

Data-driven Digital Lighting Design for Residential Indoor Spaces

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ACM Transactions on Graphics



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群核科技
MANYCORE



Interior Design



Rendering



Photograph

Interior Design

Furniture Arrangement



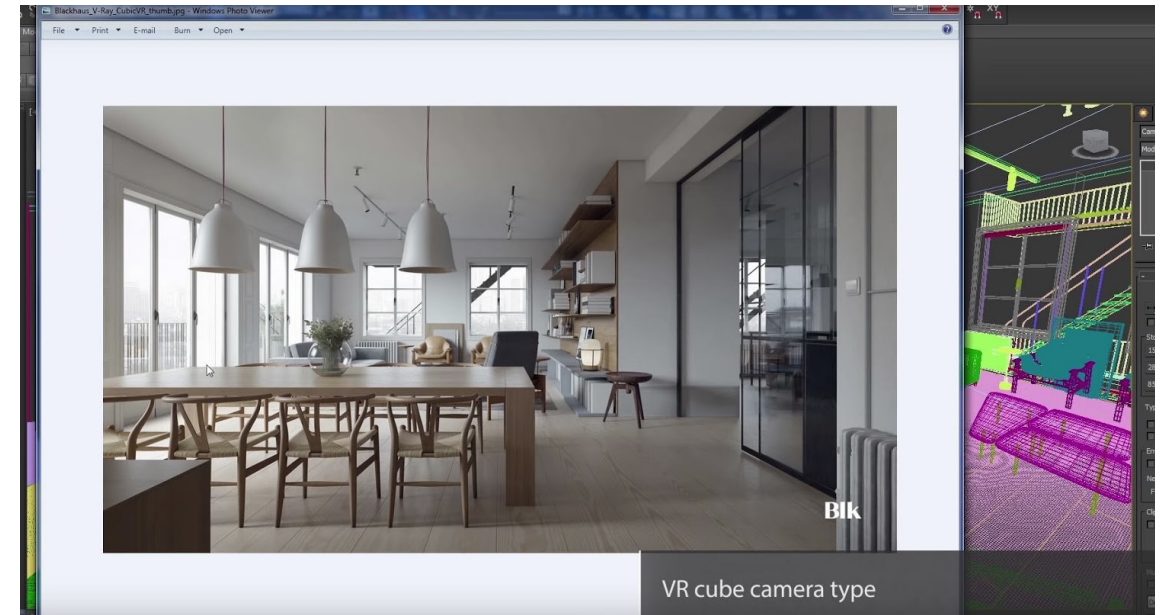
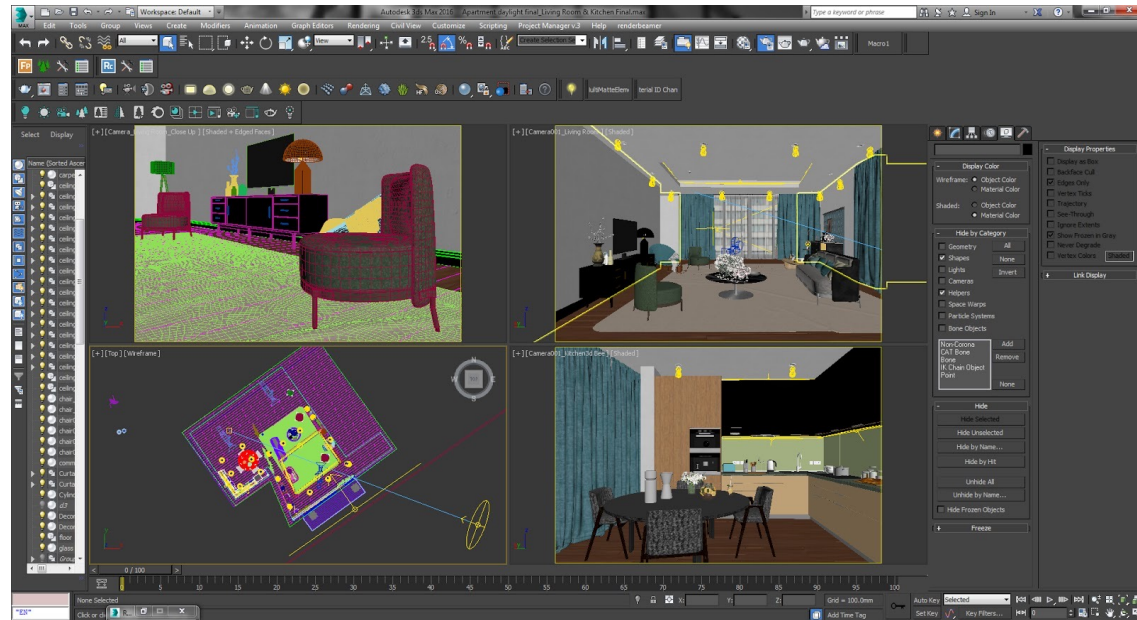
Lighting Design



Digital Lighting Design

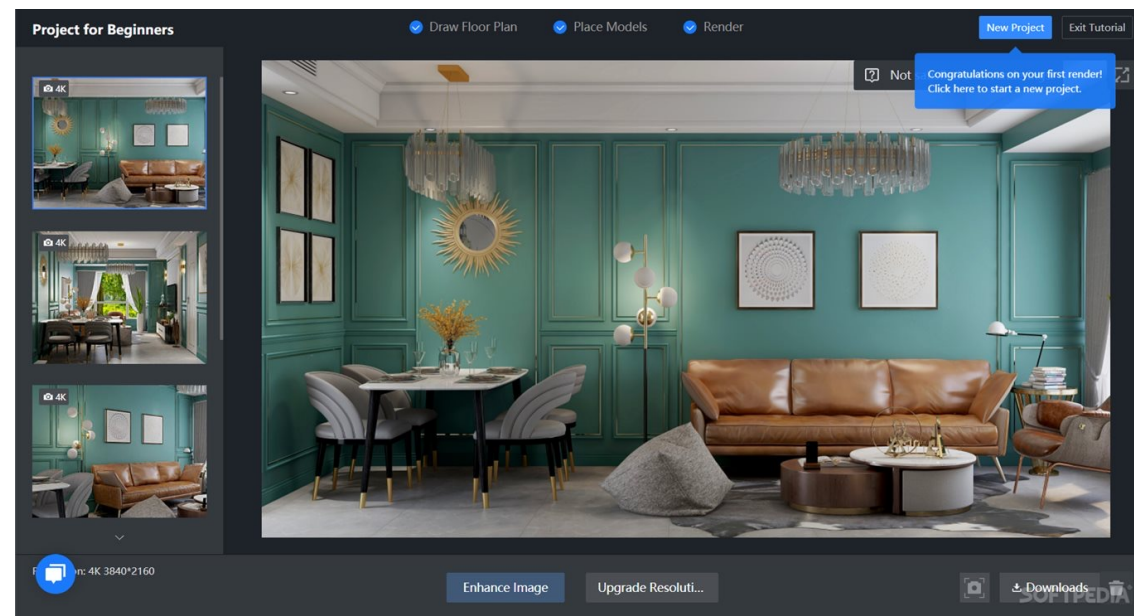
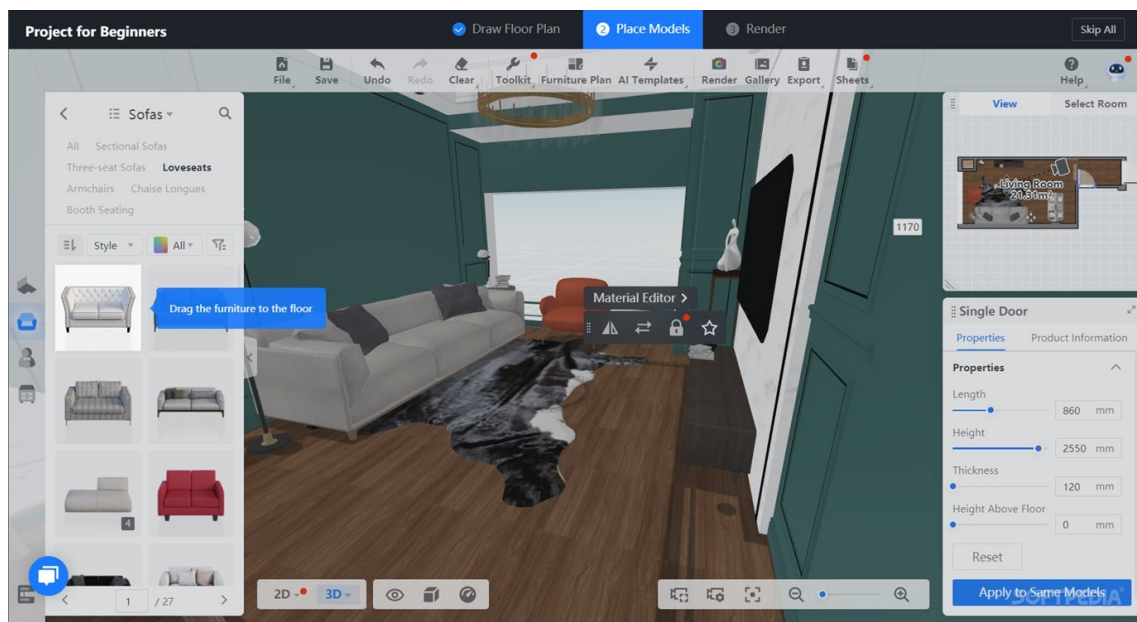
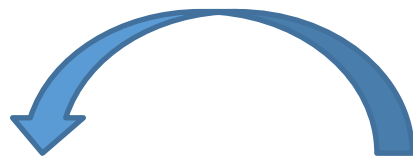


Motivation



An iterative process with trials and errors is time-consuming

Motivation



Automate it!

