

Interactive Furniture Layout Using Interior Design Guidelines

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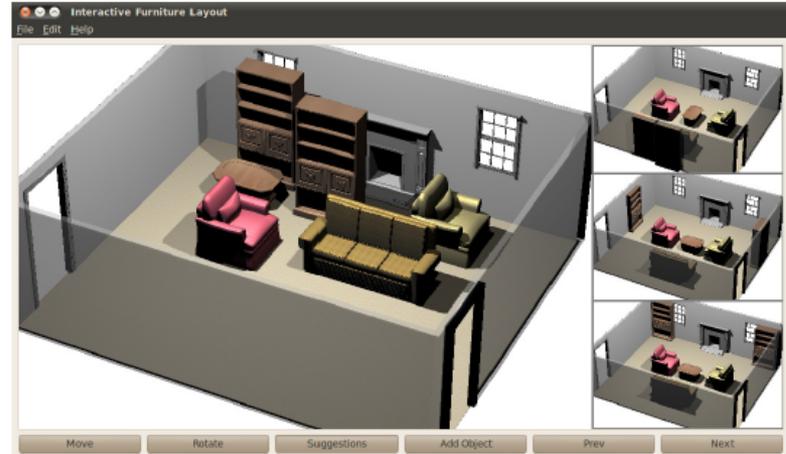
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Interactive Furniture Layout



Given Layout



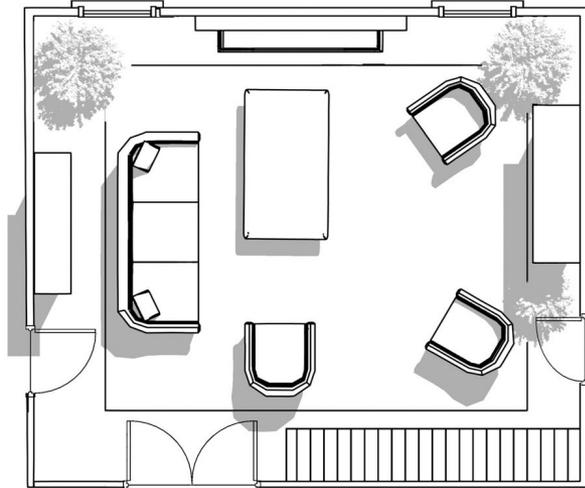
Interactive Tool



Suggested
Layout

The Challenge

- Most homeowners have no training in interior design
- Rooms “simply don’t look or feel right” [Ward, 1999]
- Difficult to pinpoint the problem



Before Professional Help

Interior Design Help

- Interior Design Literature
 - Talbott 1999, Ward 1999, Sharp 2008
- Commercial Products



