Retargeting Virtual Worlds

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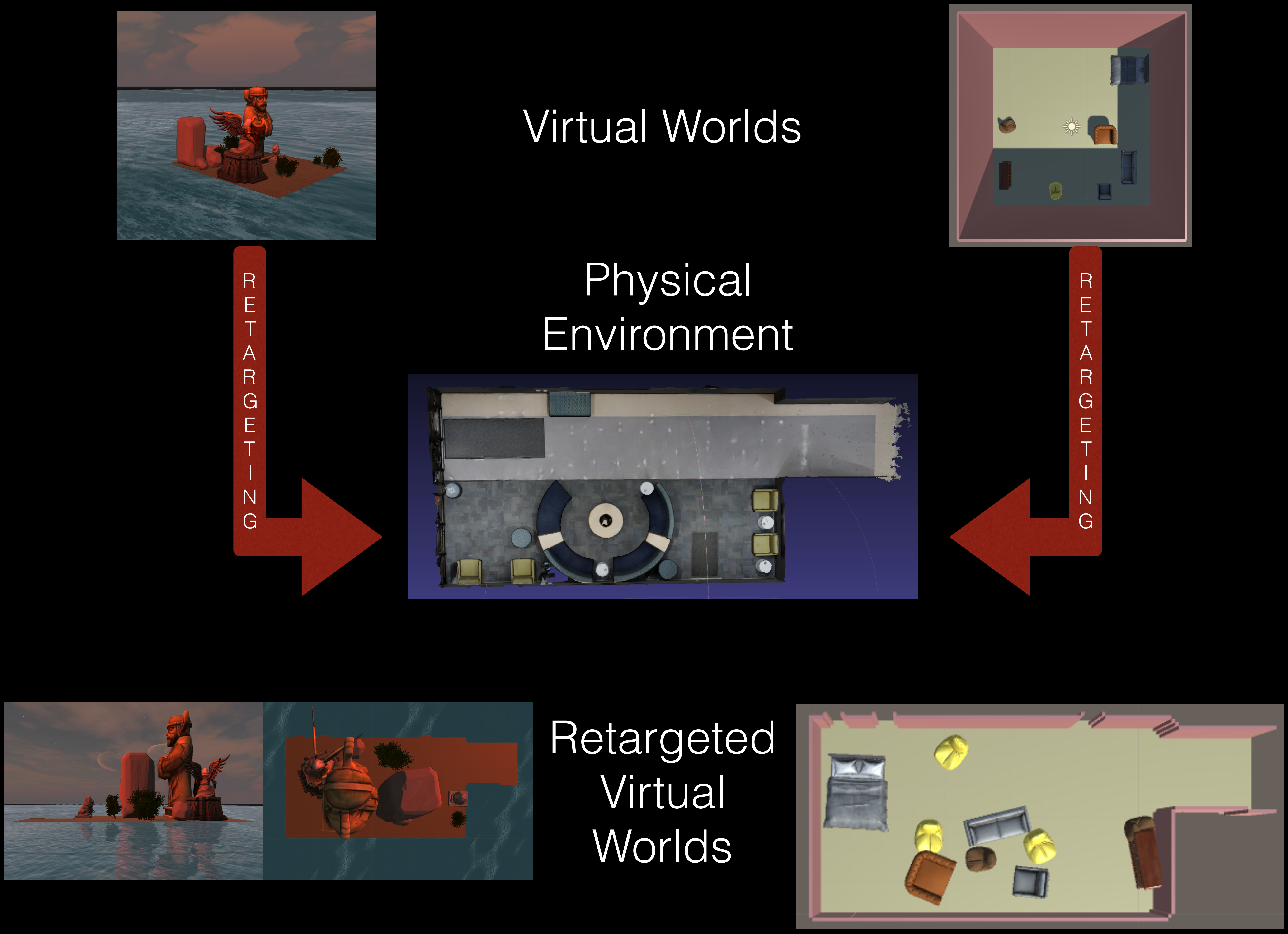
Advisors: Prof. Matthew Turk, Prof. Tobias Hollerer


Virtual Worlds
Physical Environment
RETARGETING
RETARGETING
Retargeted Virtual Worlds

Why Retarget?

Real Walking is the Best

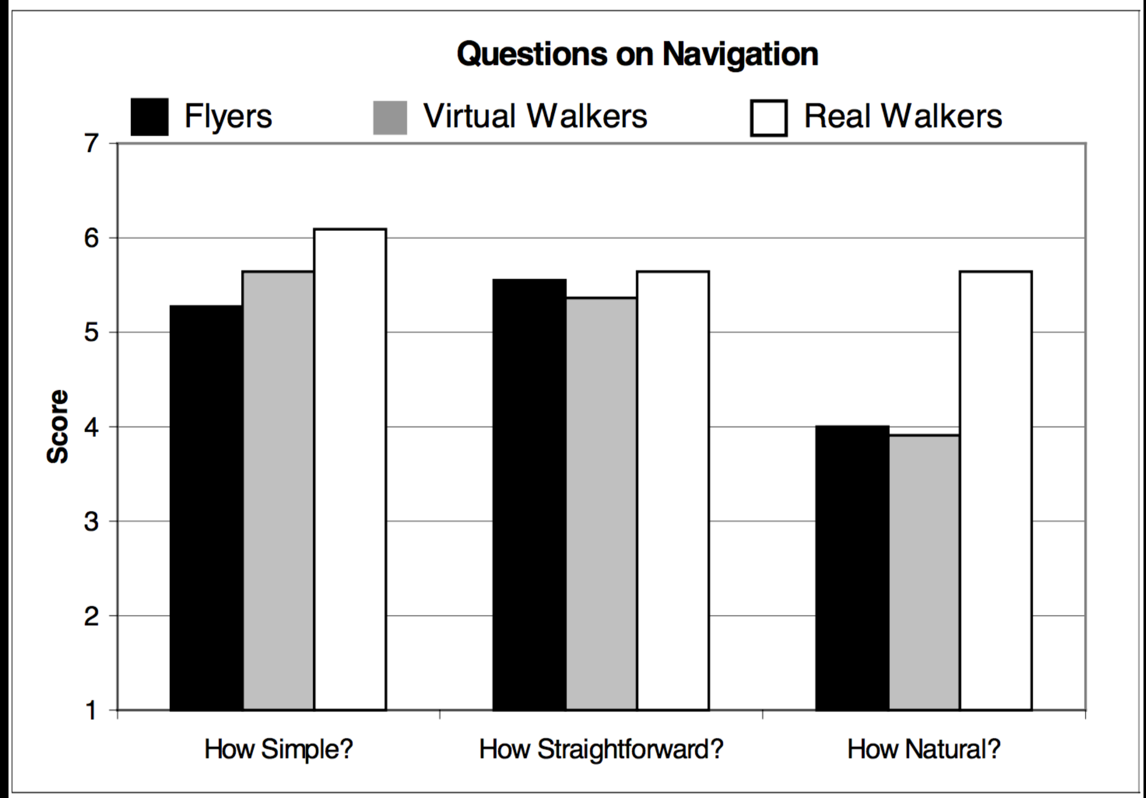
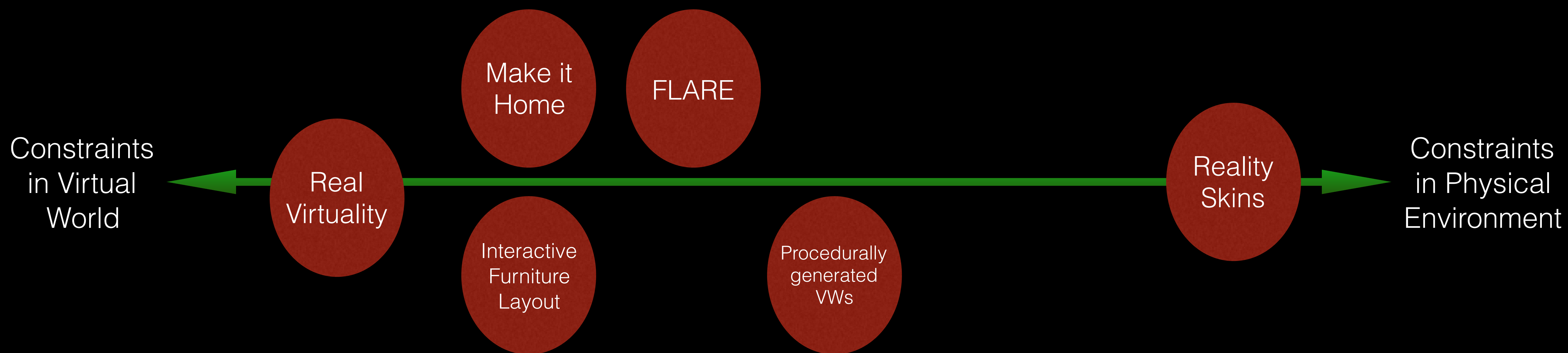


Figure 5: Ease of locomotion across groups.

