

# Assembly Planning from Observations under Physical Constraints

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**NYU**

**Center for  
Data Science**

## Willow team

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- Originally, **computer vision and image processing** team
- More recently, moving towards **robotics**
- Based in building C, 4th floor



## *Espace Robotique (Building C, 5<sup>th</sup> floor)*

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The subject:

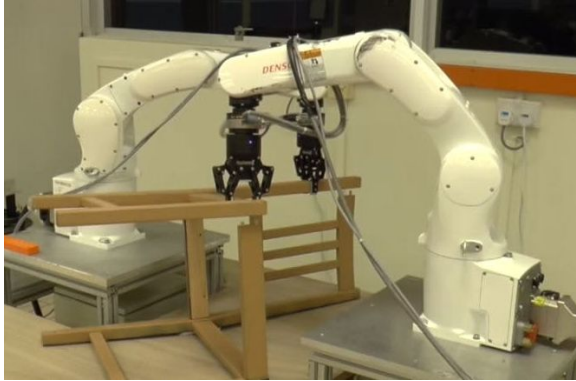
*Assembly Planning from Observations  
under Physical Constraints*



# Assembly planning ?

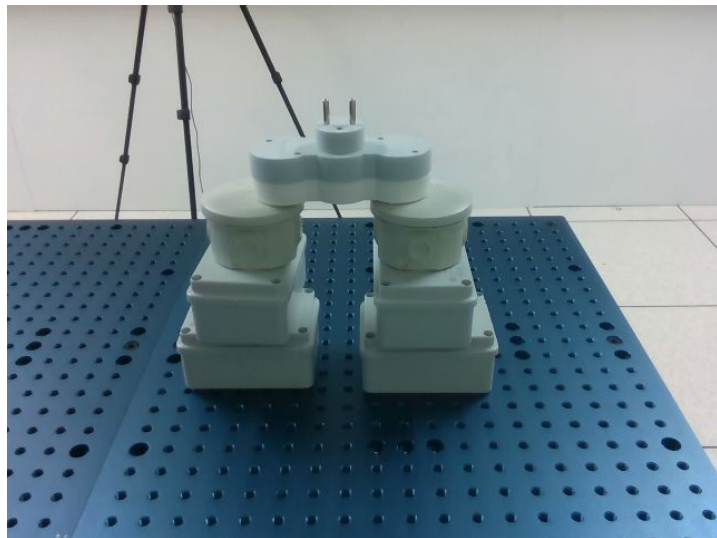
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- Put **primitives** together with a robot

