Thesis Work

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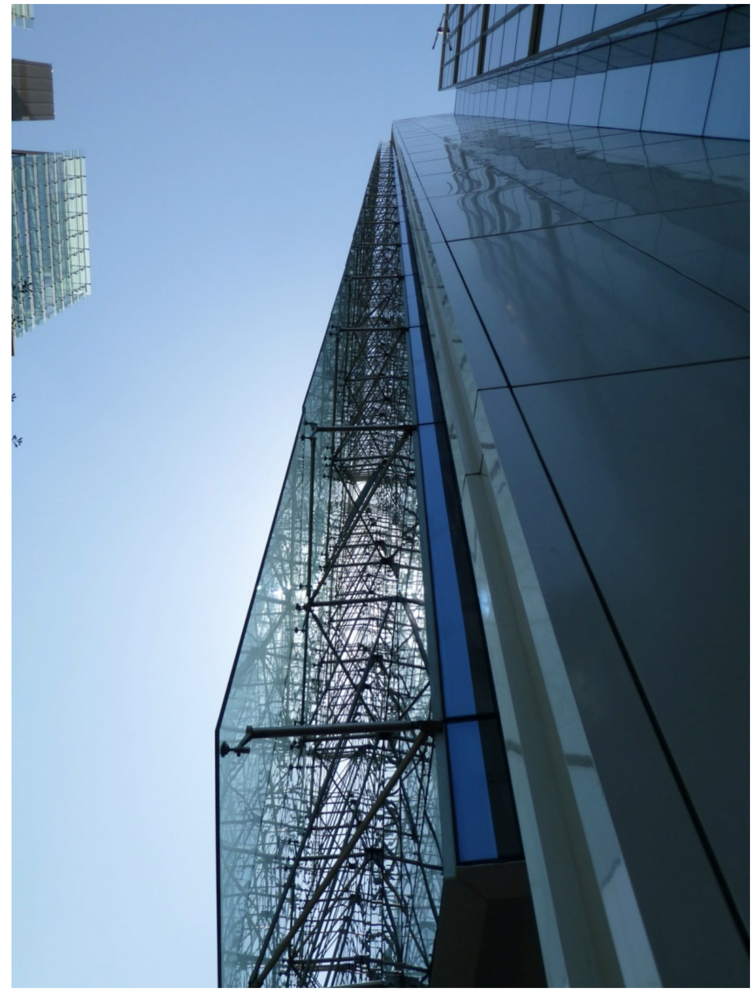
Using Radiance for the assessment of the bidirectional solar properties of complex shading devices

Motivation

- BSDFs are the Complex Fenestration System's most important properties for optical calculations (lighting and solar heat gains).
- They are required when implementing the Three or Five-phase method (lighting), EnergyPlus and ESP-r (solar heat gains).

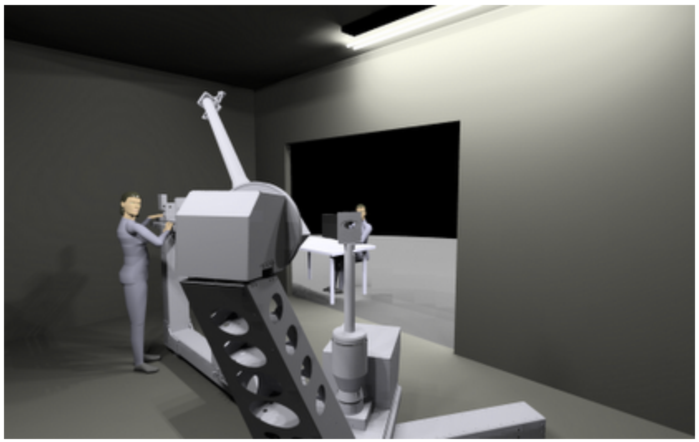


The problem and objectives

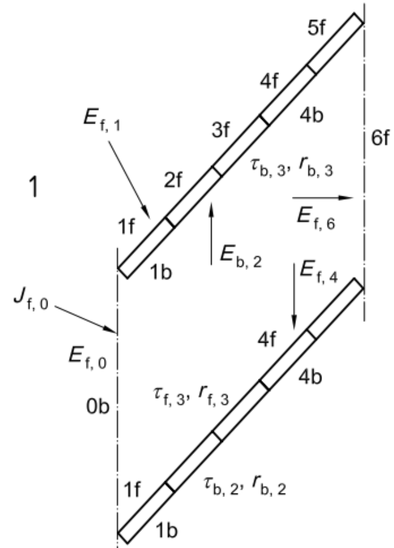
- BSDFs are required for calculations but the assessment of them is complex.
- Without them is impossible to make a virtual evaluation of the system (simulation), thus, the impacts of it on the lighting and thermal domains will remain unknown.

The objective of this study was to evaluate genBSDF as a tool for assessing the solar BSDFs.

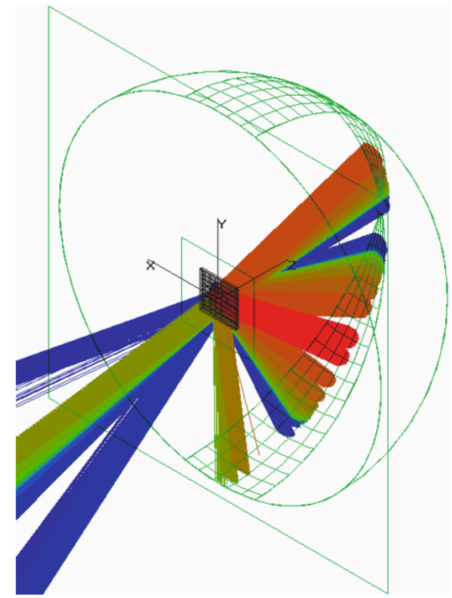
Assessment of bidirectional properties



Laboratory
(Andersen and de Boer 2006, Klems and Warner 1995)



Analytical models
(ISO 15099 2003, Carli inc. 2006)



Ray-tracing techniques,
(Konstantoglou et al. 2009, Andersen et al. 2005)

RAY-TRACING IS A ROBUST VIRTUAL WAY OF ASSESSING BIDIRECTIONAL PROPERTIES.

