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Visual & Thermal comfort with Electrochromic glass

using a adaptive control strategy

living lab smart office space

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Living Lab smart office space

We are a small team under Prof. Dr. Sabine Hoffmann working on

- Thermal comfort
- Visual comfort
- Context aware lighting
- Activity recognition
- Personal heating/cooling devices like climate chairs and movable partitions etc.

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Architectural plan – Living Lab

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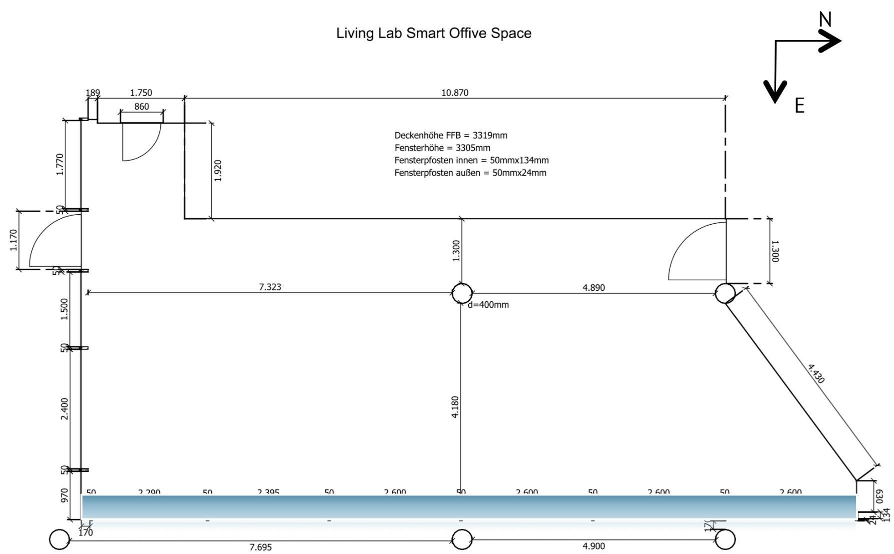

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View points – Living Lab

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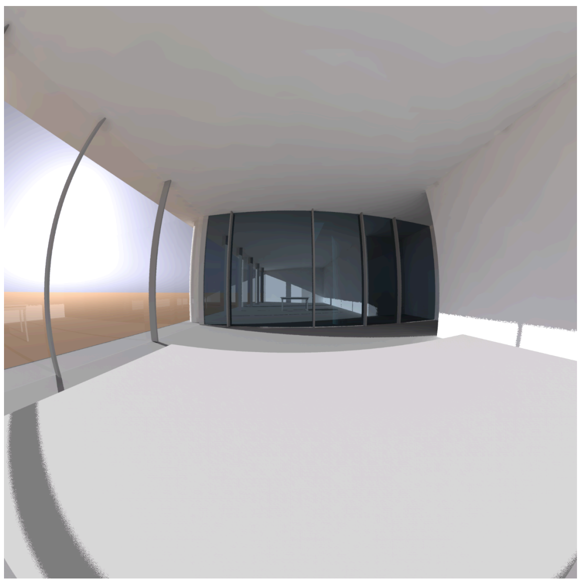
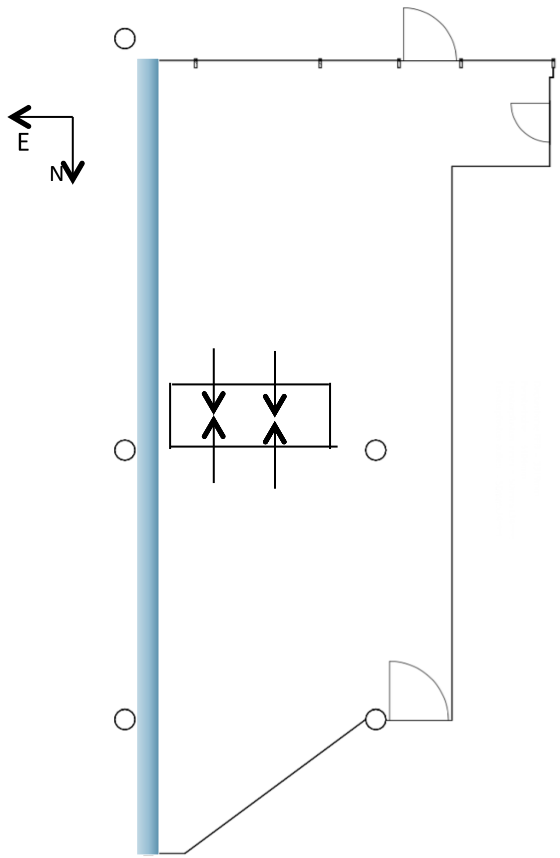
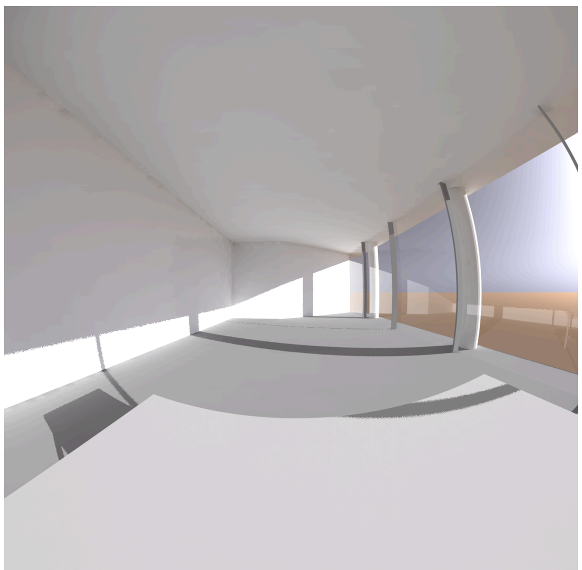
south view