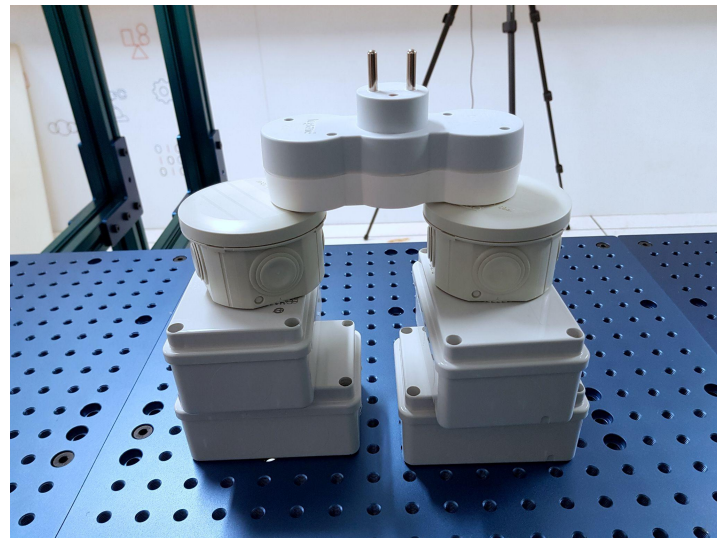


## Assembly planning from observations ?

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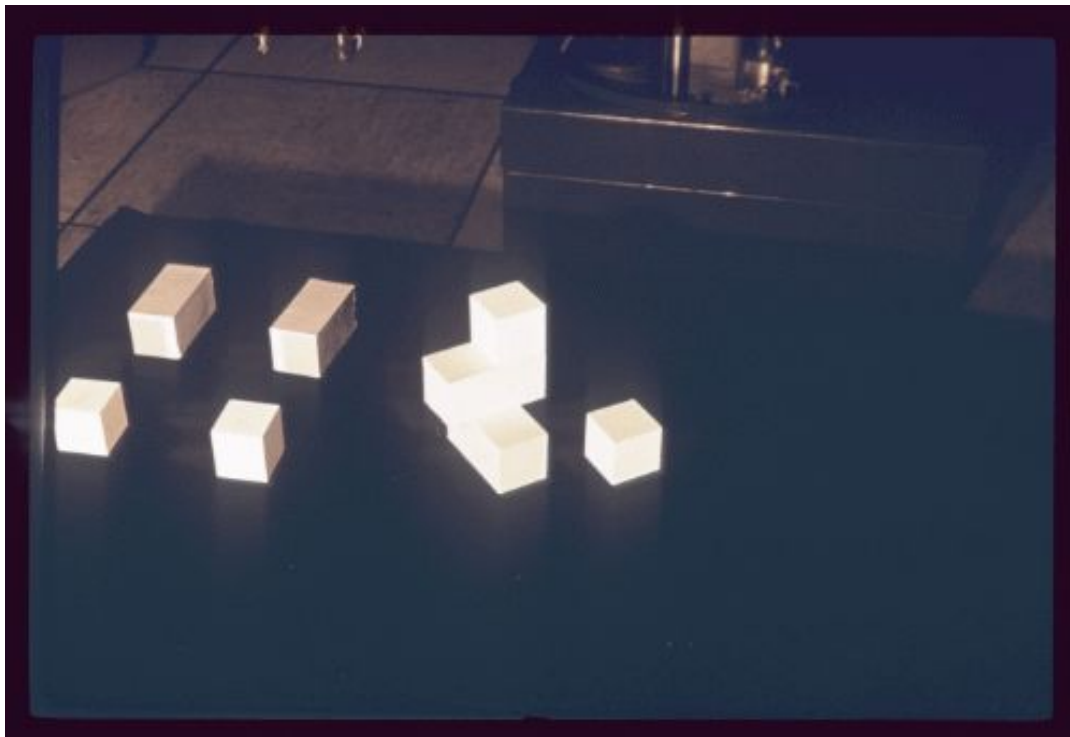
Target image



Reconstruction

Not a new topic

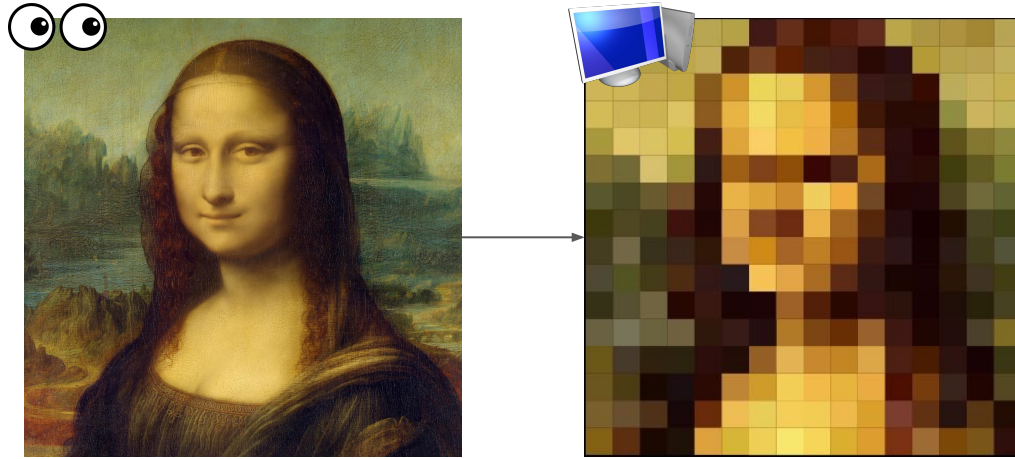
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Winston et al., early 1970s  
“Minsky Copy Demo”