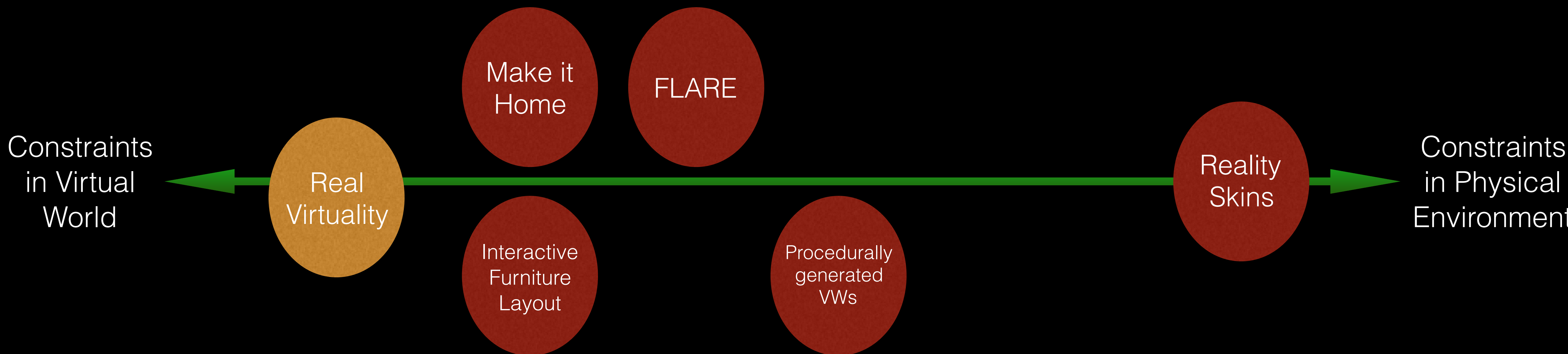
Usoh, Martin et al. (1999). “Walking> walking-in-place> flying, in virtual environments”. In: Proceedings of the 26th annual conference on Computer graphics and inter*active techniques*. ACM Press/Addison-Wesley Publishing Co., pp. 359–364

War of the Worlds

Related Work



Related Work



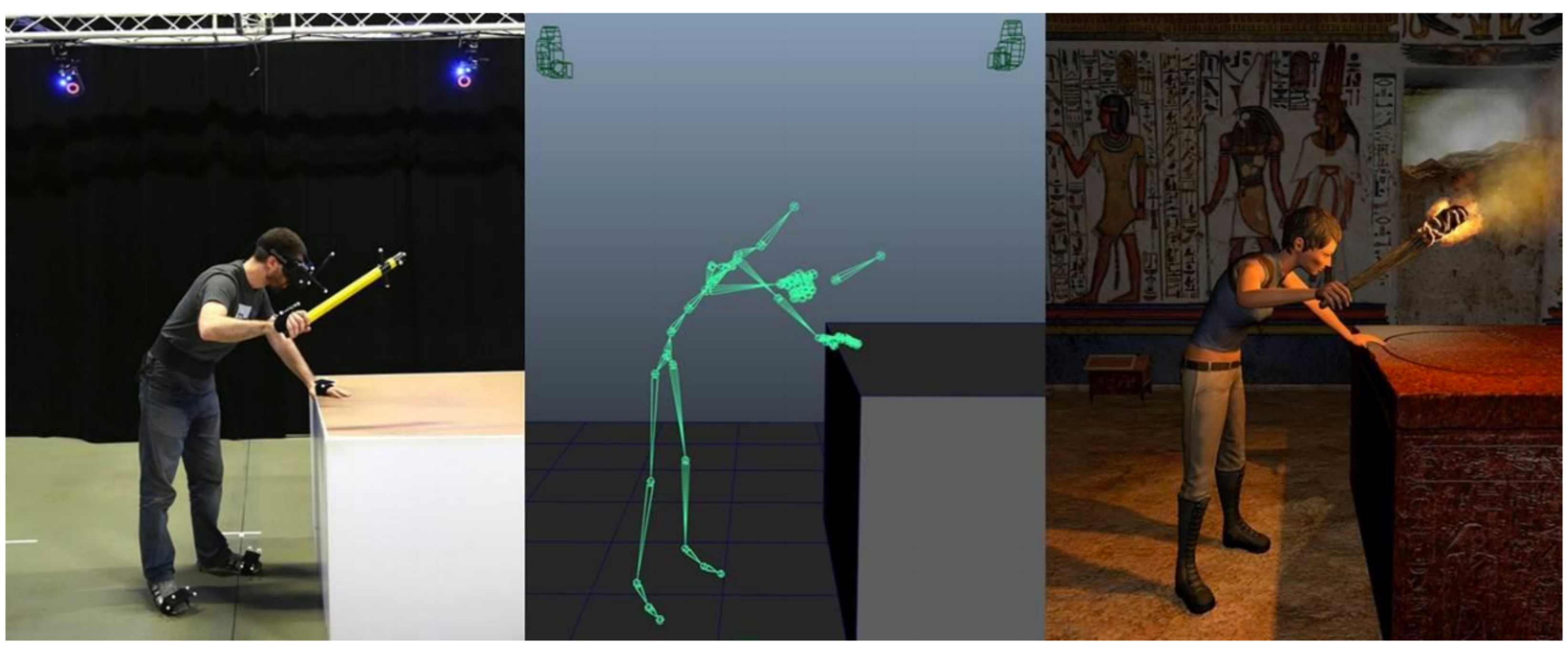


Fig.2: From Real to Virtual. How the system interprets motion capture data and renders it in a 3D environment.

C. Caecilia and V. Trouche
'*Real Virtuality*'. Tech. rep.
Artanim Interactive (2015)

Related Work

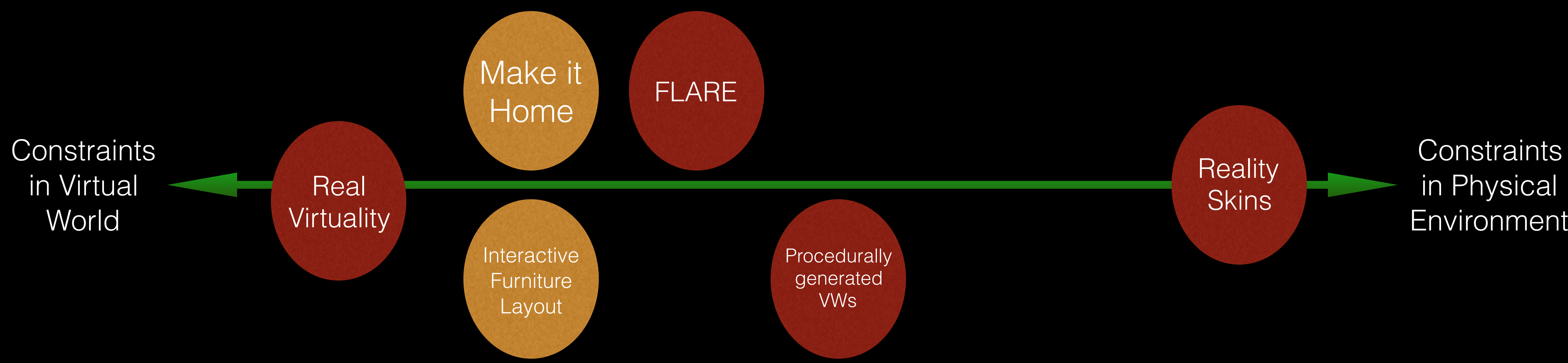


Figure 1: *Left: Initial layout where furniture pieces are placed arbitrarily. Middle and right: Two synthesized furniture arrangements optimized to satisfy ergonomic criteria, such as unobstructed accessibility and visibility, required of a realistic furniture configuration.*