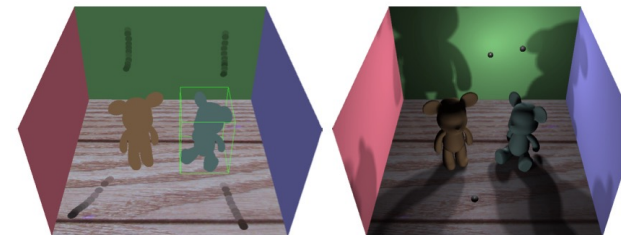


Related Work

Goal-based methods



[Pellacini et al. 2007]



[Lin et al. 2013]

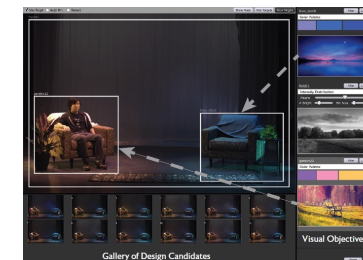
Image Gallery-based methods



[Marks et al. 1997]



[Shapira et al. 2009]



[Shimizu et al. 2019]

Automatic Rule-based methods



[Jin et al. 2019]

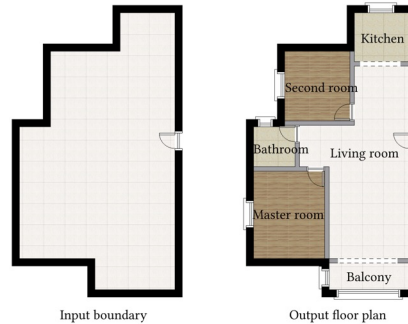
Related Work

Data-driven interior design

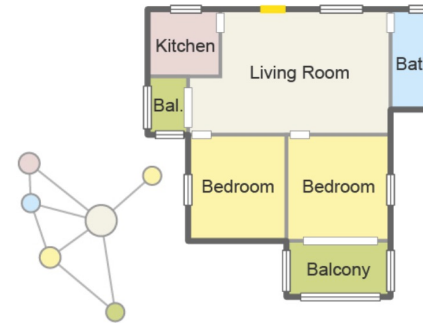
Design Process

Floorplan design

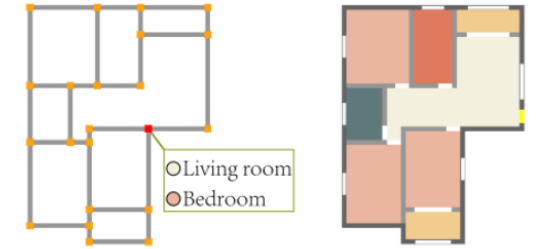
Create space



[Wu et al. 2019]



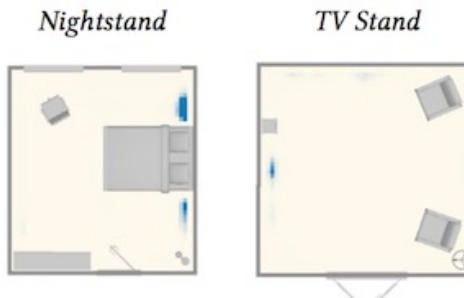
[Hu et al. 2020]



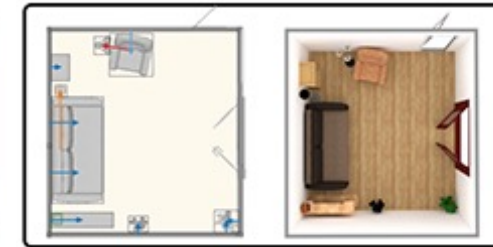
[Wu et al. 2022]

Furniture arrangement

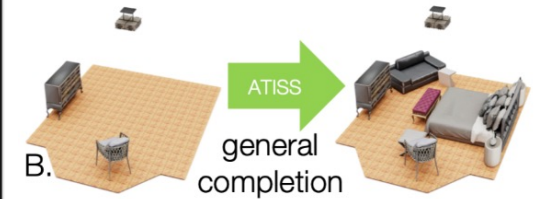
Fill space



[Wang et al. 2007]



[Wang et al. 2019]



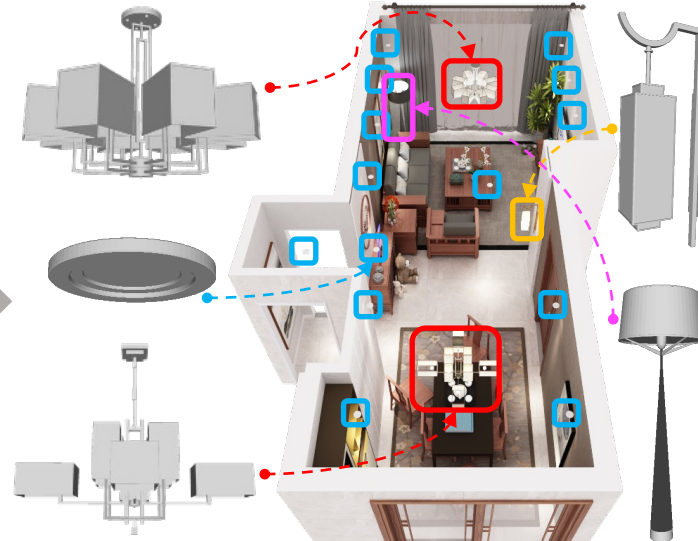
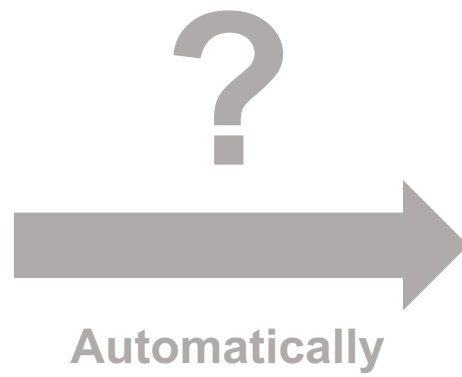
[Paschalidou et al. 2021]

This work!

Problem



Furniture-populated
Room



Digital Lighting Design



Problem



Arrangement



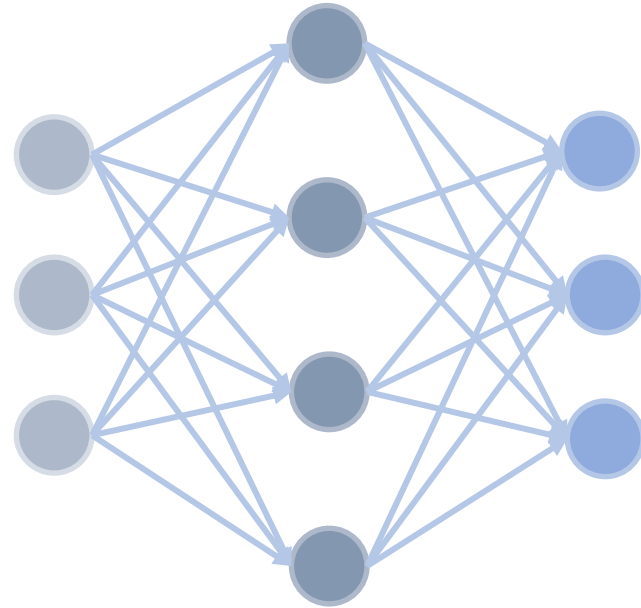
Emission

Challenges

Dataset



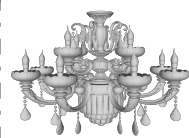
Network



Dataset



Dataset



chandeliers



ceiling lamp



downlight



table lamp



floor lamp

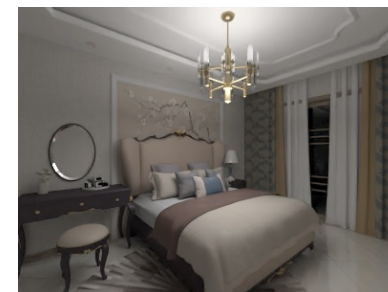
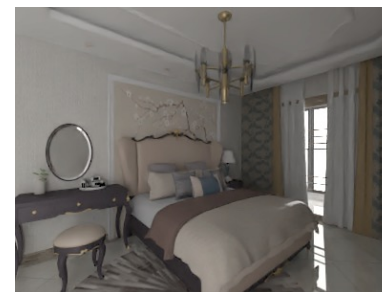
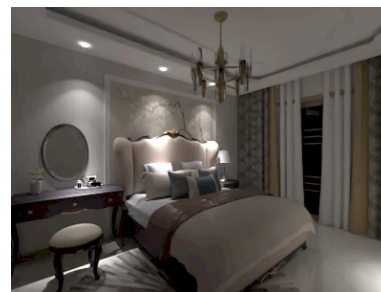