# Difficulties

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**Images**



**Robotics**

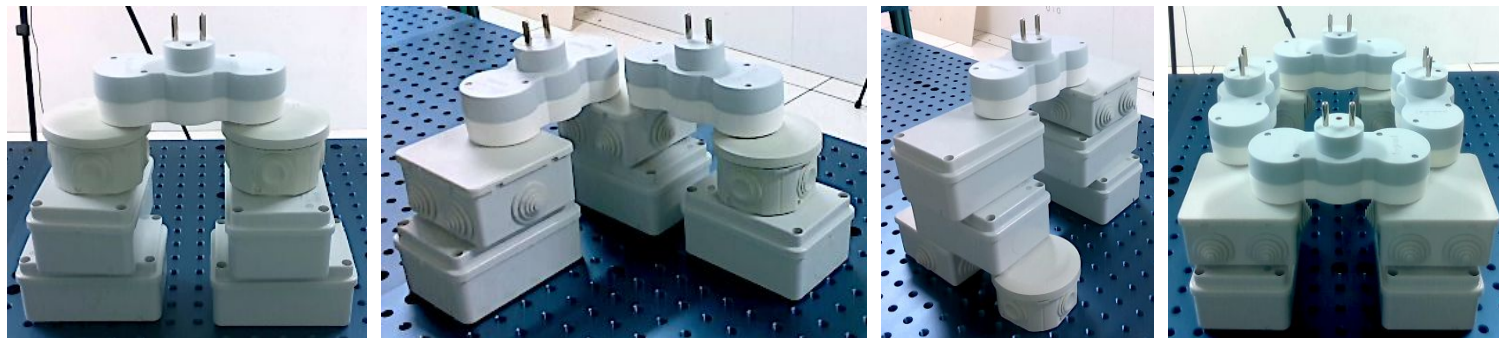
Both cases: **errors to handle**



Our problem

## First step: understand the target

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- Target = **set of rigid objects**
- **Contacts** between objects
- Objects have **6D poses**

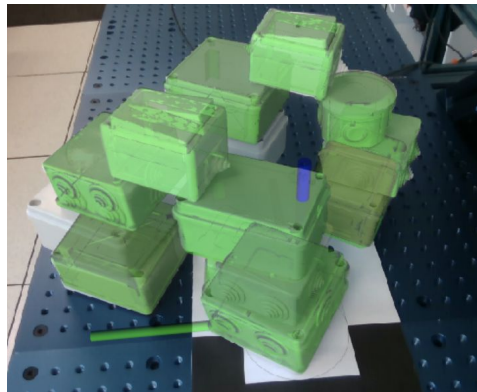
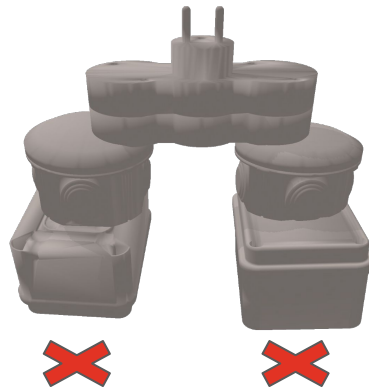
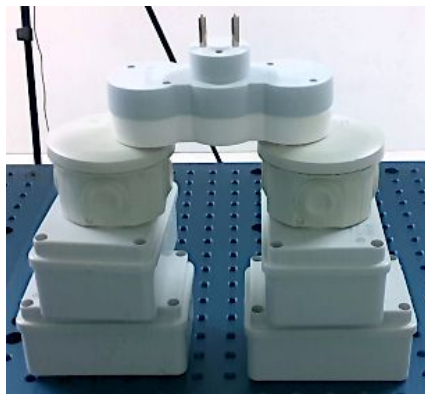
⇒ **6D object pose estimation**

Yann Labbé et al. "Cospose: Consistent multi-view multi-object 6d pose estimation." *ECCV 2020*

## CosyPose on assemblies

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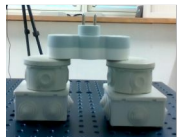
- But often **failures due to occlusions**



# Method overview

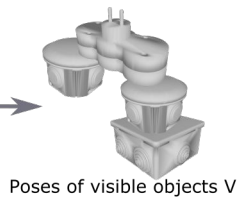
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## Inputs



