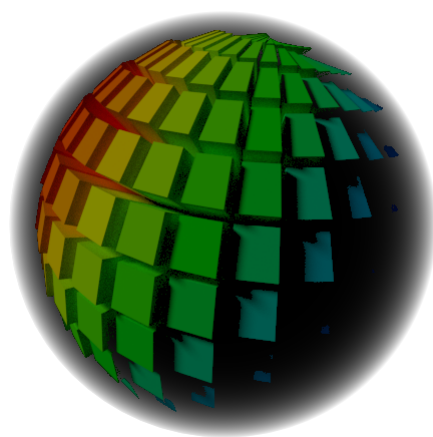


Radiance Simulations and Visualisations with LiVi

For LiVi version 0.3



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1 Introduction

The Lighting Visualiser (LiVi) is an open-source add-on to the 3D modelling and animation package Blender, which acts as a pre/post-processor for the Radiance lighting simulation suite. LiVi allows for quick geometry creation and material specification via Blender, runs the Radiance simulation with user specified parameters, and imports the data back into Blender for visualisation. LiVi is capable of simulating static or animated geometry/materials under steady state or transient natural/artificial lighting conditions. Daylight Factors, irradiance, illuminance and daylight availability on any geometry within the scene, can be calculated. Animated or static glare analysis can also be achieved and visualised using Blender's video sequencer. Background skies as illumination sources can be automatically generated with Radiance, or the user can use their own generated High Dynamic Range (HDR) light probes. The combination of LiVi, Blender and Radiance represents a streamlined and completely open-source lighting analysis work-flow that encourages the user to quickly and easily experiment with form and materiality, from within a professional visualisation environment.

2 Background

LiVi attempts to blur the distinction between software work-flows that relate to the acquisition of building technical data, and the visual building design process. Almost all relevant software either falls into one of the two camps. Notable examples for the former are EcoTect and Design Builder, and of the latter Cinema 4D and 3D Studio Max. The existence of these two distinct camps, we believe, is a barrier to communication between the design and technical sides of the architectural discipline, and that enhancement of this communication is essential to deliver buildings that are well designed, and environmentally responsive.

Although there are existing examples of this integration, for example 3DS Max Design and DIVA for Rhino, LiVi (along with Blender and Radiance) is free, open-source and aspires to an even greater level of integration. Material, form and time animations set-up in Blender can be simulated within Radiance, and conversely the results from the Radiance simulations can be expressed as 3D geometry within the blender scene, allowing them to be animated, rendered, faded in and out of view etc.

Why Blender? Well, in our opinion at least, Blender is the most professional, open-source 3D content creation suite available, and it becomes more professional by the day. It is also free and multi-platform which means there are no significant cost or hardware barriers to its use. Its open-source nature means that we can make minor changes to the source code to enhance the functionality of LiVi, and its use of Python as a scripting language, provides immense flexibility in terms of communication with other applications, and the expression of the data from these other applications within Blender.

Finally, and quite recently, Blender has incorporated a new, physically based rendering engine called Cycles, which allows accurate and interactive analysis of the visual lighting consequences of form and material decisions. Coupled with the ease with which these design choices can be assessed numerically with LiVi, the two provide a powerful and closely integrated approach to the aesthetic, and performance, of lighting scenarios within and around buildings.

3 Installation

The LiVi scripts are available from the LiVi website, which can be found at <http://arts.brighton.ac.uk/research/office-for-spatial-research/projects2/livi>. Currently LiVi can be run on Windows, OS X and Linux systems.

For full animation functionality minor changes are required to the Blender source code, which are detailed below.

3.1 Mac OS X

LiVi has been tested on OS X Version 10.5 & 10.6 (32bit) and 10.7 (64bit). First download Blender from <http://www.blender.org/download> and install. Run Blender once and select 'File' - 'Save Start Up File' to make sure the Blender configuration directory is created at `/Users/username/Library/Application Support/Blender`



`/blender_version` where *username* is your username and *blender_version* is the version of Blender downloaded (currently 2.68). Create within this directory a “scripts” directory, and within this an “addons” directory (all lowercase). Then download and install Radiance from <https://openstudio.nrel.gov/getting-started-developer/getting-started-radiance> (registration required). LiVi assumes that Radiance is installed in the `/usr/local/radiance` folder.

LiVi is available as a downloadable zip file from the LiVi website. Inside the zip file is a folder called `io_livi`. This folder should be moved to the `/Users/username/Library/Application Support/Blender/blender_version/scripts/addons/` folder created earlier.

It is also advisable to use a three-button mouse, which is set up as a three button mouse in OS X.

3.2 Windows

LiVi has been tested on a 64bit Windows 7 system, although the Radiance and Blender binaries are both 32bit and should run on older 32bit Windows versions. First download Blender from <http://www.blender.org/download> and install. Run Blender once and select ‘File’ - ‘Save Start Up File’ to make sure the Blender configuration directory is created at `C:\Users\username\AppData\Roaming\Blender Foundation\Blender\blender_version` where *username* is your user name and *blender_version* is the version number of the downloaded Blender version (2.68 at the time of writing). Create within this directory a “scripts” directory, and within this an “addons” directory (all lowercase). Then download and install Radiance from <https://openstudio.nrel.gov/getting-started-developer/getting-started-radiance> (registration required). LiVi assumes that Radiance is installed in the `C:\Program Files(x86) \Radiance` folder for 64bit windows and `C:\Program Files\Radiance` for 32bit windows.

LiVi is available as a downloadable zip file from the LiVi website. Inside the zip file is a folder called `io_livi`. This folder should be moved to the `C:\Users\username\Application Data\Blender Foundation\Blender\blender_version\scripts\addons\` folder created earlier.