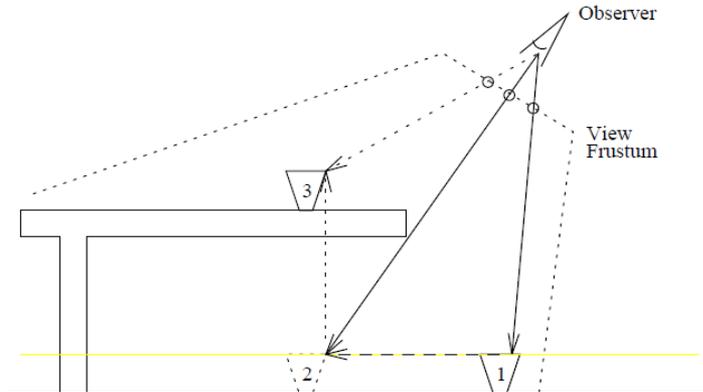
Paper Kits



Autodesk Homestyler



Related Work



Object Associations
Bukowski and Séquin, 1995



Constraint-Based Placement
Xu et al., 2002



Agent-Based Arrangement
Germer and Schwarz, 2009



Make It Home
Yu et al., 2011

Furniture Arrangement Comparison



Our Method

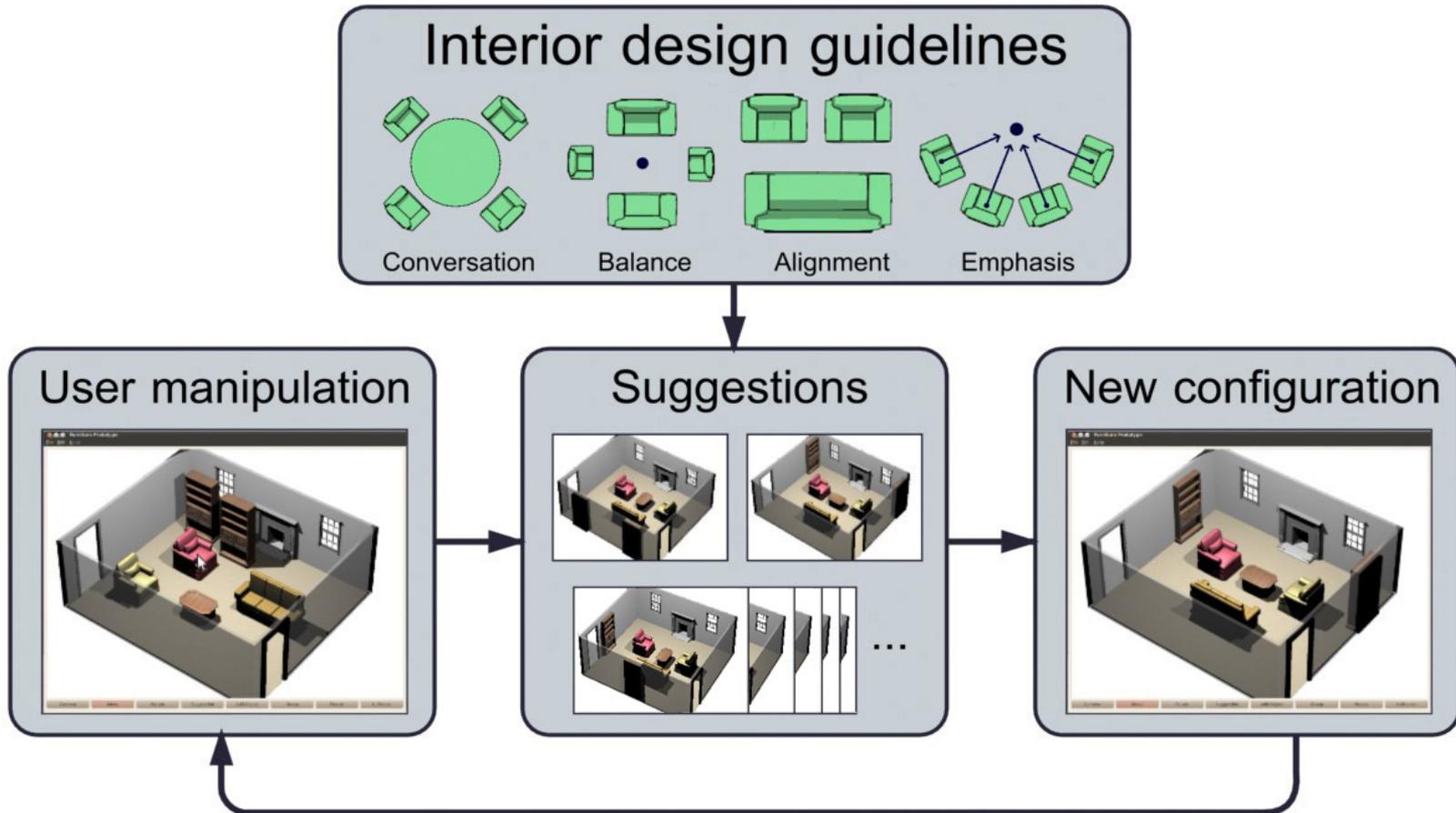
- Assisting homeowners
- Interactive & quick: user refines the suggestions
- Different cost function
 - Use design guidelines
- Different evaluation



Yu et al. 2011

- Content for virtual environments
- Fully automatic
- Different cost function
 - Based on examples
- Stacking

Overview



Interior Design Guidelines

Guideline Overview

- Functional Criteria

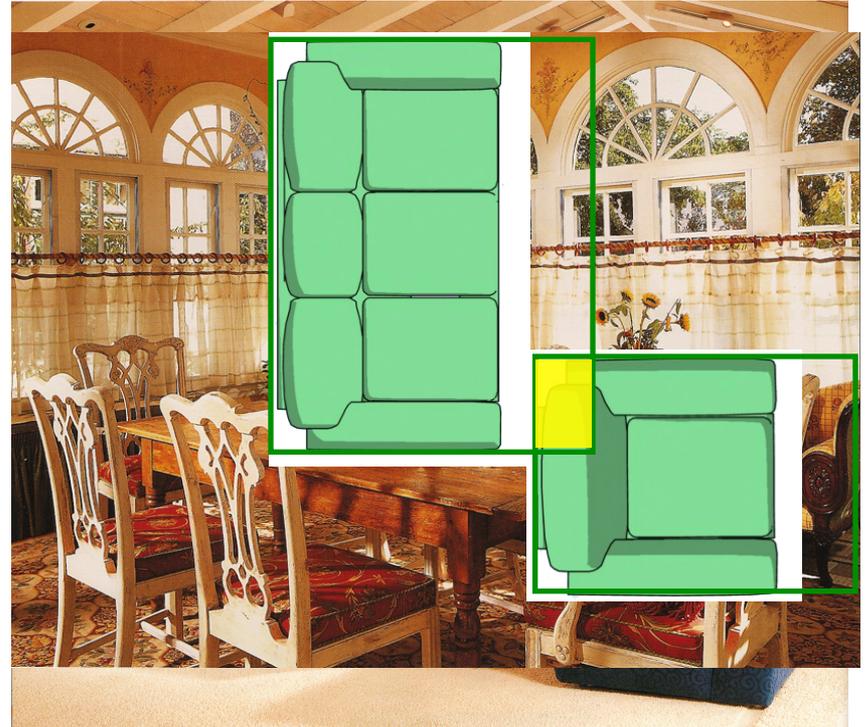
- Clearance
- Circulation
- Conversation
- Pairwise

