Co-Layout: LLM-driven Co-optimization for Interior Layout

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1. Introduction

Challenge: Interior design requires simultaneously managing room layout and furniture placement. Existing automated methods, such as Holodeck and AnyHome separate these phases (two-stage), leading to conflicts such as insufficient space for furniture or blocked paths.

Insight: Inspired by architectural concept of "Modular", interior design problem can be discretized as a grid system. Each resulting cell is assigned one room label (e.g., bedroom, living room) and associated furniture label (e.g., bed, sofa) to define spatial programming.

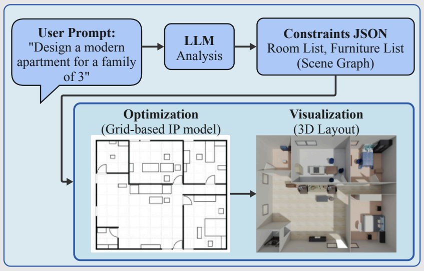
Solution: Co-Layout, the first framework that integrates LLMs to design spatial constraints and a grid-based Integer Programming model to **Co-optimize room layout and furniture placement.**

2. Framework Overview

(a) Constraint Generation: An LLM interprets user requirements to produce spatial constraints for rooms and furniture, as well as boundary conditions for the entire floor.

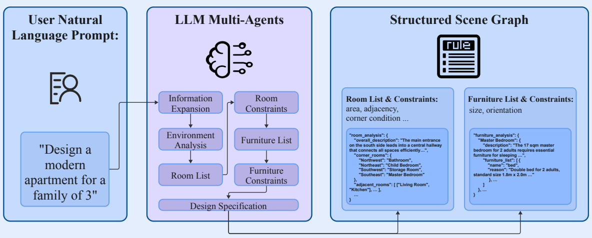
(b) Layout Optimization: These constraints are encoded into an integer programming model using a grid-based representation. The model is solved efficiently via a coarse-to-fine strategy to produce the final layout.

(c) Scene Visualization: The layout is converted into a scene white box in Blender. Suitable 3D assets are then retrieved from the 3D-FUTURE dataset and a curated library of over 2,000 assets through semantic embedding and size matching to populate the scene.

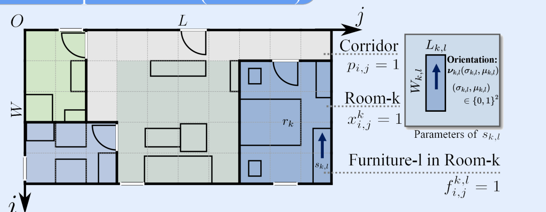


3. Methods

1 LLM-based Designers



2 Grid-based Representation ('Modular')



The floor is modeled as a 2D grid. Each cell (i, j) has binary variables indicating if it belongs to a corridor ($p_{i,j}$), room r_k ($x^k_{i,j}$), or is occupied by the l-th furniture in the k-th room $s_{k,l}$ ($f^{k,l}_{i,j}$). Each furniture $s_{k,l}$ has dimensions $W_{k,l} \times L_{k,l}$. Its orientation $\boldsymbol{\nu}_{k,l}$, chosen from 4 axis-aligned directions, is set by two binary variables $\sigma_{k,l}$ and $\mu_{k,l}$.

3 Key Constraints (Integer Programming)

$$p_{i,j} + \sum_{k=1}^{N} x^k_{i,j} = 1, \quad \forall (i,j) \in \mathcal{G}'$$

Base Constraint:
Each cell must be uniquely assigned to either a room or a corridor segment. This constraint is mathematically formulated as the left:

It's a little complicated, and please refer to our paper for details.

Corridor Connectivity:
A flow-based formulation ensures all open rooms and corridors form a single connected network. .

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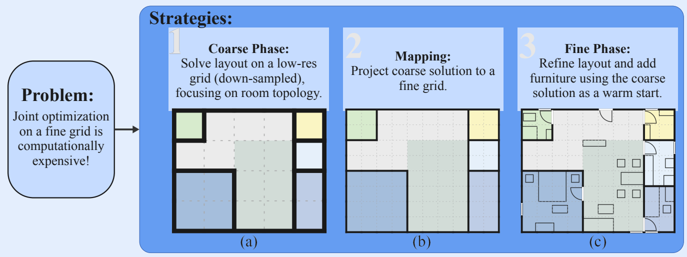
Room Accessibility:
Every room must be reachable and access points cannot be blocked by furniture.

$$f^{k,l}_{i,j} \leq x^k_{i,j}, \quad \forall (i,j) \in \mathcal{G}'$$

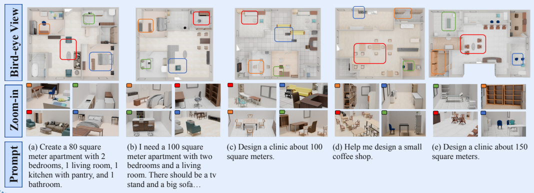
Furniture Logic:
Furniture must be contained within its assigned room and cannot overlap.

4 Coarse-to-Fine Optimization Strategy



4. Experiments

1 Qualitative Results



2 Comparison with Baselines

Table 1:

Method	OOR↓	OOB↓	IQA↑	IAA↑	CLIP↑
Holodeck	0.82	2.33	4.03	3.32	25.15
AnyHome	0.00	0.04	4.10	3.32	25.75
Ours	**0.00**	**0.00**	**4.17**	**3.35**	**26.50**

Quantitative evaluation results. Our method achieves the best performance in terms of physical plausibility, image quality/aesthetics, and text-image alignment.

Table 2:

Method	Semantic.↑	Layout.↑	Path.↑	MRR.↑
Holodeck	3.43	3.12	3.06	0.59
AnyHome	3.07	2.59	2.80	0.45
Ours	**3.77**	**3.23**	**3.41**	**0.80**

User study results. Our method achieved the highest score across all metrics, including semantic alignment, layout rationality, path clearance, and mean reciprocal rank.

3 Ablation Study

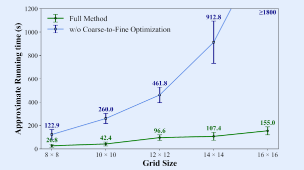


Figure 5: Ablation result of the coarse-to-fine strategy

5. Conclusion

Summary: We present a novel framework that integrates LLMs with integer programming to automate interior layout design, jointly optimizing room layout and furniture placement.

Advantages:

- Guarantees functional corridor connectivity and room accessibility.
- Zero overlap between furniture and walls.
- Efficient computation via Coarse-to-Fine strategy.

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