Parallel Beam Search for Functionality Partial Matching

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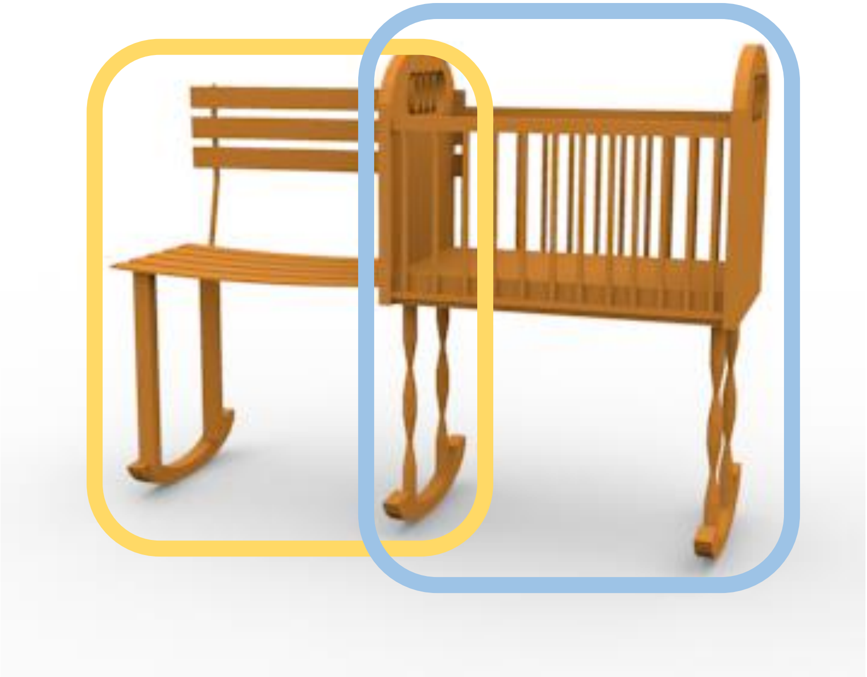
What is the functionality of an object?

Chair
Sitting + Leaning

Crib
Storage + Rocking

What is functionality partial matching?

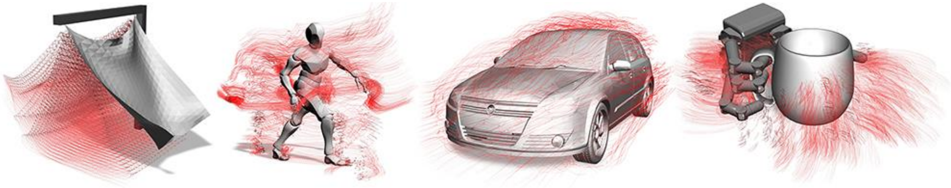


Problem Statement

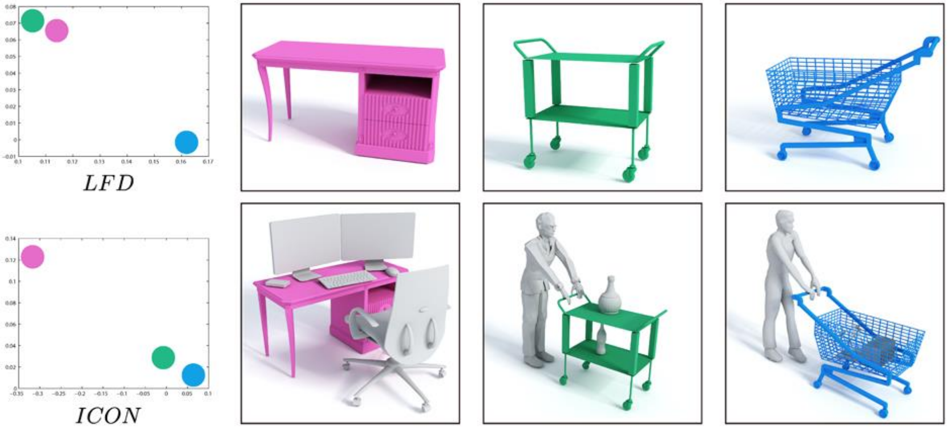
- Develop a parallel beam search algorithm
- Speed up the existing functionality partial matching method