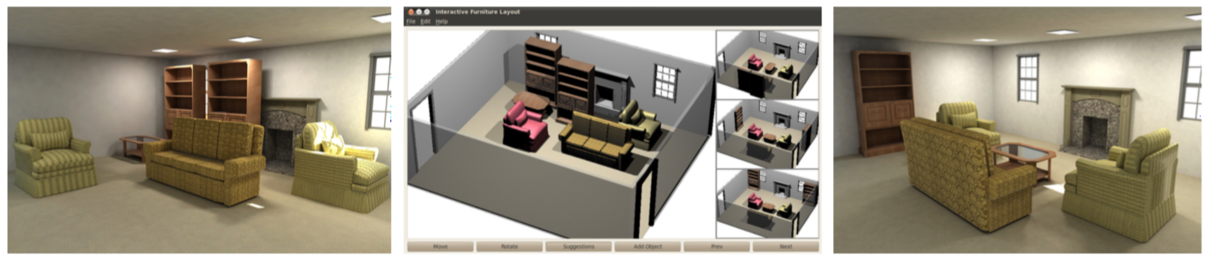
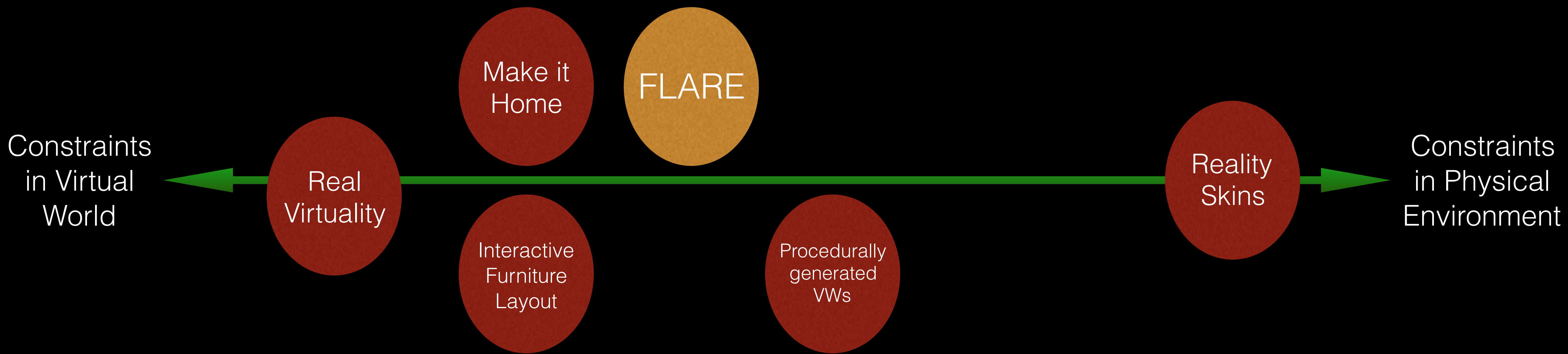


Figure 1: *Interactive furniture layout. For a given layout (left), our system suggests new layouts (middle) that respect the user's constraints and follow interior design guidelines. The red chair has been fixed in place by the user. One of the suggestions is shown on the right.*

Yu, Lap Fai et al. (2011).
"Make it home: automatic optimization of furniture arrangement"

Merrell, Paul et al. (2011).
"Interactive furniture layout using interior design guidelines".
In: ACM Transactions on Graphics (TOG). Vol. 30. 4. ACM, p. 87

Related Work



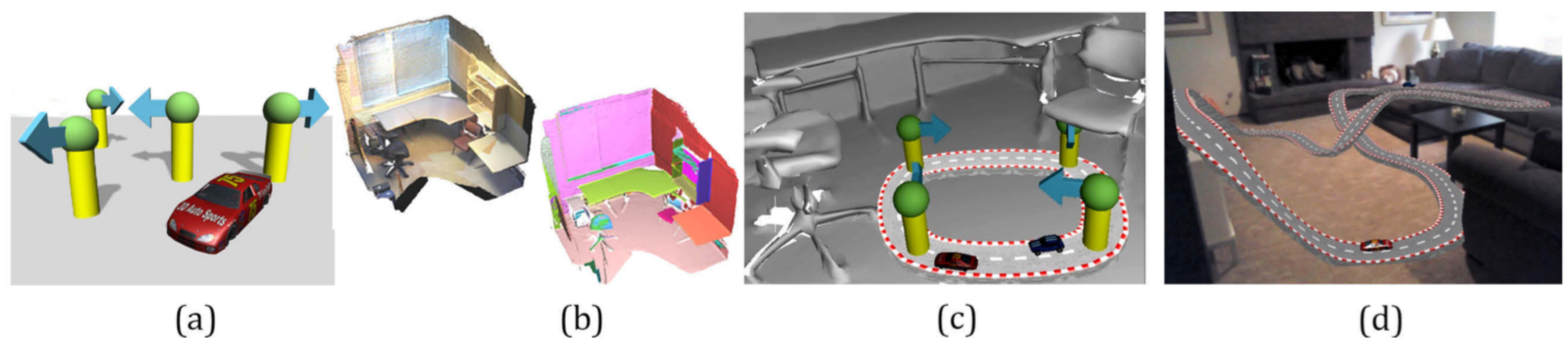
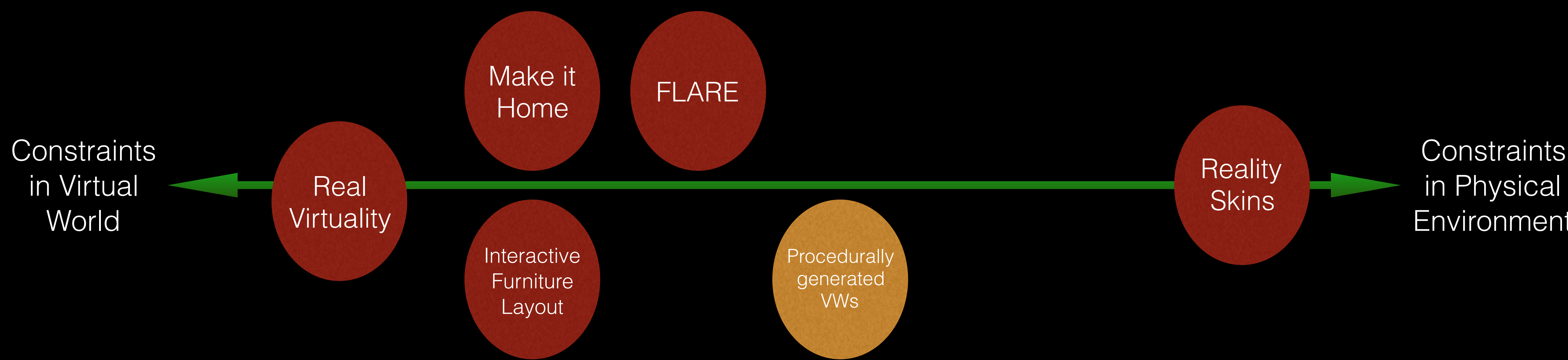


Figure 1: Designing an immersive augmented reality (AR) application such as a dynamic racing game is difficult. In our framework (a) declarative rules are used to define application elements and the rules governing them (b) in real-time we analyze an environment to extract scene geometry and horizontal and vertical planes (c) our move-making algorithm targets the application to the room (d) an additional result of our system in a different room with a longer track.

