Efficient daylight modeling for existing buildings

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overview

- Introduction
- Research problem
- Potential methods
- Conclusion and next steps

Introduction

- Circular built environment
- Higher building performance, lower environmental cost

Introduction

- Physically-based calculation

Geometrical information

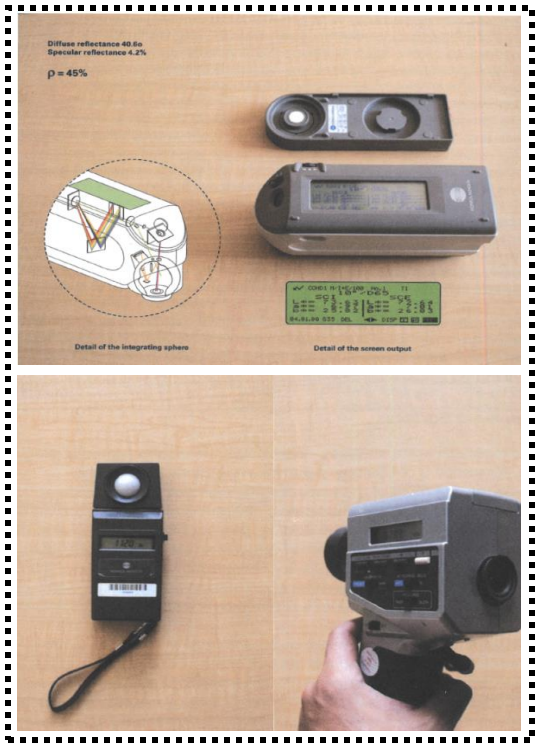
Optical properties

Neighboring obstructions

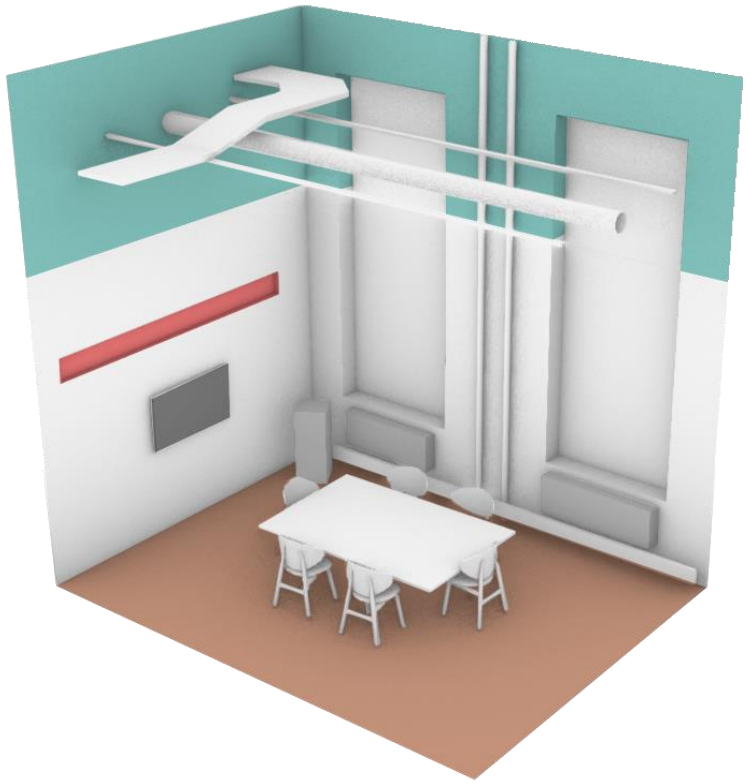
Sky radiance and location

Introduction

Material characterization



Measurement devices for material characterization [1]