Literature Review

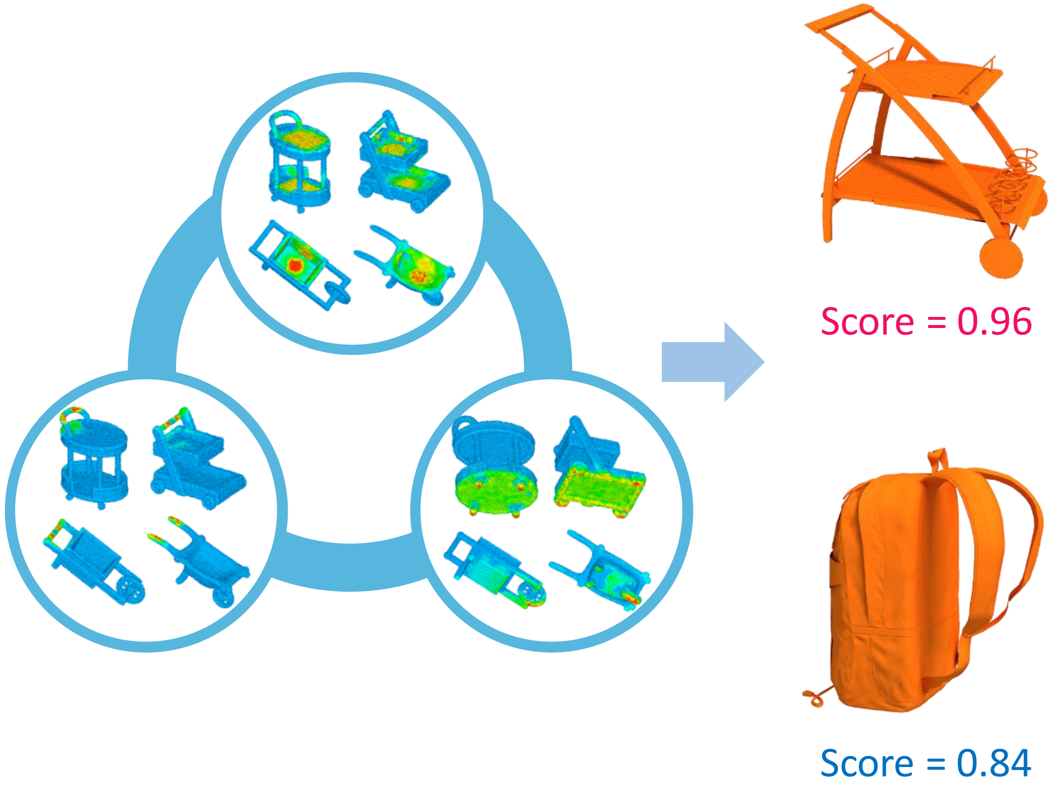
Functionality Analysis in 3D Shape Modeling



Interaction landscapes [8]

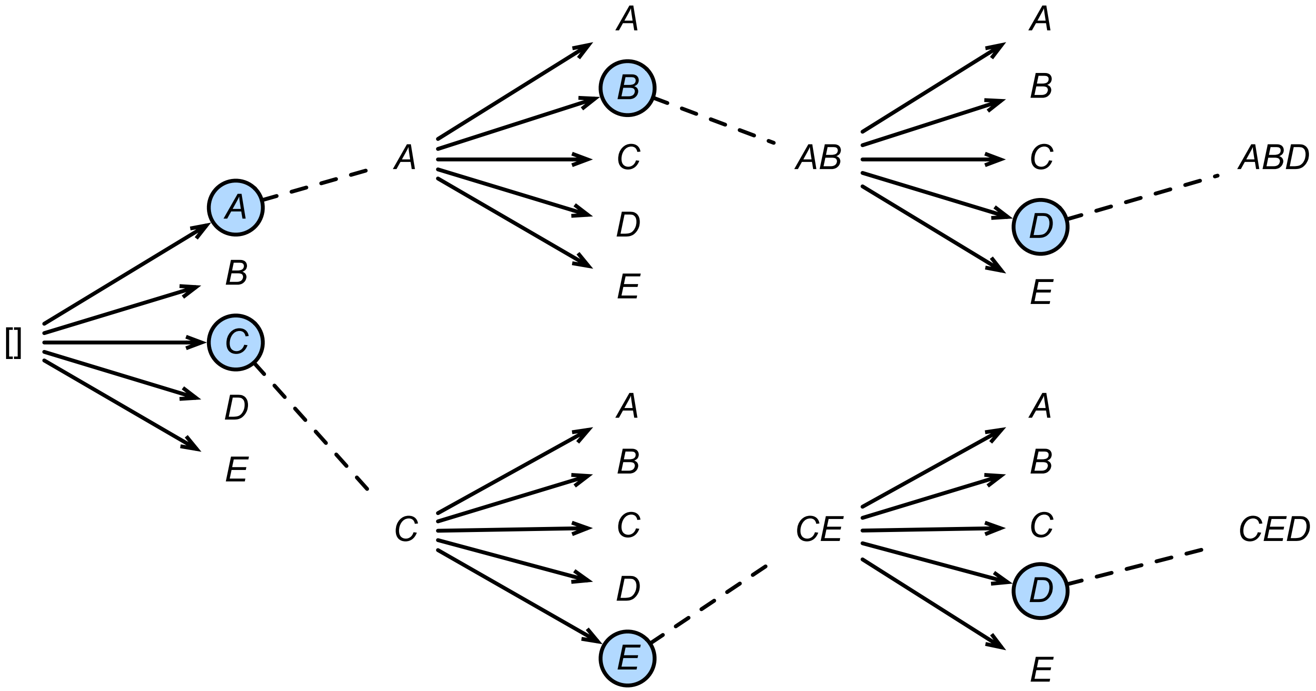


Interaction context (ICON) [5]



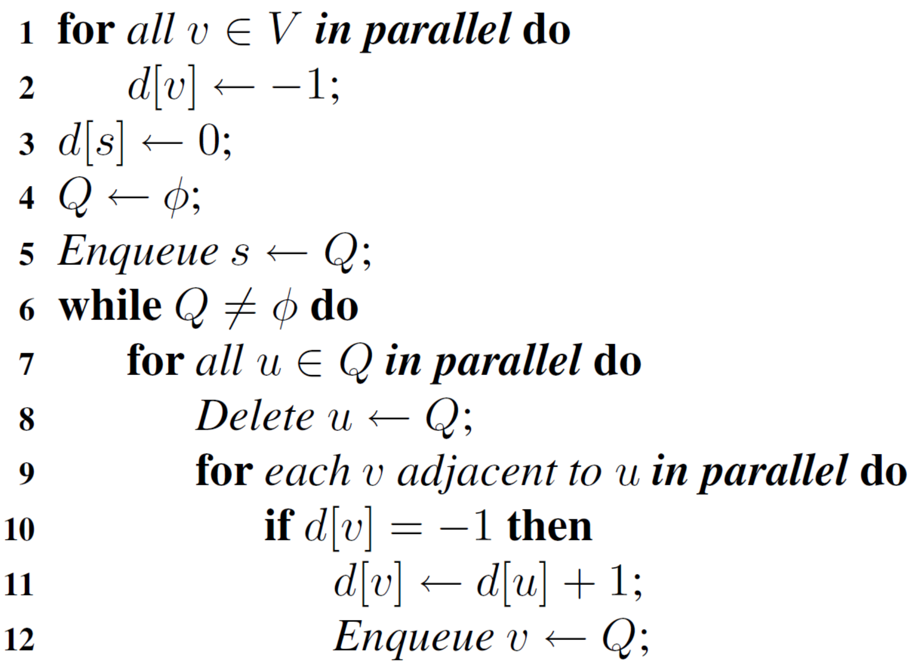
Category functionality model [4]