Images from windows.lbl.gov, ISO15099-2003 and Andersen, de Boer 2006; respectively

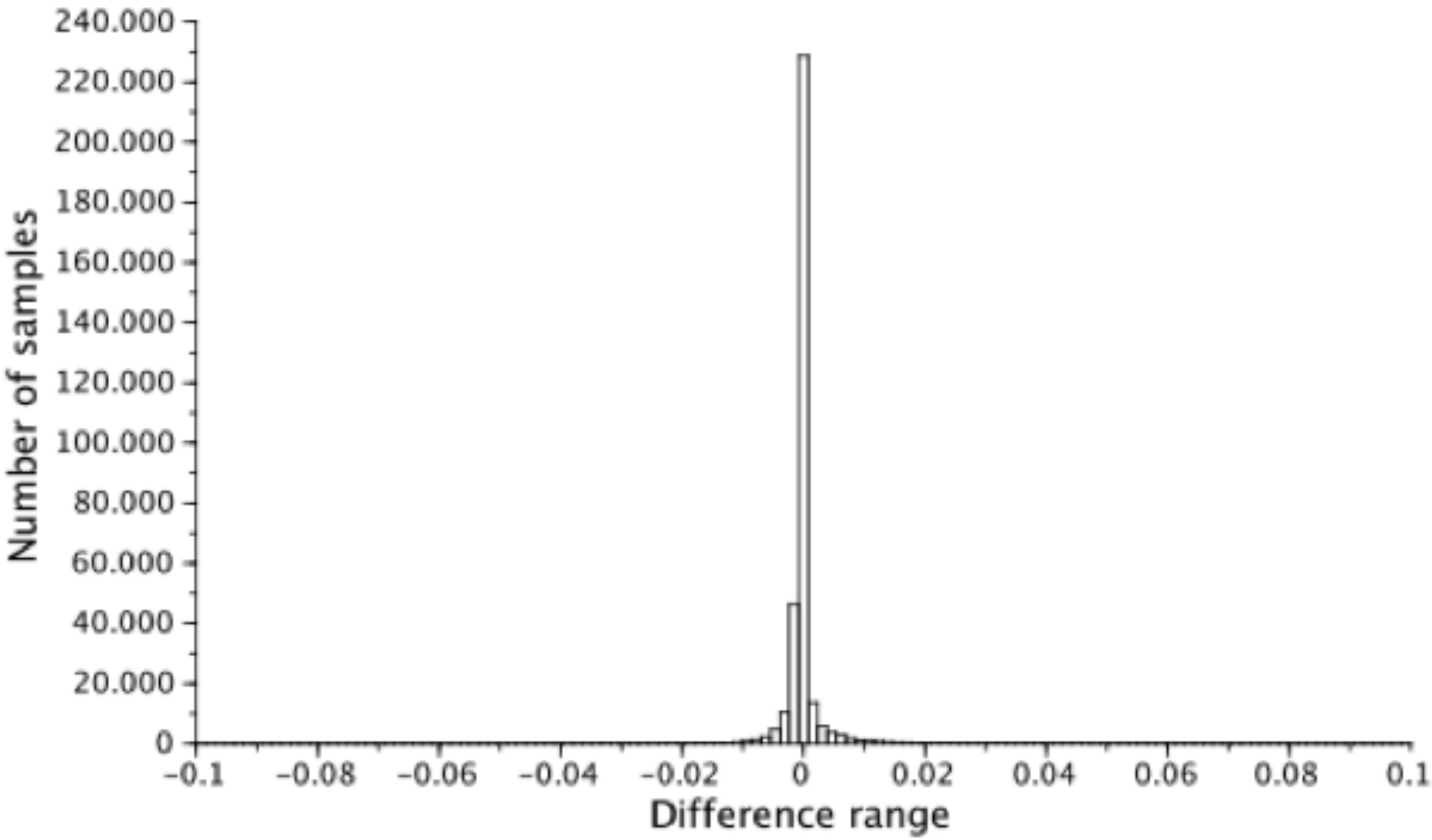
Methodology

- Results from genBSDF were compared with WINDOW 6.0 algorithm results (based on Radiosity).
- The algorithm was programmed in Scilab® since WINDOW does not allow calculations without glazing layers (only the blinds were considered).
- Combinations of four different materials (A, B, C, and D) and geometries (angles of 0°, 30°, 45° and 80°) of venetian blinds were compared. Slats were flat and zero thickness, and materials were gray (equal R, G and B colors corresponding to the solar reflectance).
- All the assumptions made in the Window 6.0 algorithm were replicated in the virtual environment. This required modifying the genBSDF script.

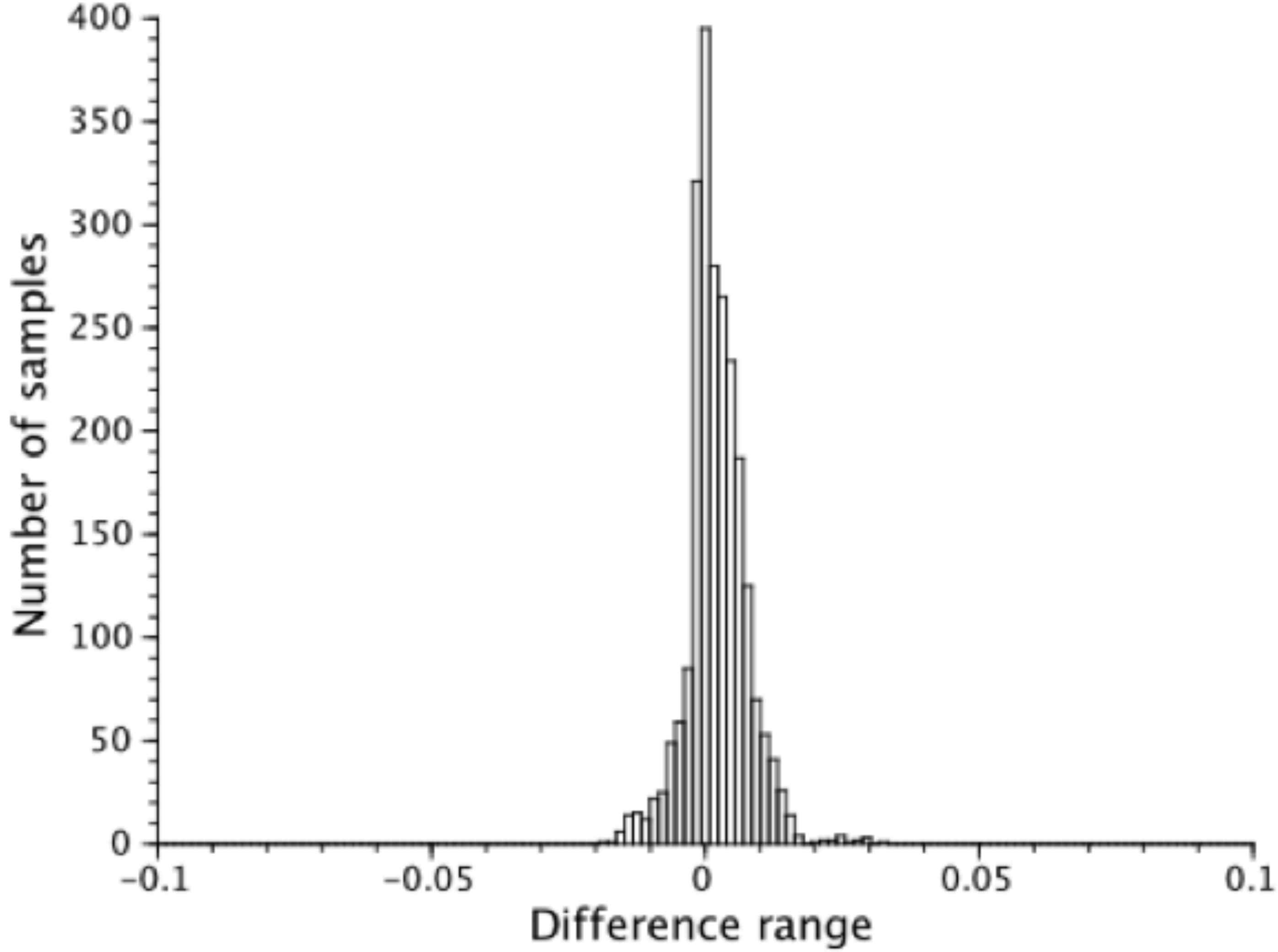
	Front Reflectance	Back Reflectance
A	0.7	0.7
B	0.55	0.55
C	0.7	0.4
D	0.1	0.65