Geometry measurements

\+

CAD

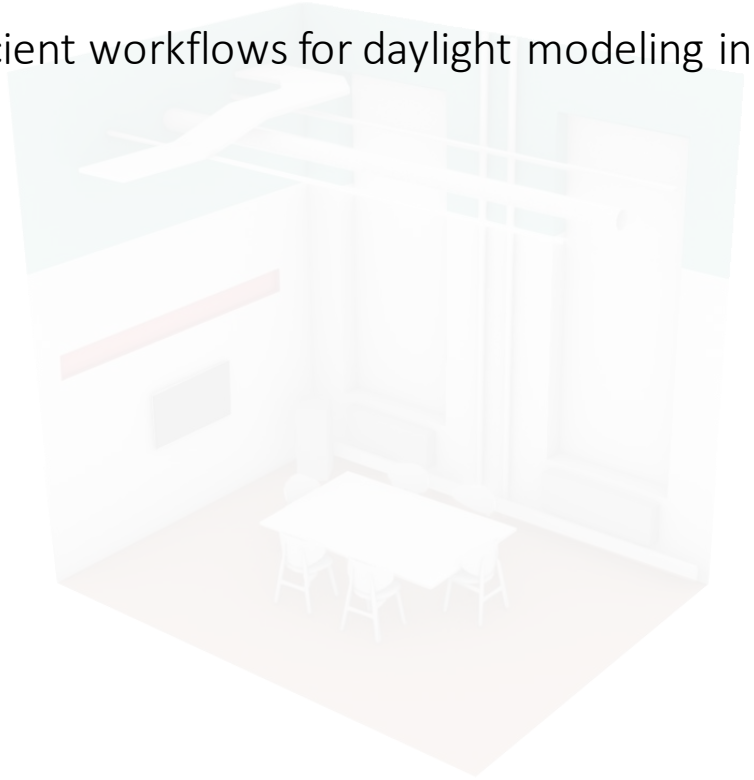
Manual steps, time-consuming, labor intensive

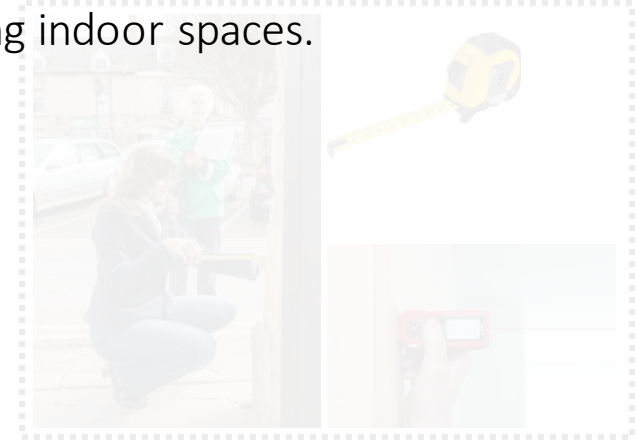
Material characterization

Geometry measurements

Goal Develop efficient workflows for daylight modeling in existing indoor spaces.

Measurement devices for material characterization [1]





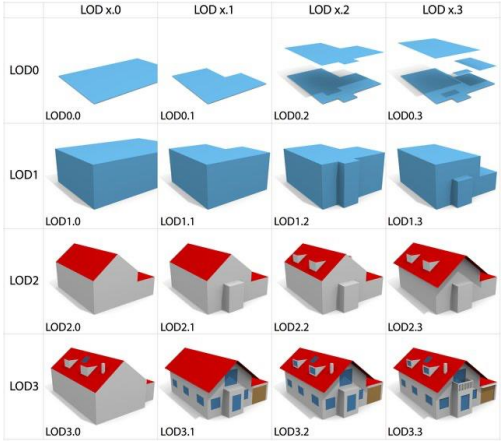
+

CAD

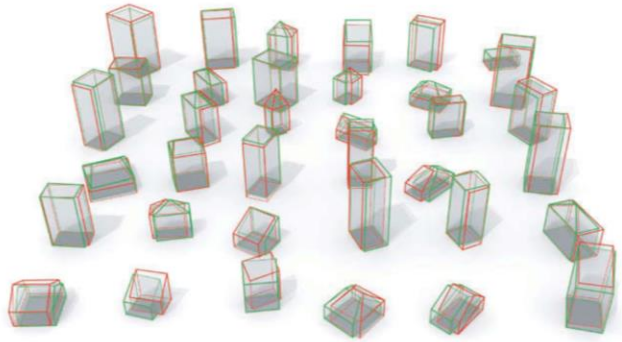
How important is the accuracy?