Beam Search and Its Applications



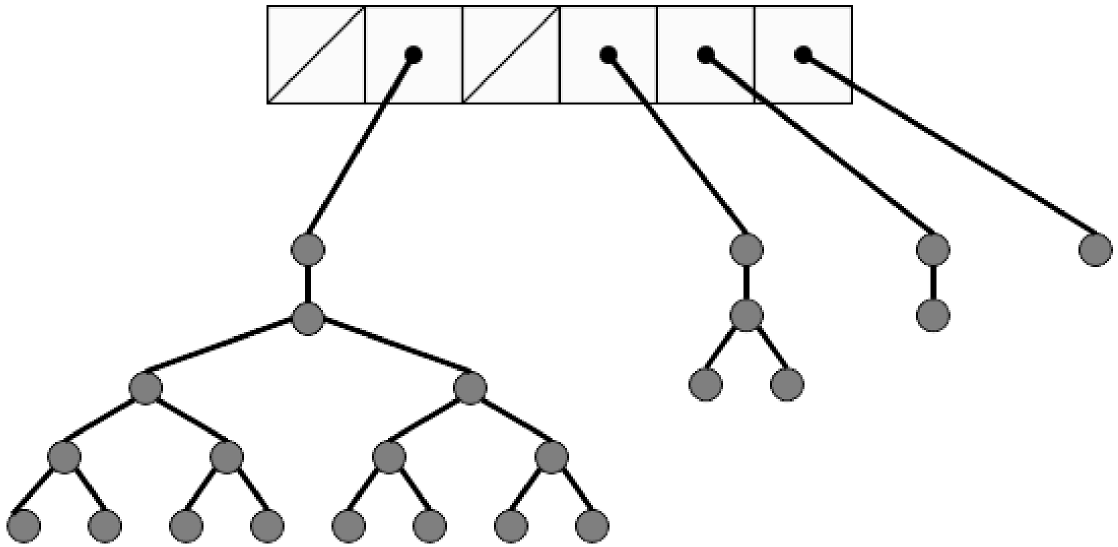
Applied in Speech recognition systems [7, 2], machine translation systems [10], sequence-to-sequence models [9], and so on…

Parallel Breadth-First Search (BFS) Algorithms



```
for all $v \in V$ in parallel do
    $d[v] \leftarrow -1$;
$d[s] \leftarrow 0$;
$Q \leftarrow \phi$;
Enqueue $s \leftarrow Q$;
while $Q \neq \phi$ do
    for all $u \in Q$ in parallel do
        Delete $u \leftarrow Q$;
        for each $v$ adjacent to $u$ in parallel do
            if $d[v] = -1$ then
                $d[v] \leftarrow d[u] + 1$;
                Enqueue $v \leftarrow Q$;
```

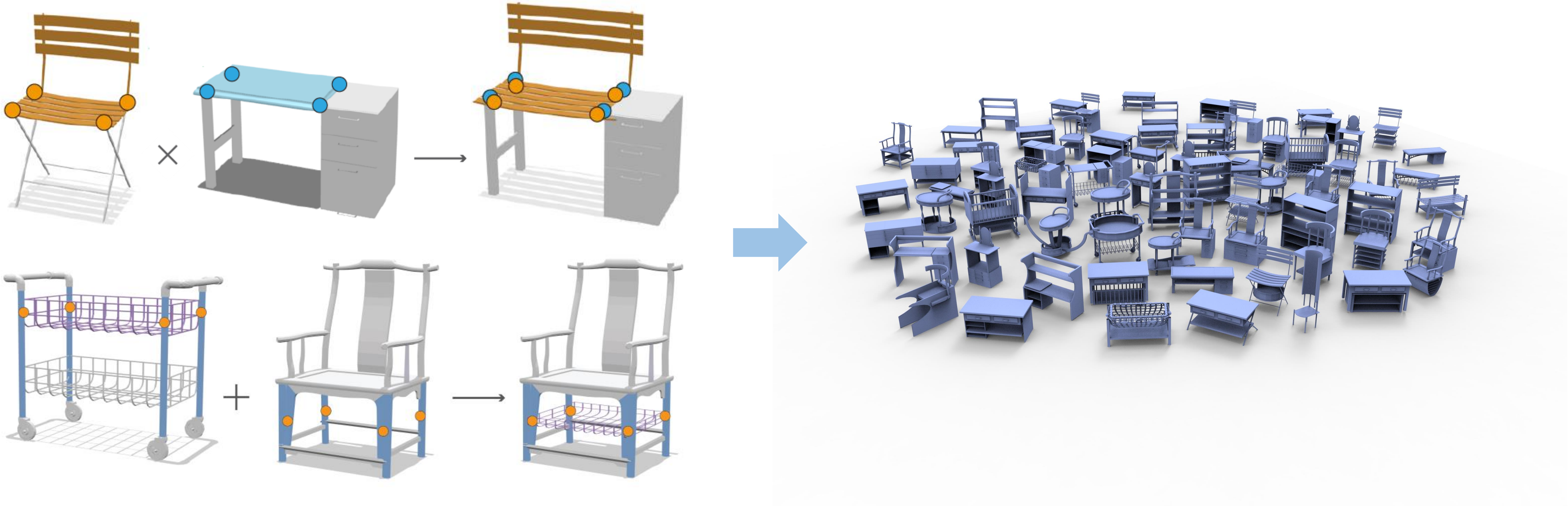
Level synchronization [1, 11]