wall lamp



bedside pendant light

Library of lights



Dataset



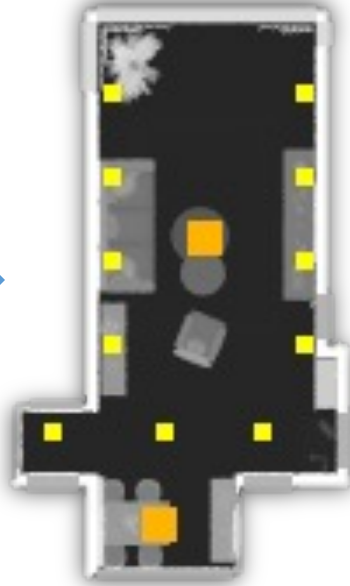
Photographs

Approach

Two-stage pipeline



Light Layout
Arrangement



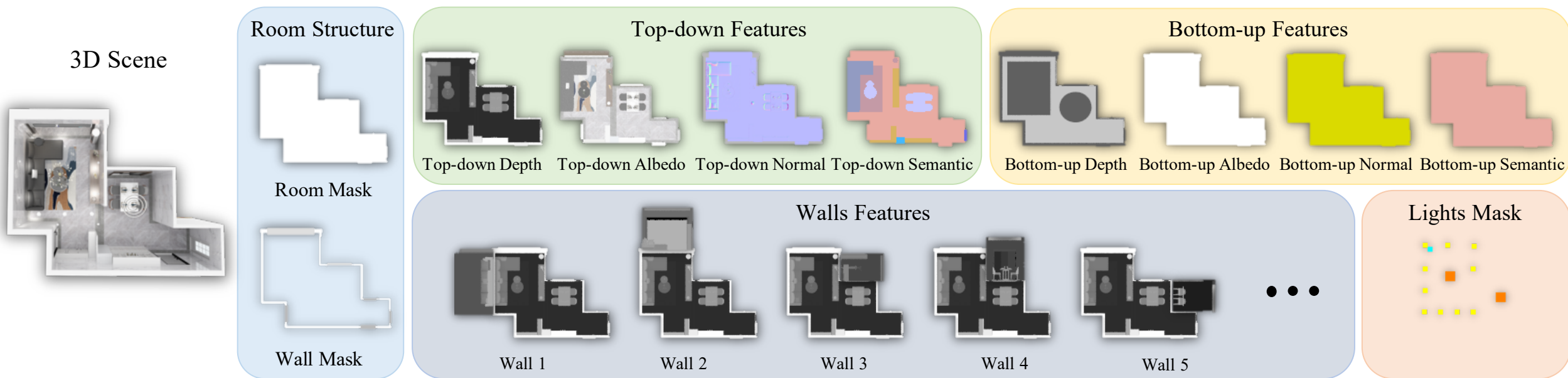
Light Emission
Optimization



Approach

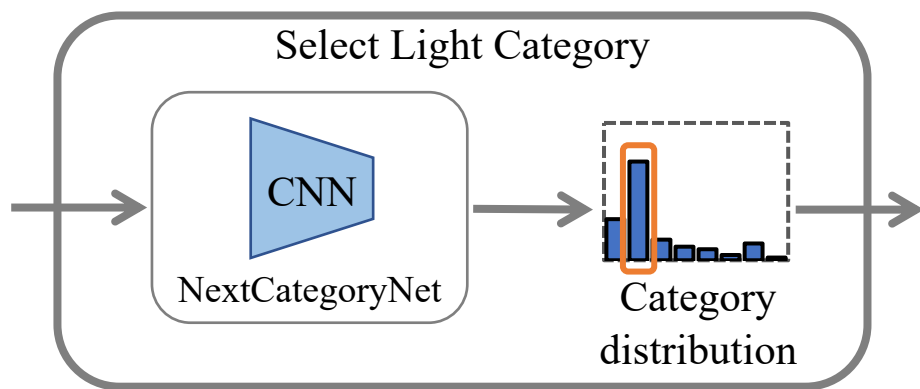
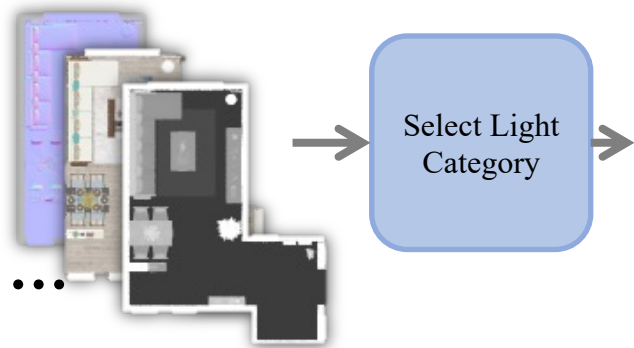
Light layout arrangement