- What is the acceptable level of detail and accuracy for a geometrical and material definition for daylight simulation?
- Are exiting geometrical LODs useful enough for daylight applications? Is it possible to develop them?

- Level of detail



- Geometrical accuracy



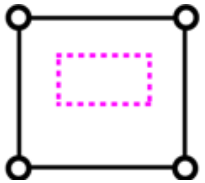
- Optical properties
  - Reflectance RGB
  - Specularity
  - Roughness

Biljecki, F., Ledoux, H., & Stoter, J. (2016). An improved LOD specification for 3D building models. *Computers, Environment and Urban Systems*, *59*, 25-37.
Biljecki, F., Heuvelink, G. B., Ledoux, H., & Stoter, J. (2015). Propagation of positional error in 3D GIS: estimation of the solar irradiation of building roofs. *International Journal of Geographical Information Science*, *29*(12), 2269-2294.

Geometrical reconstruction

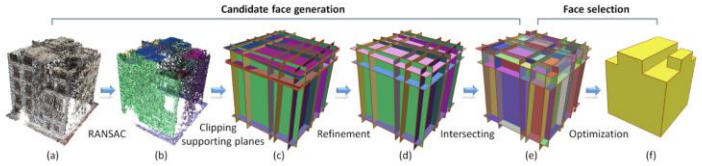
Watertight
(permanent structures)

Window boundaries

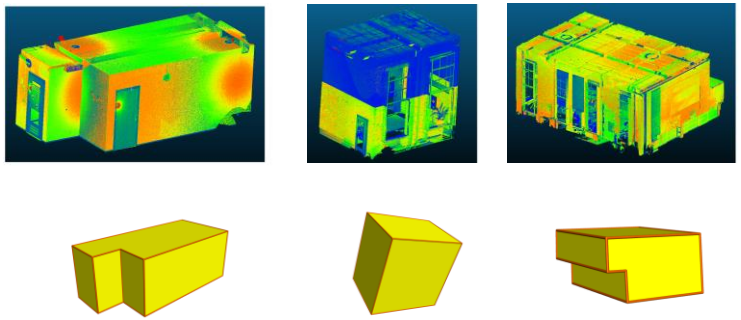


Major furniture pieces

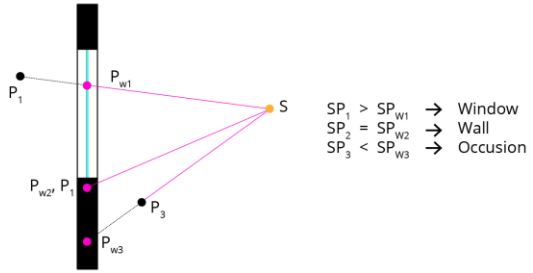
1. Polyfit



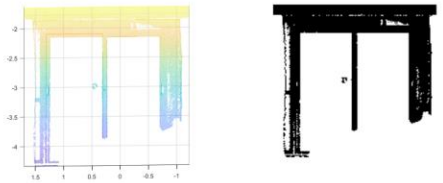
Test results:



1. Window boundaries from relative position of permanent structures and points
2. Wall plane detection > hole detection



Wall plane



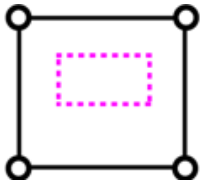
Hole detection for window boundary reconstruction [7]

Nan, L., & Wonka, P. (2017). Polyfit: Polygonal surface reconstruction from point clouds. In *Proceedings of the IEEE International Conference on Computer Vision* (pp. 2353-2361).
Energy Function Algorithm for Detection of Openings in Indoor Point Clouds.