- Visual Criteria

- Alignment
 - Balance
 - Emphasis
-

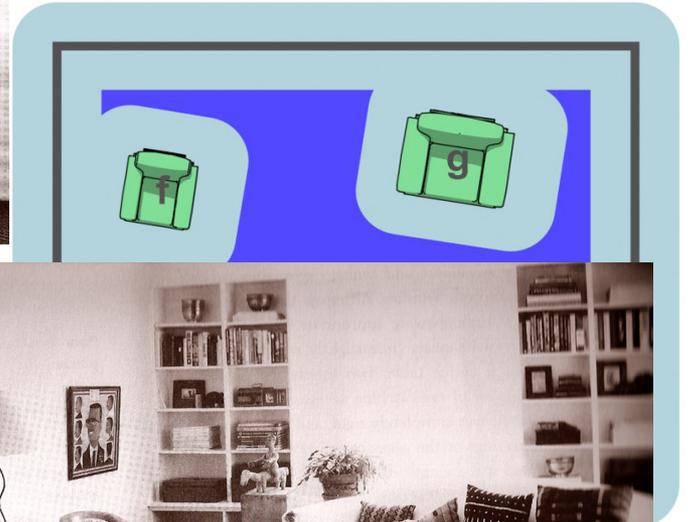
Functional Criteria

- Clearance
 - Kitchen tables need space around them
 - Sofas need space in front of them
 - Test for object intersection



Circulation

- A person needs about a 1.5 ft radius of circulation space
- Check if any part of the room becomes unreachable



Conversation

- Common mistake:
Seats too far apart
- Within a conversation group:
 - Seats should be about 4 – 8 ft apart
 - Seats should face each other