3.3 Linux

LiVi has been tested on a 64bit Arch Linux installation. First install Blender, which is available through most Linux distributions package management system. Run Blender once to make sure the Blender configuration directory is created at `/home/username/.config/blender/blender_version` where *username* is your user name and *blender_version* is the version number of the downloaded Blender version (2.68 at the time of writing). Create within this directory a “scripts” folder and within this an “addons” folder. Then download and install Radiance from <https://openstudio.nrel.gov/getting-started-developer/getting-started-radiance> (registration required). LiVi assumes that Radiance is installed in the `/usr/local/radiance` folder.

LiVi is available as a downloadable zip file from the LiVi website. Inside the zip file is a folder called `io_livi`. This folder should be moved to the `/home/username/.config/blender/blender_version/scripts/addons/` folder created earlier.

3.4 Compiling Blender for Enhanced Animation Capabilities

The current version of Blender (2.68) is limited to 17 vertex colour layers on an object. As vertex colour layers are used to store the Radiance results, only 17 animation steps can be calculated with the stock Blender release. Minor source code changes to Blender do however permit many more vertex colour layers and therefore many more animation steps to be simulated. The three files that need editing and the changes to be made are:

- Within the file `source/blender/makesdna/DNA_customdata_types.h` change the value ‘8’ in line 180 `#define MAX_MCOL 8` to the desired number of vertex layers.
- In the file `source/blender/render/extern/include/RE_shader_ext.h` change the ‘8’ in line 143 `ShadeInputCol col[8];` to the desired number of vertex layers.
- And in file `source/blender/editors/mesh/mesh_data.c` change line 419 `if (layernum >= CD_MLOOPCOL) {` to `if (layernum >= MAX_MCOL) {`



The changes have been tested up to 256 vertex colour layers. Subsequent releases of Blender may change the line numbering for these edits. Once the changes have been made Blender must be recompiled for the target system.

4 Configuration

Running Blender launches the main Blender interface, which should look similar to the one shown in figure 1.

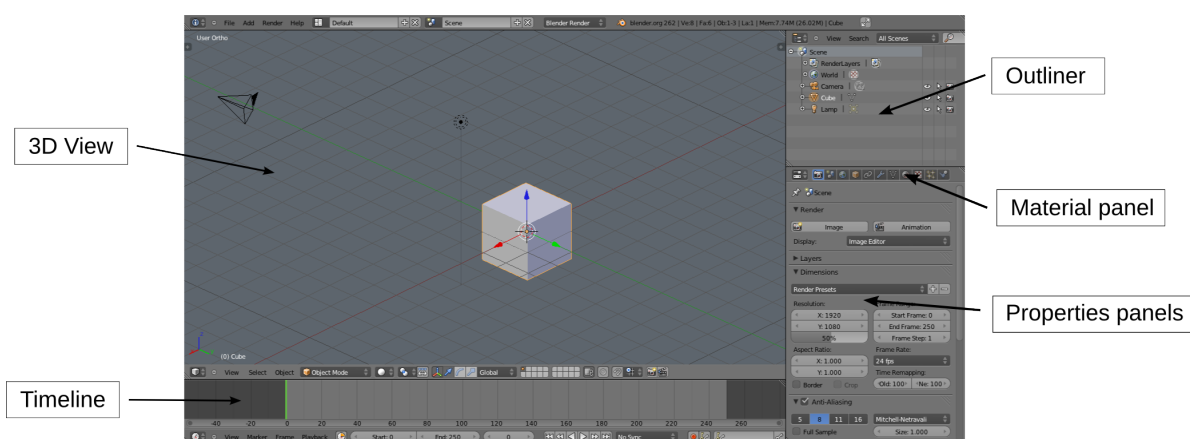


Figure 1: The default Blender interface

The main window is the 3D view where the default cube, lamp and camera can be seen. Below this is the animation timeline, on the top right is the project outliner that contains a list of everything in the scene and bottom right are the properties panels where much of the Blender functions reside. Detailed instructions on how to use Blender are beyond the scope of this document, but there are excellent and free beginners documents available by James Chronister, available [here](#) and by John Blain, available [here](#) and a good on-line modelling tutorial available [here](#). The former is meant for high school students so it takes a slightly younger approach. There is also a very comprehensive set of video tutorials available from [here](#). In addition, there is a wealth of books [1, 2, 3], websites and You Tube and Vimeo videos dealing with many aspects of Blender's capabilities.

LiVi is an add-on to Blender and will need to be activated on a fresh install. This can be done from Blender's user preferences. Go to 'File' menu at the top of the 3D view and from the drop down list select 'User Preferences'. Along the top of the new preferences window there will be an 'Addons' tab. Click on this and from the 'Import-Export' list on the left select the 'Lighting Visualiser (LiVi)'. There are other settings within the 'User Preferences' that can be altered as desired, for example to control how the 3D view is navigated. The resources above contain sections on customising the Blender user interface. By default the 3D view can be rotated with the middle mouse button, zoomed with the mouse wheel and objects are selected with the right mouse button.

Once LiVi has been activated it sits within the 3D View Panel which, with the mouse over the 3D view, can be toggled on and off with the 'n' key. Alternatively you should see a small '+' sign in the top right of the 3D view. Clicking on this will also open the 3D view panel. At the bottom of this panel is the LiVi interface which should look something like figure 2. The triangles to the left of each section name expand and collapse each section.

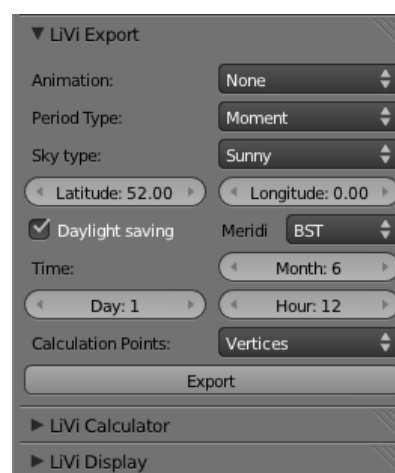


Figure 2: The LiVi interface



The LiVi interface consists of three sections: LiVi Export, LiVi Calculate and LiVi Display, and as you might have guessed the first section controls the export of Blender data to the Radiance format, the second controls the Radiance calculation, and the third controls how Blender visualises the Radiance results. The sections are context sensitive so if the Blender scene has not been exported nothing will be available in the calculation or display panels. An exception to this is if a Blender file is opened that contains results within it from a previous simulation; the display panel will then be available in this case.