Gal, Ran et al. (2014). "FLARE: Fast layout for augmented reality applications".
In: *Mixed and Augmented Reality (ISMAR), 2014 IEEE International Symposium on*. IEEE, pp. 207–212

Related Work



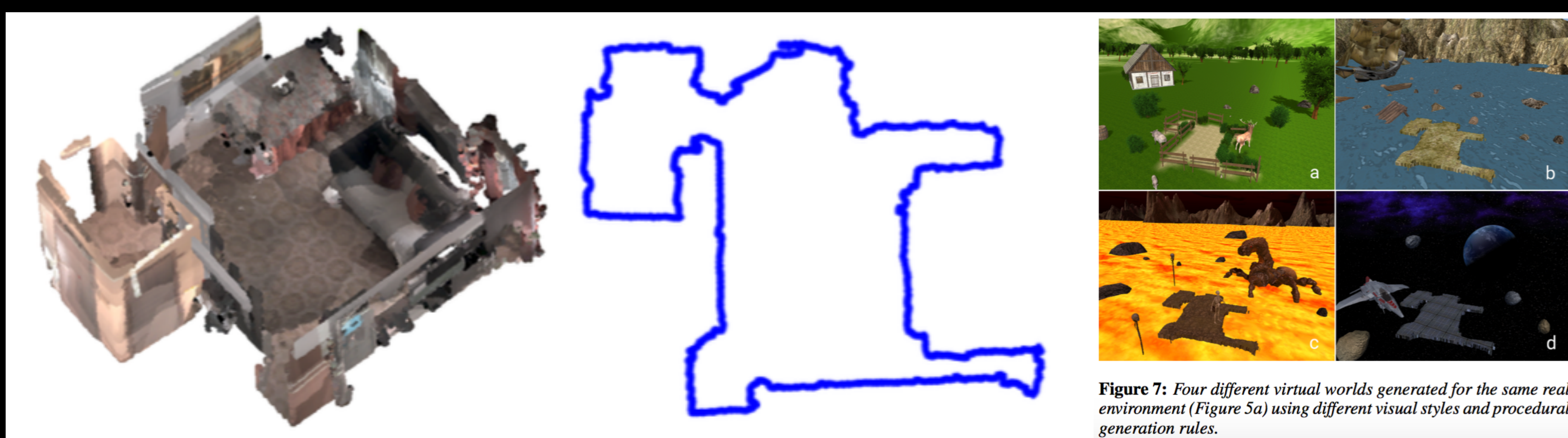
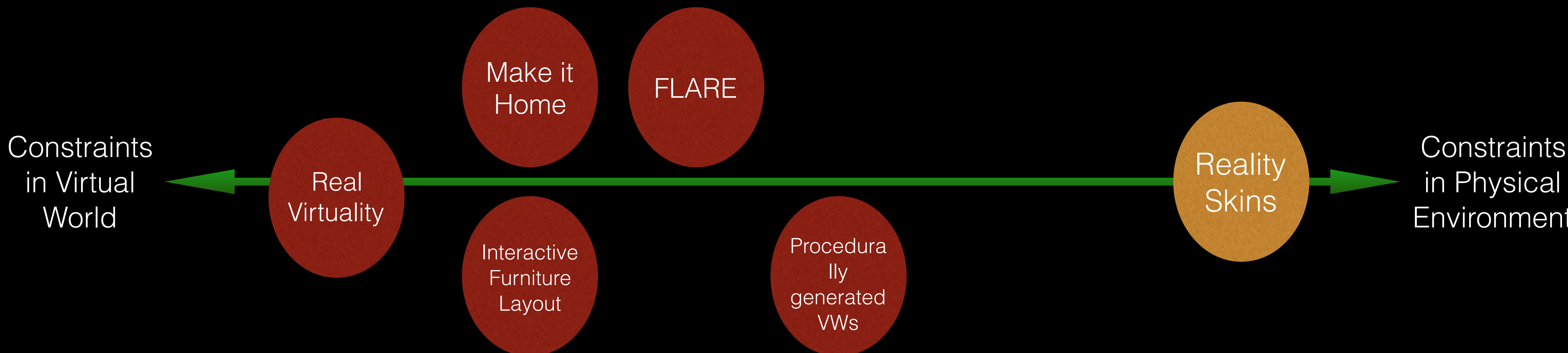


Figure 7: *Four different virtual worlds generated for the same real environment (Figure 5a) using different visual styles and procedural generation rules.*

Sra, Misha et al. (2016).
"Procedurally generated virtual reality from 3D reconstructed physical space".
In: Proceedings of the 22nd ACM Conference on Virtual Reality Software and Technology. ACM, pp. 191–200

Related Work



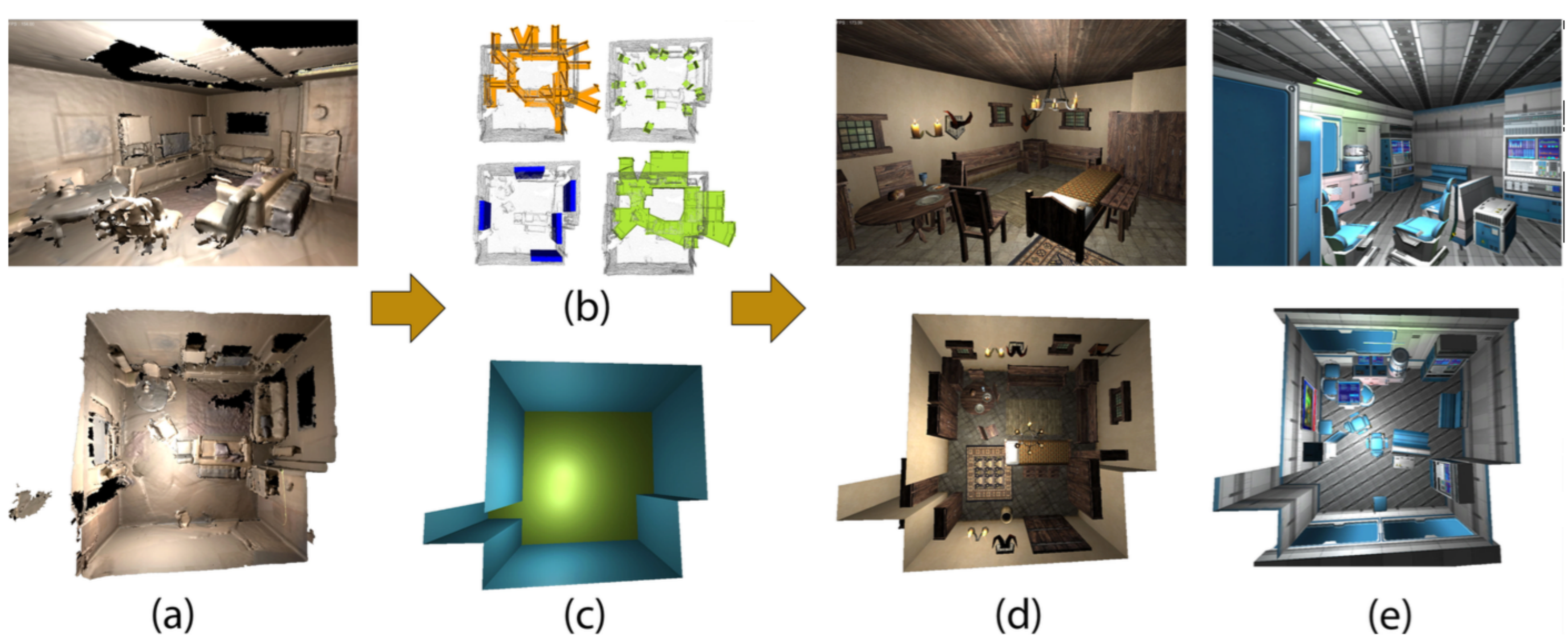
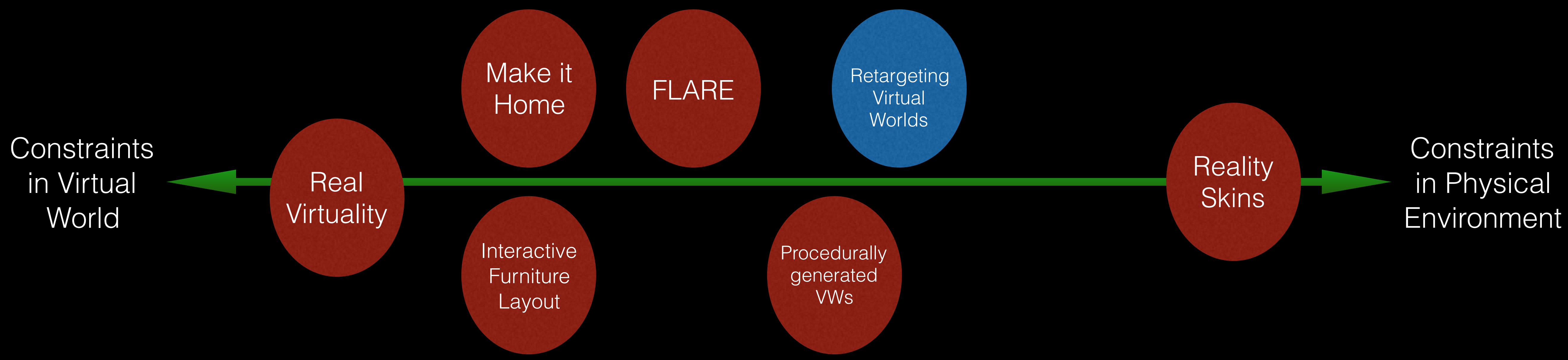


Figure 1: (a) We scan and process the surrounding environment (b) We populate the scene with different objects from a specialized data-set, and optimize to find the best combined layout (c) We detect planar areas and infer a complete floor-plan (d) We combine the floor-plan and object layout, creating a **Reality Skin**, a large scale, dynamic and tactile VR experience (e) Each scene can be transformed into a variety of worlds, such as this space station.