Target Image

## (a) Object detection + 6D Pose estimation



Poses of visible objects  $V$



Available  
primitives

# Task planning: STRIPS

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## Predicates

*OnTable(a)*

*Clear(a)*

*Rot(a)*

*On(a, b)*

*OnAlongX(a, b, c)*

*OnAlongY(a, b, c)*

## Operators

*PutOn(a, b)*

*Precond:*  $\text{Clear}(a) \square \text{Clear}(b) \square$

$\text{OnTable}(a)$

*Postcond:*  $\text{Clear}(a) \square \text{On}(a, b)$

*PutOnAlongX(a, b, c)*

*Pre:*  $\text{Clear}(a) \square \text{OnTable}(a)$

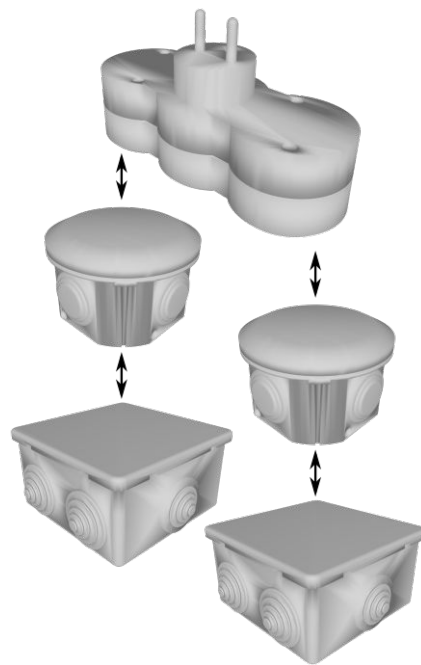
*Post:*  $\text{Clear}(a) \square \text{OnAlongX}(a, b, c)$

*PutOnAlongY(a, b, c)*

*Pre/Post:* ...

*Rotate(a)*

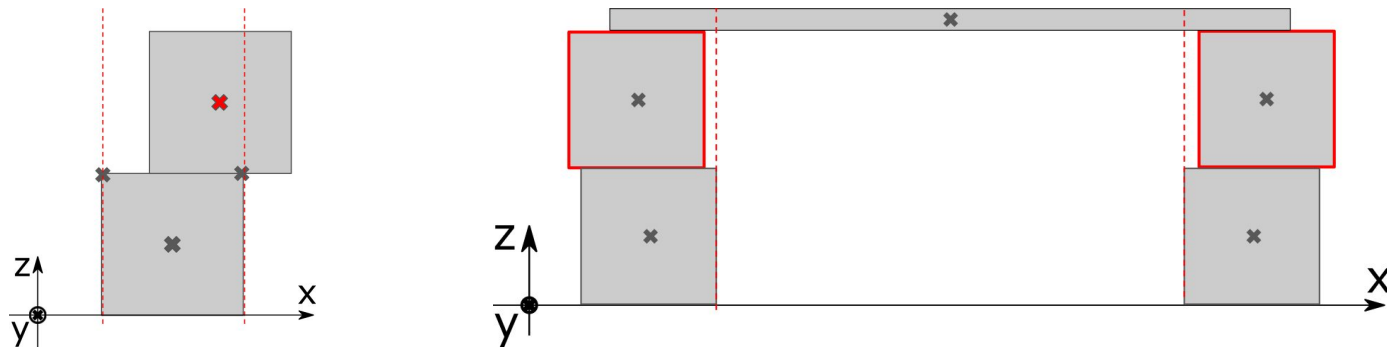
*Pre/Post:* ...





## From operators to equilibrium constraints

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Poses of primitives  $\{q_i^{\mathcal{P}}\}_{i \in \mathcal{P}} \Rightarrow$  Set of constraints  $\mathcal{C}(q_1^{\mathcal{P}}, \dots, q_N^{\mathcal{P}}) \leq 0$

## Formulating the goal

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Poses of all available objects

Only previously seen objects

Pose errors

$$\min_{q_1^{\mathcal{P}}, \dots, q_N^{\mathcal{P}} \in \mathbb{R}^6} \sum_{i \in \mathcal{V}} \|q_i^{\mathcal{P}} - q_i^{\mathcal{V}}\|_2^2$$