Other Pairwise Relationships



Coffee Table - Seat



End Table - Seat

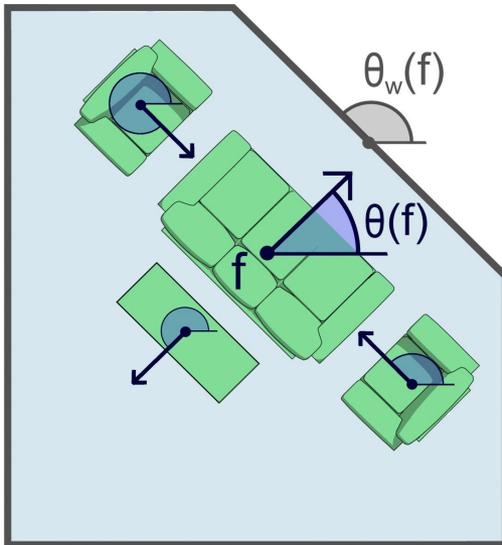


Nightstand
– Bed

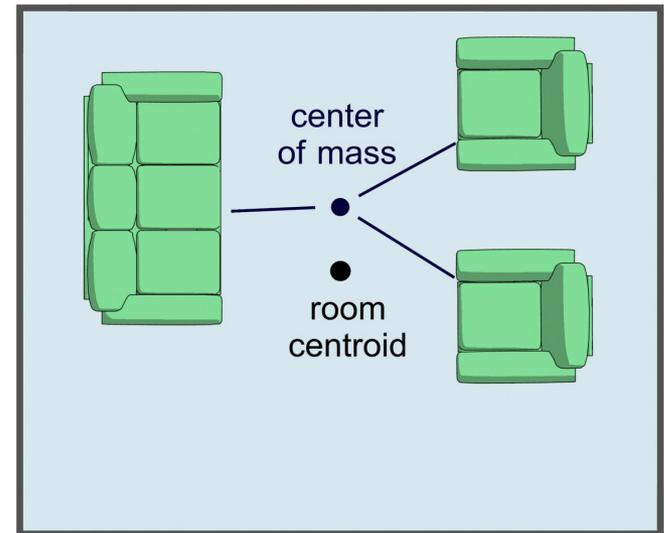
User can author
new constraints

Visual Criteria

- Objects are aligned...
 - to each other
 - to the nearest wall



- Balance



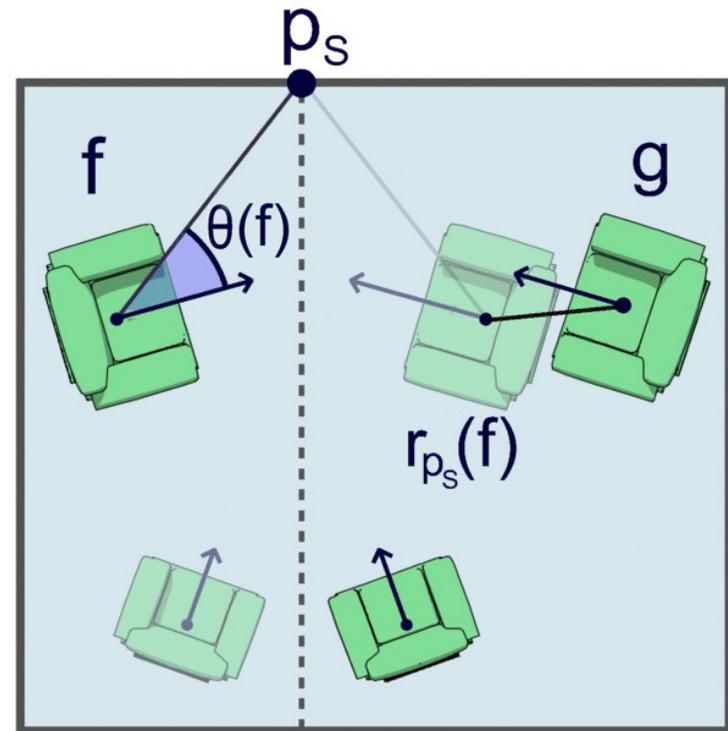
Emphasis

- Pick a focal point
 - Prominent architecture feature
- Fireplace, windows

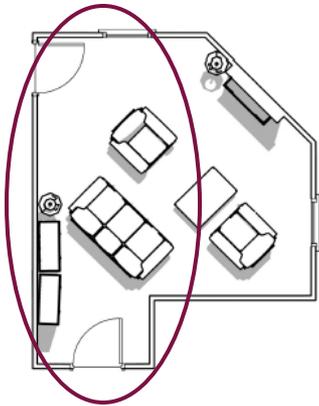


Emphasis

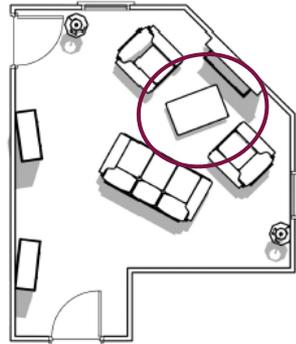
- Seats should face the focal point
- Similar objects should be placed symmetrically