Results for Bidirectional

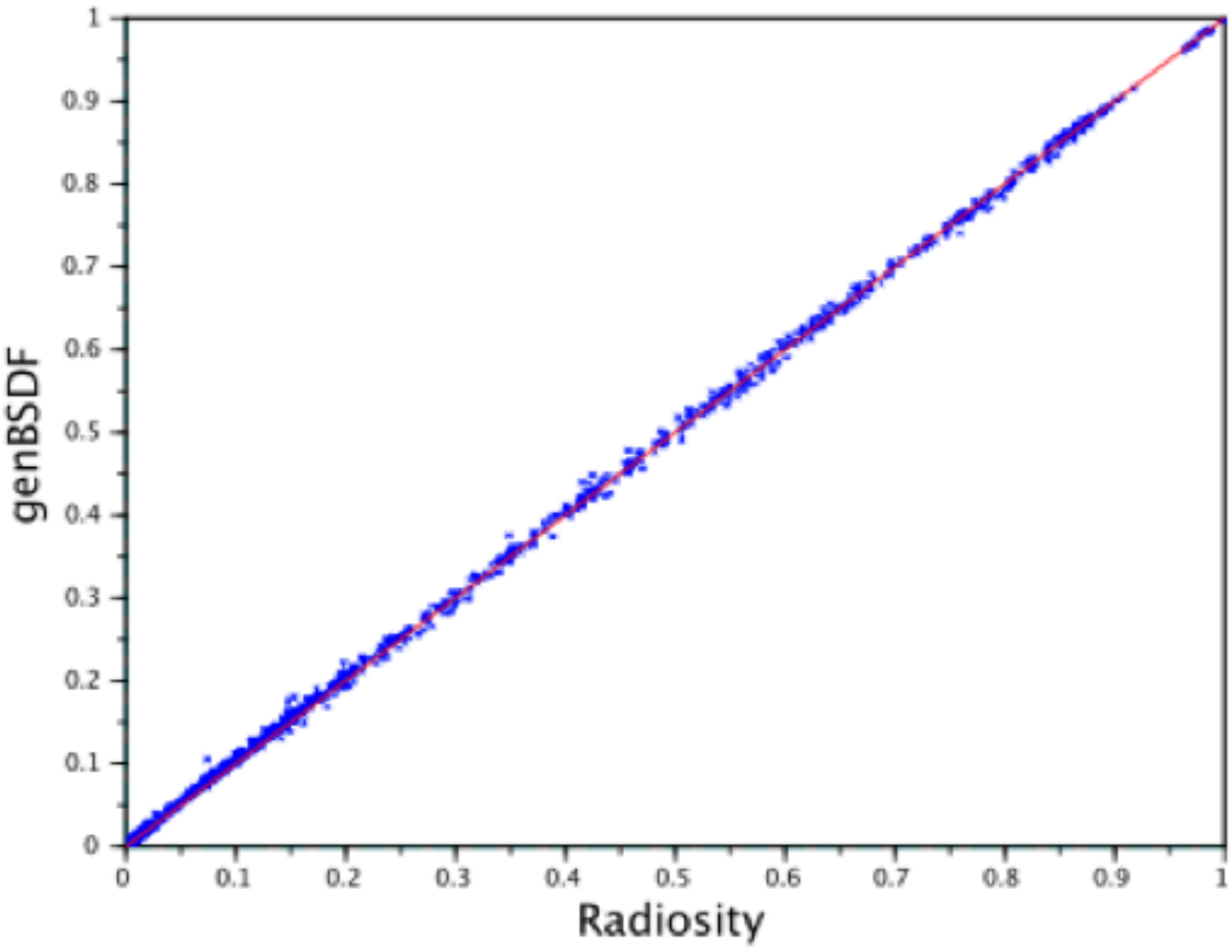
Each element of each matrix was compared.