Image-based indoor scene representation



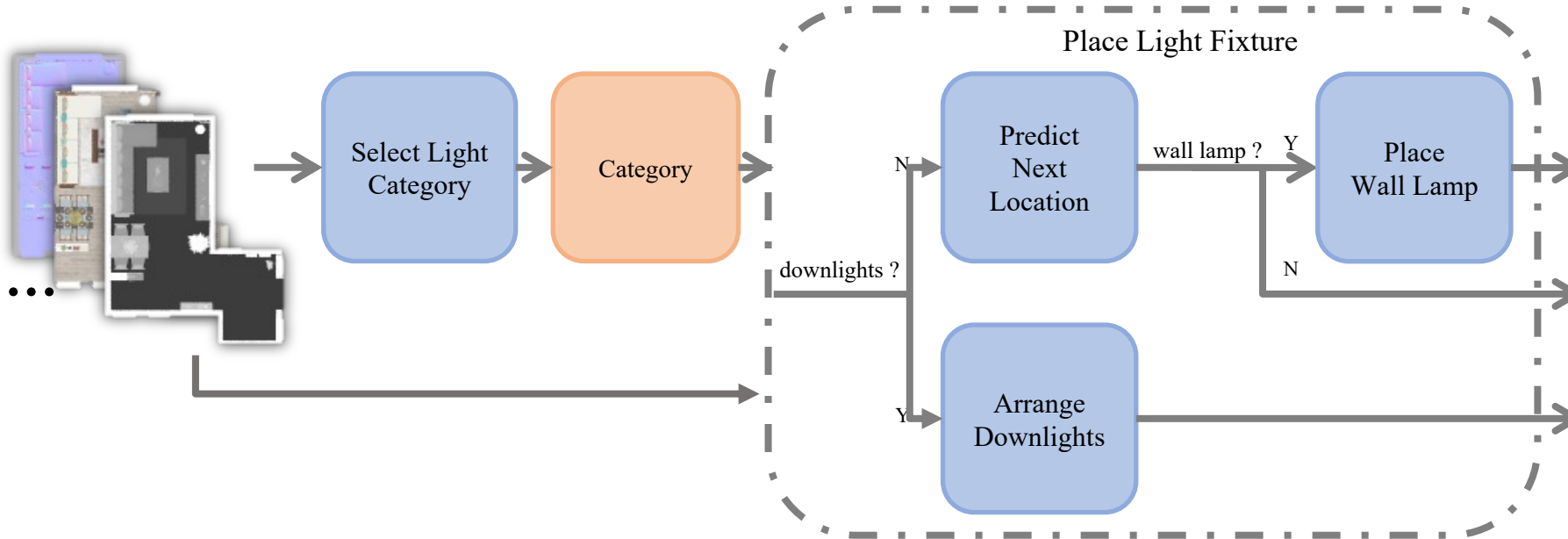
Approach

Light layout arrangement



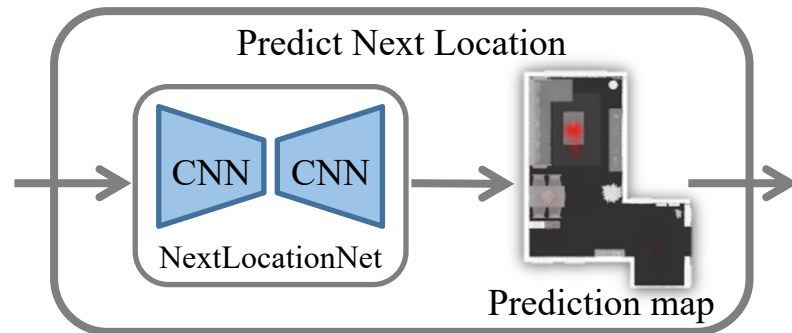
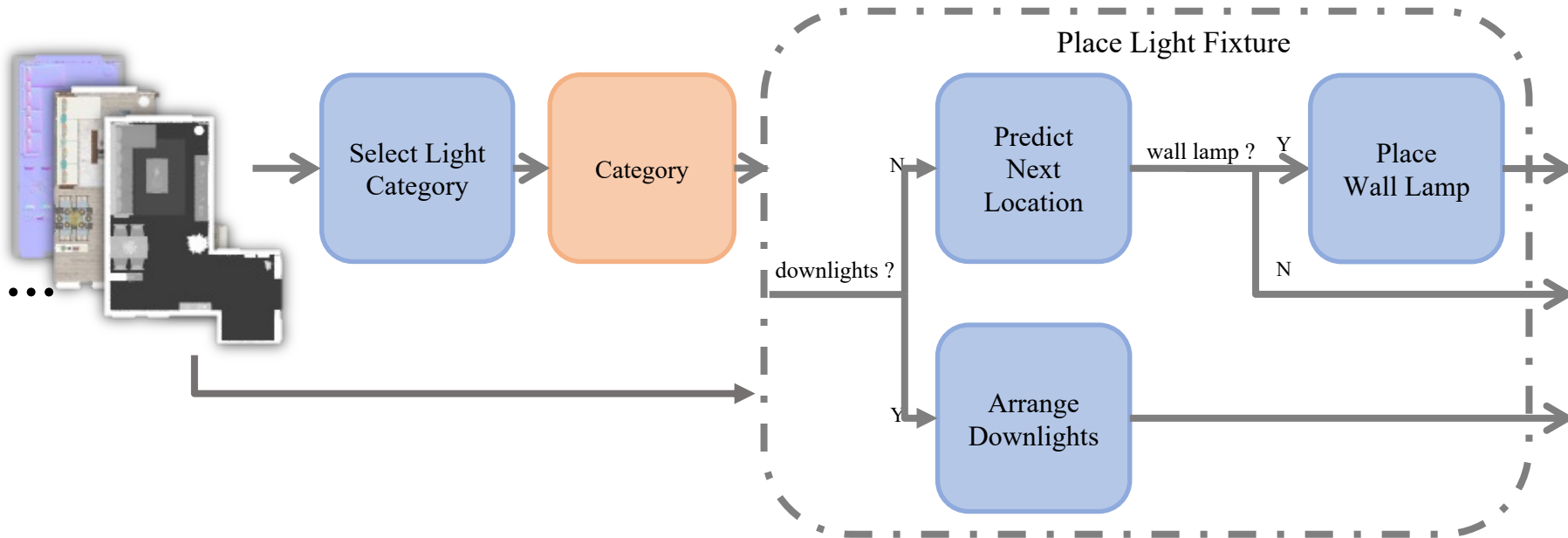
Approach

Light layout arrangement



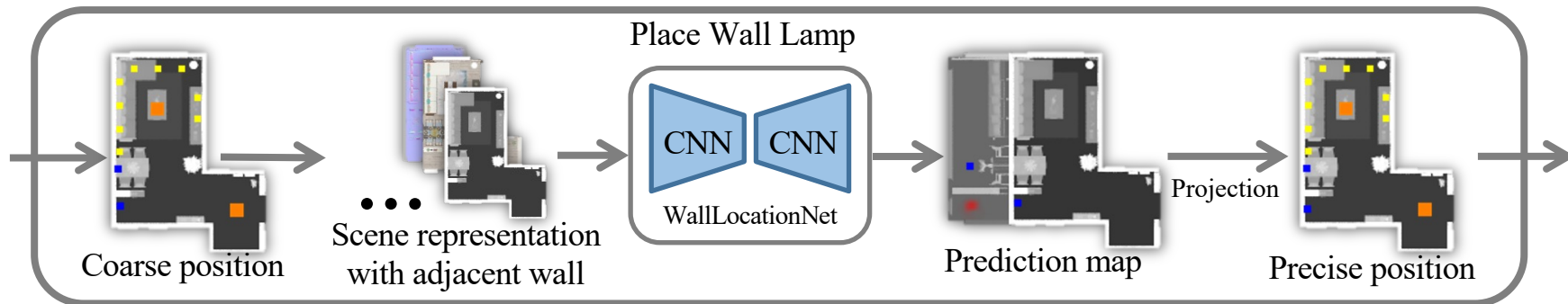
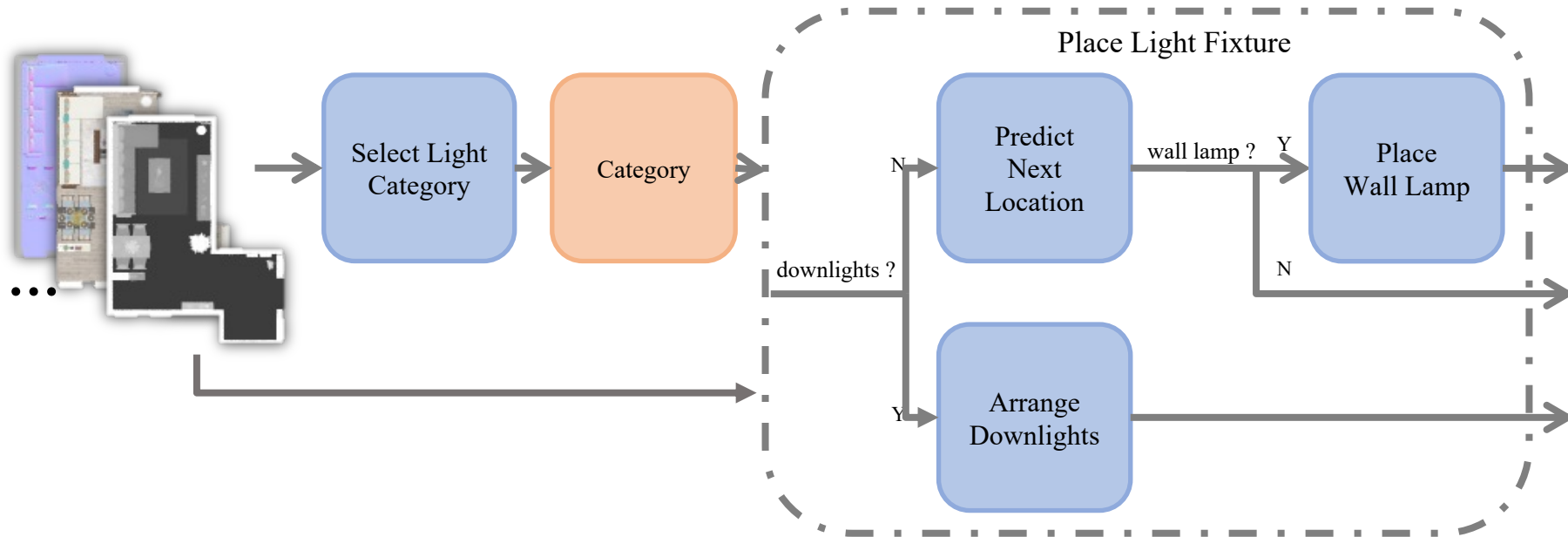
Approach