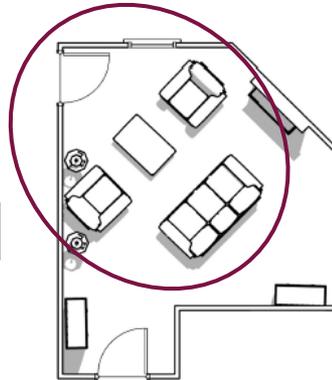
Effect of each term



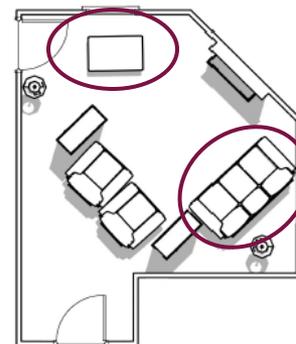
Clearance &
Circulation
Excluded



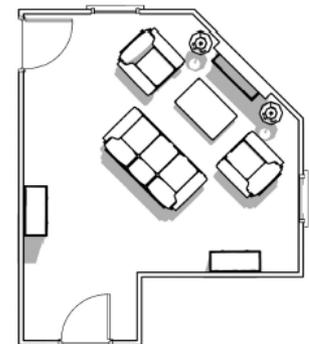
Alignment
Excluded



Emphasis
Excluded



Conversation
& Pairwise
Excluded

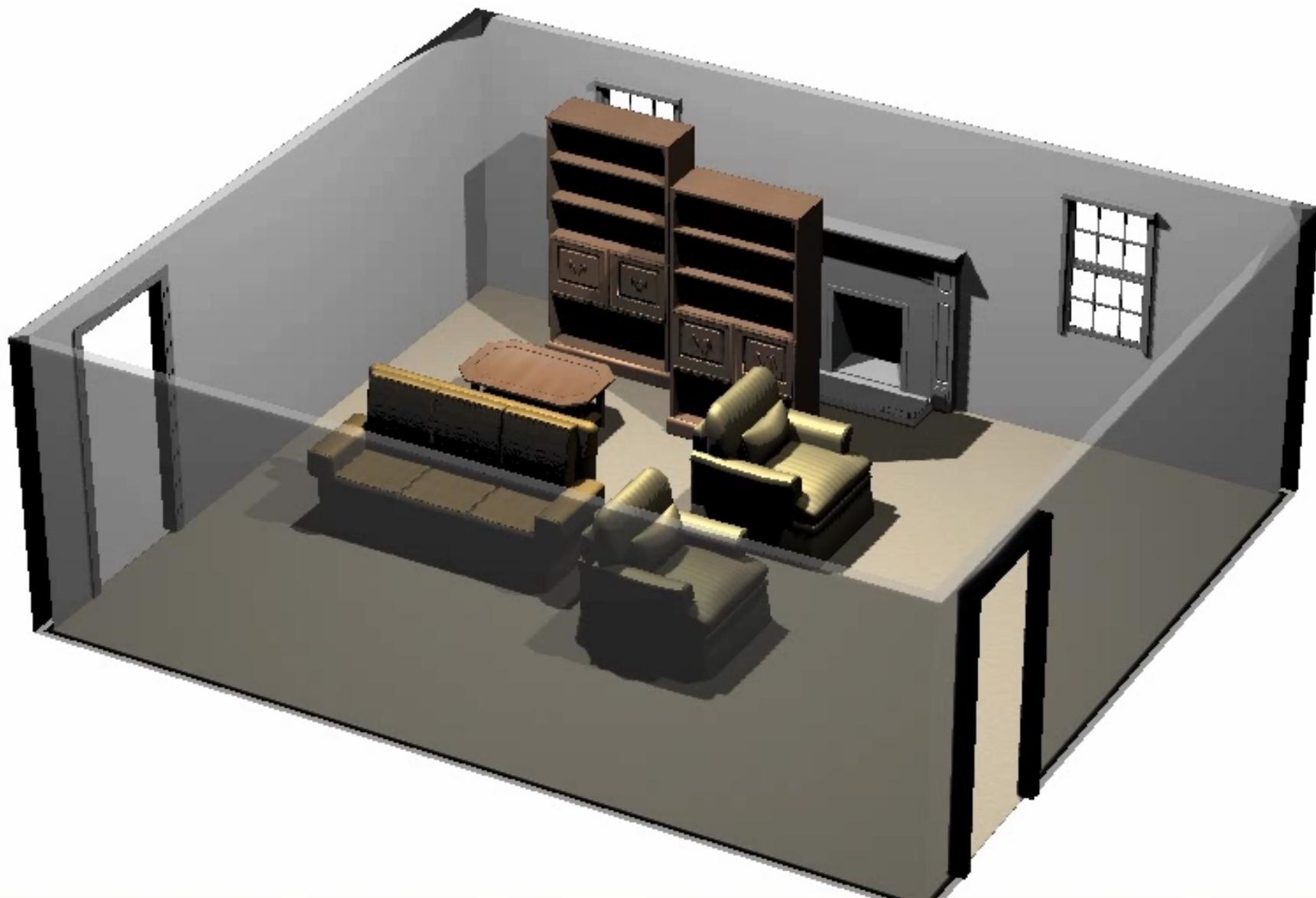


All Terms
Included



Interactive Furniture Arrangement

File Edit Help



Move

Rotate

Suggestion

Add Object

Freeze

Unfreeze

Suggestion Generator

- \mathcal{F} is the current furniture layout
- Guidelines are used in a cost function

$$c(\mathcal{F}) = w_{cv}m_{cv}(\mathcal{F}) + w_{ci}m_{ci}(\mathcal{F}) + w_{pw}m_{pw}(\mathcal{F}) + w_{cn}m_{cn}(\mathcal{F}) \\ + w_{vb}m_{vb}(\mathcal{F}) + w_{al}m_{al}(\mathcal{F}) + w_{em}m_{em}(\mathcal{F})$$

- Suggestions are samples from a probability distribution

$$p(\mathcal{F}) = \frac{1}{Z} \exp(-\beta c(\mathcal{F})) \quad \beta, Z \text{ Constants}$$

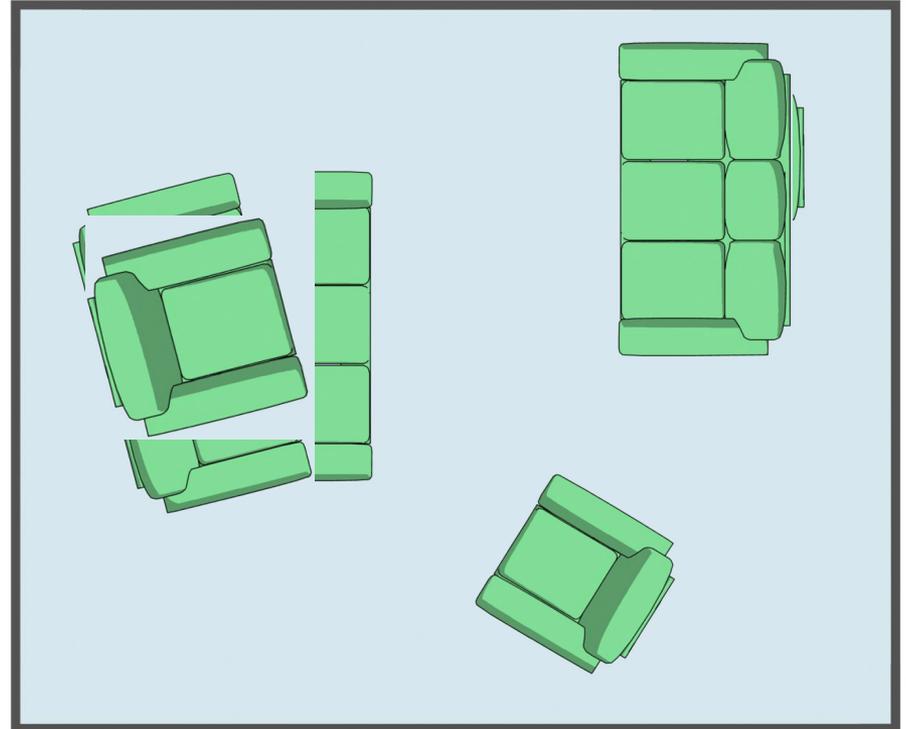
Metropolis-Hastings Algorithm

- Each iteration, propose a new layout \mathcal{F}^*
- Accept with probability

$$\alpha(\mathcal{F} \rightarrow \mathcal{F}^*) = \min \left(1, \frac{p(\mathcal{F}^*)}{p(\mathcal{F})} \right)$$