Shapira, Lior and Daniel Freedman (2016). “Reality Skins: Creating Immersive and Tactile Virtual Environments”.
In: *Mixed and Augmented Reality (ISMAR), 2016*

Related Work



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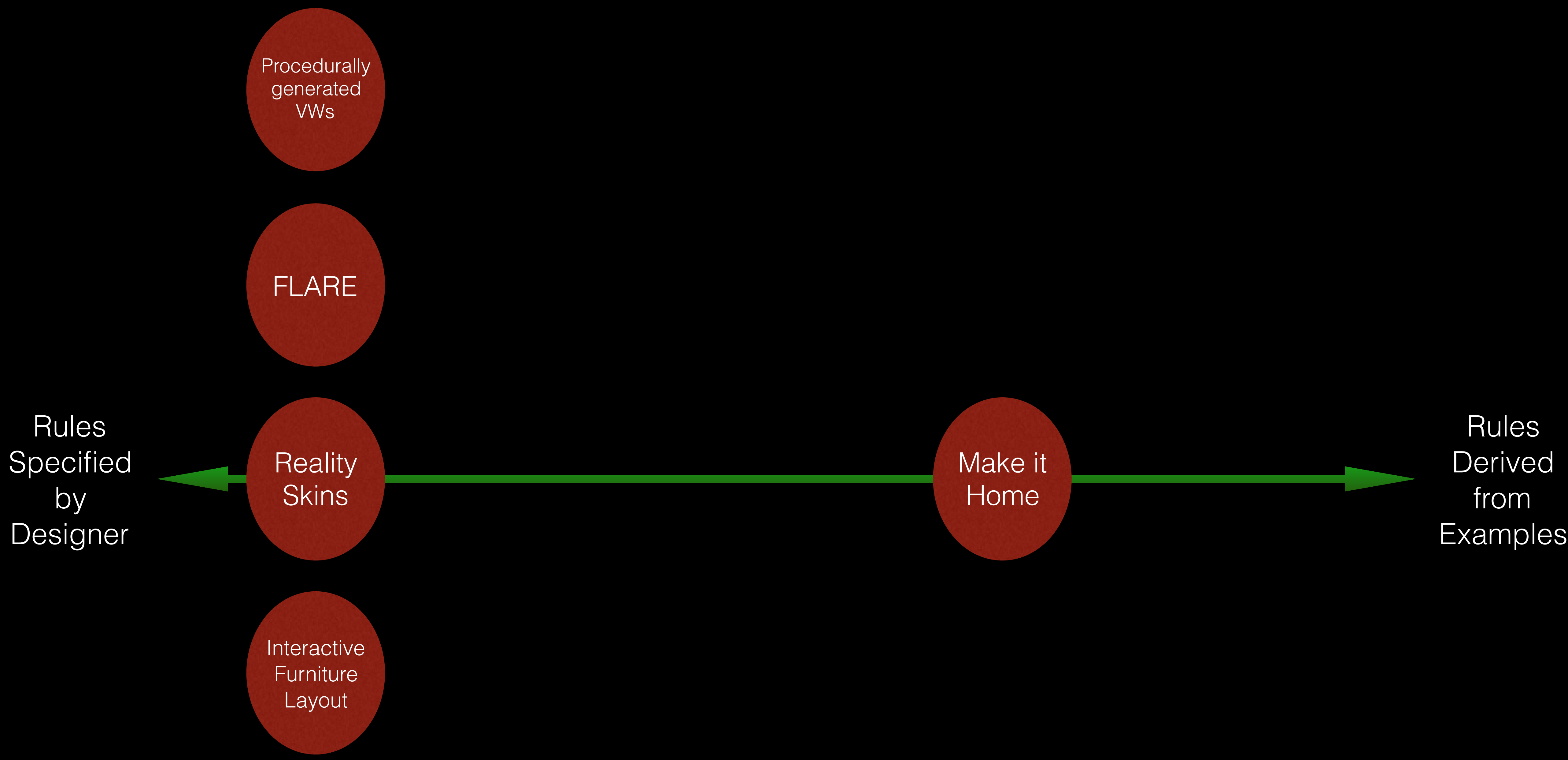

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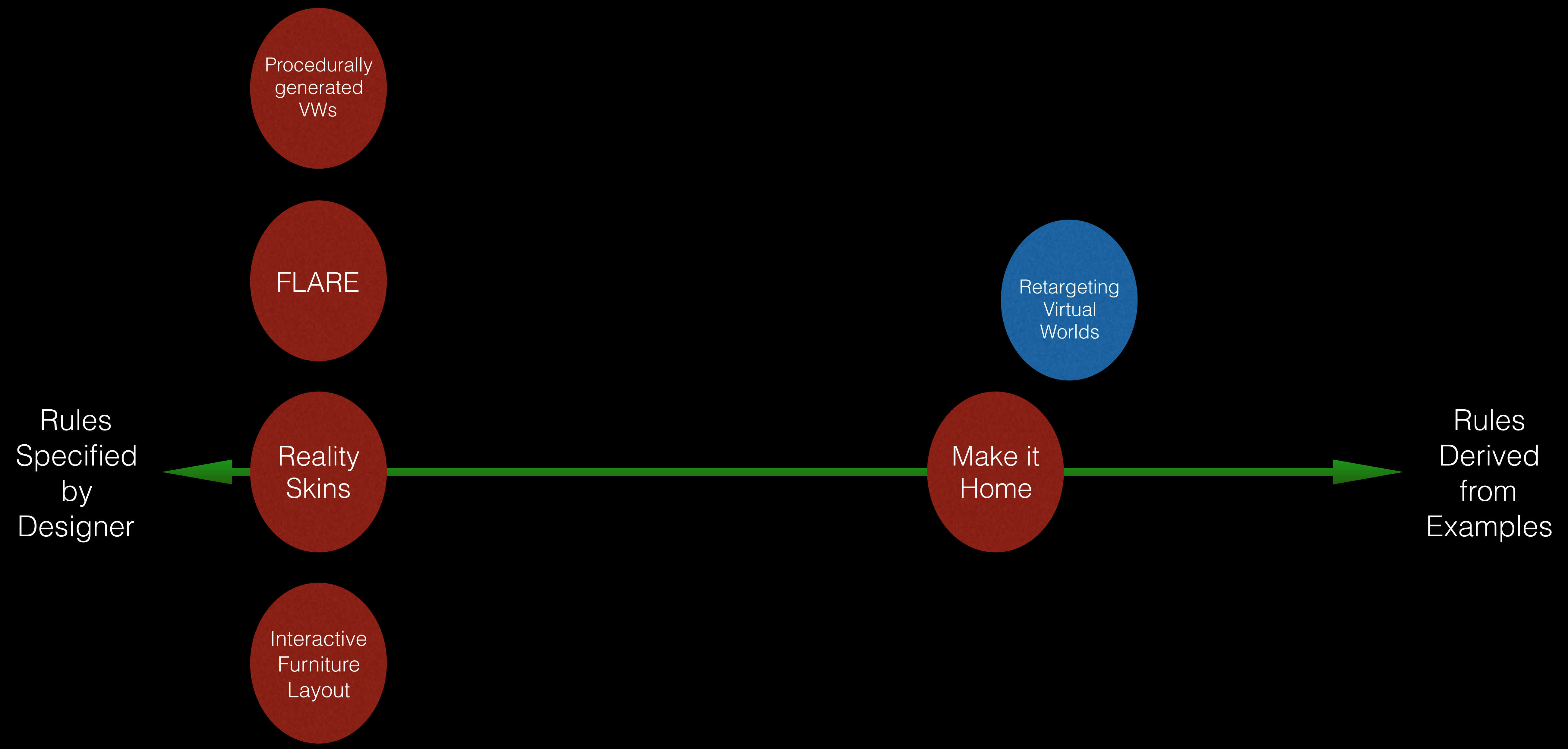