5 The LiVi Interface

5.1 Export

The first selection dialogue within the export panel controls the type of animation to be conducted. The default is 'None' meaning a static simulation will be conducted. Other options are: 'Time' where a period of time is simulated, 'Geometry' where animated geometry is simulated, 'Materials' where material changes are simulated and 'Lights' where IES lamp strength changes are simulated. The rest of the export menu is context sensitive and displays different menus depending on this first selection.

Static analysis

If no animation is selected the next menu item to be selected is the type of sky data to be used. The options here are 'Moment', where a single moment in time is simulated, or 'DDS', which stands for Dynamic Daylight Simulation, where an overall annual simulation can be conducted. If 'Moment' is selected the next menu is sky type, where the type of sky for this momentary simulation can be selected. The sky types available are:

- Sunny. A standard CIE¹ sunny sky is used for the simulation.
- Partly Cloudy. A standard CIE intermediate sky is used for the simulation.
- Cloudy. A standard CIE cloudy sky is used for the simulation.
- DF Sky. This sky is for Daylight Factor analysis and is a homogeneous overcast sky that delivers 10,000 lux on an exposed horizontal surface.
- Radiance Sky. A valid Radiance sky description text file can be selected with this option.
- HDR Sky. A 360° high dynamic range (HDR) panorama image in 'angmap' format for custom site specific analysis.

As the first three of these skies have a sun position dependency when they are selected menus appear to choose the site location and time of day to determine sun position. If the final 'HDR Sky' option is selected a button appears to select the HDR image. Pressing this button opens up Blender's file selection dialogue where the required file can be navigated to and selected.

If 'DDS' is selected the sky menu will disappear and a file browser button appears to navigate to and select a weather file in EPW² format. From this file LiVi will generate an annual sky description in HDR format. As the process of generating an annual sky can take some time, if an HDR sky description has already been generated for a particular EPW file, the HDR file can be loaded here directly.

5.1.1 Time animation

If time animation is selected the next options relate to the setting of the site location, beginning, end and interval of the analysis period as these will all influence sun position. If the interval is set to 24hrs, for example, then the same time of every day in the total period will be simulated, which can be useful to determine design sensitivity to solar altitude changes. Upon export LiVi will automatically create the correct number of animation frames for each step of the period.

¹Commission International de l'Eclairage (CIE) have specified mathematical models to describe the luminance distributions of typical types of sky.

²EPW stands for EnergyPlus weather file. EPW files contain hourly weather data for a whole year and can be downloaded for a number of locations. The EnergyPlus [website](#) is a good source of EPW files.



5.1.2 Geometry animation

When geometry animation is selected any geometry animations set up in Blender will be sent to Radiance. There are two main methods to animate geometry in Blender: object and shapekey. Object animation is an animation applied at the object level, and shapekeys are applied at the mesh level.

To set up an object animation, the start and end frame of the animation must be set-up in the animation timeline window at the bottom of the default Blender interface. The start frame must be kept at '0' and the end-frame set to the desired number (a simulation will be run for each frame step between the start and end frame). An object can be animated in terms of its location, rotation and scale which can be altered with the 'g', 'r' and 's' keys or with the menu entries at the top of the 3D view properties panel, in the 'Transform' section, above LiVi. With the current frame set to '0', and geometry set-up in its initial condition the 'i' key can either be pressed while the mouse is over the 3D view, or while over the desired transformation panel (figure 3). The former will bring up a menu asking which kind of object transformation (location, rotation, scale or combination) is to be keyframed.

The latter will automatically keyframe the transformation panel the mouse is over. The transformation panels will turn yellow when they have been keyframed.

Now specify the current frame to be the end frame, make the desired object transformations and press 'i' in the same way again. The two object shapes/locations are now represented at the beginning and end frame and Blender will smoothly transform between the two at intermediary frames. To play the animation press the play button at the bottom of the animation timeline. You should now see the geometry transition between the two positions. Intermediary keyframes can also be added if more complex object manipulation is required.

If a more detailed animation of an object shape is desired then shapekeys will be required. Shapekeys allow the shape of the mesh to be keyframed as long as the number of vertices, edges and faces do not change. Again, specify a desired end frame and set the current frame to '0'. With the object to be animated selected go to the 'Object Data' panel where there is a section called 'Shape keys' and click the add symbol on the right hand side. This first shape key is called 'Basis'. Add another Shape key. With this second shape key selected enter the objects 'Mesh' mode (with the tab key) and make the desired alterations to the mesh by rotating, moving scaling the vertices, edges or faces of the mesh. Leave 'Mesh' mode by pressing 'tab' again. Underneath the shape key panel is a 'Value' slider. Changing the value of this slider will make the mesh change from the basis shape to the new modified shape. This value slider can now be key framed by pressing 'i' with the mouse over the slider. For example a value of 0 at frame 0, and a value of 1 at the end frame will make the object slowly change form the basis shape to the new shape. Pressing play in the timeline panel should now play the changing geometry.

5.1.3 Material Animation

Animation of materials is done in a similar manner by placing the mouse over the appropriate slider and pressing 'i' for the appropriate current frame and value. Bear in mind the values in table 2 and the values appropriate for the Radiance material desired. Material colour, diffuse reflectivity, specular reflectivity, translucency and transparency can all be animated.