Geometrical reconstruction

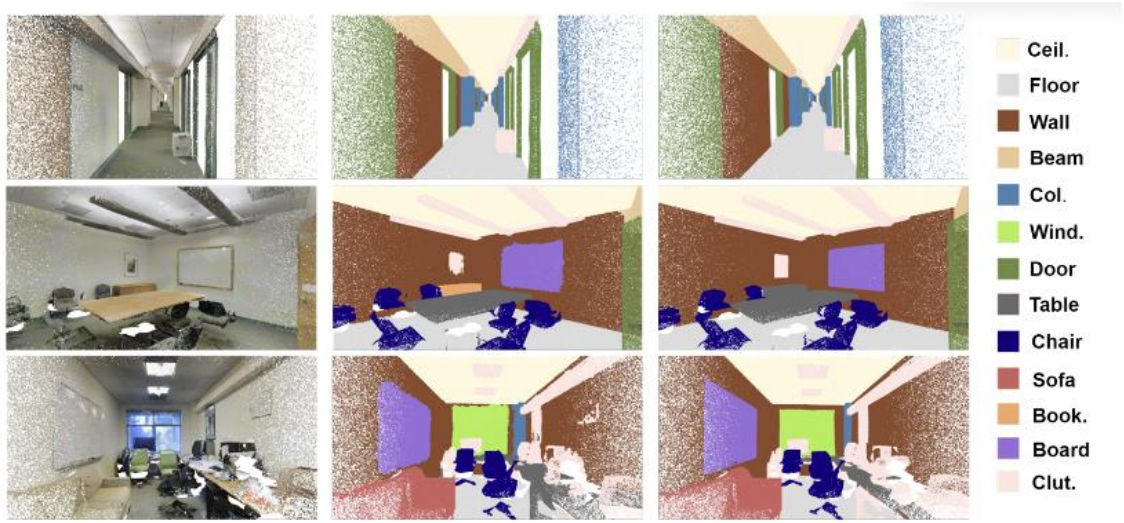
Watertight
(permanent structures)

Window boundaries



Major furniture pieces

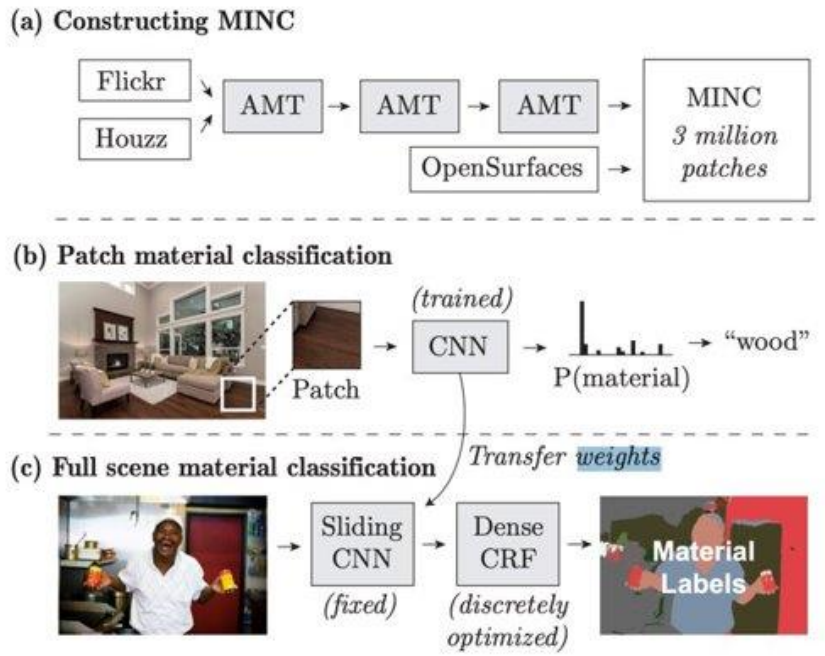
Learning-based semantic segmentation
> mesh and surface reconstruction



Siqi Fan et al. "SCF-Net: Learning spatial contextual features for large-scale point cloud segmentation". In: Proceedings of the IEEE Computer Society Conference on Computer Vision and Pattern Recognition (2021), pp. 14499–14508. issn: 10636919. doi: 10.1109/CVPR46437.2021.01427.