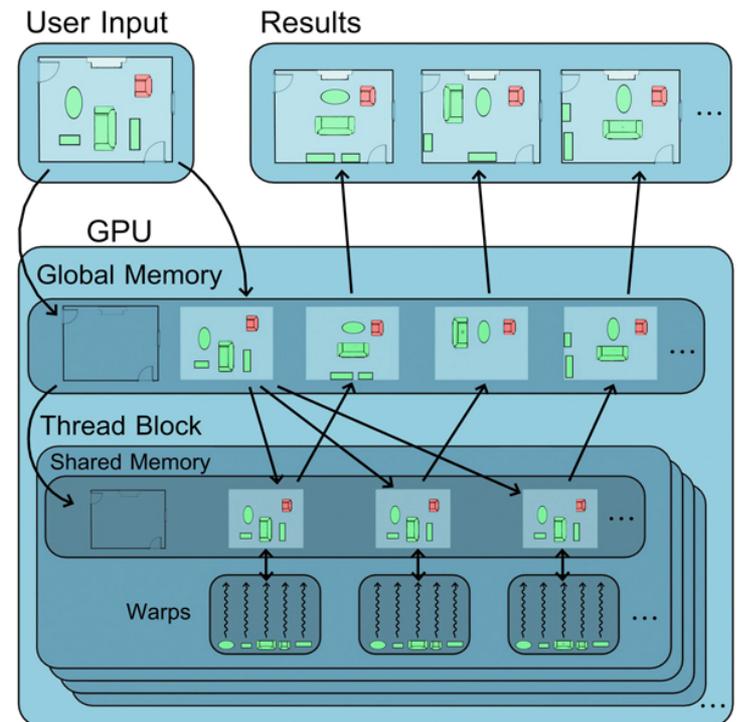
Proposed Move

- Change one item's position
- Change one item's orientation
- Swap the positions and orientations of two items



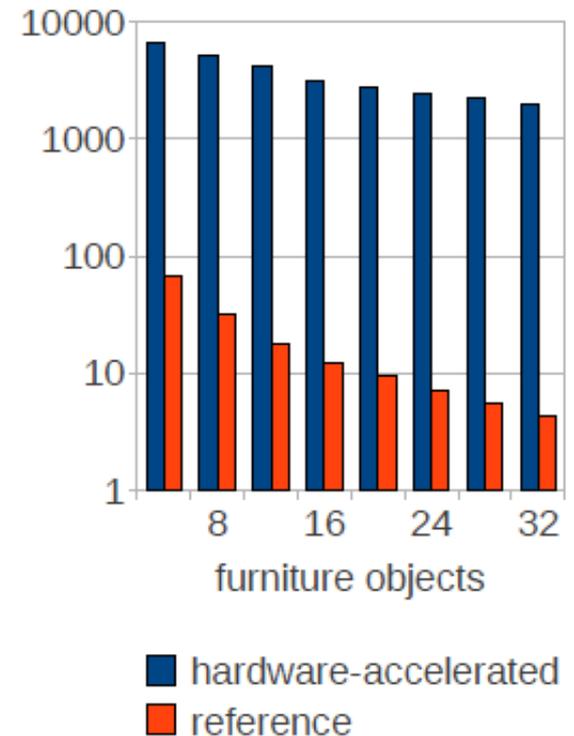
Implementation

- Metropolis-Hastings algorithm is slow
- Parallel implementation in graphics hardware
- Parallel tempering
 - Set of independent Markov chains
 - Different temperature constants
 - Swap samples between the chains



Computation Time

- Hardware-accelerated implementation is over two orders of magnitude faster
- 36 suggestions generated in about one second



Suggestions

- User can look at dozens of suggestions
 - The suggestions are ranked
 - Diversify the list using the Maximal Marginal Relevance criterion
-