north view



head height = 1.2 m

living lab

smart office space

head height = 1.2 m

Challenges

- Visual discomfort
  - Direct glare from Sun
  - Exterior & interior Reflections

- Thermal Discomfort
  - Direct radiation on head
  - High indoor temperature(solar heat gains)

- Energy Consumption
  - Internal heat gains
  - Increase in cooling and heating Loads

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Façade – Living Lab

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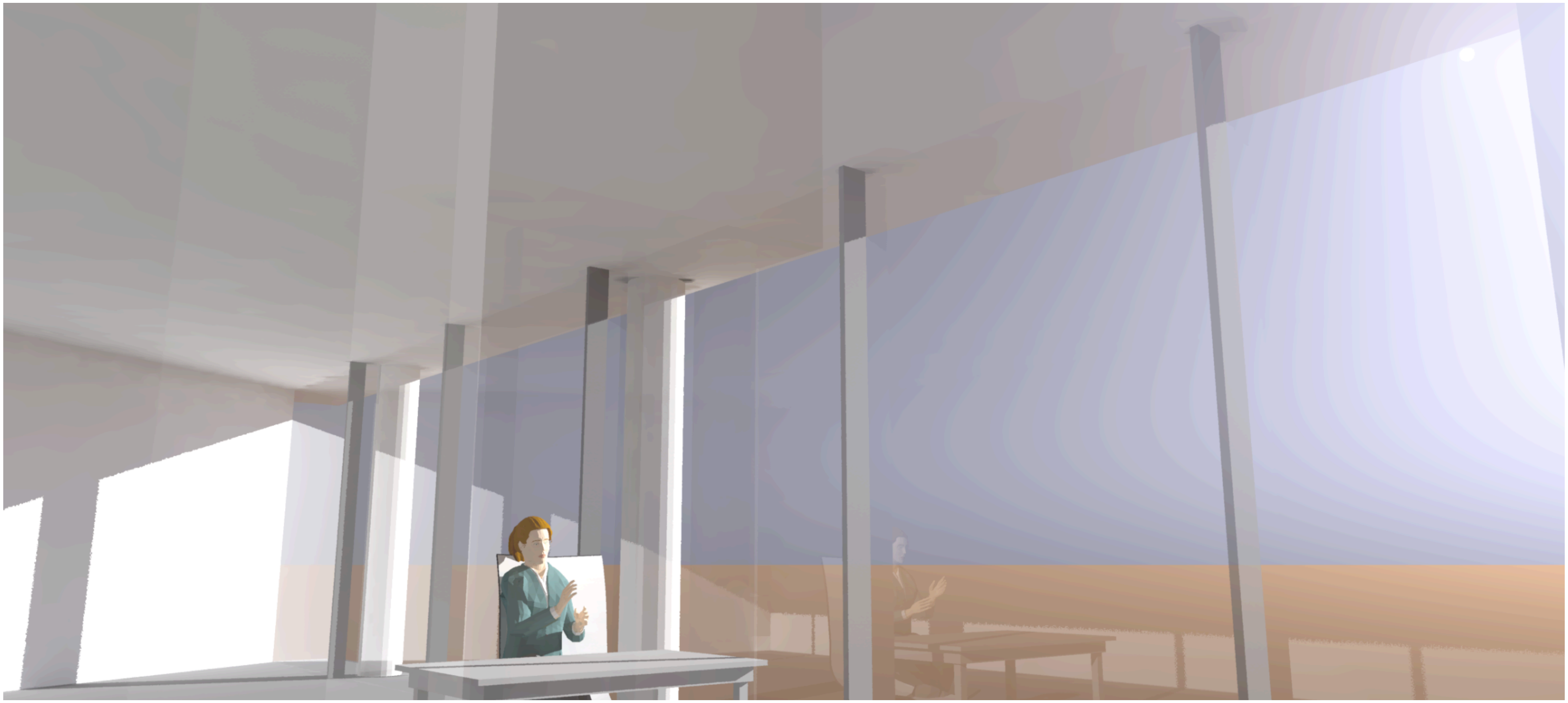