Retargeting Scheme

- Representation
- Fitness Computation
- Optimization
- Retargeted Virtual World Generation

Retargeting Scheme

- Representation
- Fitness Computation
- Optimization
- Retargeted Virtual World Generation

Representation - Physical Environment

- Mesh model of Physical Environment from Matterport System
- Mesh processed to get voxel representation of scene occupancy
- 0 - unoccupied and 1 - occupied

Representation - Virtual World Objects

- Mesh models of Virtual World Objects from Unity Game Engine
- Meshes processed to get a voxel representation of scene occupancy
- 0 - unoccupied and 1 - occupied
- Designer specified properties
    - Limits on Scaling
    - Limits on Rotation
    - Limits on Instantiation
    - Priority or Filler

Retargeting Scheme

- Representation
- Fitness Computation
- Optimization
- Retargeted Virtual World Generation

Fitness Computation

- Maximize geometric match with Physical Environment.
- Avoid Collision between Virtual World Objects
- Preserve Semantics of the Virtual World after Retargeting

Fitness = w1 x Mismatch Score + w2 x Collision Score + w3 x Semantic Score

Fitness Computation

Fitness = w1 x Mismatch Score + w2 x Collision Score + w3 x Semantic Score

- MMS quantifies the mismatch between the placement of the virtual world objects and the geometry of the physical environment

$$MMS = m_1 \frac{\sum_{i \in PE}(PE(i)).(1 - RVW(i))}{\sum_{i \in PE} PE(i)} + m_2 \frac{\sum_{i \in PE}(1 - PE(i)).\,(RVW(i))}{\sum_{i \in PE}(1 - PE(i))}$$

- MMS should ideally be very low to indicate a very good match with the scene geometry

Fitness Computation

Fitness = w1 x Mismatch Score + w2 x Collision Score + w3 x Semantic Score

- CS quantifies the collision between the objects in the retargeted virtual world

$$CS = \frac{1}{2N(N-1)} \sum_{m,n<N,m\neq n} \left(\frac{\sum_{i\in O_m,O_n} O_m(i).O_n(i)}{\sum_{i\in O_m} O_m(i)} + \frac{\sum_{i\in O_m,O_n} O_m(i).O_n(i)}{\sum_{i\in O_n} O_n(i)} \right)$$

- Ideally, CS is zero to indicate no collision between objects

Fitness Computation

Fitness = w1 x Mismatch Score + w2 x Collision Score + w3 x Semantic Score

Semantic Score

- Distance Rank Score - Preserves the distance order of priority objects
- Relative Orientation Score - Preserves the relative orientation of priority objects
- Weighted by the object priority

Retargeting Scheme

- Representation
- Fitness Computation
- Optimization
- Retargeted Virtual World Generation

Optimization

- Number of objects in a virtual world is variable but maximum number of occurrences of each object is specified.
- The goal is to determine, for all objects,
    - Presence / Absence
    - Position
    - Orientation
    - Scale

Genetic Algorithm

- Each individual in the population is a Retargeted Virtual World.
- Population of 200 individuals
- Elite Count of 10
- Random Initialization in occupied areas of the physical environment
- The best individual from the last generation gives us the configuration of objects in the optimally retargeted virtual world

Retargeting Scheme

- Representation
- Fitness Computation
- Optimization
- Retargeted Virtual World Generation

Retargeted Virtual World Generation

- Best individual in the last generation gives us the optimal placement of objects in the Retargeted Virtual World

- Floor textures, boundary elements and skybox comprise the environment of the virtual world and these are preserved in the Retargeted Virtual World

Results

- For different levels of constraints in the physical environment
- For different levels of constraints in the virtual world
- For real world scenes

Results

- For different levels of constraints in the physical environment
- For different levels of constraints in the virtual world
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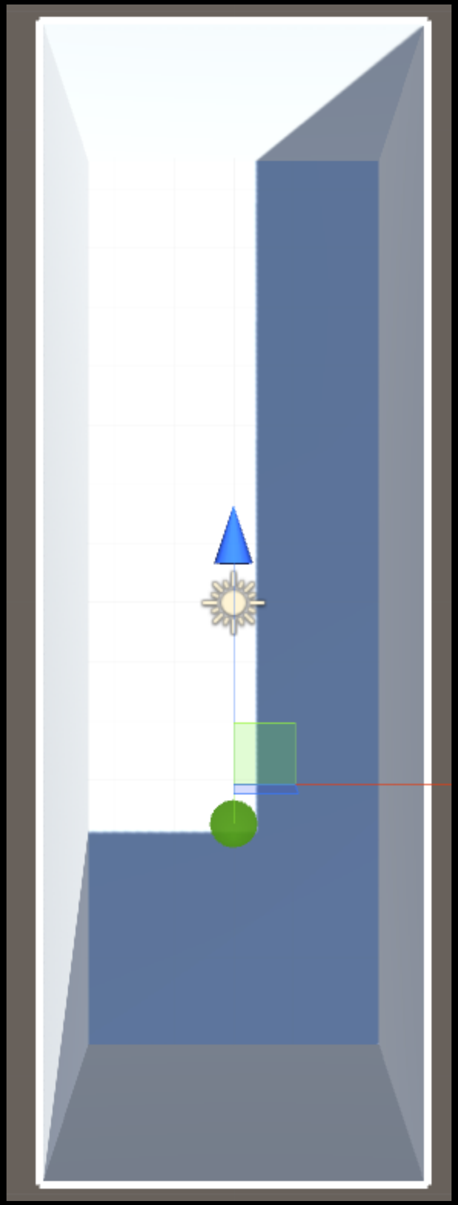
Only Layout Constraint