Evaluation & Results

User Study

- Users arrange furniture in several rooms
 - Assisted mode
 - Unassisted mode



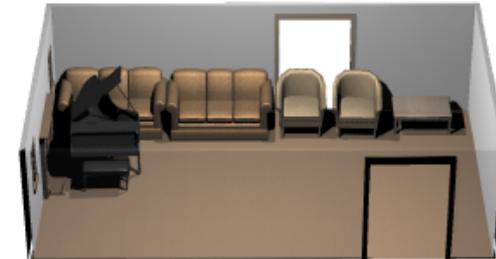
(a) Living Room



(b) Living Room



(c) Game Room



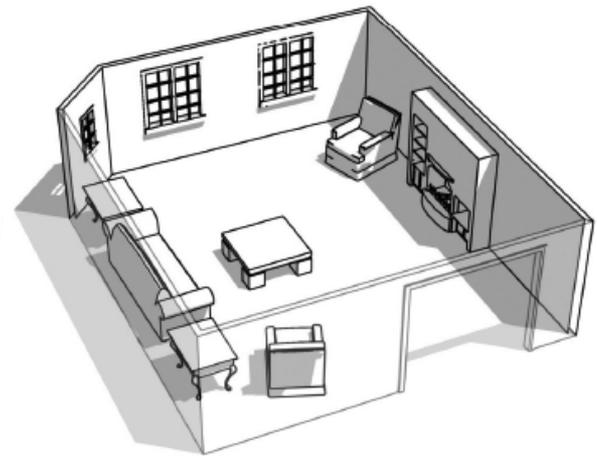
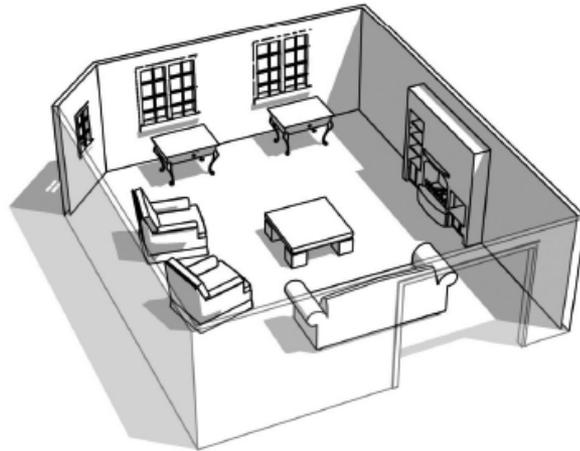
(d) Piano Room



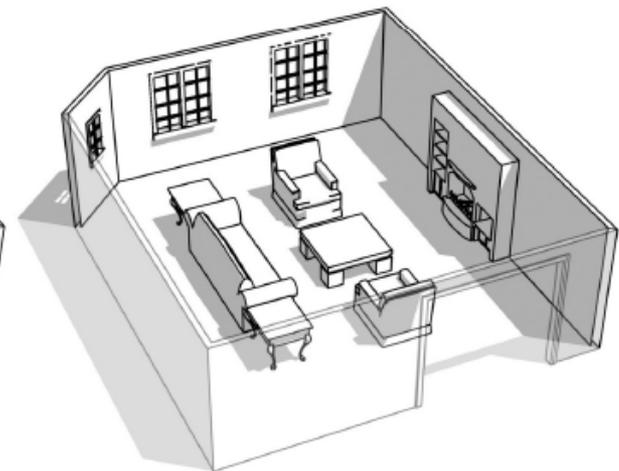
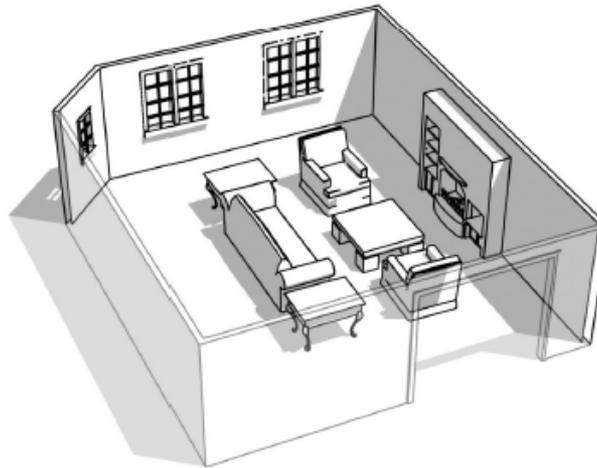
(e) Living and Dining

User Study Results

Layouts
produced
without
suggestions

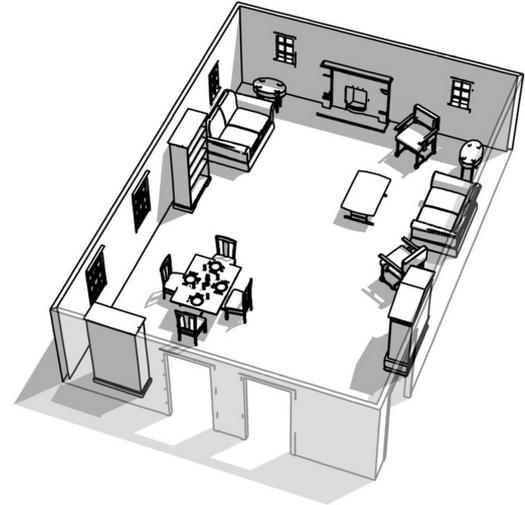
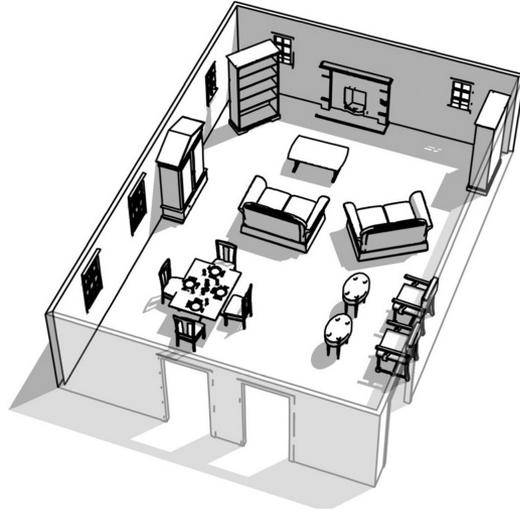