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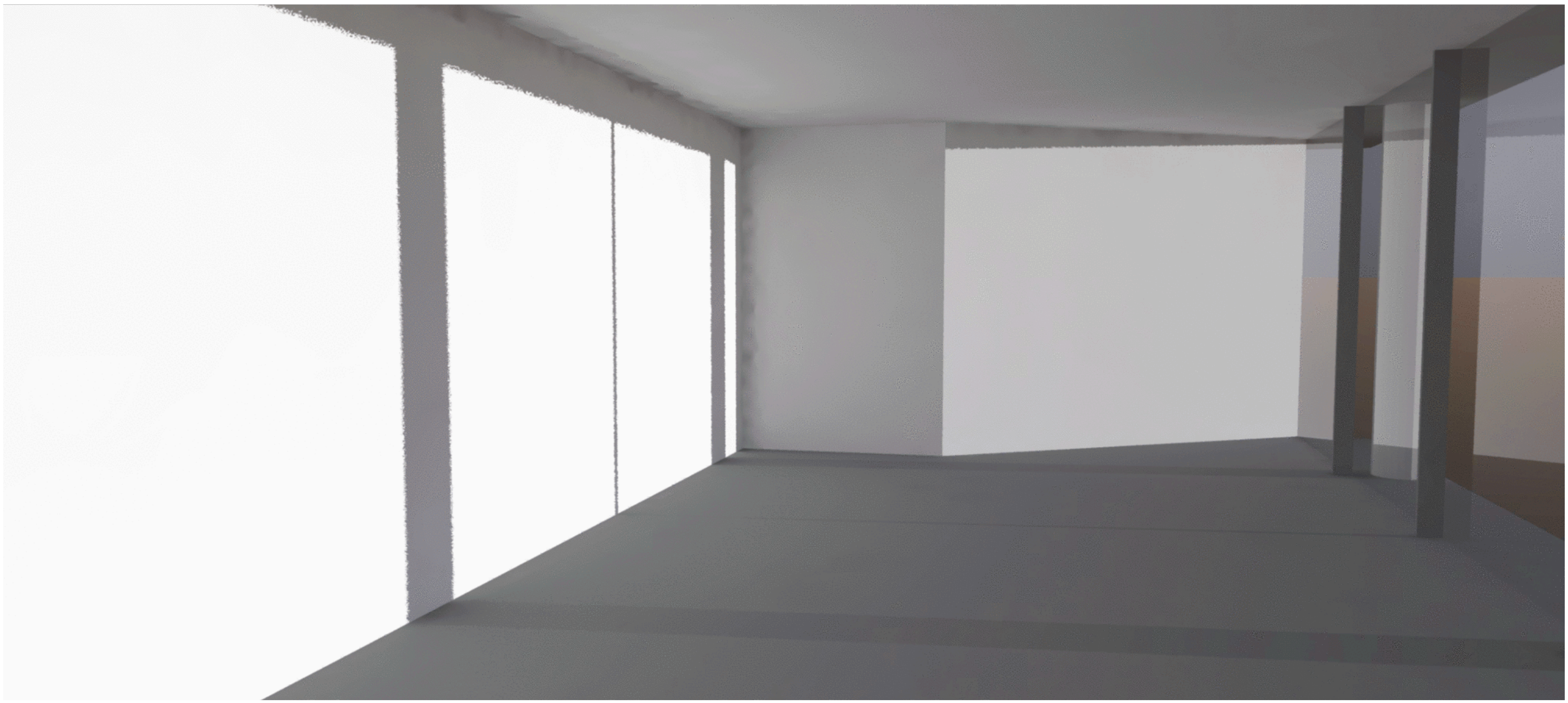

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Solution – Electrochromic Glass