Virtual World

Retargeting



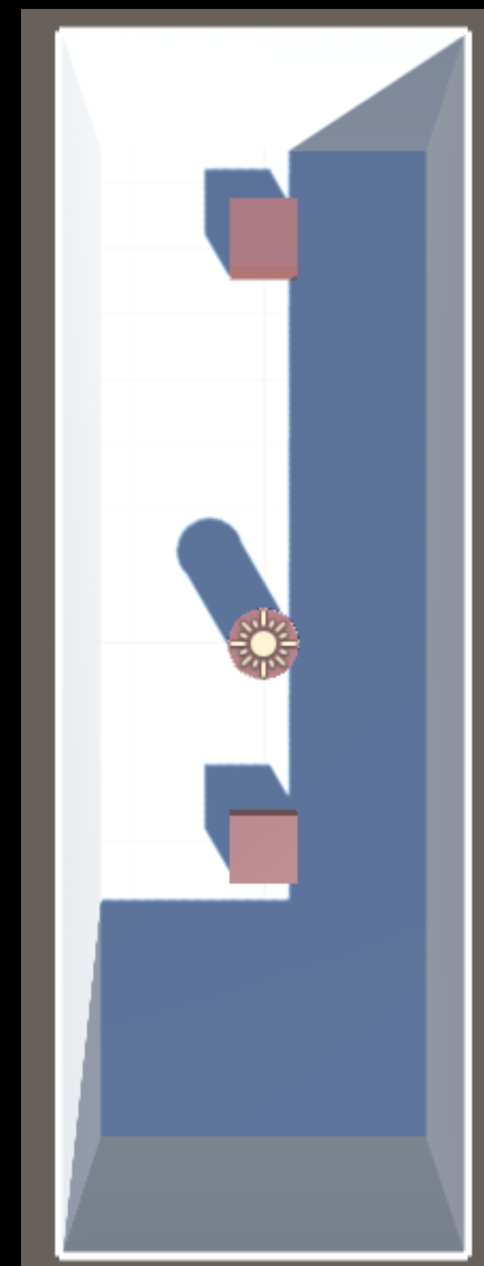
Physical Environment

Retargeted Virtual World

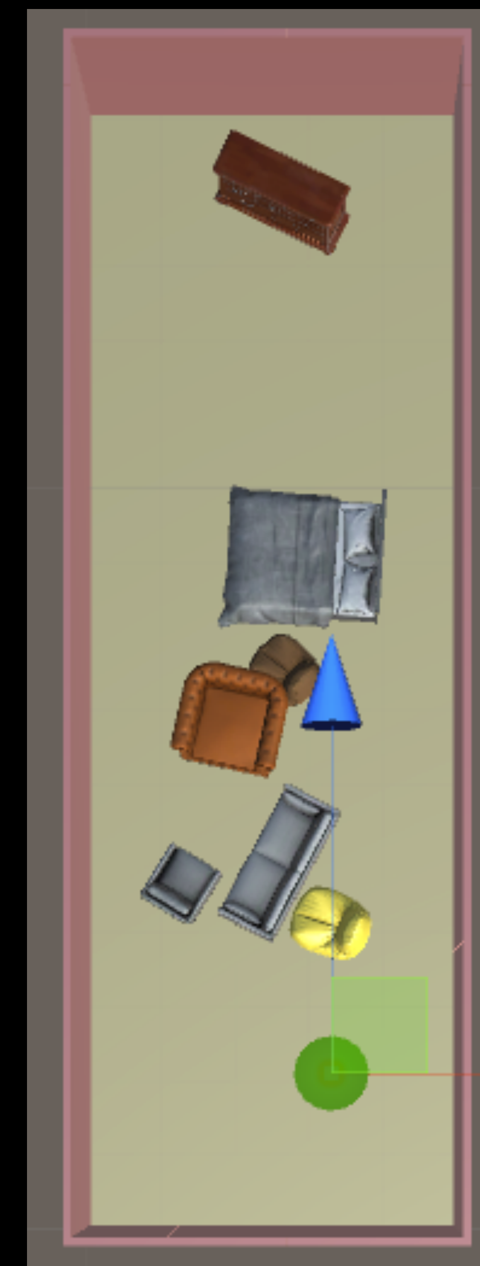
Few Obstacles

Virtual World

Retargeting



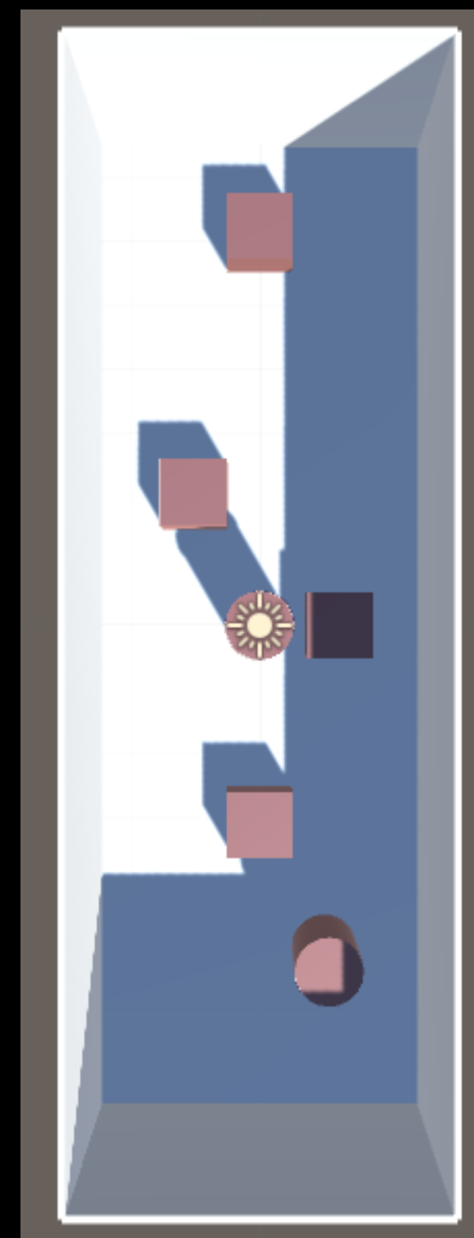
Physical Environment



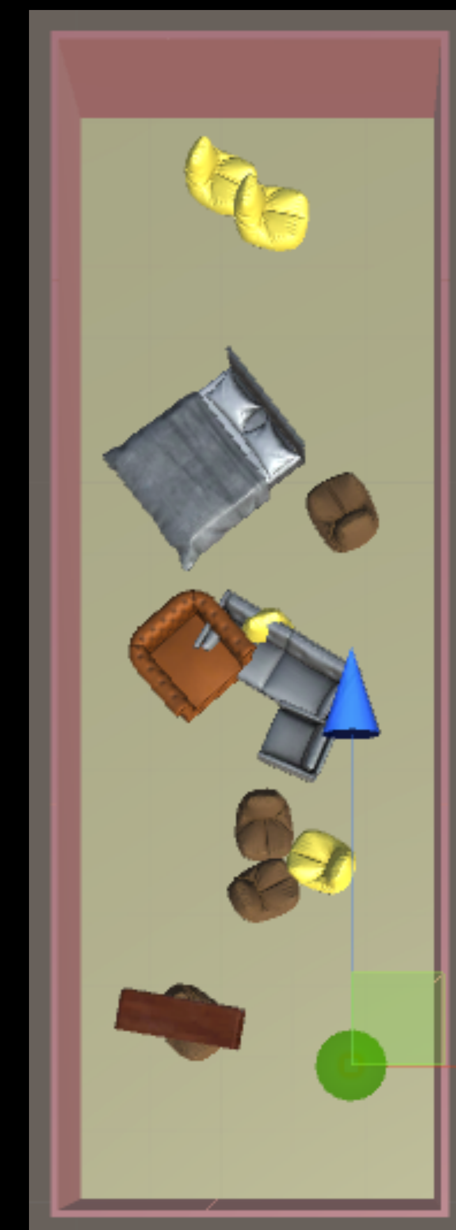
Retargeted Virtual World

More Obstacles

Virtual World



Physical Environment



Retargeted Virtual World

Conclusion

Retargeting is hard when

- Layout of the physical environment is too different from that of the virtual world
- Too many obstacles in the physical environment

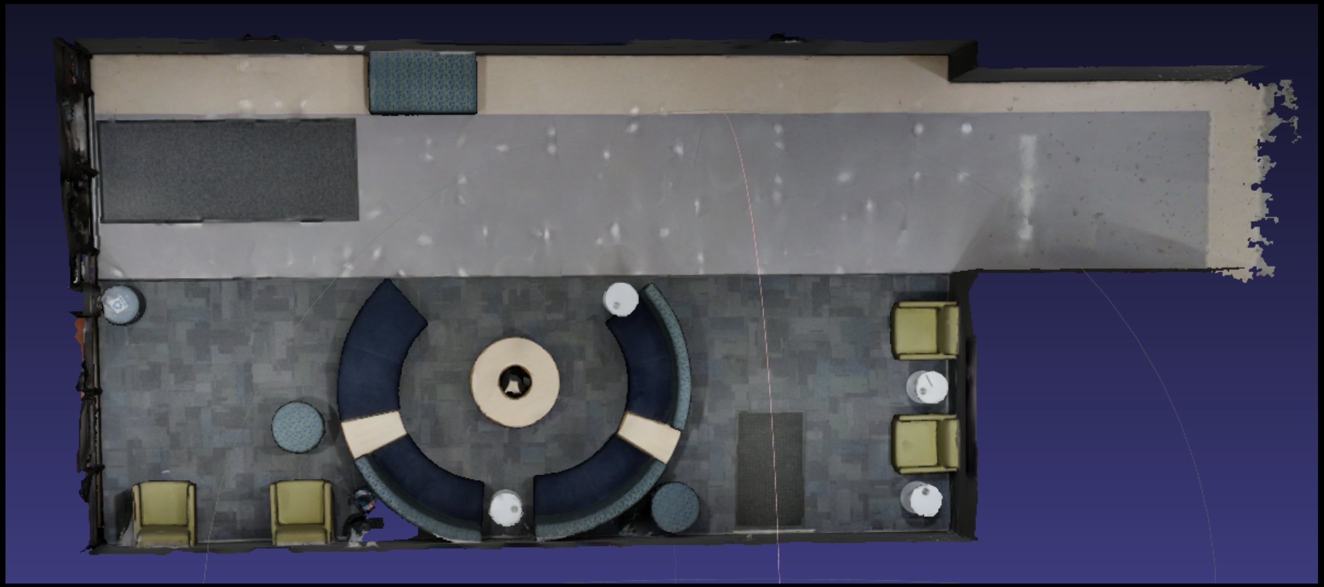
Results

- For different levels of constraints in the physical environment
- For different levels of constraints in the virtual world
- For real world scenes