Multi-set data structure [6]

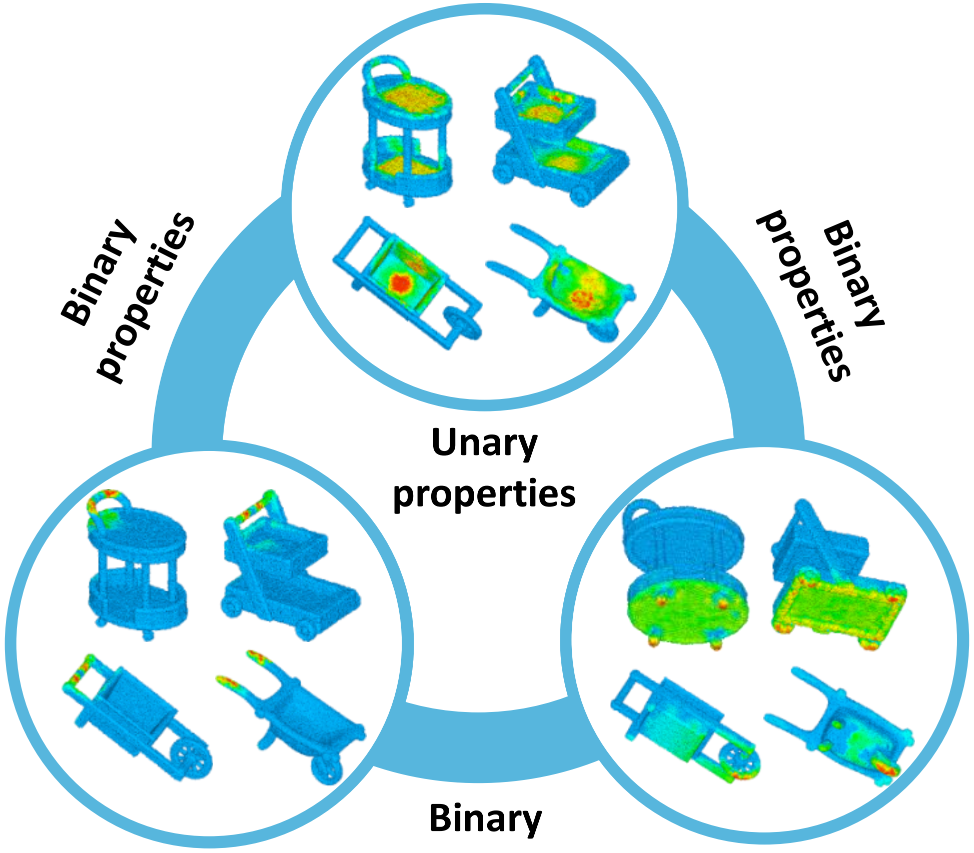
Our Method

Input: Hybrid Shapes



Shape hybridization via evolution [3]