Material characterization for daylight/ Opaque

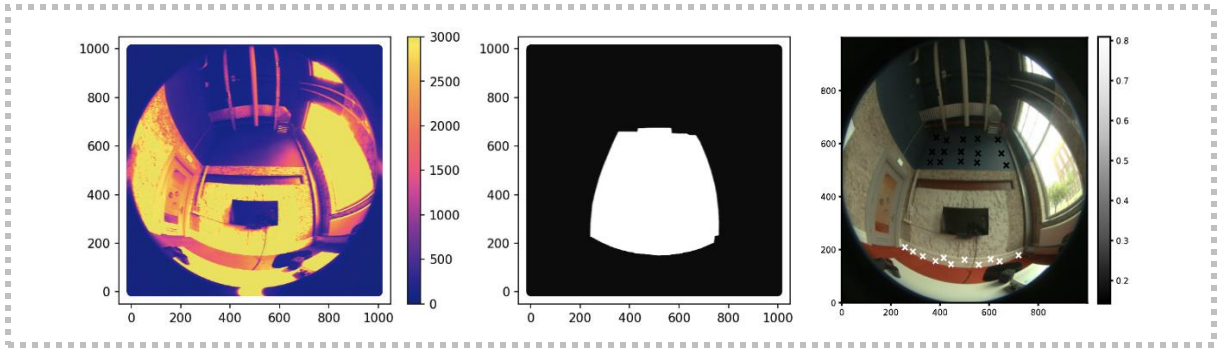
- Material patch labeling (+ image segmentation)



Sean Bell et al. "Material Recognition in the Wild with the Materials in Context Database". In: Proceedings of the IEEE Computer Society Conference on Computer Vision and Pattern Recognition 07-12-June (Dec. 2014), pp. 3479–3487. issn: 10636919.

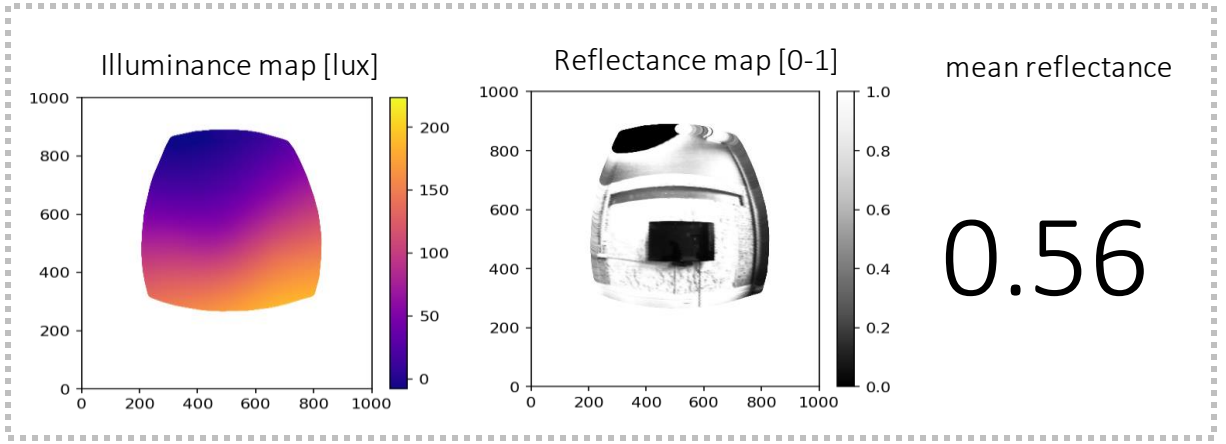
Material characterization for daylight/ Opaque