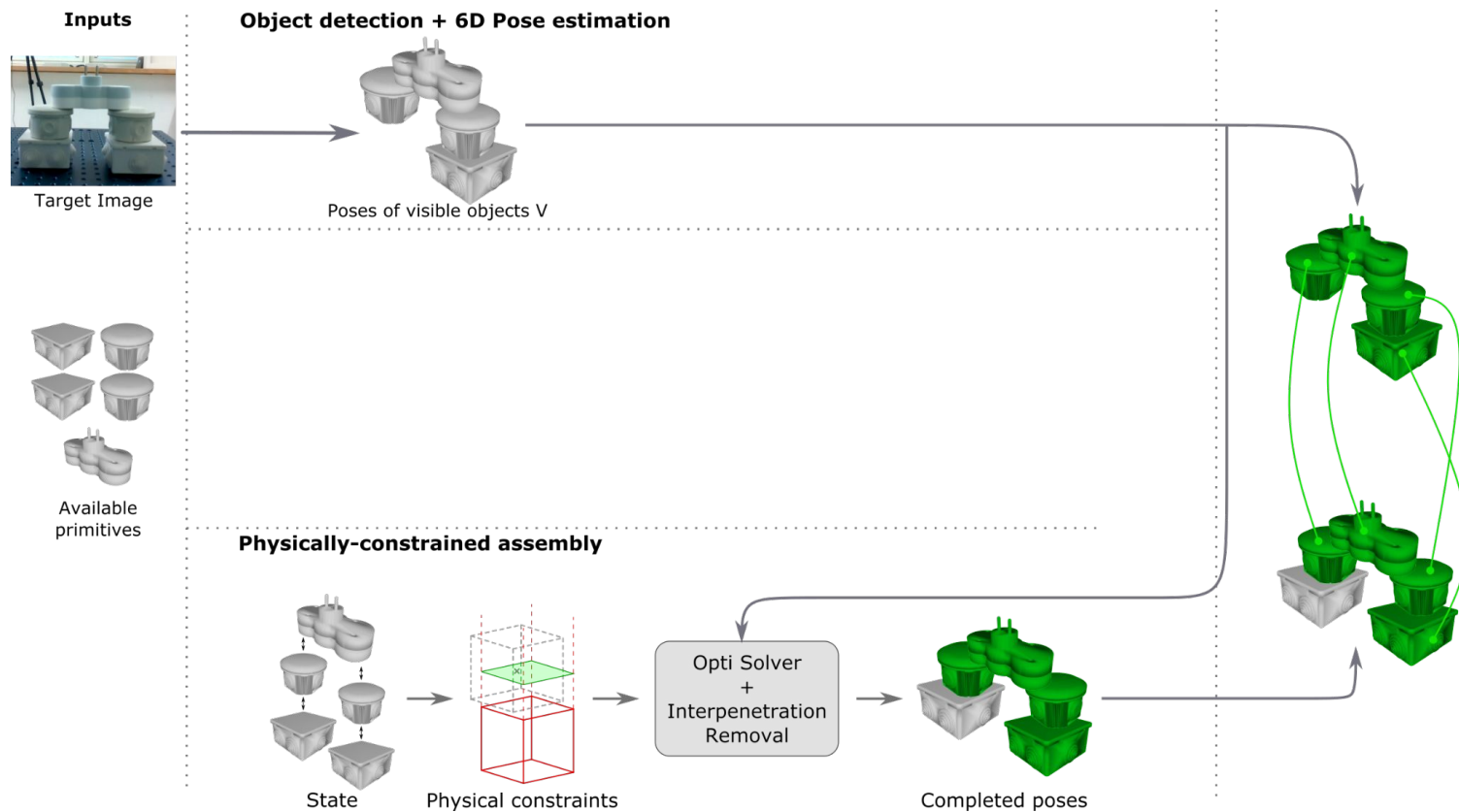
Match the reconstruction with the target