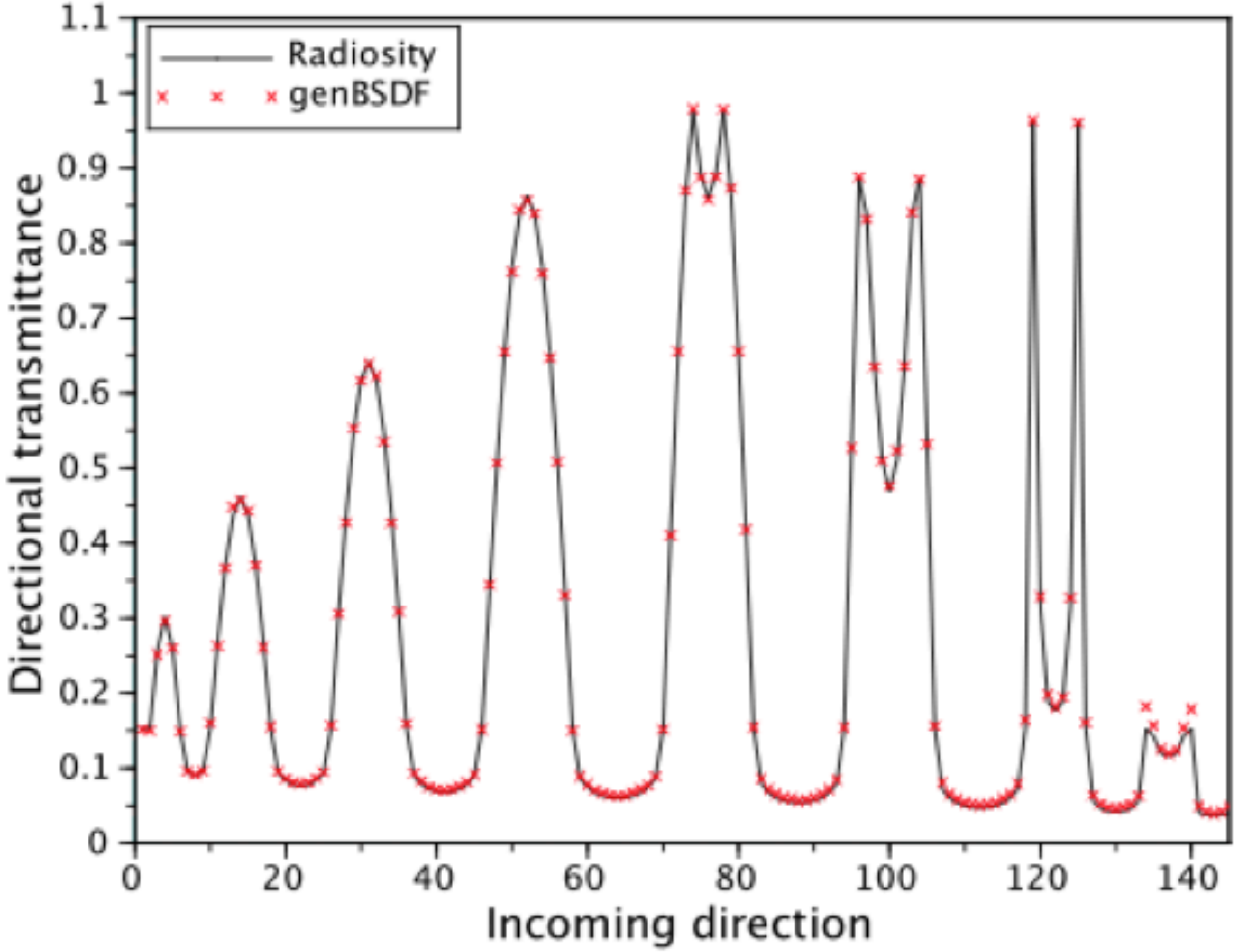
Results for Directional



Results for Directional



Results for directional case C45



Conclusions

- genBSDF is a very accurate tool for the assessment of Bidirectional Solar Properties of shading devices.
- Everything suggests that it is possible to consider any geometry and level of specularity.
- Calculation times are around 40 minutes in a home Laptop.

A simple methodology to couple lighting and thermal simulations of spaces with controlled lighting and Complex Fenestration Systems

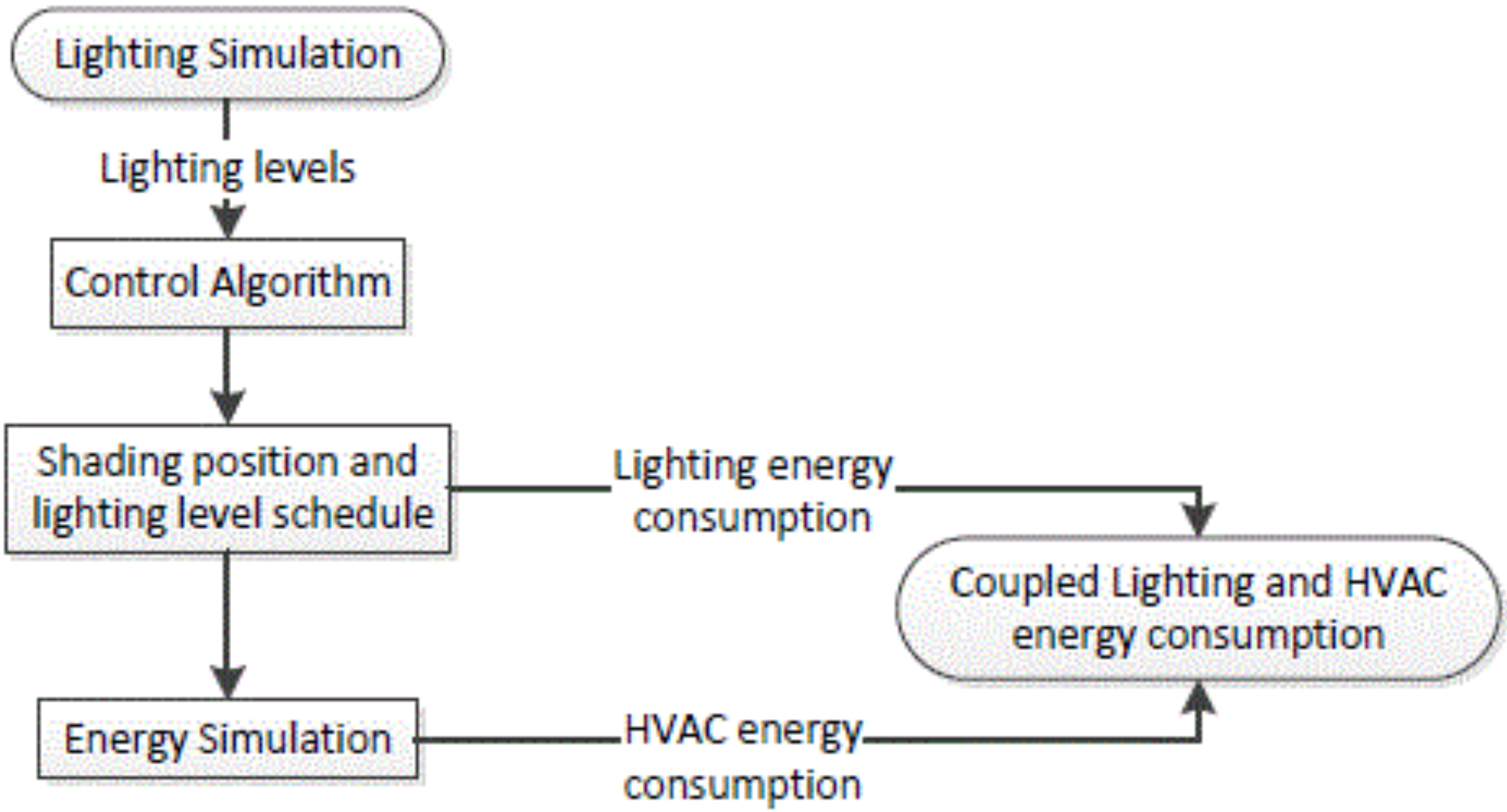
Motivation

- Complex fenestration systems (CFS) are often installed for providing enhanced thermal and visual environments.
- Daylight is intrinsically related with Solar Heat Gains.
- Trade-offs can be accounted only when control (automatic or occupant's behavioural) is implemented.