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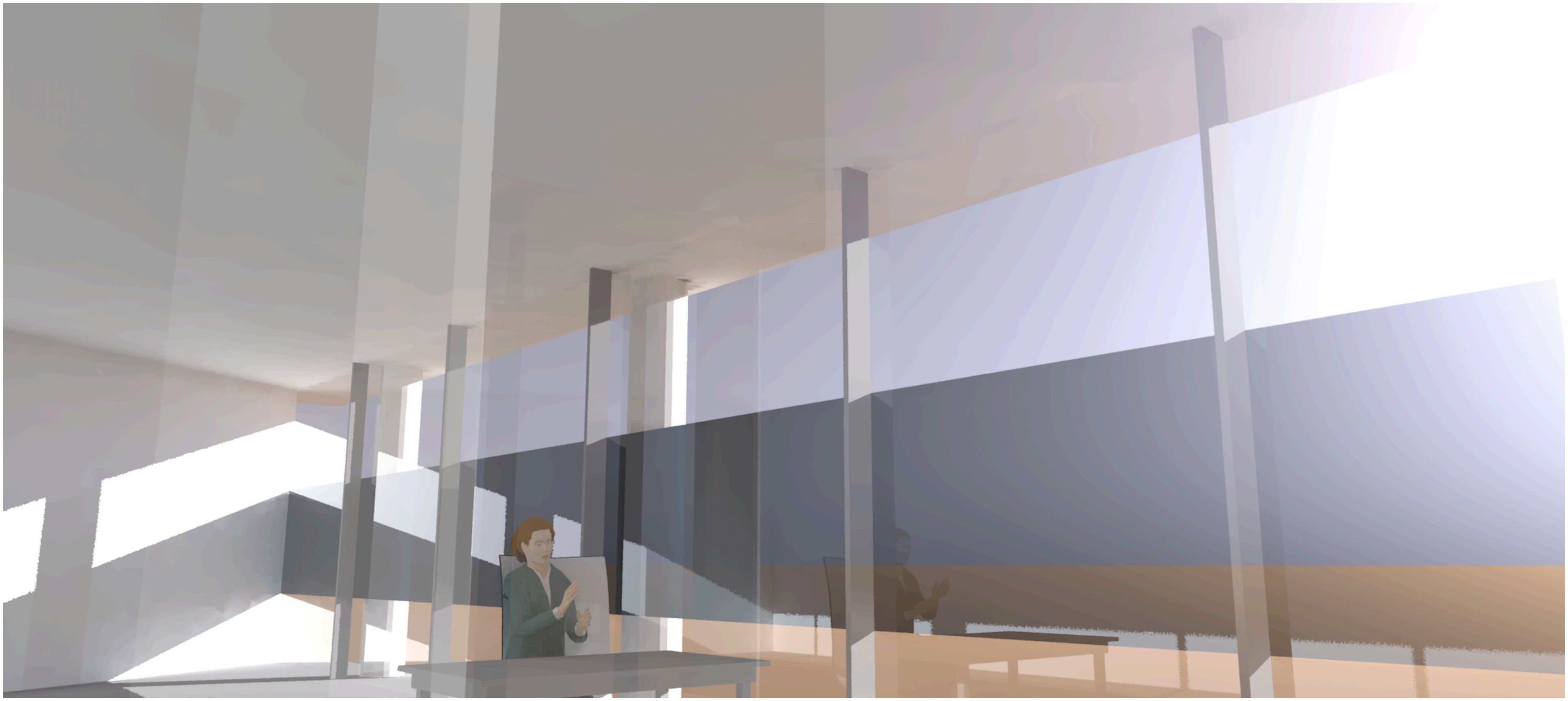