Category Functionality Model



Binary properties

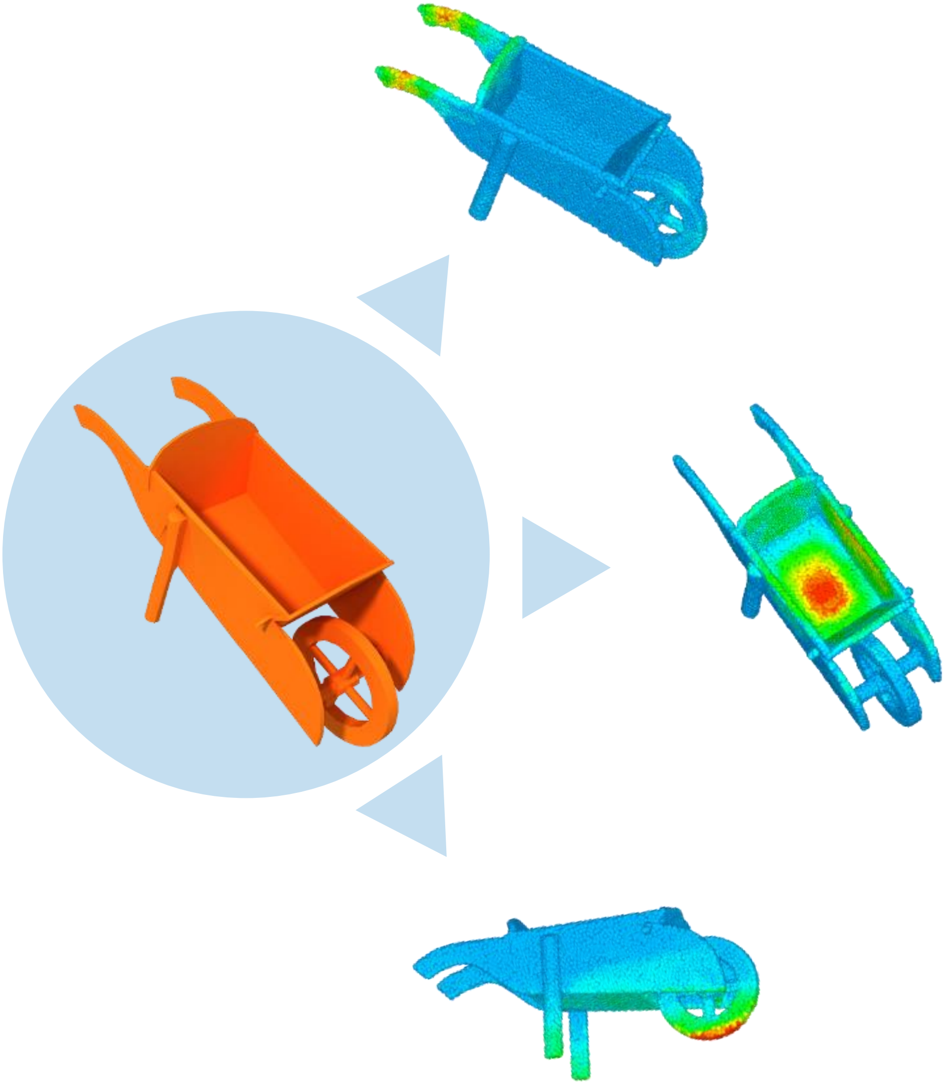
Unary properties

Binary properties

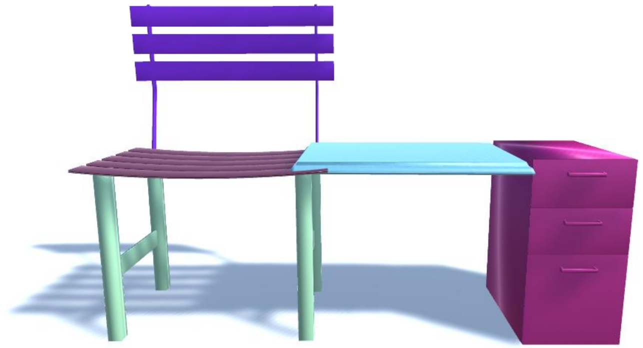
Unary properties

Binary properties

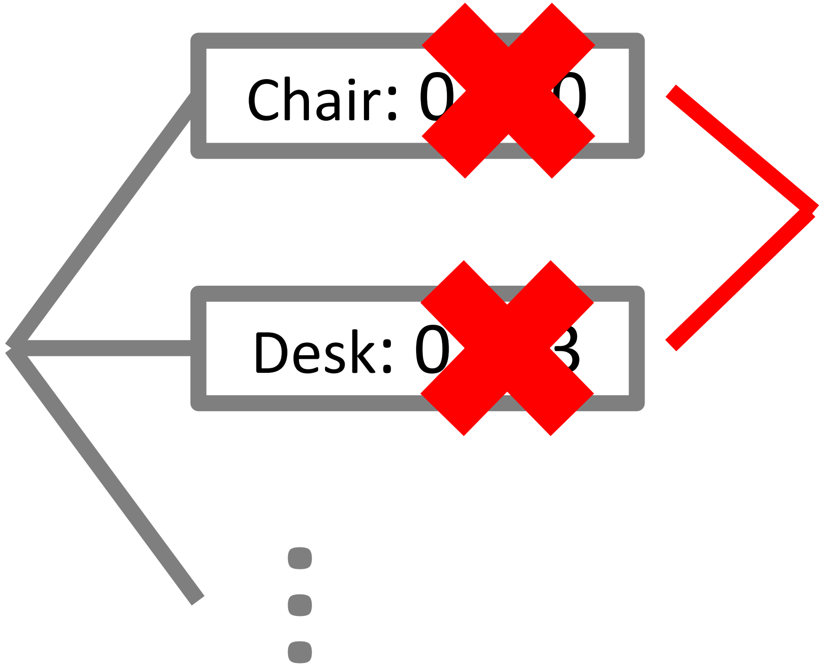
Unary properties



Category Functionality Model



Hybrid shape



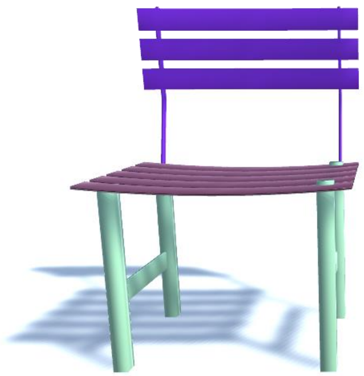
Chair: 0 0

Desk: 0 3

category scores

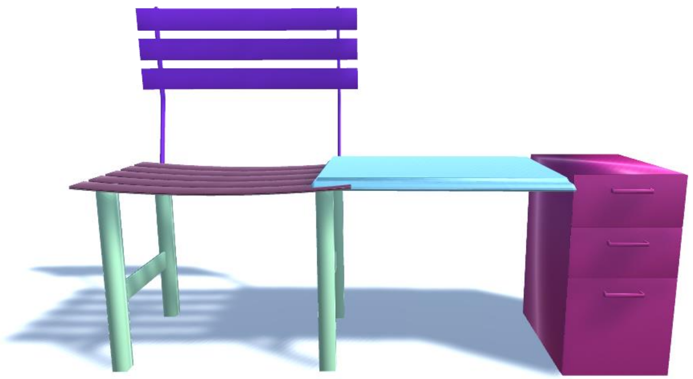
Category models [4]