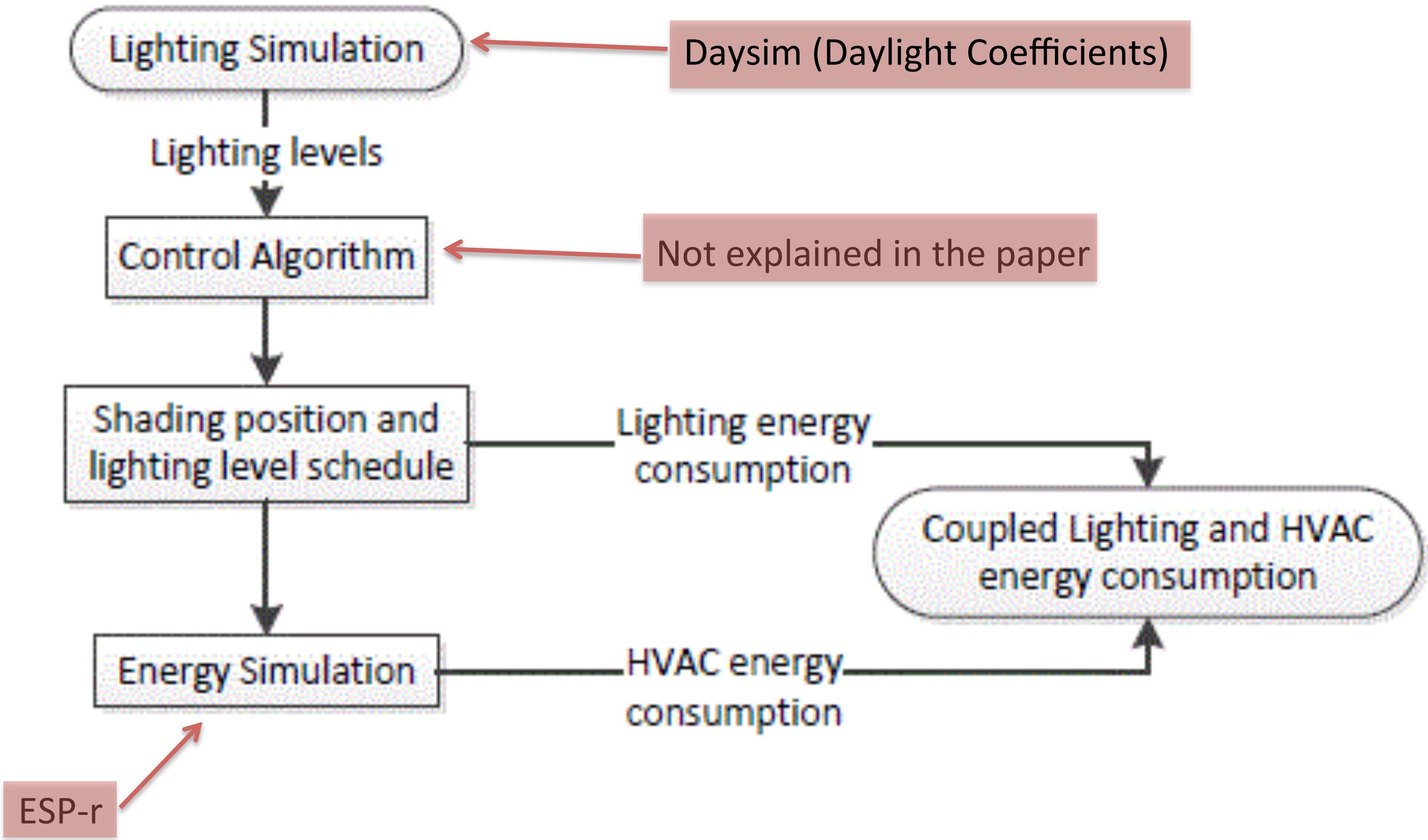
Related works

- Custom analytical models (i.e. Tzempelikos & Athienitis, 2007).
- *iDbuild* (Petersen et al. 2010), a program focused on early stages of design. Limited to one rectangular office with one window.
- OpenStudio (Guglielmetti et al. 2011).
- Radiance + ESP-r direct run-time coupling coupling (Janak 1997).
- ESP-r + Daysim semi-coupling (Wienold et al., 2011).

Workflow based on Wienold’s work



Workflow based on Wienold’s work



Daysim’s dynamic shading

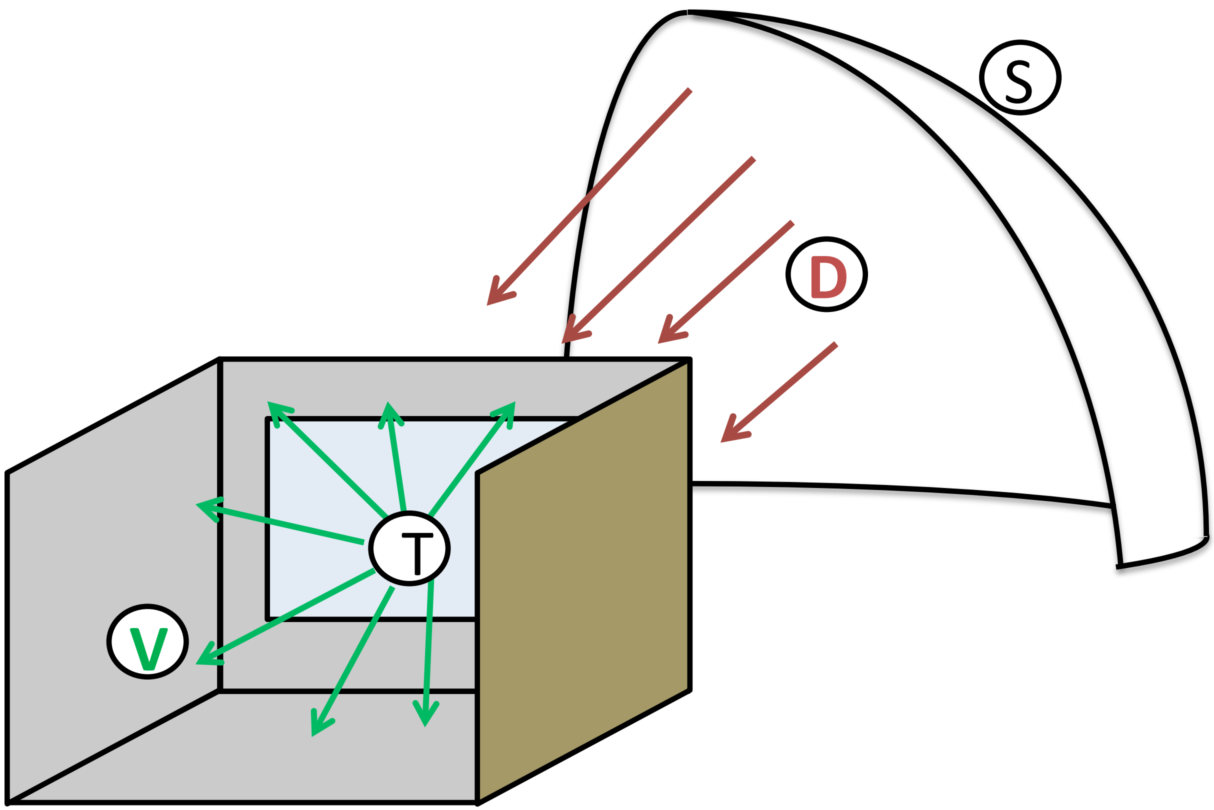
“For example, in case of a single shading device group with three states, blinds up, slats horizontal and closed DAYSIM will calculate three sets of daylight coefficient and illuminance files for the blinds in all three states. In case there are two shading groups with two sets of blinds in three states each, DAYSIM will calculate five sets of DC and ILL files…”