All Filler Objects

Virtual World

Physical Environment



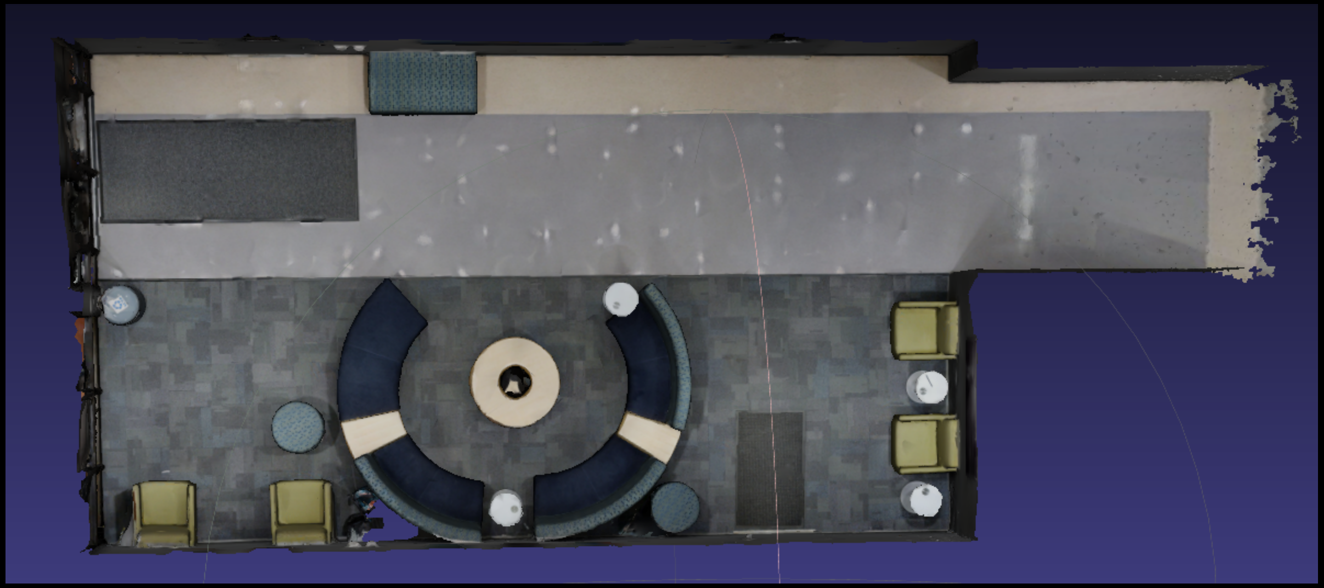
Retargeted Virtual World

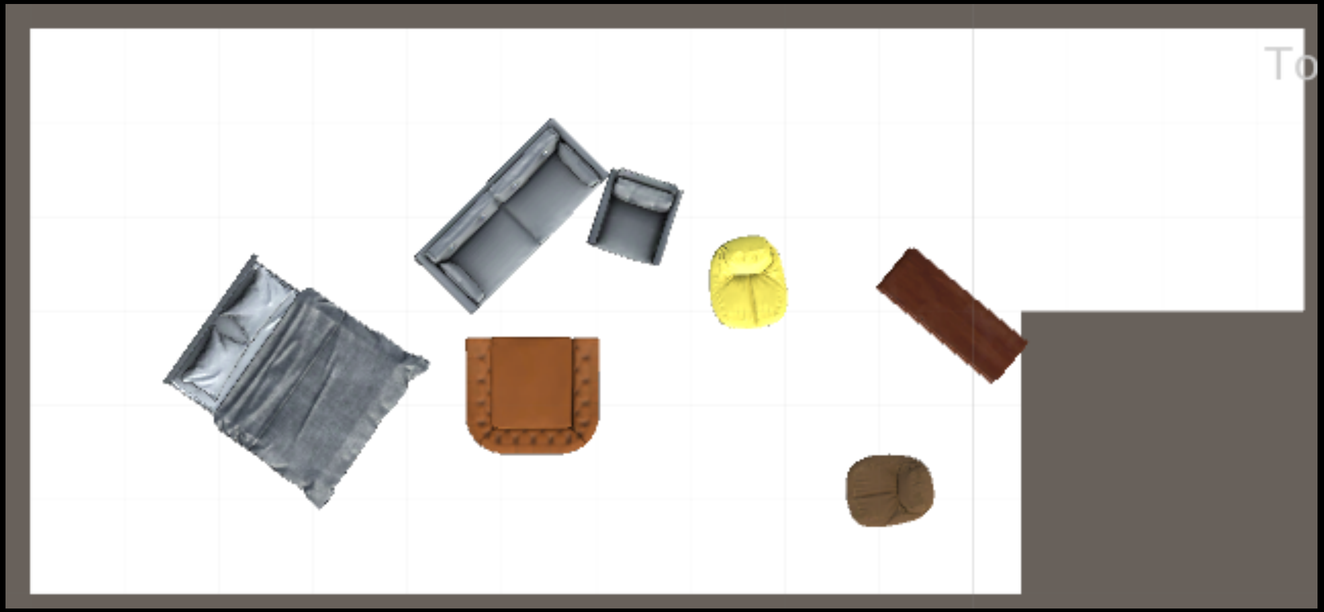
All Priority Objects

Virtual World

Retargeting

Physical Environment





Retargeted Virtual World

Conclusion

Virtual worlds with fewer priority objects and many filler objects are ‘**more retargetable**'

Results

- For different levels of constraints in the physical environment
- For different levels of constraints in the virtual world
- For real world scenes

Virtual World

Retargeting

Physical Environment

MMS = 0.5419
CS = 0.0048
SS = 0.9908

Retargeted Virtual World

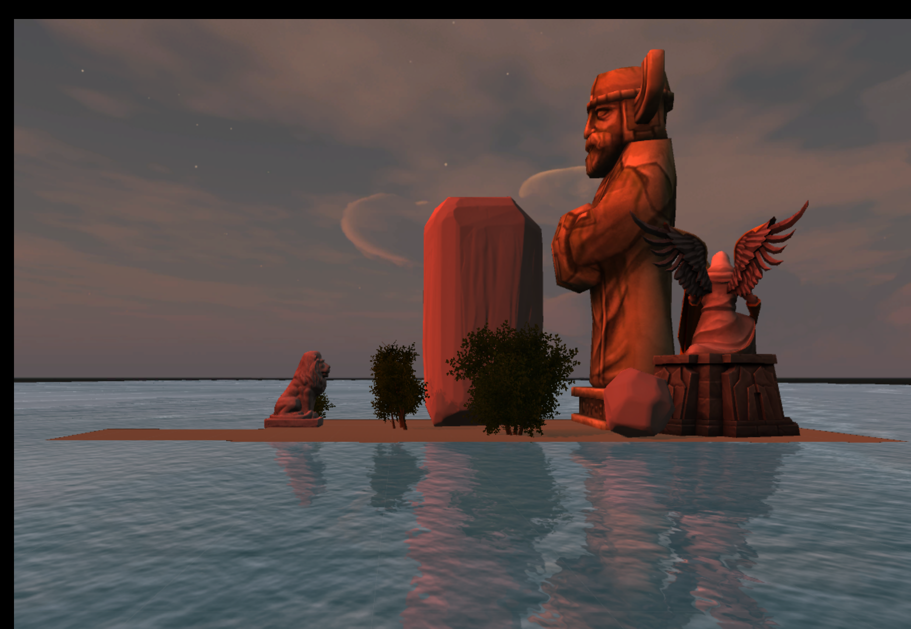
Virtual World

Retargeting

Physical Environment

Retargeted Virtual World

MMS = 0.4862
CS = 0.0009
SS = 0.8219



Another Run

Virtual World

Retargeting

Physical Environment

MMS = 0.5
CS = 0.0085
SS = 0.9612

Retargeted Virtual World

Future Work

- More sophisticated methods of extracting semantics from the virtual world - an AI problem
- Optimum weighting of MMS, CS and SS
- Convergence to global optimum in the large non convex solution space

Acknowledgment

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References

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Q & A