Functionality Partial Matching



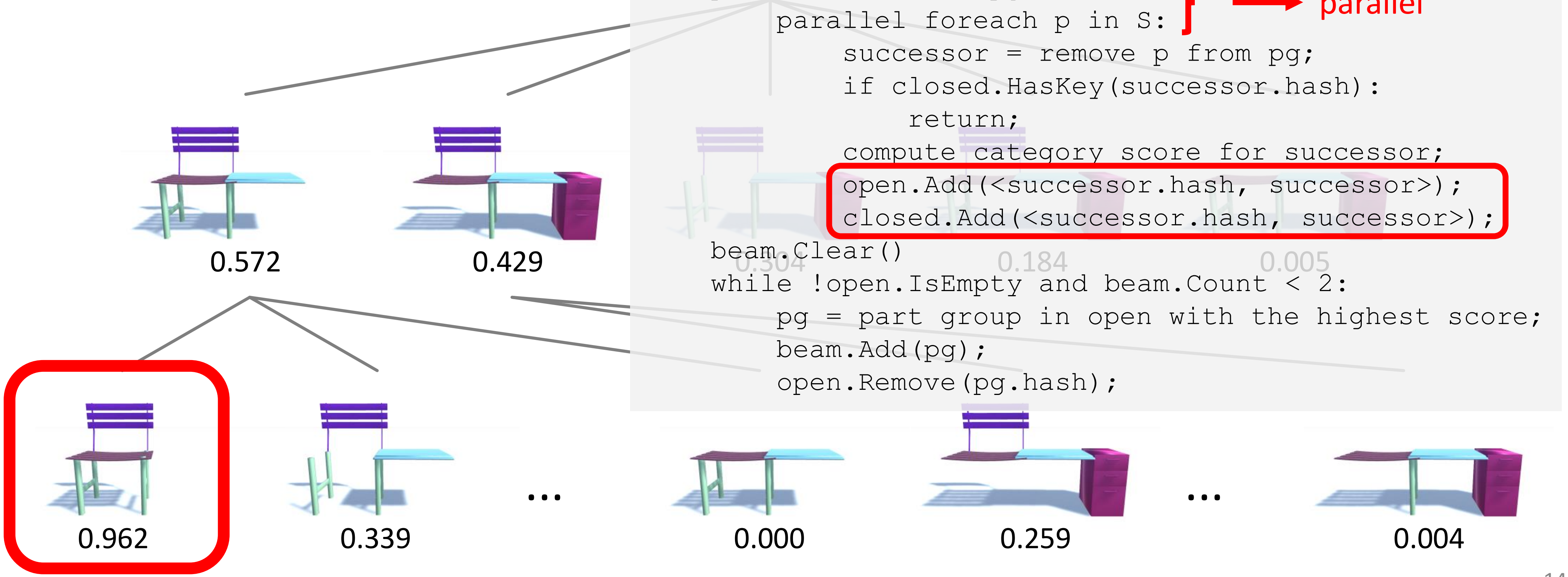
Chair: 0.962

Desk: 0.988



Final score: 0.988

Parallel Beam Search

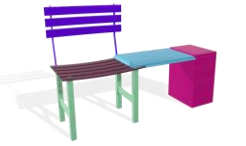
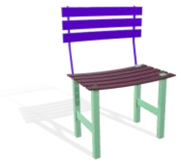
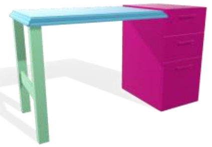
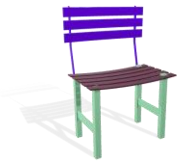
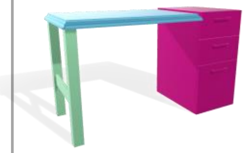
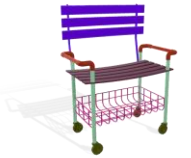
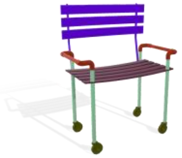
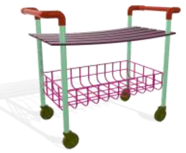
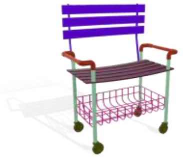
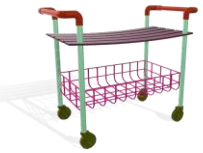
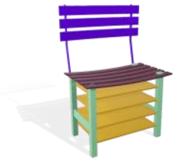
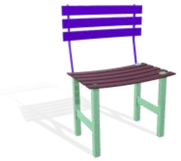
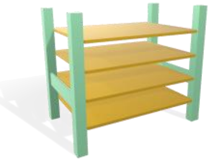
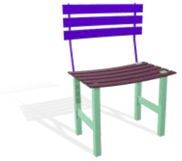
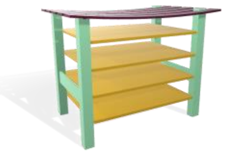
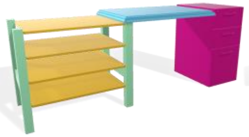
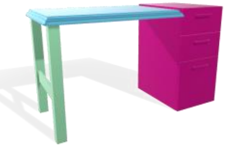
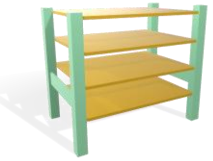
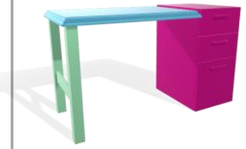
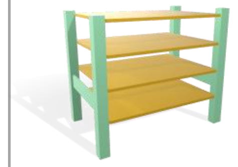
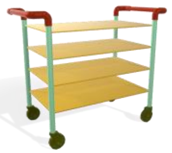
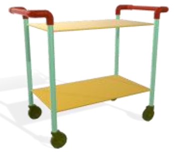
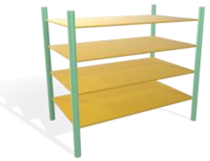
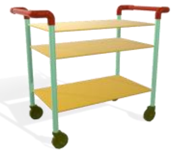
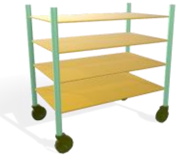


```
beam = {S};
closed = {<S.hash, S>};
while beam.Count > 0:
    open = {};
    parallel foreach pg in beam:
        parallel foreach p in S:
            successor = remove p from pg;
            if closed.HasKey(successor.hash):
                return;
            compute category score for successor;
            open.Add(<successor.hash, successor>);
            closed.Add(<successor.hash, successor>);
    beam.Clear()
    while !open.IsEmpty and beam.Count < 2:
        pg = part group in open with the highest score;
        beam.Add(pg);
        open.Remove(pg.hash);
```