Fenestration Groups	Fenestration States	Number of DC
1	3	3
2	3	5

“It is worthwhile noting that using the advanced Dynamic Shading Module can be quite time consuming due to the number of ray-tracing runs required…”

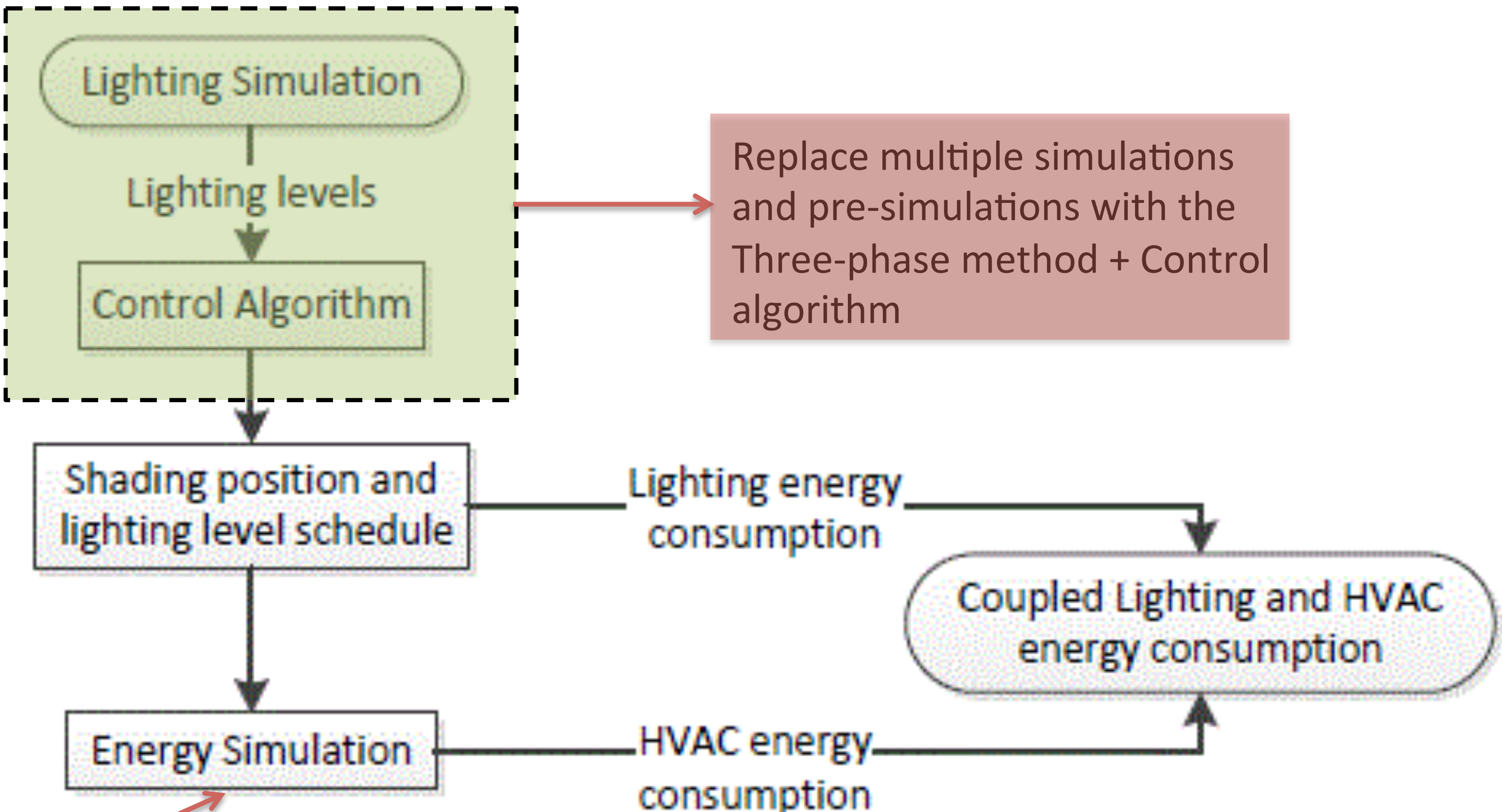
from http://daysim.ning.com/

Proposed (ongoing) work



On the Three-phase method, only one ray-tracing precalculation is required for each fenestration group, the BTDFs are supposed to be stored on a library, and can be reused.

Proposed (ongoing) work



Replace multiple simulations and pre-simulations with the Three-phase method + Control algorithm

Implement in EnergyPlus

Requirements

- Relatively fast
- Easy to implement (use)
- Standarizable (implementable in software)
- The definition of the control algorithm must be as simple as possible.