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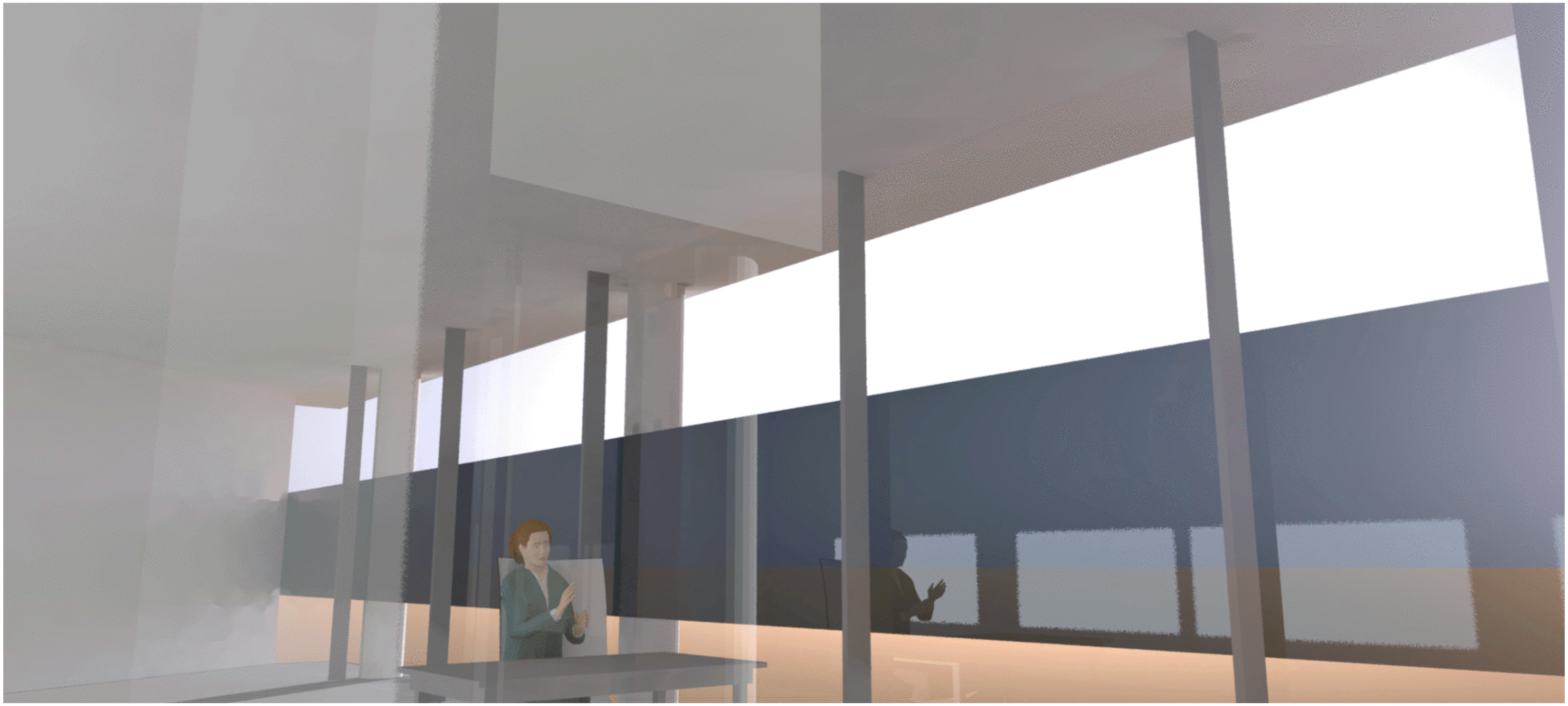