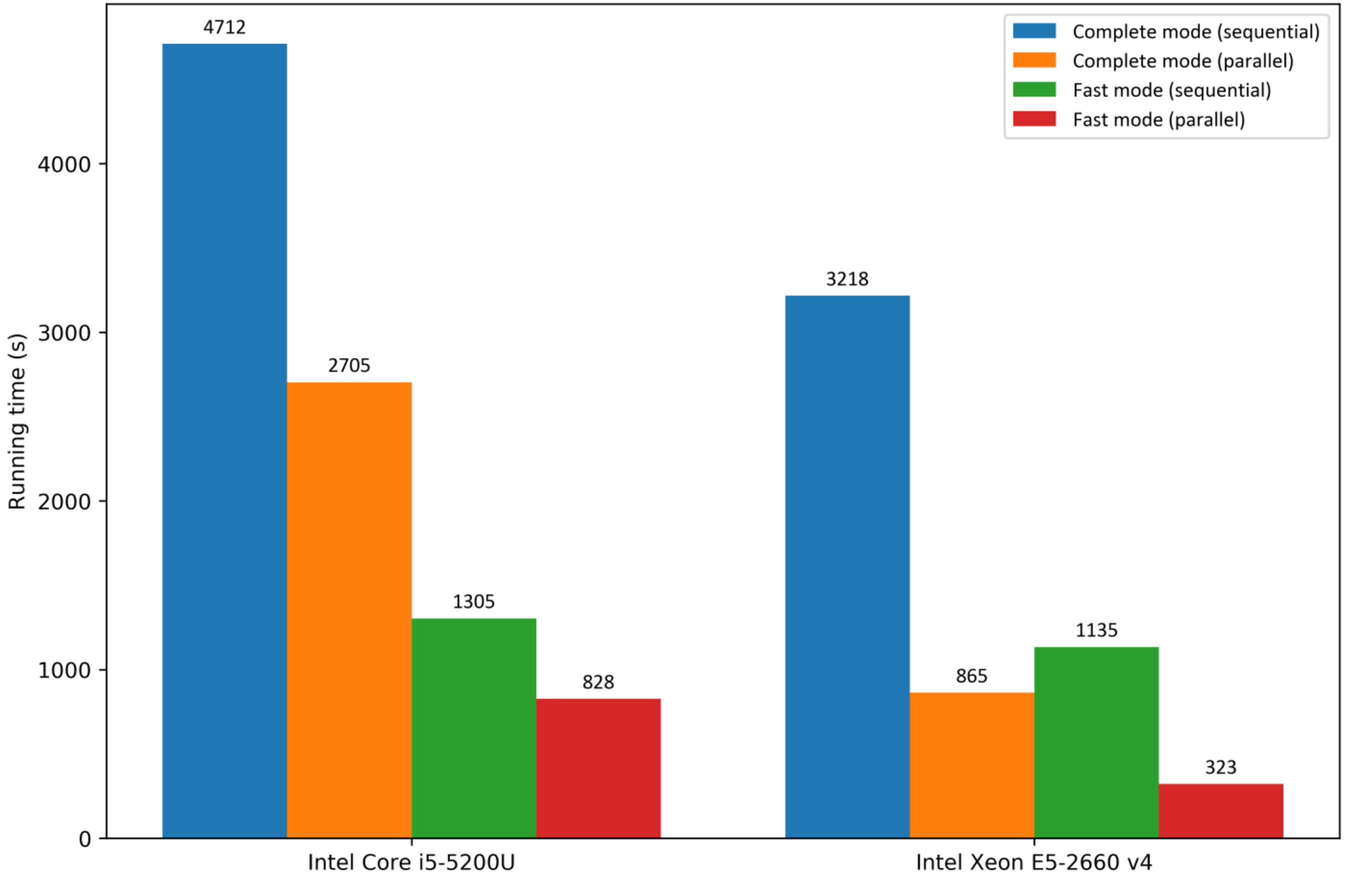
sequential

parallel

Results and Applications

Shape	Combinatorial search		Beam search		Time
	 $s_{\text{chair}} = 0.96$	 $s_{\text{desk}} = 0.98$	 $s_{\text{chair}} = 0.96$	 $s_{\text{desk}} = 0.98$	722s
	 $s_{\text{chair}} = 0.93$	 $s_{\text{handcart}} = 0.98$	 $s_{\text{chair}} = 0.90$	 $s_{\text{handcart}} = 0.98$	1161s
	 $s_{\text{chair}} = 0.96$	 $s_{\text{shelf}} = 0.94$	 $s_{\text{chair}} = 0.96$	 $s_{\text{shelf}} = 0.93$	232s
	 $s_{\text{desk}} = 0.98$	 $s_{\text{shelf}} = 0.96$	 $s_{\text{desk}} = 0.98$	 $s_{\text{shelf}} = 0.96$	1258s
	 $s_{\text{handcart}} = 0.96$	 $s_{\text{shelf}} = 0.97$	 $s_{\text{handcart}} = 0.92$	 $s_{\text{shelf}} = 0.96$	765s