Layouts
produced
with
suggestions

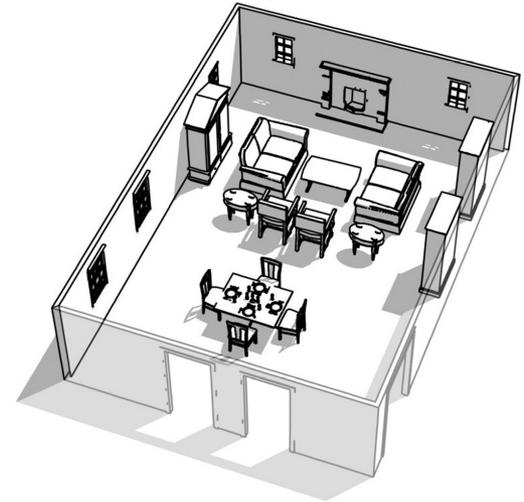
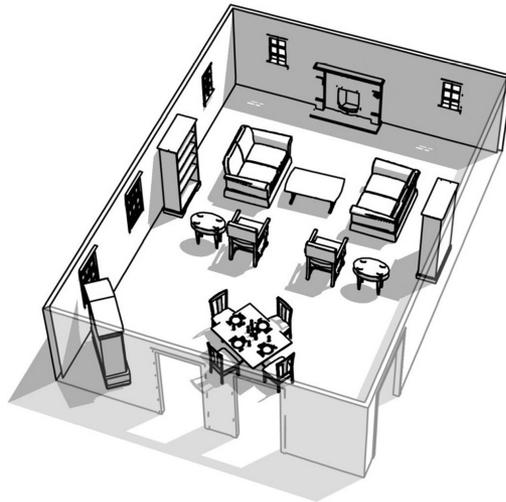


User Study Results

Layouts
produced
without
suggestions

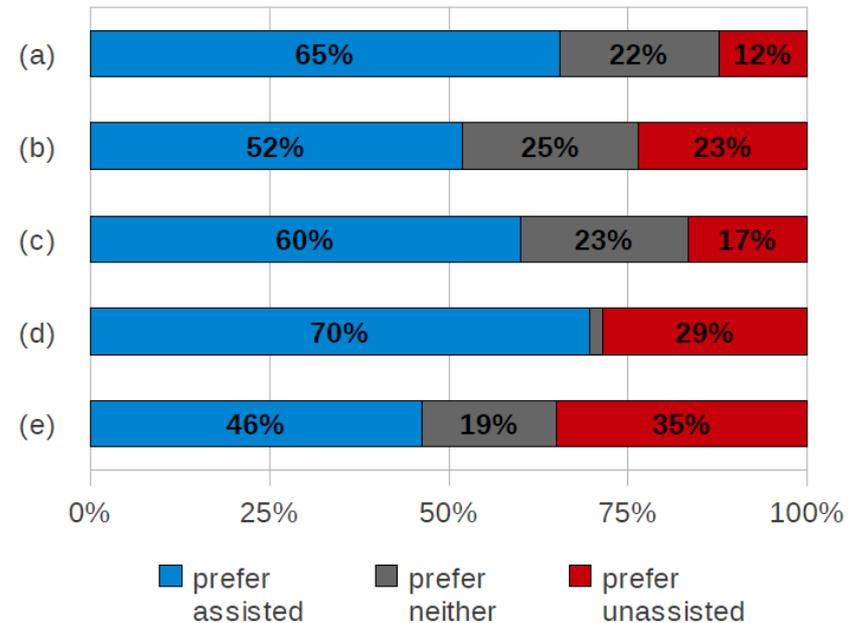


Layouts
produced
with
suggestions



User Study Results

- Participants produced 40 unassisted layouts, 40 assisted layouts
- Layouts evaluated by interior designers
- Randomized pairwise comparison



Future Directions

- Non-residential spaces
 - Suggest furniture items to add or remove
 - Much more to interior design
 - Color and material
 - Art and accessories
 - Lighting
-

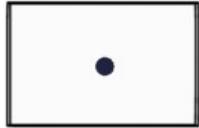
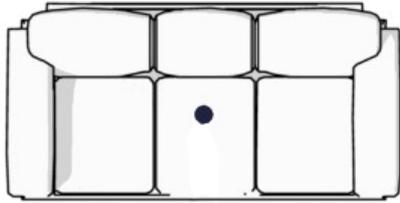
Conclusion

- Operationalized a set of design guidelines
 - Created an interactive system based on these guidelines
-

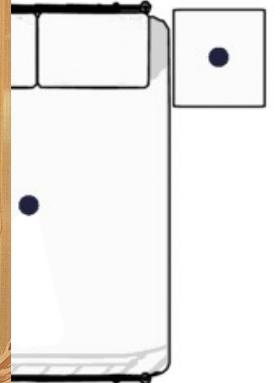


Unassisted Layout

Other Pairwise Relationships



Coffee Table - Seat



and - Bed

■ Us