Requirements

- Relatively fast

Main program in C

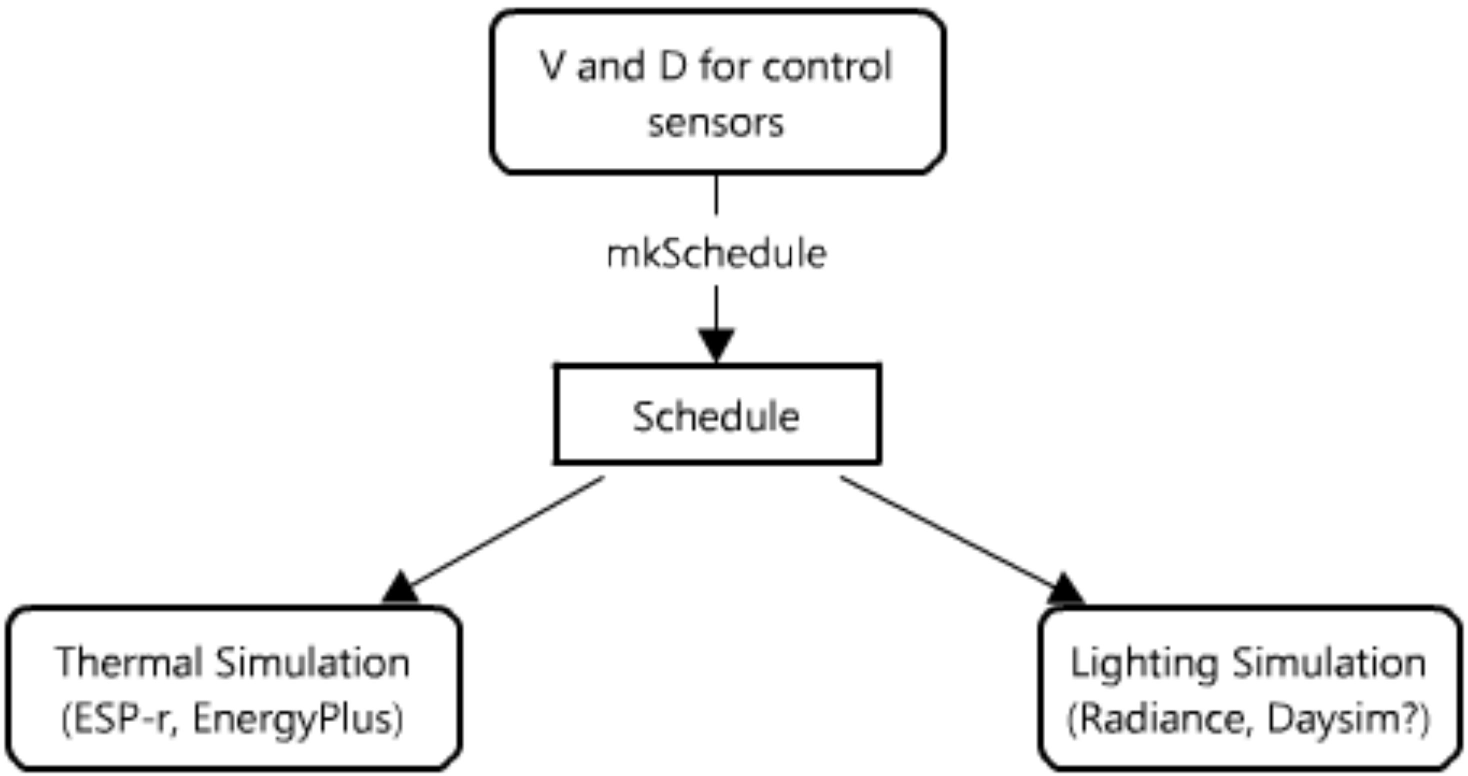
- Easy to implement (use)
- Standarizable (implementable in software)
- The definition of the control algorithm must be relatively simple and general.