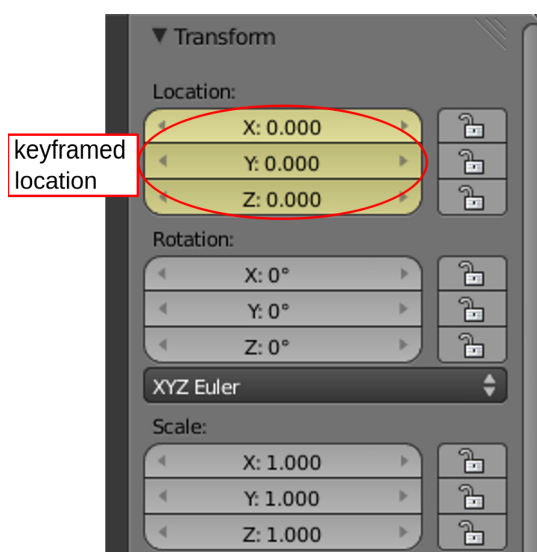


Figure 3: Keyframing in the transform panel



5.1.4 Light Animation

Finally, artificial light strength can be animated. Artificial lights can be included in the Radiance scene in two ways; via lamp entities or planar meshes. In the first case a lamp is added to the scene with the 'Add' - 'Lamp' - 'Point' menu at the top of the 3D View. In the 'Object Data' panel for this new lamp there should now be a section called 'LiVi IES Lamp'. In this section a file browser allows the selection of the manufacturer's IES file, the units within the file and the strength of the lamp. It is the strength of the lamp that can be animated in a similar way to above; pressing 'i' with the cursor over the lamp strength slider will keyframe it. The rotation of the lamp in Blender will control the rotation of the lamp in Radiance and if the rotation or location of the lamp is animated these changes will also be sent to Radiance for simulation.

The other way to specify artificial lights is to create a regular plane, moving and sub-dividing it so that the centre of each face corresponds to the desired position of a light, and calling it 'lightarray'. In the 'Object 'Data' panel of the mesh the same LiVi IES Lamp panel should now appear and an IES file selected. The strength can again be animated. Simple rotations of the mesh will also be reflected in the positioning of the lights in the Radiance scene, although more complex rotations may not be correctly reported to Radiance. In general keep IES mesh rotations to a single axis rotation.

5.1.5 Final Export

The final menu item chooses whether the vertices or faces of the calculation surfaces determines the location of the sensor points within Radiance. This option will be discussed more fully in section 6.1, but in general if the sensor mesh is made up of triangles, vertices is a good option, and if made of squares then faces is a good option. For very complex animated scenes vertices is also less resource hungry.

After saving the Blender file the export button can finally be pressed which will convert all the relevant data within the Blender scene into Radiance format (note that only visible geometry on Blender's layer 1 will be exported). A directory will be created in the same directory as the saved blender file and given the same name as the Blender file. In future these text files will be stored within Blender.

5.2 Calculation

5.2.1 Simple Metrics

The Calculation panel is also context sensitive and will display menus based on the selections within the export menu. The first menu selects the metric to be simulated. If 'Moment' was selected as the period type within the export section then the options here can include:

- Illuminance (in lux) useful to assess whether lighting conditions are suitable for particular activities.
- Irradiance (in W/m^2) useful for assessing solar energy potential
- Daylight factor (in %) useful for assessing how receptive a building is to natural light. Only available if a Daylight Factor sky has been selected in the export panel.
- Glare (various metrics)

In the case of the first three option types the desired metric is calculated for each of the specified sensor points. Glare however is slightly different.

5.2.2 Glare Analysis

Glare is the sense of visual discomfort arising from luminance variations within a scene. Absolute, relative and positional factors all come into play when ascertaining whether luminance values are likely to cause discomfort. Glare analysis is achieved with the Evalglare program created by Jan Wienold of the Fraunhofer Institut für Solare Energiesysteme ISE, more information about which can be found within the Evalglare download [web-site](#). Evalglare is included within the LiVi package and does not need to be downloaded separately. Evalglare can evaluate the following glare metrics:



- Daylight Glare Probability (DGP)[5] - A relatively new metric that states the probability (0 - 1) that a person will experience visual discomfort. A score below 0.2 indicates an acceptable environment. More than 0.45 an unacceptable one. This new metric attempts to account for natural and artificial lighting sources.
- Daylight Glare Index (DGI) - The first metric to try and account for larger natural sources of luminance. Has been superseded to some extent by the UGR metric.
- CIE Glare Index (CGI) - For artificial sources of lighting. More than 28 is unacceptable, 13 barely noticeable.
- Unified Glare Rating (UGR) - A widely accepted general glare assessment metric based on a simplified CGI and geared towards regular arrays of artificial lighting. Preferred metric of the CIE. Some example maximum UGR's are shown in table 1.
- Visual Comfort Probability (VCP) - A percentage value indicating the % of observers in the worst case scenario position that would not experience visual discomfort. Closely related to luminaire performance positioned in a regular grid.

A good reference document discussing these metrics is available [here](#).

As glare is a visual phenomena, closely linked to the view direction, it would not be appropriate to plot their values at sensor positions as with the other metrics. The analysis of glare therefore makes use of Radiance's ability to generate images of the scene, evalglare and Blender's video sequencer, discussed in the [Display](#) section.

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

Table 1: Recommended maximum UGR values.

5.2.3 Dynamic Daylight Simulations

Dynamic daylight simulations, as previously mentioned, take longer term climate data and uses it to evaluate radiation and lighting metrics over the course of this longer period. This type of analysis is often considered to be more useful than the 'instantaneous' metrics above, especially in terms of evaluating building energy flows, as it can be more reflective of actual sky conditions at a particular site, and can give a picture of performance over more representative periods of time.

If DDS was selected in the export panel for the period type then three Dynamic Daylight Simulation metrics are available.