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Zoning

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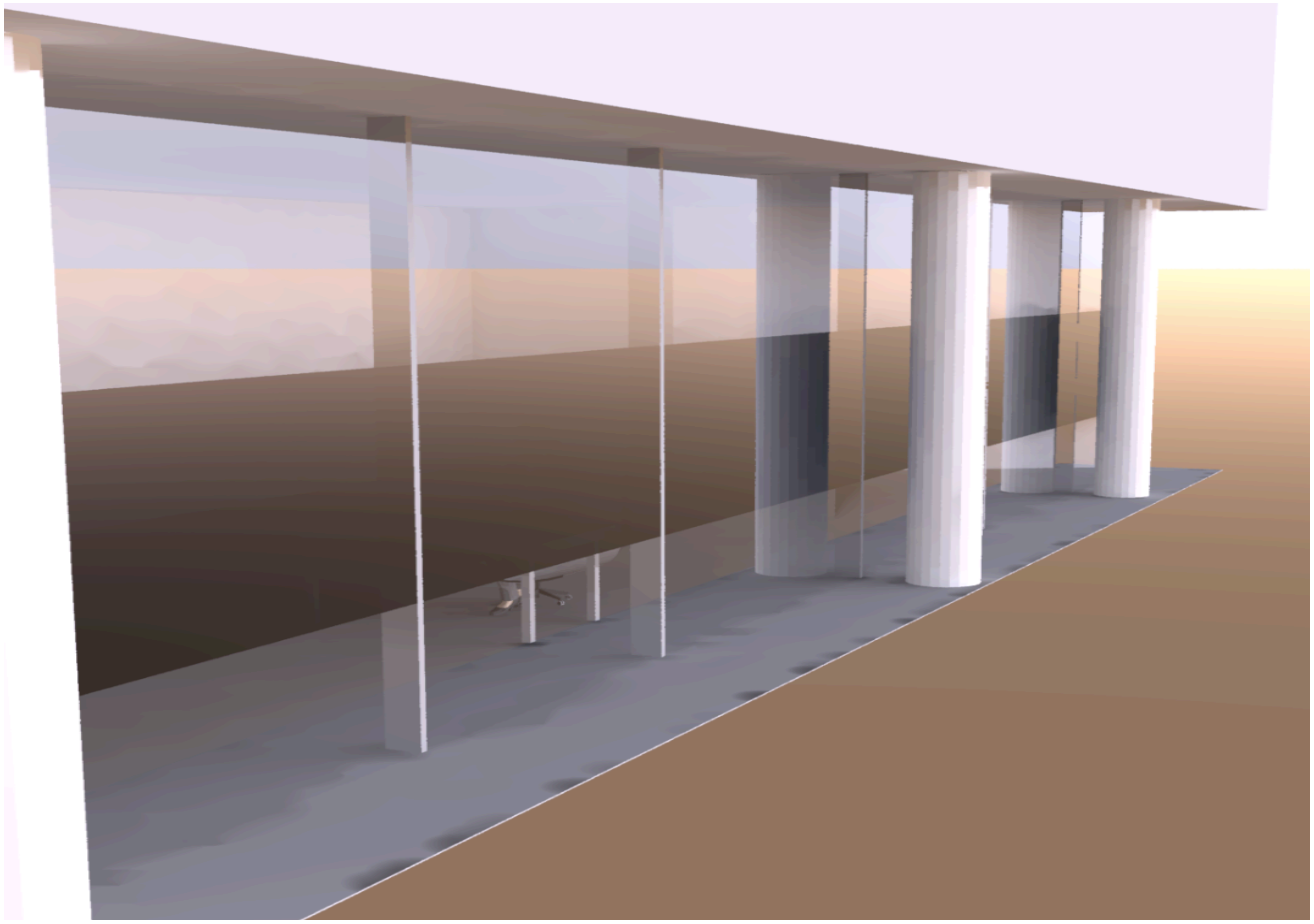
3 Zones

Upper zone -1.10m

Middle zone -1.10m

Lower zone - 0.80m



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States

NFRC_ID	8905	8906	8908	8909
T_{vis}	0.677	0.199	0.064	0.011

Tools

Simulation
SketchUp & Groundhog
EnergyPlus
Daysim & Radiance

Outputs
Heating/cooling loads
DGP profiles
Illumination Profiles
Ranked combination of states

Implementation
Illuminance sensors
Pyranometers
Raspberry Pi
HDR camera
Temperature sensors
EC glass