Light layout arrangement



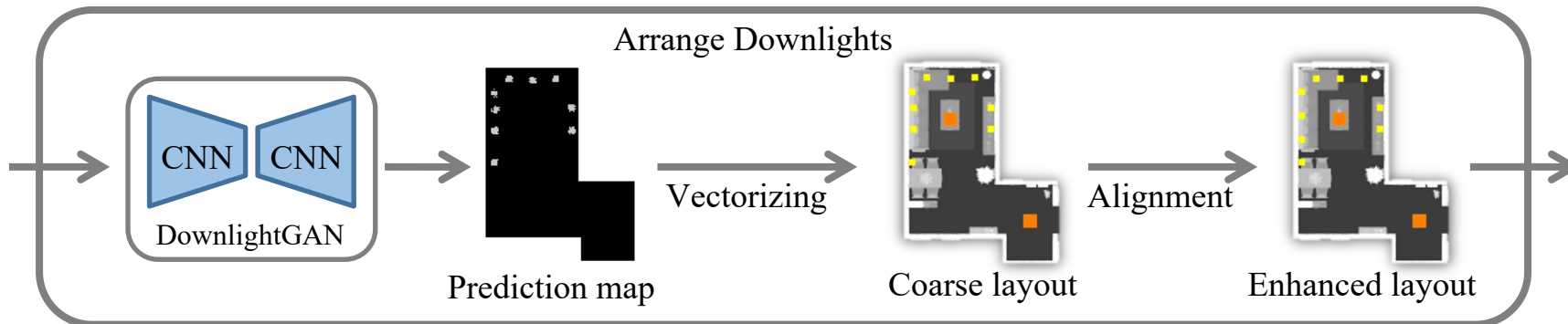
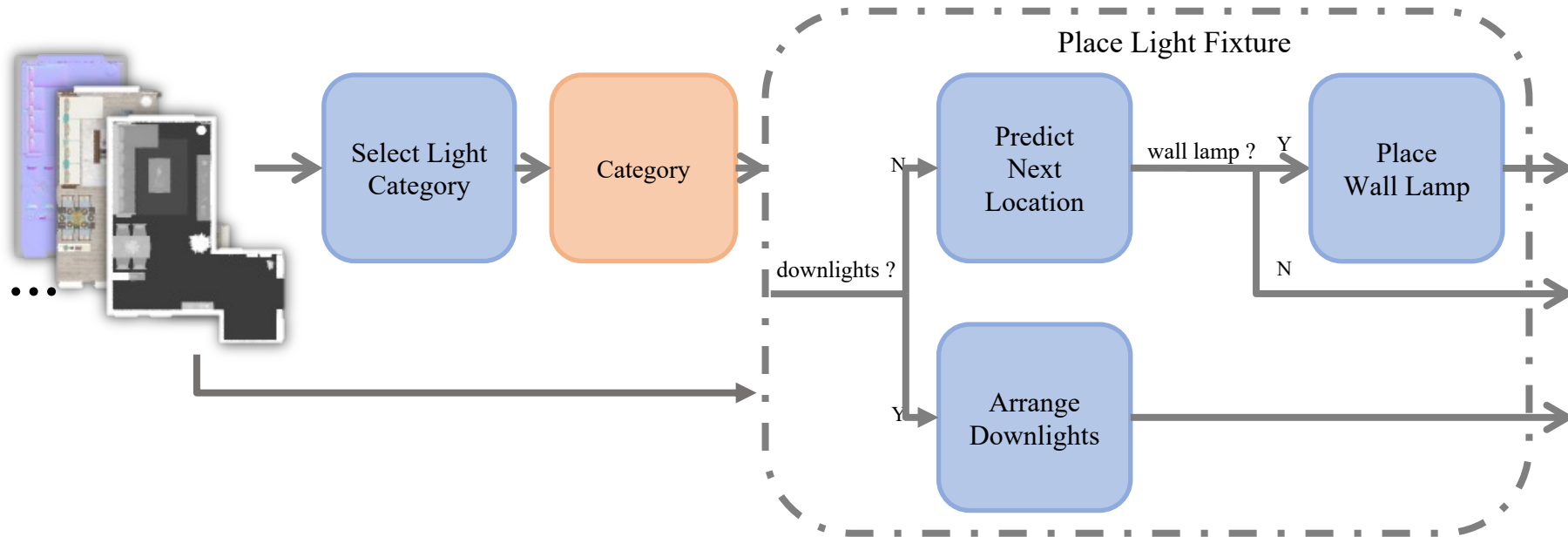
Approach