Control scripts written in Lua

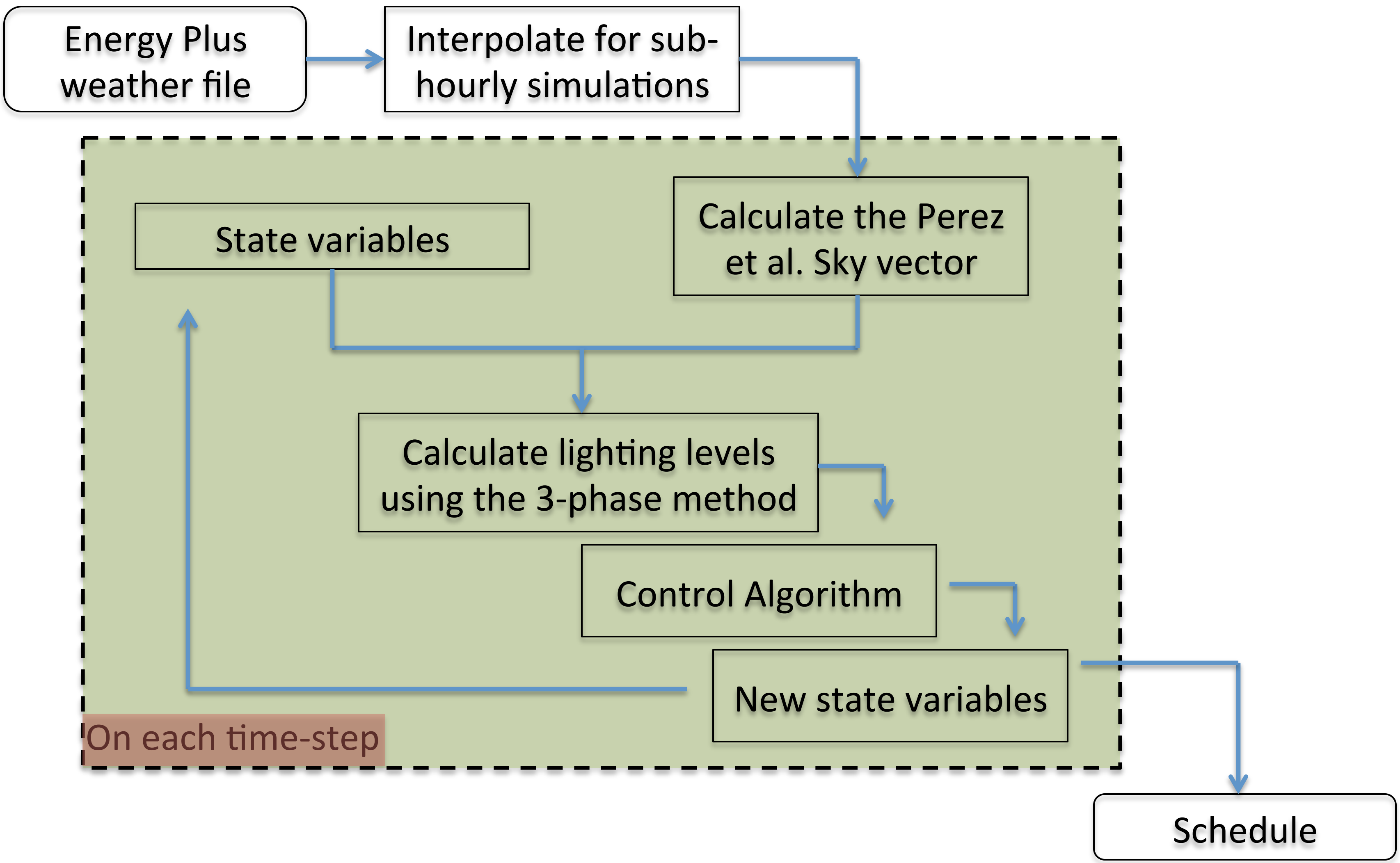
Considerations

- Control is usually done using a few sensors that are not on any workplane.
- It is advisable to separate "workplane" sensors from "control" sensors, and create the schedules using smaller DC (or V and D) matrices.

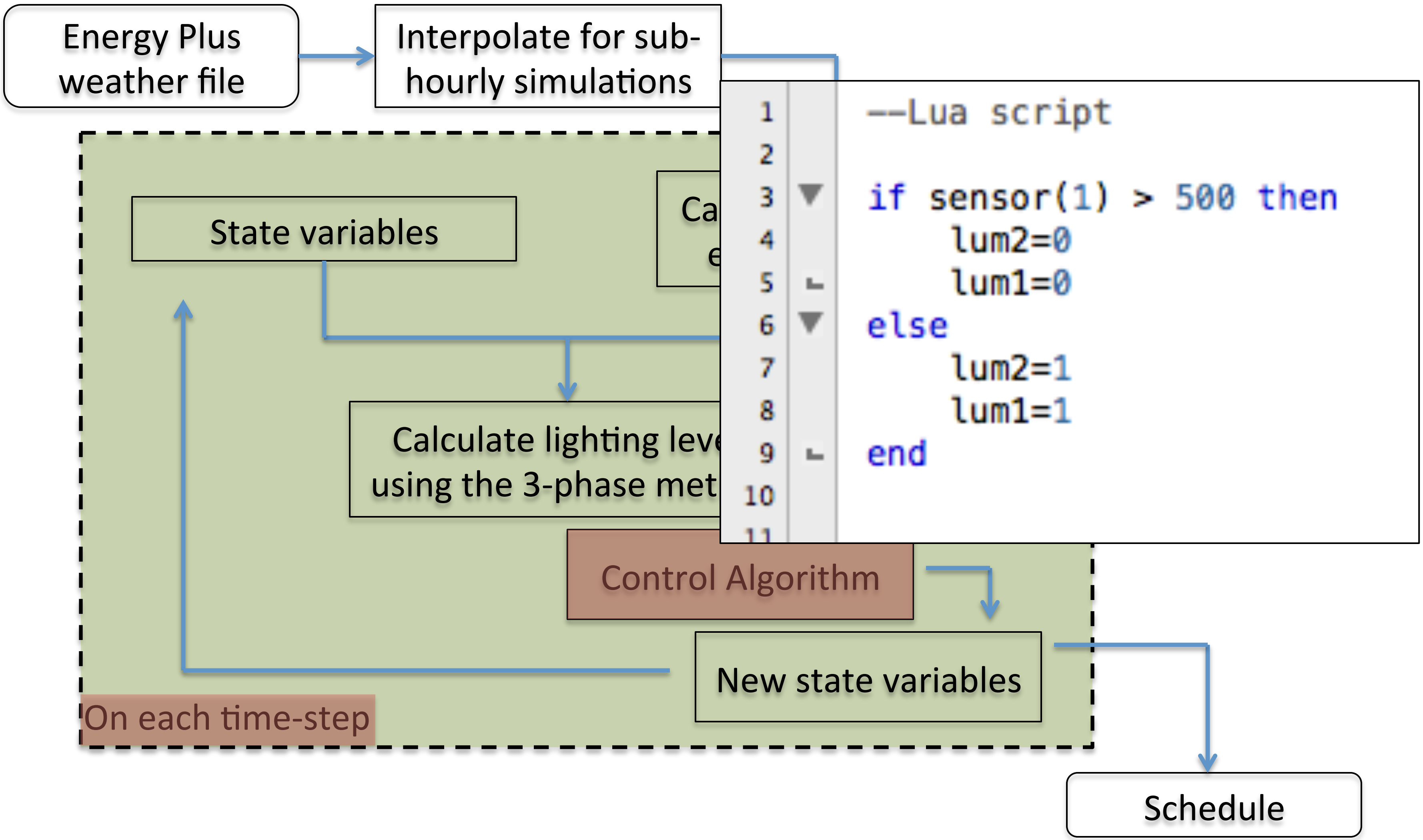
Considerations



Proposed program: mkSchedule



Proposed program: mkSchedule



mkSchedule inputs

- V and D matrices of the windows on the sensors
- Shading positions (BSDFs of the different positions of the shading devices)
- Luminaires contributions at full power
- Lua control script
- Energy Plus Weather File
- Latitude and Longitude of location (overwrite the EPW file)

mkSchedule inputs

mkSchedule	
-f Santiago.epw	- EnergyPlus weather file
-m 4	- # of sky bins
-n 500	- Lines of the EPW to simulate
-x 2 -l 2	- # of sensors / luminaires
-L LMX%d.lmx	- Name format of the luminaires
-V V-Control-%d.vmx	- Name format of the VMX
-T T%d.xml	- Name format of the BSDF
-w 2	- # of windows
-D D-%d.dmx	- Name format of the DMX
-u testLua.lua	- Lua control script
> FILE.txt	- Schedule file

mkSchedule inputs

mkSchedule
-f Santiago.epw
-m 4
-n 500
-x 2 -l 2
-L LMX%d.lmx
-V V-Control-%d.vmx
-T T%d.xml
-w 2
-D D-%d.dmx
-u testLua.lua

> FILE.txt

LMX1.lmx and LMX2.lmx are the contributions of the different luminaires sets at full power.

mkSchedule possible control information

- Illuminance in sensors
- Exterior dry-bulb temperature
- Solar positions angles
- Time of the day
- Any information inside the EnergyPlus weather file
- Derived information from these parameters

Limitations

- Still Semi-coupled: Cannot control using internal dry-bulb temperature.
- Glare-based control has not been implemented (out of scope).

- Work still in progress
- The first test has been successful, but the program requires modifications

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- Radiance mailing list

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