Outputs
Optimal state

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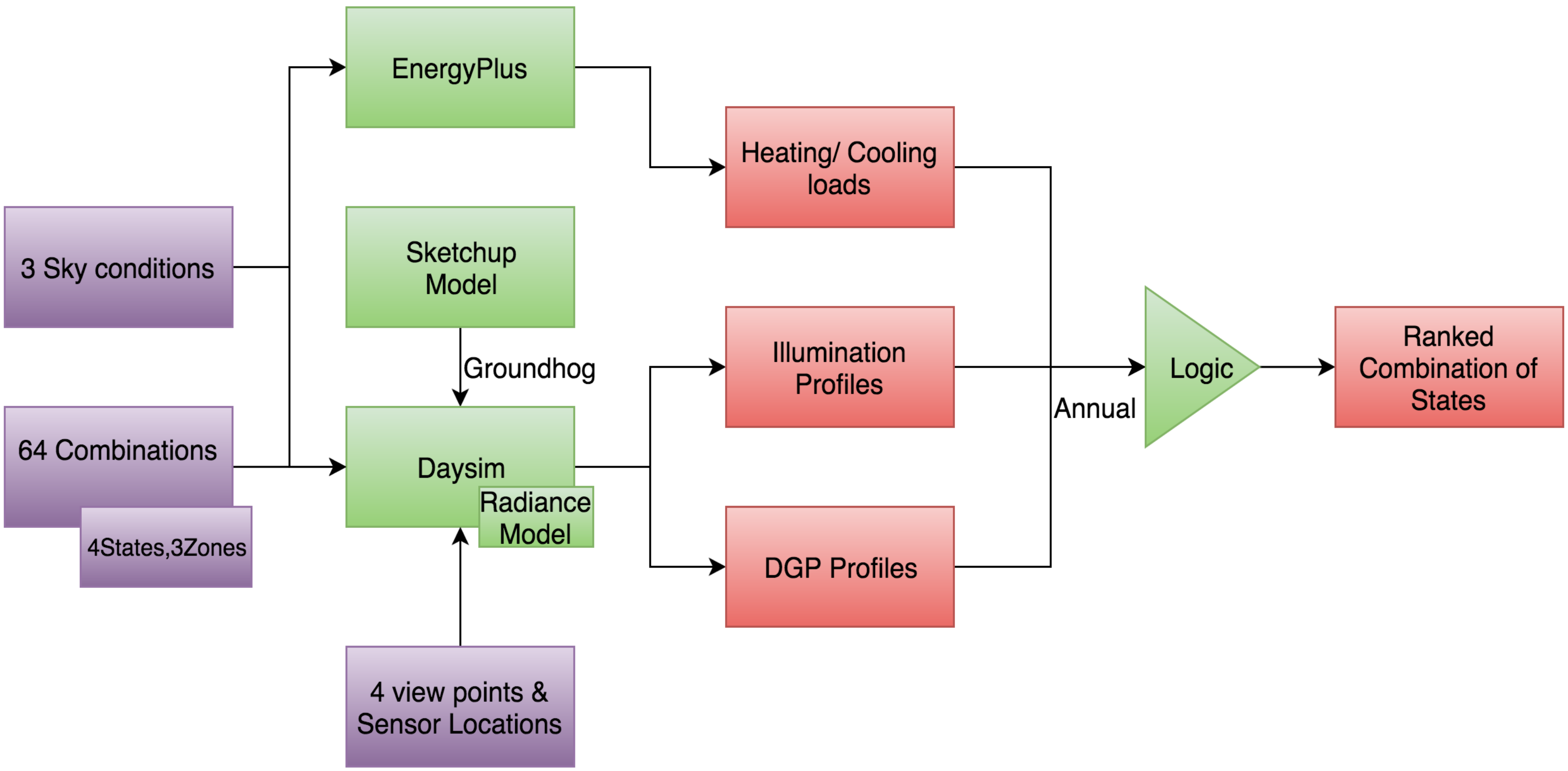
Simulation parameters

- 3 Different sky conditions
- 3 Zones with each 4 states i.e. 64 (4x4x4) combination of states per time step
- 4 View points/ sitting positions

All together a combination of 3 x 64 x 4 simulations for each time step over 365 days.

Running Simulations

- Convert Sketchup Model to Radiance Model using Groundhog
- Get the glass states from Optics
- Add the glass state to each zone as texture (Automate using a script)
- Define Sky condition, View Points and sensor locations for Daysim and Generate Annual Illuminance & DGP Profiles
- Generate Heating and Cooling loads using EnergyPlus
- Rank Combination of states per Sky Condition based on DGP, Illuminance Values & Heating/Cooling Loads


EnergyPlus
Heating/ Cooling loads
3 Sky conditions
Sketchup Model
Groundhog
Illumination Profiles
Logic
Ranked Combination of States
Annual
64 Combinations
4States,3Zones
Daysim
Radiance Model
DGP Profiles
4 view points & Sensor Locations

Implementation

Ranked combination of states for each time step, sky condition and viewpoint

Rank	States Combination	DGP	Illuminance (lux)	Sensible Heating Rate [W](Hourly)	Sensible Cooling Rate [W](Hourly)
1	8909-8909-8909	0.26	1500	0	2020.8
2	8909-8909-8906	0.34	2200	0	2349.6

……………………

64	8905-8905-8905	0.56	5021	0	6440.8

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Determining sky condition

A.Fakra* et al. has given some valuable analysis

Sky Ratio $= d_h / G_h$

d_h is Diffuse horizontal terrestrial-irradiance (W/m^2)

G_h is Global horizontal terrestrial-irradiance (W/m^2)

sky ratio	sky type	success rate
SR$\geq$0.8	Overcast	81%
0.3<SR <0.8	Intermediate	60%
SR $\leq$ 0.3	Clear	98%