- Material patch labeling (+ image segmentation)
- HDRI and illuminance proxy



Input

$$\rho = \frac{(L * \pi)}{E}$$ + *Surface interpolation*



output

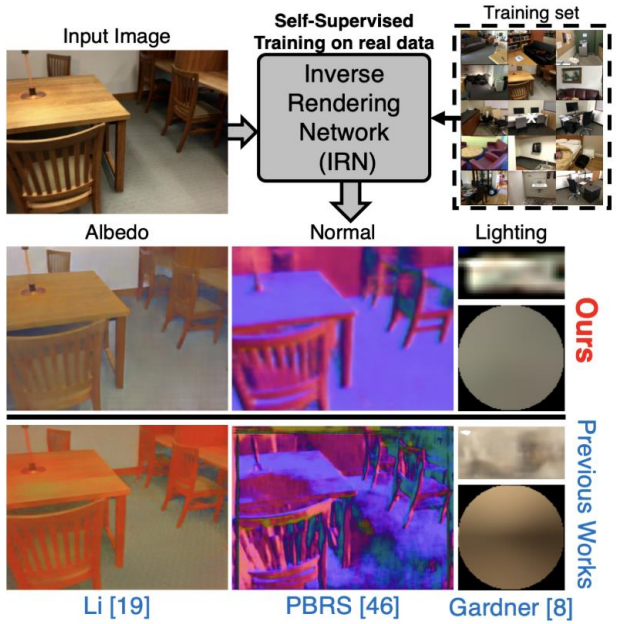
Mardaljevic, J., Brembilla, E., & Drosou, N. (2015). Illuminance-proxy high dynamic range imaging: a simple method to measure surface reflectance.
Forouzandeh, N., Brembilla, E., & Jakubiec, A. (2022), Image-based material characterization for daylight simulation using illuminance-proxy and artificial neural networks, *LUX EUROPA 2022, Prague, Czech.*

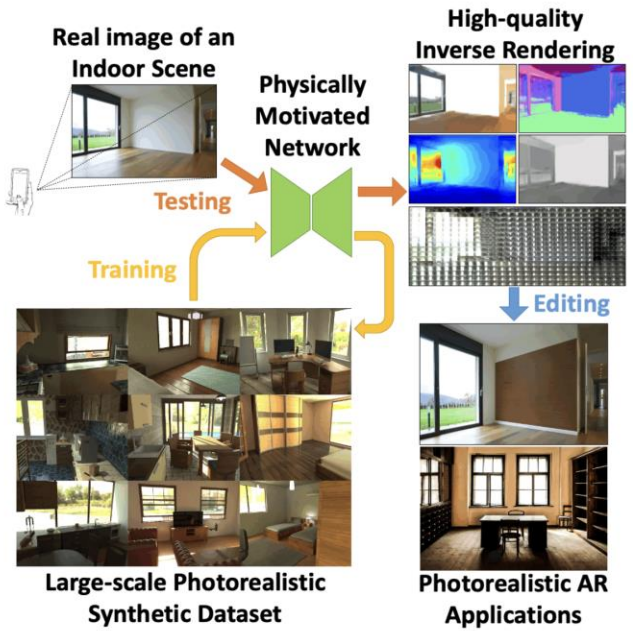
Material characterization for daylight/ Opaque

- Material patch labeling (+ image segmentation)
- HDRI and illuminance proxy
- Inverse rendering and Intrinsic image decomposition

•**Inverse rendering**: estimating render equation such as geometry, lights, materials, or the camera model.

•**Intrinsic decomposition:** albedo and shading.





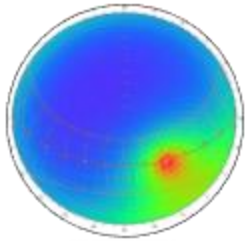
Sengupta, S., Gu, J., Kim, K., Liu, G., Jacobs, D. W., & Kautz, J. (2019). Neural inverse rendering of an indoor scene from a single image. In *Proceedings of the IEEE/CVF International Conference on Computer Vision* (pp. 8598-8607).
Li, Z., Shafiei, M., Ramamoorthi, R., Sunkavalli, K., & Chandraker, M. (2020). Inverse rendering for complex indoor scenes: Shape, spatially-varying lighting and svbrdf from a single image. In *Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition* (pp. 2475-2484).