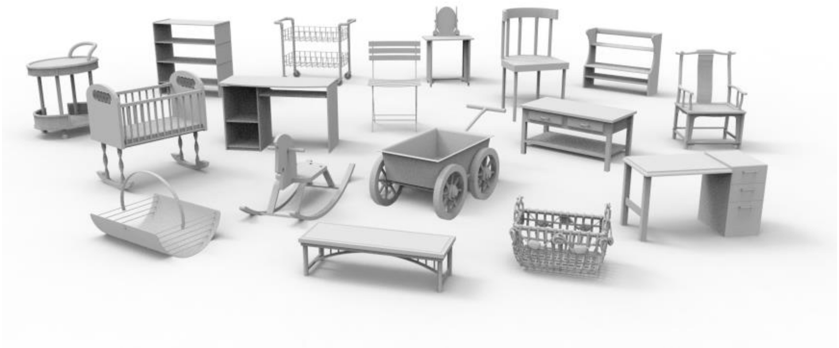
Performance and Scalability



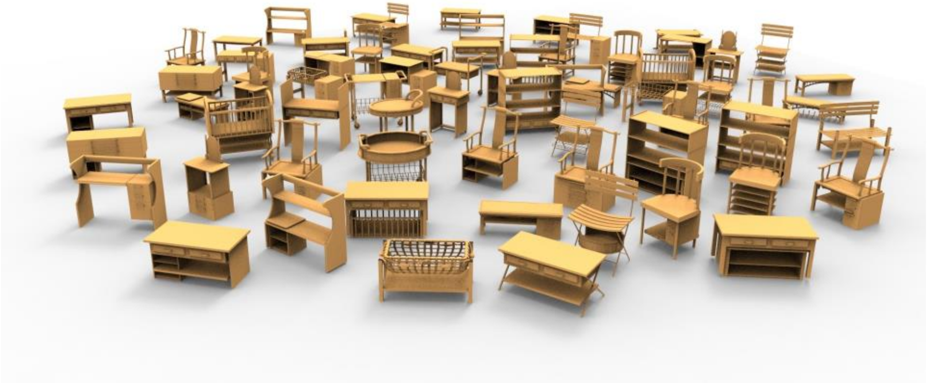
Applications

Functionally plausible

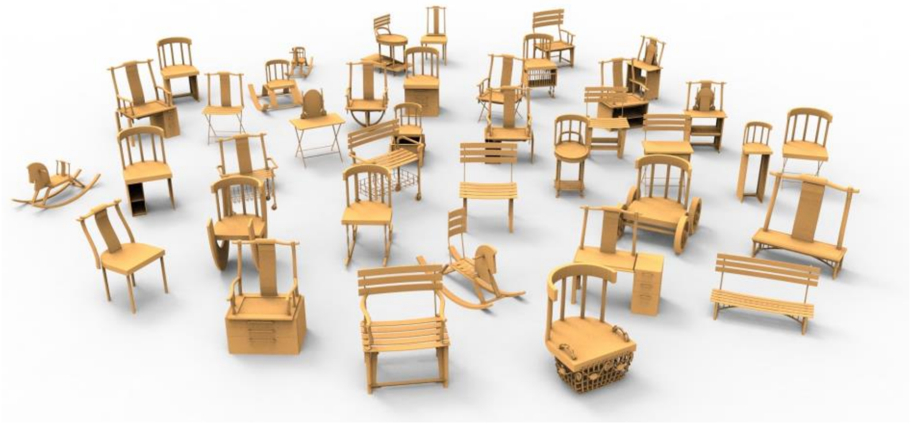
Applications



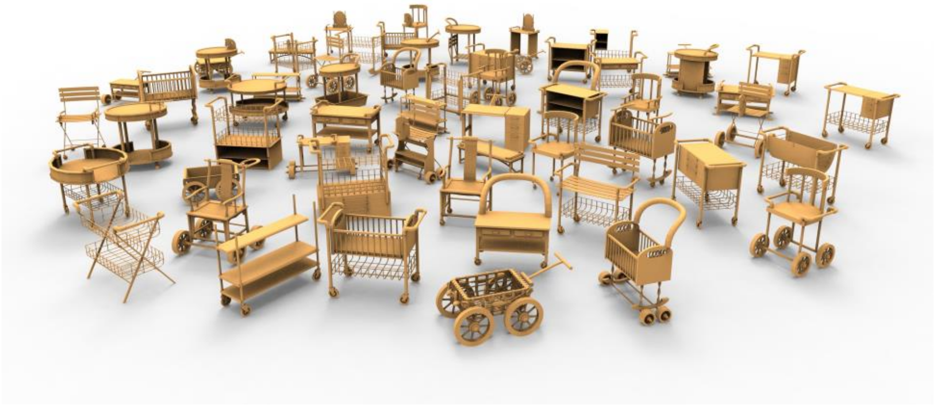
Initial population



Placement + Storage



Sitting + Leaning



Grasping + Rolling

Conclusion and Future Work

- A parallel beam search can largely speed up the process of functionality partial matching
- The implementation of the category functionality model can be further optimized

References

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Questions

- Why do we need functionality partial matching?
- What is the key idea of parallelizing a beam search?
- Why do we need concurrent open and closed lists in the parallel beam search?