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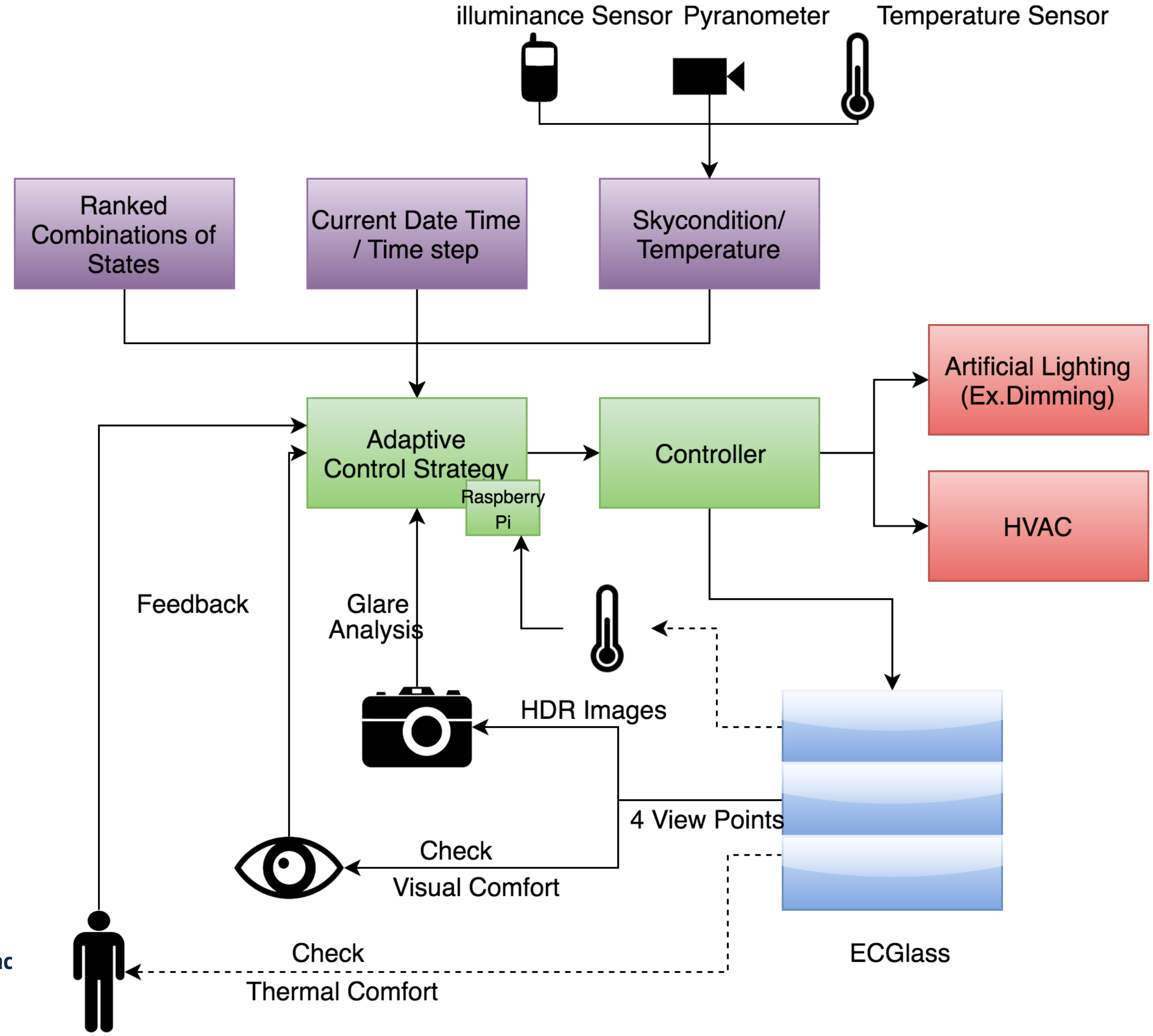
*Fakra, A. H., Boyer, H., Miranville, F., & Bigot, D. (2011). A simple evaluation of global and diffuse luminous efficacy for all sky conditions in tropical and humid climate. *Renewable Energy*


illuminance Sensor
Pyranometer
Temperature Sensor
Ranked Combinations of States
Current Date Time / Time step
Skycondition/ Temperature
Adaptive Control Strategy
Raspberry Pi
Controller
Artificial Lighting (Ex.Dimming)
HVAC
Feedback
Glare Analysis
HDR Images
4 View Points
Check Visual Comfort
Check Thermal Comfort
ECGlass

Visual and thermal comfort feedback

1 Completely uncomfortable
2 Uncomfortable
3 Slightly uncomfortable
4 Comfortable
5 Very Comfortable

Conclusion

- To avoid discomfort glare electrochromic glazing can be used.
- Dividing the EC-window in different zones allows for an optimum control.
- Choosing the right states depending on the season and on sky condition, can reduce the heating and cooling load significantly.
- Machine learning techniques will be used in combination with user feedback when sky conditions are difficult to predict.

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EC glass states

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SageGlass Type	%T_{vis}	%T_{sol}	SHGC
Clear state	60	33	0.41
Intermediate state 2	18	7	0.15
Intermediate state 1	6	2	0.10
Fully Tinted	1	0.4	0.09