Light layout arrangement



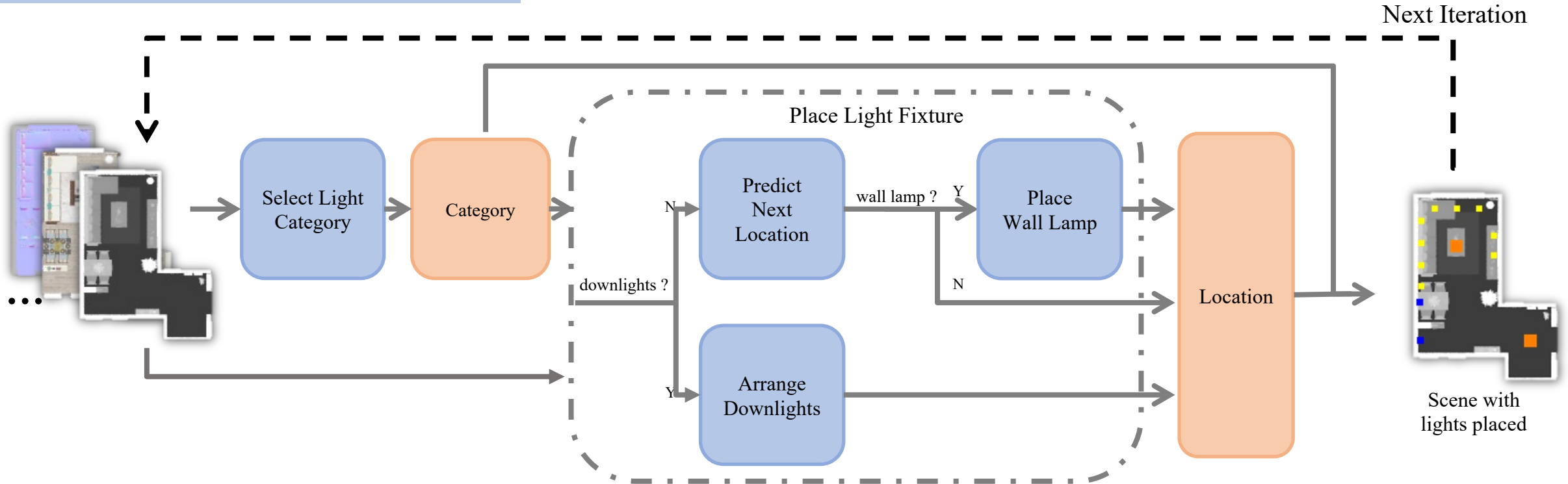
Approach

Light layout arrangement



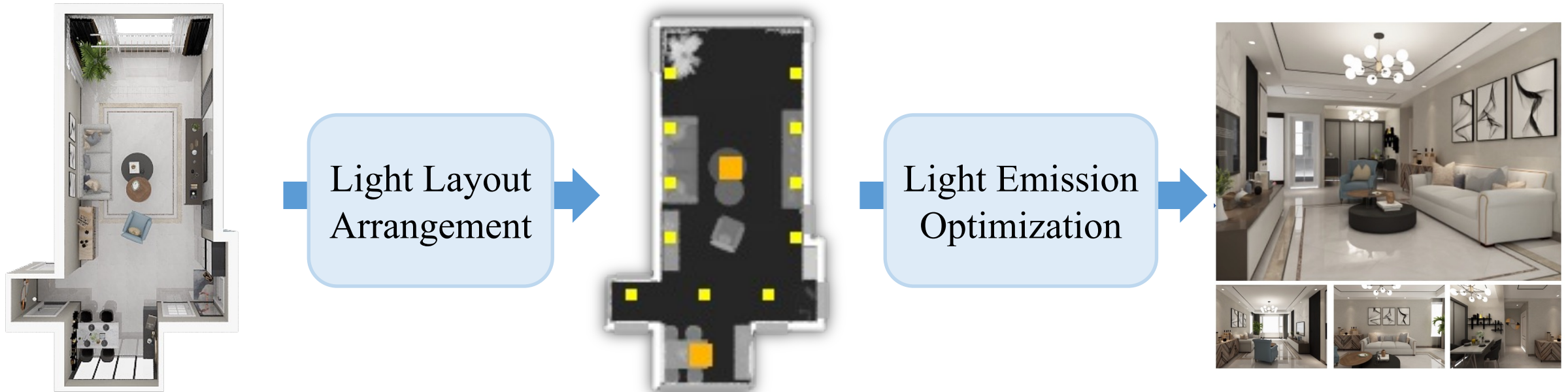
Approach

Light layout arrangement



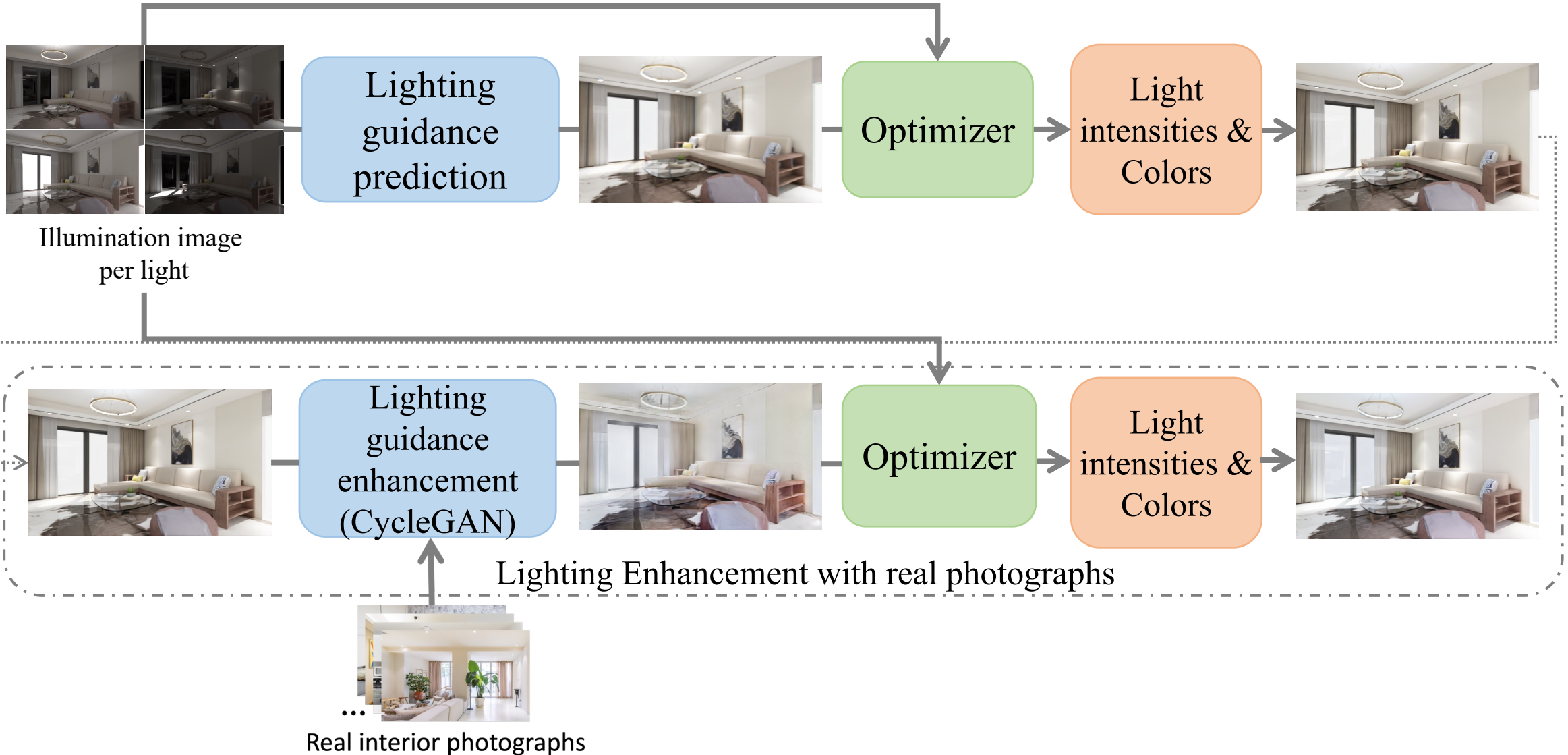
Approach

Two-stage pipeline



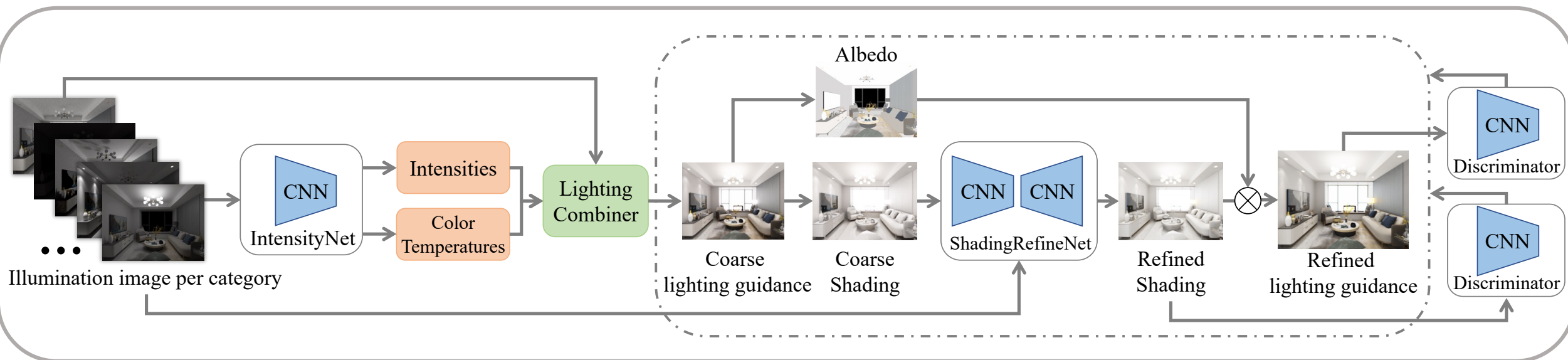
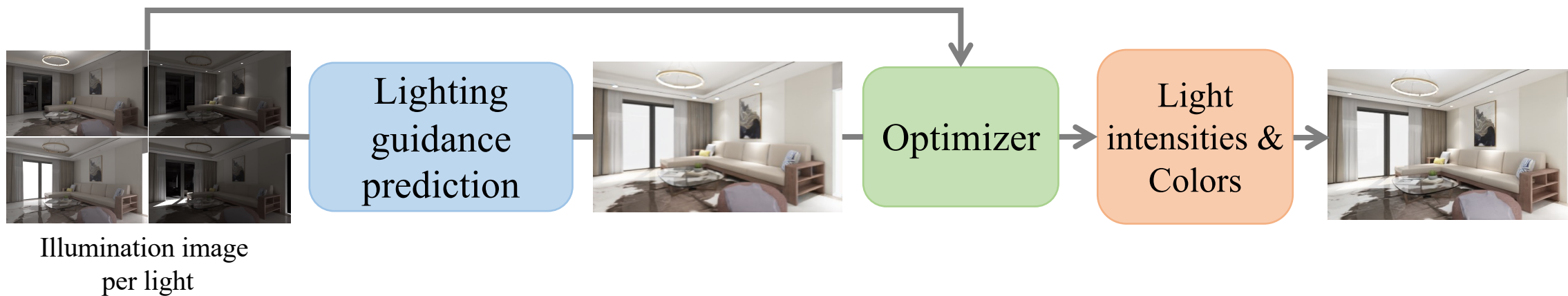
Approach