- Cumulative Light Exposure (in luxhours) - Useful for the museum and exhibition space sector where the amount of natural light entering a space often has to be strictly controlled. Recommended maximum lux and luxhours levels for different types of exhibited material are given by Gary Thomson in his book 'The Museum Environment' [4] and various on-line sources.
- Cumulative Radiation Exposure (in Wh/m²) - Useful for assessing solar energy potential at a local or urban scale.
- Daylight Availability (in %) - Percentage of time, within a specified daily period, that a sensor point achieves a certain threshold lux level. Useful for determining artificial lighting energy demands.

If Daylight Availability (DA) is selected the next menu items control the parameters for it's calculation. If DA is selected and if an HDR image file was selected within the Export Panels's EPW Select Dialog then a .mtx file needs to be chosen. These mtx files are created, in the Blender file directory, when LiVi exports



with an EPW file in the EPW file select dialog. Creating a mtz file takes some time but only needs to be done once for each EPW file. To speed up the export phase a .mtz file, or the final HDR image file, can be selected in the export panel. It is when an HDR file is selected that the VEC file open dialog appears in the calculation panel. It is important that the VEC file chosen here has been generated from the same source EPW file as the HDR image file selected in the export panel. The weekdays tick box disregards weekends in the DA calculation, which is useful for commercial environments. Start Hour and End Hour specify the start and end hour of the daily calculation period and the lux threshold value has to be exceeded by a sensor point to register a contribution to the DA.

5.2.4 Simulation Accuracy

The next menu item is the simulation accuracy desired, for which there are 4 settings: Low, Medium, High and Custom. As a general rule if one expects that the light/radiation levels are mostly due to a direct contribution from the sky or artificial light sources, low accuracy can be selected. However if light levels are a product of reflections and transmission through transparent/translucent objects, then higher simulation accuracy should be selected to generate final results. If undertaking a dynamic daylight simulation at least medium accuracy should be used and preferably high, although this may take some time to solve. The Custom setting is for 'Expert' users where the Radiance simulation parameters can be specified directly.

Finally, the two buttons at the bottom of the calculation panel control a Radiance preview of the scene, and the calculation of the chosen metric at the sensor points. The radiance preview button will open up a new window where the Radiance scene can be previewed. The scene is viewed from the perspective of Blender's camera, so one must exist and be orientated as desired. This Radiance preview can be useful to check that conversion of Blender materials to Radiance is as expected. The new window may show a white or black image if it is over/under exposed. On OSX and Linux press the 'e' key, then press 'enter' and click somewhere on the image to normalise the exposure to that point. On windows the new window has a menu at the top which can control exposure.

If not doing a glare analysis then once the Calculate button has been pressed, and the simulation has completed, the Display panel should become visible.

5.3 Display

The Display panel contains the display button, a 'Only Render' toggle and a '3D Results' toggle. The 'Only Render' toggle controls Blender's 3D view and switches between a simple rendering of the scene, and the default gridded view. The 3D Results toggle controls whether the results planes should be extruded to make the results plane 3 dimensional. If this toggle is selected then a slider option will appear below to control the level of extrusion. Pressing the Display button will now visualise the results by colour-coding the sensor geometry according to a legend key that appears on the left of the 3D view. Some simple statistics are also displayed above the legend. If 3D Results was selected the plane will be distorted according to results. If an animated analysis was selected pressing play in the timeline will play the animated results. Animation frames can be stepped through with the left and right arrow keys.

Once the Display button has been pressed the 'Point Visualisation' section will appear which controls whether values are plotted in the 3D view for each of the sensing faces/vertices. The first toggle 'Display' turns point visualisation on and off, the second 'Selected Only' specifies if point visualisation should only be done on the selected object in the 3D view, and the font size slider controls the font size of the displayed numbers.

5.3.1 Glare

If a Glare analysis was selected then when the simulate button is pressed LiVi will create a hemispherical fish-eye image of the scene, aligned with the Blender camera, and use evglare to process the image. The image processing turns the image black & white and colours the glare sources within the image. Discrete glare sources are given different colours. These images now appear in Blender's video sequencer (figure 4), which can be opened by clicking on the cube button at the very bottom left of the 3D View and selecting 'Video Sequence Editor' from the list. Once in the video sequence editor the left and right arrow keys will step forward and backwards through the animation frames (there will be only one animation frame, '0', if a static analysis was



selected). To lighten or darken the image press the 'n' key in the Video Sequence Editor and in the 'Filter - Colors' panel that appears on the right, turn up or down the multiply parameter.

On the right of the image appears a print out of the time and date of the moment the image pertains to, and the glare metric values. Subsequent glare calculations will result in new sequences being added to the video sequence editor. It is the uppermost sequence in the editor window which is visible in the sequencer viewer. Sequences can be moved around by right clicking and dragging them in the editor. The view buttons at the bottom of the sequencer control whether the editor, viewer or both editor and viewer are displayed. If choosing to display both, as in figure 4, the whole sequencer window needs to be scaled to a reasonable size by dragging the boundaries of the video sequencer window.