Material characterization for daylight/ Transparent

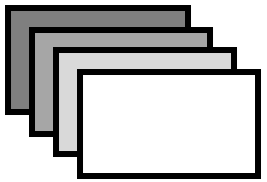
Transparent surfaces

- HDR photography from the windows at two states.

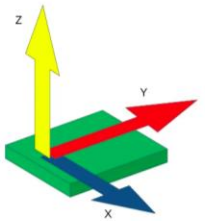
- HDR photography with known external camera parameters, simulated sky.



Simulated sky



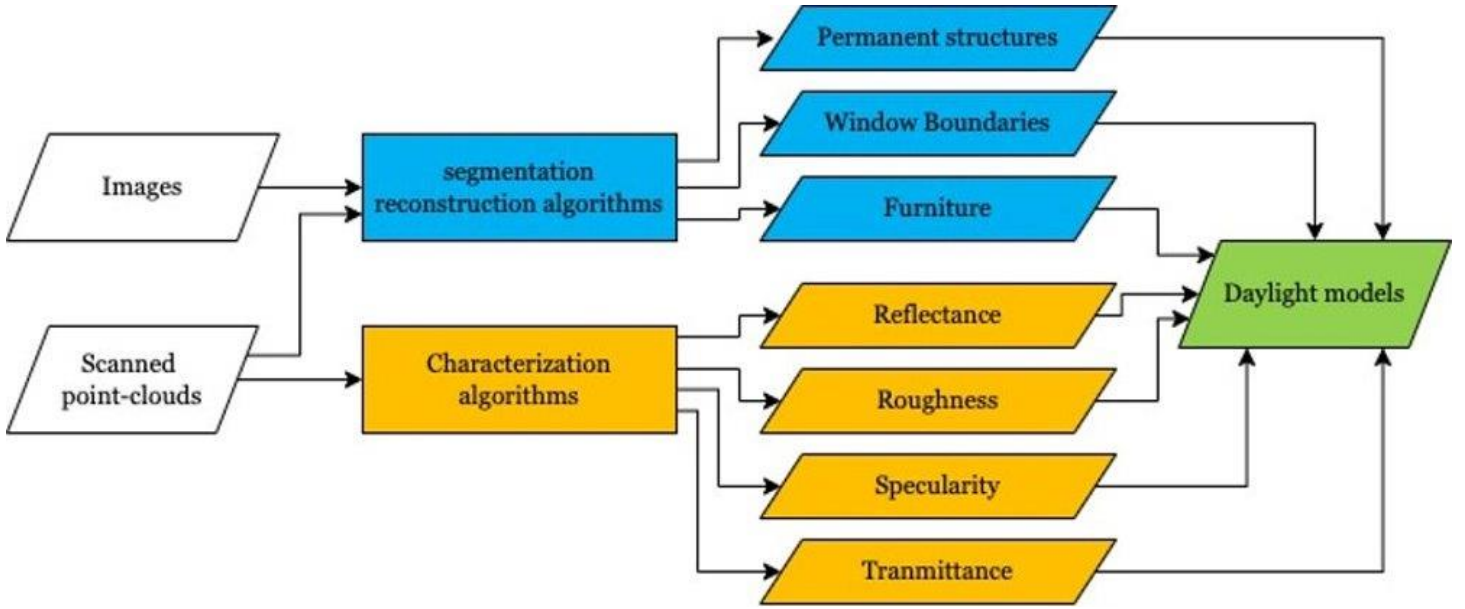
HDRI



Camera direction

Conclusion and future work

- Less manual steps
- Affordable daylight modeling
- Faster IEQ improvement



Thank you for your attention,

Questions and comments are welcome!

Project updates on: https://www.researchgate.net/project/AIM-FRAME

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