*s.t.*  $\mathcal{C}(q_1^{\mathcal{P}}, \dots, q_N^{\mathcal{P}}) \leq 0$

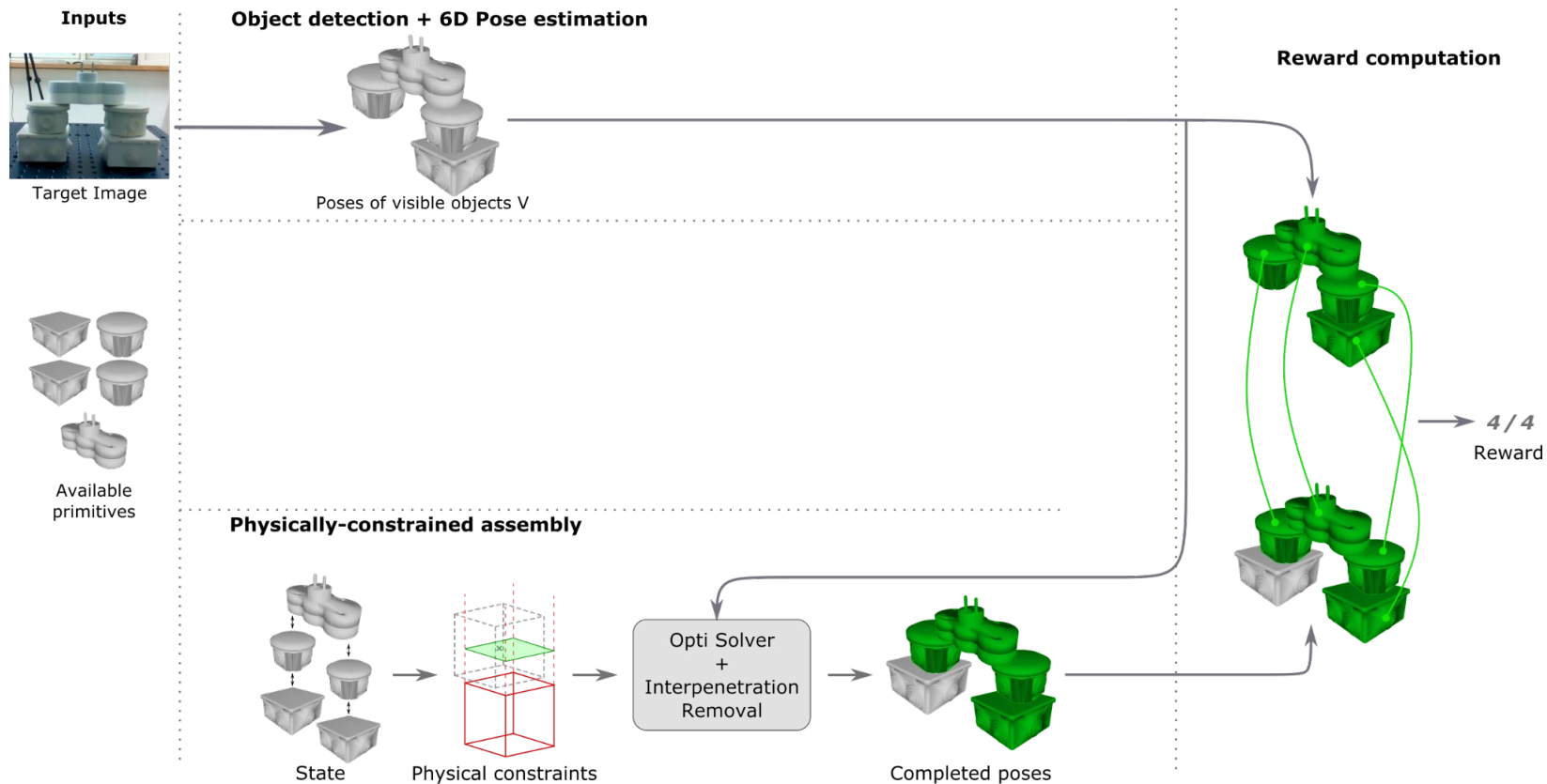
Equilibrium constraints

Ensure we build a stable structure

# Method overview

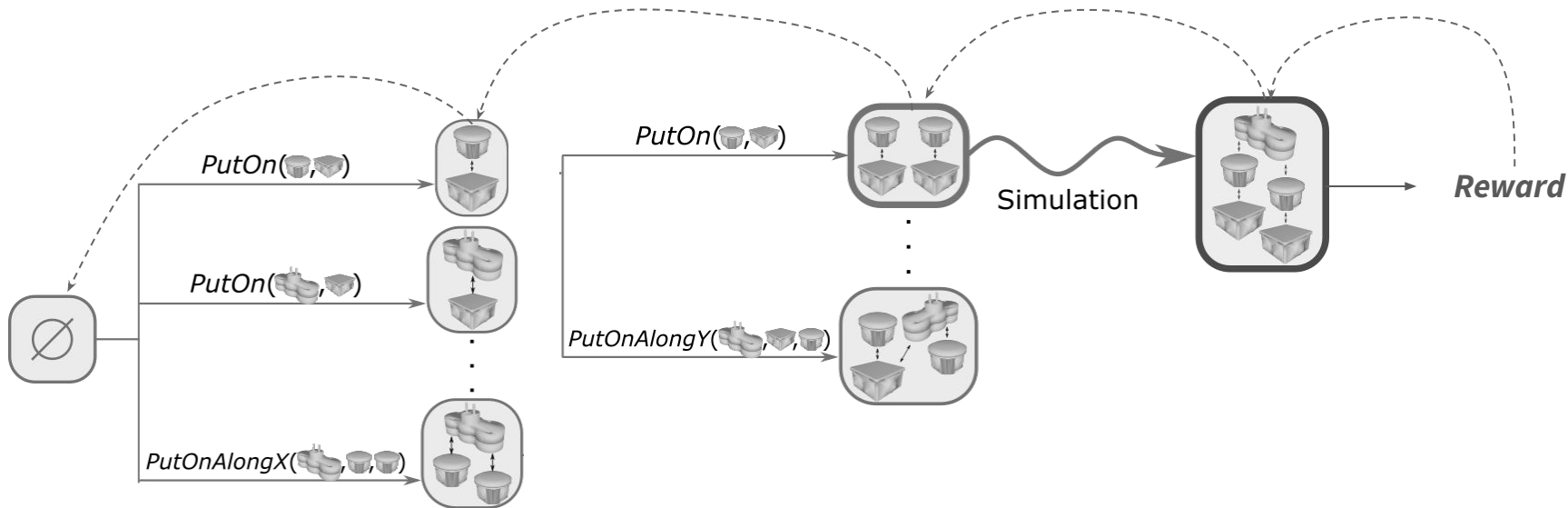


# Method overview



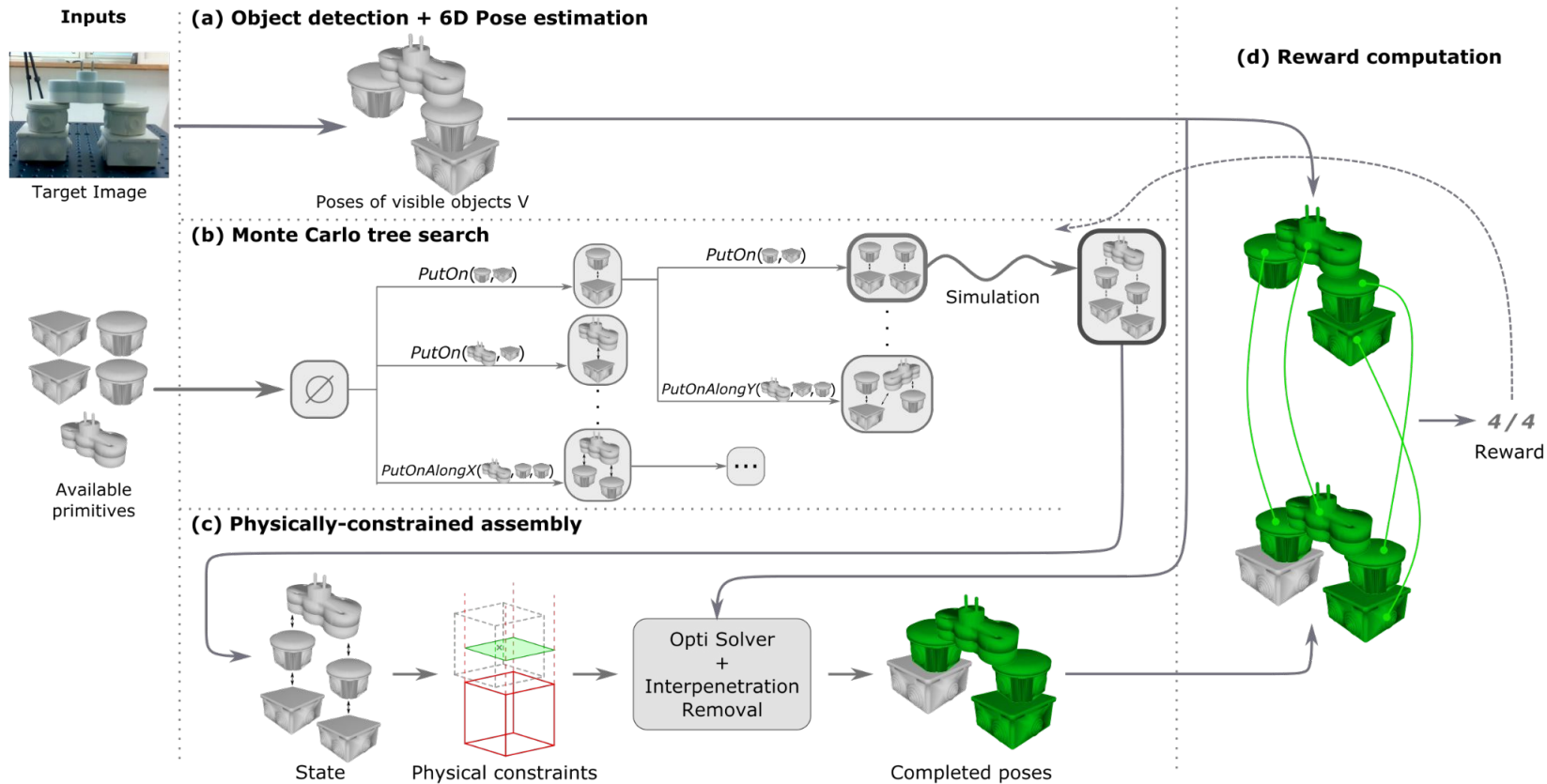
# Monte-Carlo tree search

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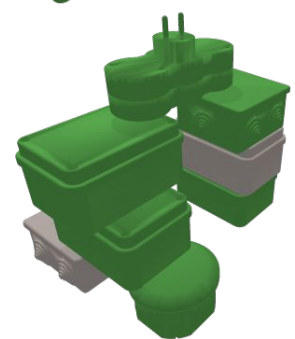
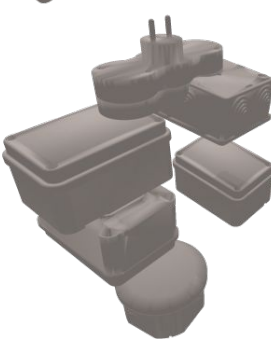
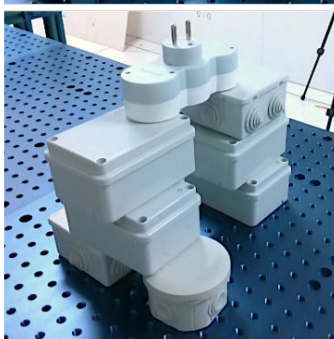