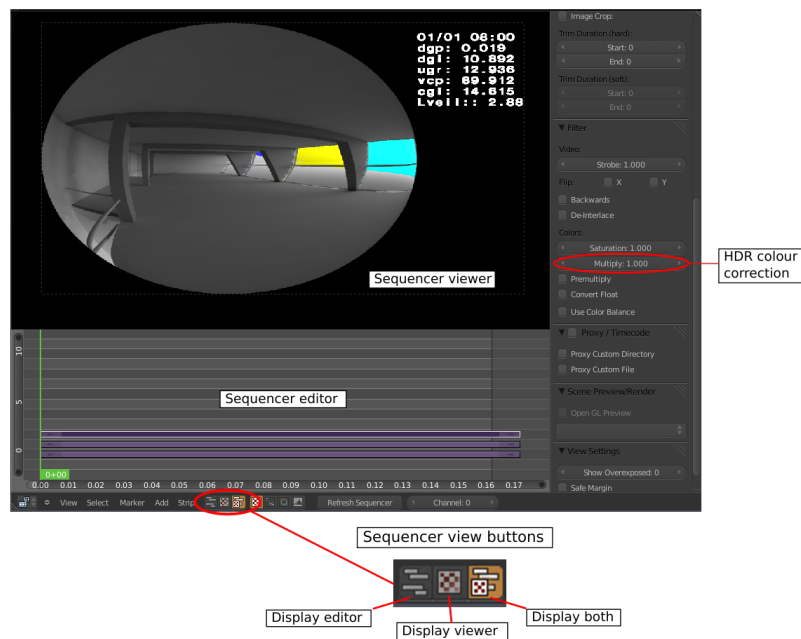


Figure 4: Video sequencer panel for glare analysis

6 Usage

6.1 Export

So, let's get stuck in and do our first Radiance simulation. If you do not have a default cube in the scene then press 'shift+c' to centre the view and then go to the 'Add' menu at the top of the 3D view and select 'Mesh - Cube'. The new cube should appear in the centre of the 3D view and be automatically selected, but 'right-clicking' on it will make sure. Radiance needs to be told which geometric objects within the scene are to be the sensor points for the calculation, and to do this we give the desired geometry a material with the word 'calcsurf' in it. For this first simulation the faces of our default cube are going to be our sensor points. At the top of the properties panels section is a button for the material panel (shown in figures 1 and 5). Clicking on this button will reveal the material panel, which as the cube is hopefully selected, is specific to the cube material. If the cube has just been created it may have no material currently attached, or

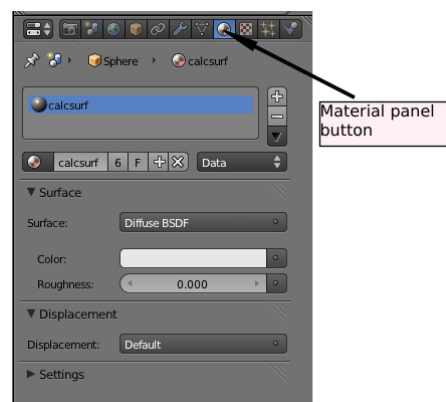


Figure 5: Property panel buttons



it may have the default material called 'Material' attached. If there is no material click on the 'New' button and the material pane should look roughly as it does in figure 6.

At the top of the material panel is a list displaying all the materials associated with the object. At the moment there should be just one, the default material or the one just created. Below that is the material name, which is altered to contain the word 'calcsurf' to designate the object as a sensing location. Below this are the material characteristics which are altered not only to change its appearance in Blender, but to control what type of material description is sent to Radiance for simulation; important sections of the panel are 'Mirror' and 'Transparency'.

Table 2 shows how Blender material characteristics are translated into Radiance materials. Going down the table the first Blender material condition that is met is the one that will be exported to Radiance, and the lower ones ignored. In addition the colour of objects specified in the 'Diffuse' and 'Specular' panels will automatically be exported to Radiance where appropriate. For the moment a plastic material is fine so make the cube diffuse colour as desired by clicking on the colour bar area of the diffuse panel, and make sure transparency and mirror are turned off. Save the Blender file with 'File - Save'.

Before the scene is exported the settings in the LiVi Export panel should be altered to create the desired simulation scenario. The first setting is 'Animation' which controls whether the simulation is for a static or dynamic physical context. Leave this at 'None' for now. The next option is 'Period Type' which controls whether a moment in time or a dynamic daylight simulation is to be conducted. Leave this at 'Moment' for now, select a 'Sunny' sky and control the time of the year and location with the latitude, longitude, summer daylight saving and longitude meridian (and can be left at their default values for now), month, day and hour options. Pick any time of year as long as the sun will be above the horizon at that time. Finally, 'Calculation Points' controls the nature of the sensor points on the object. 'Faces' means that the centre of the faces of the cube will be the sensor points; 'Vertices' means corners of the cube will be sensor points. Select 'Faces' for now. As we are using a sky to illuminate our scene the default lamp in the scene is not required so can be selected with a 'right-click' and deleted by pressing 'x'. The scene can now be exported by clicking on the 'Export' button at the bottom of the LiVi Export panel. The interface will become unresponsive while the export takes place, a weakness in the current LiVi implementation which will be corrected in future versions, but should not take very long for this very simple scene.

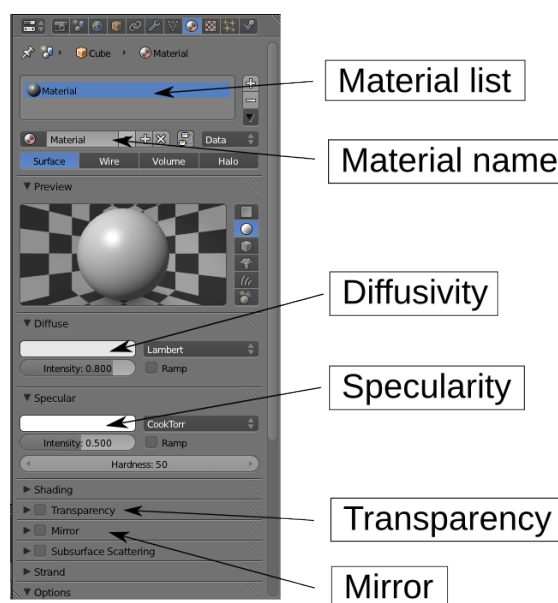


Figure 6: Material panel

6.1.1 Geometry import

Although geometry can be created within Blender, if the user is used to creating geometry within another package, this geometry can be imported into Blender. In the 'Import-Export' section of the 'Addons' user preferences panel the import of different file formats can be enabled. By default the import of Wavefront OBJ and 3DS files should be enabled, and these are both good choices for geometry transfer. Upon importing the geometry the scaling of the new object may be too large or small to be seen in Blender's default view. If this is the case make sure that the model unit is set to metres when exporting from the original software, and make sure that the model sits near the origin point of 3D space within the original package. Upon importing pressing '.' on the keyboard numpad, or going to the 'View' menu at the bottom of the 3D view and selecting 'View Selected', will centre the view on the new geometry.

