128	-aa 0.25	-ad 256
VAR= Medium	-ad 196	-as 0	-ad 400	-as 64	-ad 768	-as 196
	-aa 0.15		-aa 0.125		-aa 0.8	
VAR= High	-ad 256	-as 0	-ad 512	-as 256	-ad 1024	-as 512

Figure 28: Parameter settings corresponding to *rad* input variables; I represents the Indirect variable [1].

Mkillum parameters defining radiance calculations are located at the right-bottom part of GERONIMO interface. The variables are set according to the quality and desired CPU time for rendering. See Figure 29.

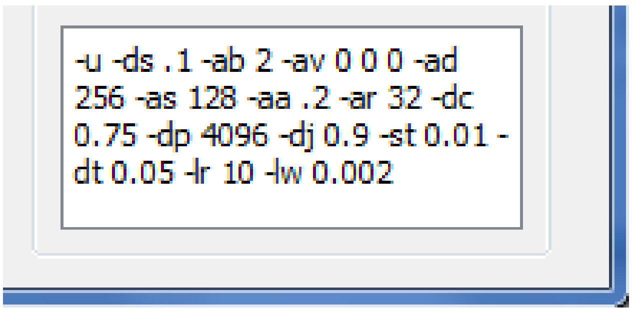

Figure 29: Dialogue box located at the right-bottom part of the Geronimo interface allowing setting of the *mkillum* parameters

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