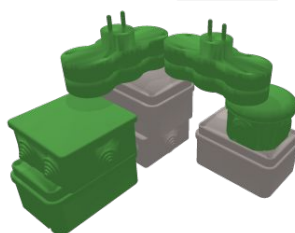
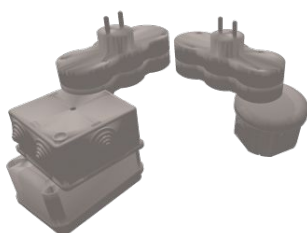
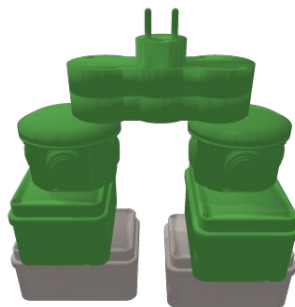
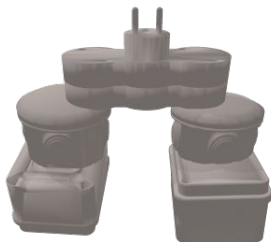
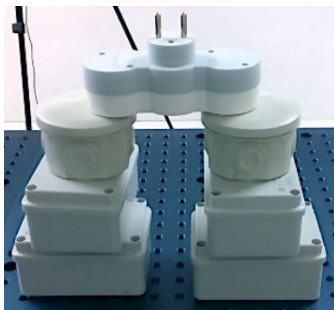
# Summary of the method



# Results

## Some reconstructions

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# Conclusion

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- Method connecting **several fields**:
  - Task planning
  - 6D Pose estimation
  - Convex optimization
- Combine vision and robotics with **robustness**
  - Provide **guarantees, interpretable** model
- Still, robotics is tough
  - $\Rightarrow$  **Hence our research**



# Thank you for your attention !



→ Chabal, T., Strudel, R., Arlaud, E., Ponce, J., & Schmid, C. (2022). Assembly Planning from Observations under Physical Constraints. *arXiv preprint arXiv:2204.09616*.



→ <https://www.di.ens.fr/willow/research/assembly-planning/>



→ [thomas.chabal@inria.fr](mailto:thomas.chabal@inria.fr)