Once the geometry is imported then if objects were defined as separate entities with separate materials in the original program they should be separate objects, with distinct materials, in Blender. The Materials may not be correct however and may need to be changed in Blender's material panel for conversion to Radiance.



| Blender material | Radiance material | Notes |
|---|-------------------|---|
| Set 'Shading' - 'Shadeless' | Antimatter | Invisible in Radiance. Good for bespoke calculation surfaces |
| Set 'Mirror' - 'Reflectivity' > 0.99 | Mirror | Blender 'Diffuse' colour sets colour of reflection |
| Set 'Transparency' - 'Raytrace' - 'Alpha' < 0.0, Set 'Translucency' = 0.0 | Glass | Blender 'Diffuse' colour sets the transmitted light colour, 'Alpha' sets opacity and 'IOR' the glass IOR |
| Set 'Transparency' - 'Raytrace' - 'Alpha' < 1.0, Set 'Translucency' > 0 | Translucent | Blender 'Diffuse' colour sets transmitted colour and diffuse transmission, 'Alpha' sets direct transmission. |
| Set 'Mirror' - 'Reflectivity' < 0.99 | Metal (specular) | Blender 'Diffuse' colour sets reflected colour, 'Hardness' sets material roughness, 'Specular intensity' sets reflectivity. |
| None of the above | Plastic (diffuse) | Blender 'Diffuse' colour sets reflected colour, 'Hardness' sets material roughness, 'Specular intensity' sets reflectivity. |

Table 2: Blender - Radiance materials conversion

Note that in Radiance space the positive Y-direction (green arrow in Blender) is North, so orientate objects accordingly.

If a piece of existing geometry is desired as a sensing region, associate a material, with 'calcsurf' in the title, to that geometry. If a bespoke sensing plane is required then create a plane ('Add' - 'Mesh' - 'Plane') and manipulate it to the desired position. It is important that more than one face is designated as a sensing region when using the 'Faces' calculation points option, and as a new plane by default only has one face it is necessary to sub-divide it. A plane can be subdivided by pressing 'Tab' with the plane selected. This enters 'Edit' mode (It is useful to have the Tools panel visible for this operation, which can be toggled with the 't' key when the mouse is over the 3D view). The first drop-down menu at the bottom of the 3D View will say whether the current object is in 'Edit' or 'Object' mode. Once in 'Edit' mode pressing 'w' will bring up a specials menu. Selecting 'Subdivide' from the specials menu will split the plane once. Greater number of sub-divisions can be achieved by increasing the 'number of cuts' option that should now be visible at the bottom of the tools panel. It is also useful at this point to check that the face normals are pointing in the right direction. Normals define which way the faces are facing in 3D space, and they decide which way the Radiance sensor point are measuring. They can be viewed by selecting 'Face' from the 'Normals' sub-section of the 'Mesh display' section of the 3D View panel (the 'Normal size' may also need to be increased to see the normals properly). If the normals are facing in the wrong direction, for example they are pointing towards the floor, then they can be flipped by going, whilst still in 'Edit' mode, to the 'Mesh' menu at the bottom of the 3D view and selecting 'Normals' - 'Flip Normals'. Once the plane is sub-divided as required leave 'Edit' mode by pressing 'Tab' again. Associate a material with 'calcsurf' in the title to the plane.

6.2 Calculation

Once the scene has been exported the calculation panel should become active. The context sensitive options within this panel control the lighting metric to be assessed ('Simulation Metric'), and the simulation accuracy. As we have chosen a momentary analysis illuminance in lux, irradiance in W/m^2 and Daylight Factor (if a DF Sky was selected) are currently available along with 'Glare'. The 'Simulation Accuracy' menu is fairly self-explanatory. Greater accuracy will generate more accurate lighting, taking into account more inter-reflections, but may take considerably longer. Select 'Irradiance' and 'Low' for these two menus.

There are two buttons below these options. The first allows a preview of the scene, as calculated by Radiance, to be viewed. This can be useful to check that the material definitions specified have been translated correctly into Radiance format. The scene will be previewed from the perspective of the Blender camera. To manipulate the camera into the desired position the 3D view can be manipulated to give the desired view and



then from the bottom of the 3D view window select 'View - Align View - Align Active Camera to View'. This will then align the camera to the current view and view the scene through the camera. To break out of the camera view rotate with the middle mouse button (the camera will be left in its new position).

Once the camera is in position pressing the 'Radiance Preview' button will open up Radiance's visualisation window. This window may display an image that is totally white, black or other wise incorrectly exposed. The method to correct the exposure level of the window is dependant on the operating system the software is being run on. On OS X and Linux, with the new window selected, press 'e - enter' and click somewhere on the window. This should normalise the exposure to the brightness of the part of the image clicked on. On Windows the menu entry 'Exposure' can be used to alter the image (lower the value to darken the image and increase it to brighten it).

Once the materials have been checked the preview window can be closed. Make sure the X11 application is totally closed, especially on OS X, and control will return to the Blender interface.

The simulate button tells Radiance to calculate the lighting metric specified, at the points specified. When the calculation has finished, a message will pop up to say the calculation is finished. The Blender interface will again be unresponsive while simulating. The LiVi display panel should now be populated.