Light emission optimization



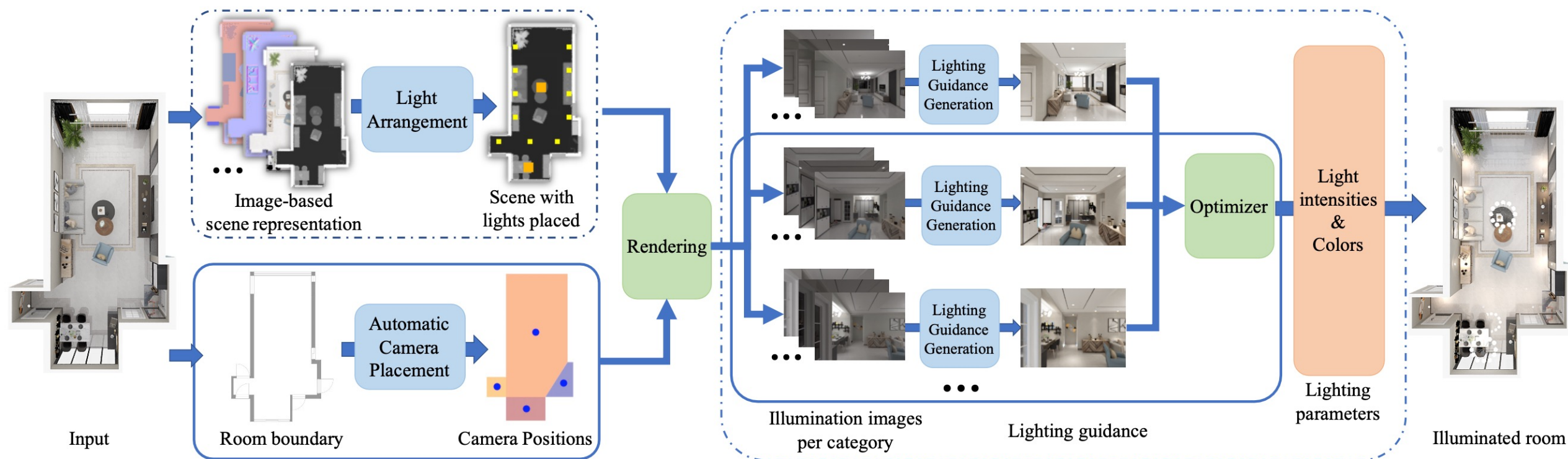
Approach

Light emission optimization

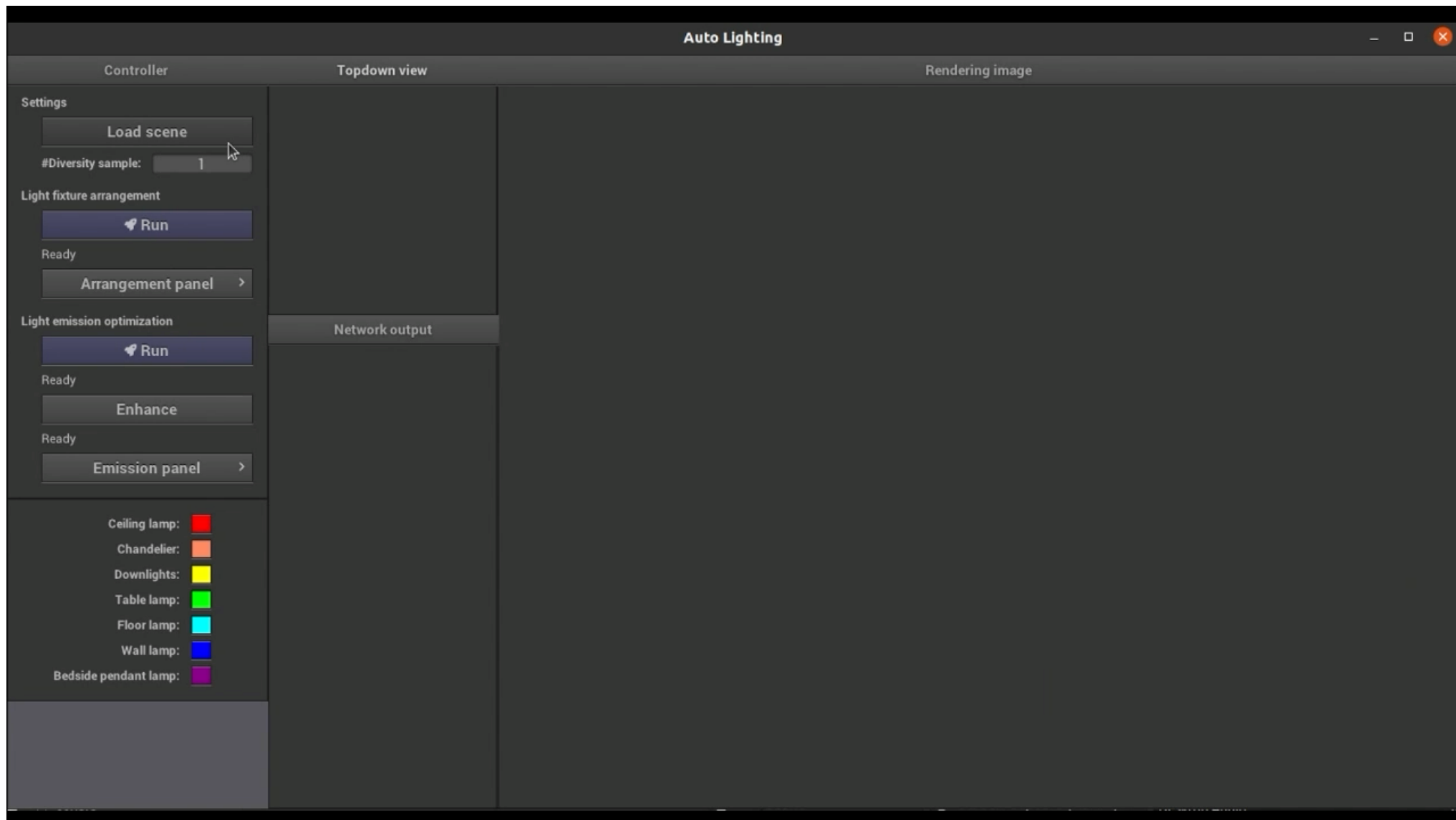


Approach

Whole-room lighting optimization



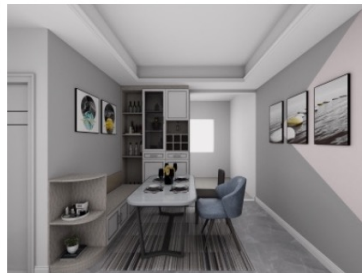
Demo



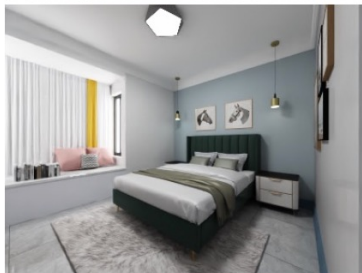
Qualitative Evaluation

Comparison with designers

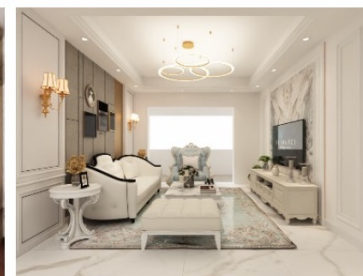
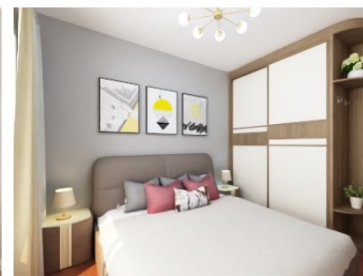
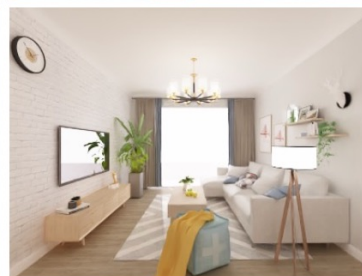
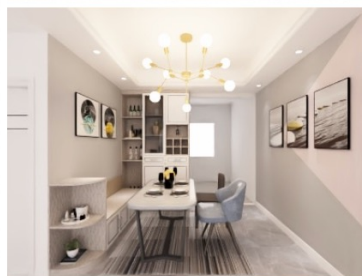
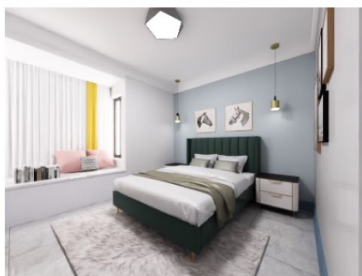
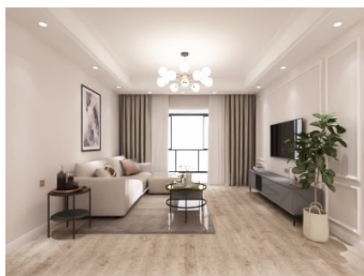
Initial Scene



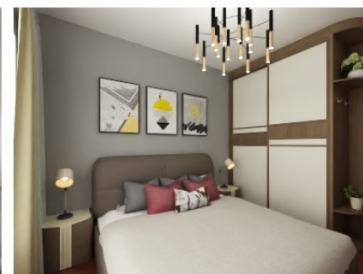
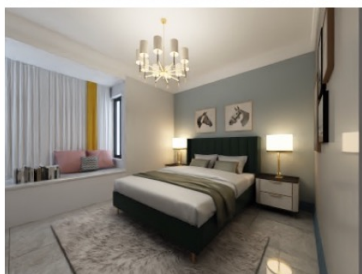
Ours



Ours (enhanced)



Human



Qualitative Evaluation

Comparison with rule-based method



[Jin et al. 2019]

- State-of-the-art rule-based lighting layout optimization method
- Optimizes the light placements and intensities simultaneously using simulated annealing
- Require high-quality prespecified light objects for a scene as input
- Rendering in the loop -> Time consuming

Qualitative Evaluation

Comparison with rule-based method



Qualitative Evaluation

Perceptual Studies

Perceptual studies:

- Ours vs. Rule-based baseline
- Ours vs. Human
- Ours(enhanced) vs. Human

Questions:

- Q1: Which scene has a more appropriate light arrangement (position and number)?
- Q2: Which scene has a more visually comfortable lighting effect?
- Q3: Which scene has a more appropriate light placement and brightness to interact with the furniture?



Note:

1. Red is ceiling lamp, orange is chandeliers, yellow is downlights, green is table lamp, cyan is floor lamp, blue is wall lamp, purple is bedside pendant lamp
2. The orange, green, and blue arrows represent the label of cameras in the first, second, and third rendering images.

* Q1: which scene has a more appropriate light arrangement (position and number) ?

☐ A

☐ B

* Q2: which scene has a more visually comfortable lighting effect?

☐ A

☐ B

* Q3: which scene has a more appropriate light placement and brightness to interact with the furniture?

☐ A

☐ B

Qualitative Evaluation

Perceptual Studies

Comparison	Method	Competitor	Users	Ratio
Light Arrangement	Ours	Rule-based	General	
			Professional	
		Human	General	
			Professional	
Lighting Effect	Ours	Rule-based	General	
			Professional	
		Human	General	
			Professional	
	Ours-E	Human	General	
			Professional	
Interaction	Ours	Rule-based	General	
			Professional	
		Human	General	
			Professional	
	Ours-E	Human	General	
			Professional	

0.4 0.5 0.6 0.7 0.8 0.9



Note:

1. Red is ceiling lamp, orange is chandeliers, yellow is downlights, green is table lamp, cyan is floor lamp, blue is wall lamp, purple is bedside pendant lamp
2. The orange, green, and blue arrows represent the label of cameras in the first, second, and third rendering images.

* Q1: which scene has a more appropriate light arrangement (position and number) ?

☐ A

☐ B

* Q2: which scene has a more visually comfortable lighting effect?