6.3 Display

In the LiVi display panel there is a display button, 'Only Render' toggle switch and '3D Display' toggle switch. The 'Only Render' toggle controls how the 3D view represents the scene. When on, only renderable objects are shown in the 3D view. The '3D Display' toggle, when on, will make the results plane 3-dimensional when displayed and exposes the '3D Level' slider which controls the level of 3D distortion of the results plane each time the Radiance display button is pressed. Pressing the 'Display' button will colour code the results plane, and bring up a legend in the 3D view to relate the colour to metric values. Below the legend should appear some simple statistics about the results. The background colour of the OpenGL 3D view can be changed in the 'World' tab in the properties panel with the 'Horizon Colour' setting.

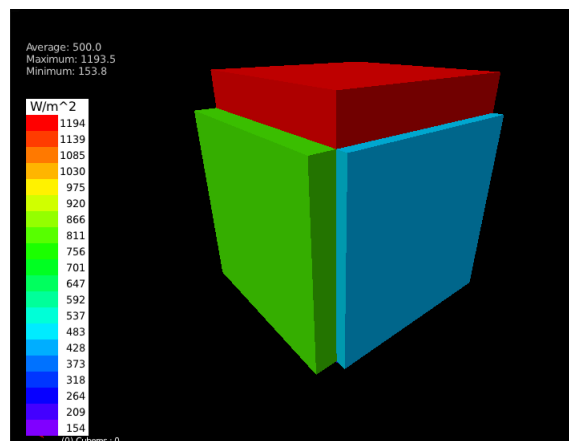



Figure 7: Results visualisation

In the case of the default cube the sides of the cube should have changed colour to correctly relate to the legend key. If the 3D results setting was selected, the sides of the cube should have been extruded by an amount proportional to the result on that face and the 3D level set in the LiVi interface, and may look something like figure 7.

At the bottom of the display panel options now appear to control the display of the numerical metric values at the centre of each face. The first toggle turns this capability on and off and the second toggles whether the numbers are to be displayed only on selected geometry.

If a dynamic simulation, either time or geometry, was requested then the resulting animation of the results can be viewed by pressing 'alt - a' ('esc' will halt playback). Or each frame of the animation can be stepped through by pressing the left and right arrow keys. The total frame range and the current frame are shown at the bottom of the screen in the animation time line window (figure 8).

To generate static images of the results a screen grab incorporating the 3D view is probably the simplest method and will automatically include the legend and statistics display in the window. Alternatively the OpenGL view can be rendered to an image with the camera icon situated on the bottom right of the 3D View. After the rendered image is complete press 'F3' to open a file save dialogue. If a dynamic simulation was run, and an

animation of the results desired then the clapper-board icon , next to the camera icon, can be used. The location and type of animation saved is controlled in the 'Render' properties panel in the 'Output' section. Using these OpenGL renders loses the the legend display, so a screen-grab of the 3D view, and cropping the im-

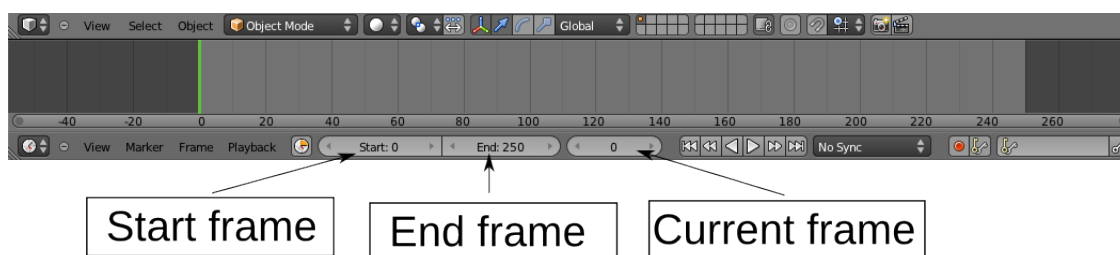


Figure 8: Animation time-line

age down to the legend, generates an image that can be superimposed onto the rendered image with an image editing tool.

7 Known Issues

- If using an unaltered Blender 2.68 release, then only up to 16 frames can be animated. Going above this is likely to crash LiVi.
- When specifying the rotation of IES lamps via lamp objects or a mesh plane, then successive rotations of the mesh or lamp may result in incorrect rotation of the IES lamps. Instead of multiple successive rotations it is advised to clear any existing rotation and apply the desired rotation anew for each rotational change.
- Animating an object which has the calcsurf material attached may cause LiVi to crash. Make sure that the calcsurf material is deleted from an object's material list if the object is to be animated.
- Exporting meshes without faces, e.g. mesh curves, may cause LiVi to crash.
- Glare analysis is not currently available when using a user specified HDR background.

8 Acknowledgements

Hats off to Ton Roosendaal and the rest of the Blender foundation, and its contributors, for creating, and distributing for free, Blender.

This product uses the evalglare software, developed at Fraunhofer ISE by J. Wienold.

This product uses Radiance software (<http://radsite.lbl.gov/>) developed by the Lawrence Berkeley National Laboratory (<http://www.lbl.gov/>).

Thanks to National Renewable Energy Laboratory's OpenStudio team for releasing multi-platform Radiance binaries.

Changelog v 0.2 to v. 0.3

- *Gendaymtx* is now used to generate dynamic daylight simulation data, removing the need for Perl.
- Numerical results can now be visualised on a per calculation point basis in the 3D View.
- Radiance sky description files can now be selected as a sky type.

Changelog v 0.1 to v. 0.2

- Radiance material colour is now the product of the Blender diffuse colour and the diffuse intensity, where appropriate.



- *Added the capability to include IES luminaire descriptions for artificial lighting analysis within Radiance. Generic lights have to be added manually in Blender for rendering.*
- *Added the capability to animate materials and artificial lamp strength.*
- *Fixed a bug that incorrectly reported irradiance.*
- *Added the capability to calculate the Dynamic Daylight Simulation metrics LuxHours, annual cumulative irradiance (Wh/m^2), and daylight availability based on occupancy time and lux target level.*
- *Added the capability to specify custom Radiance simulation parameters.*
- *Added the capability to do static and animated glare analysis via the evalglare program.*

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