☐ A

☐ B

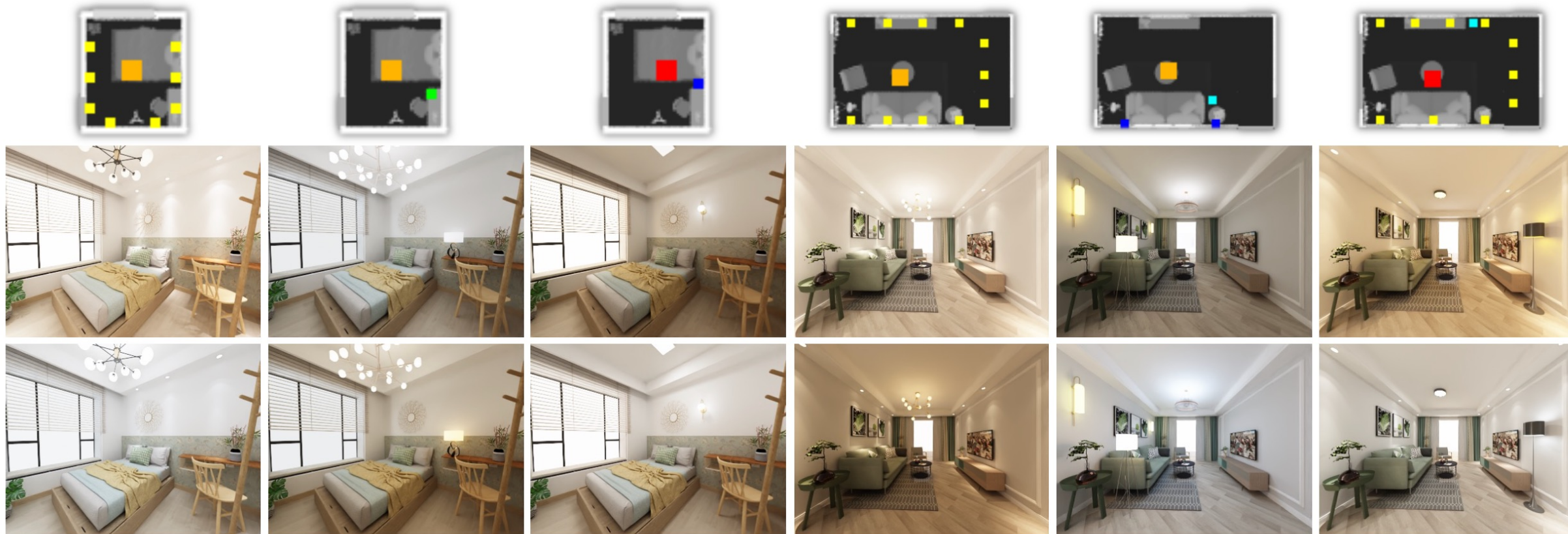
* Q3: which scene has a more appropriate light placement and brightness to interact with the furniture?

☐ A

☐ B

Qualitative Evaluation

Result diversity



different lighting designs for the same scene

Qualitative Evaluation

Whole-room walk-through



Quantitative Evaluation

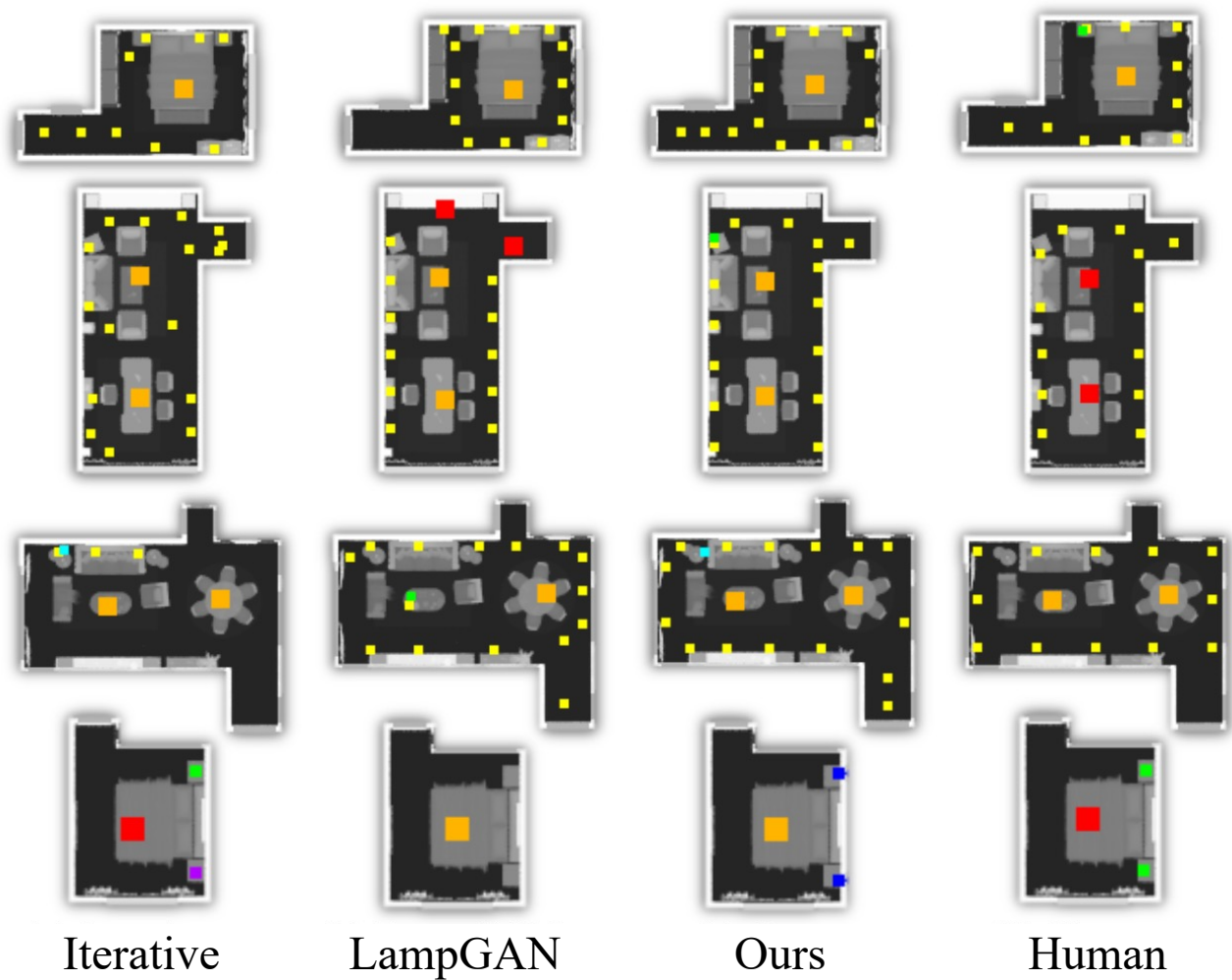
Neural image assessment

- NIMA: Neural Image Assessment [Talebi and Milanfar 2018]
- A neural network trained on the Aesthetic Visual Analysis (AVA) dataset [Murray et al. 2012] for aesthetic evaluation.

Metrics	Ours	Ours (enhanced)	GT
Preference percentage	49.23%	62.69%	-
Average score	5.329	5.384	5.337
Standard deviation	0.217	0.215	0.221

Quantitative Evaluation

Light arrangements



Two baselines:

- *Iterative model*
- *LampGAN*

Our approach:

- *Hybrid model of these two baselines*

Metrics	Iterative model	LampGAN	Ours
classification	78.25	76.00	62.75
KL-divergence	0.0570	0.1062	0.0072

Limitations



Orientation of light fixture

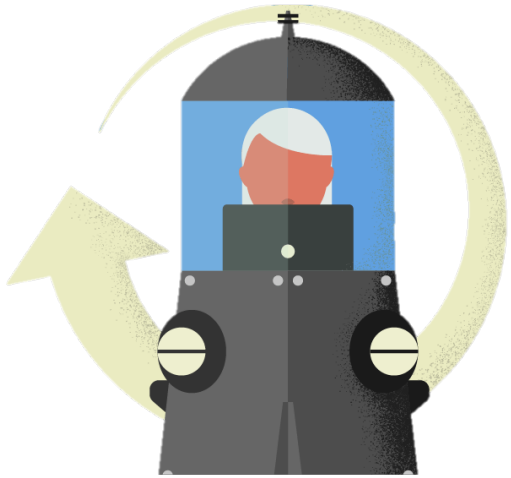


Complex ceiling pattern

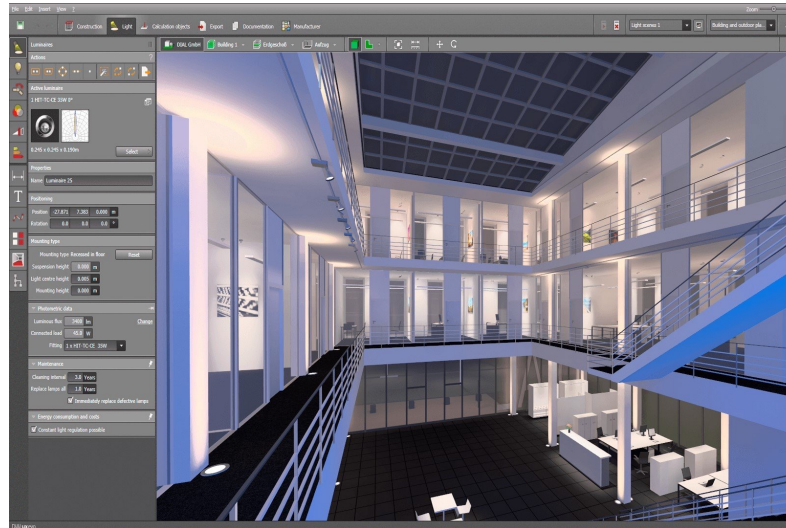


incompatible model selection

Future Work



Interactive human-in-the-loop design



More types of spaces



Real-world lighting design

Conclusion

- The first deep learning-based automatic interior digital lighting design framework
- An interior scene dataset including good lighting layouts
 - will be available online in the MINERVAS platform.

