Quality and Uncertainty

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Robotics Institute
Foam Robotics Lab

Quality Metrics in Grasping & Manipulation

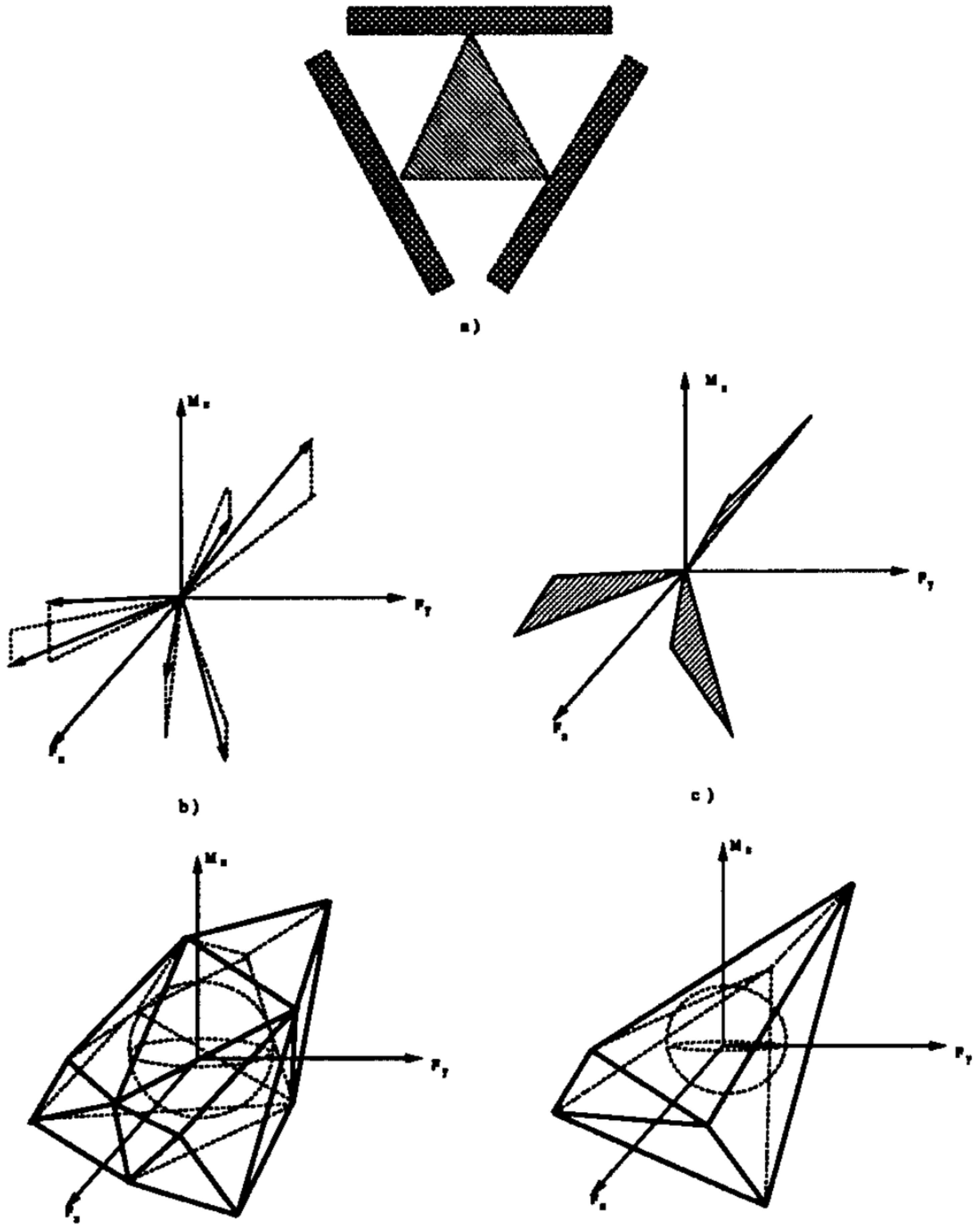
The Basics — Force and Form Closure

Form Closure (Geometric): If you could freeze / lock the hand in this configuration, the object would be restrained. There is no reliance on friction.

Force Closure (Relies on Friction): For any external wrench, there exists a set of contact forces that can oppose that wrench such that friction constraints are satisfied.

Quality Metrics in Grasping & Manipulation

The Standard Numerical Measure — Wrench Space Ball



Ferrari, Carlo, and John F. Canny. "Planning optimal grasps." ICRA 1992.

+ Easy to implement
+ Relatively fast
+ Widely used standard

- Does not capture task
- Does not capture hardware
- Search is exponential in #contacts





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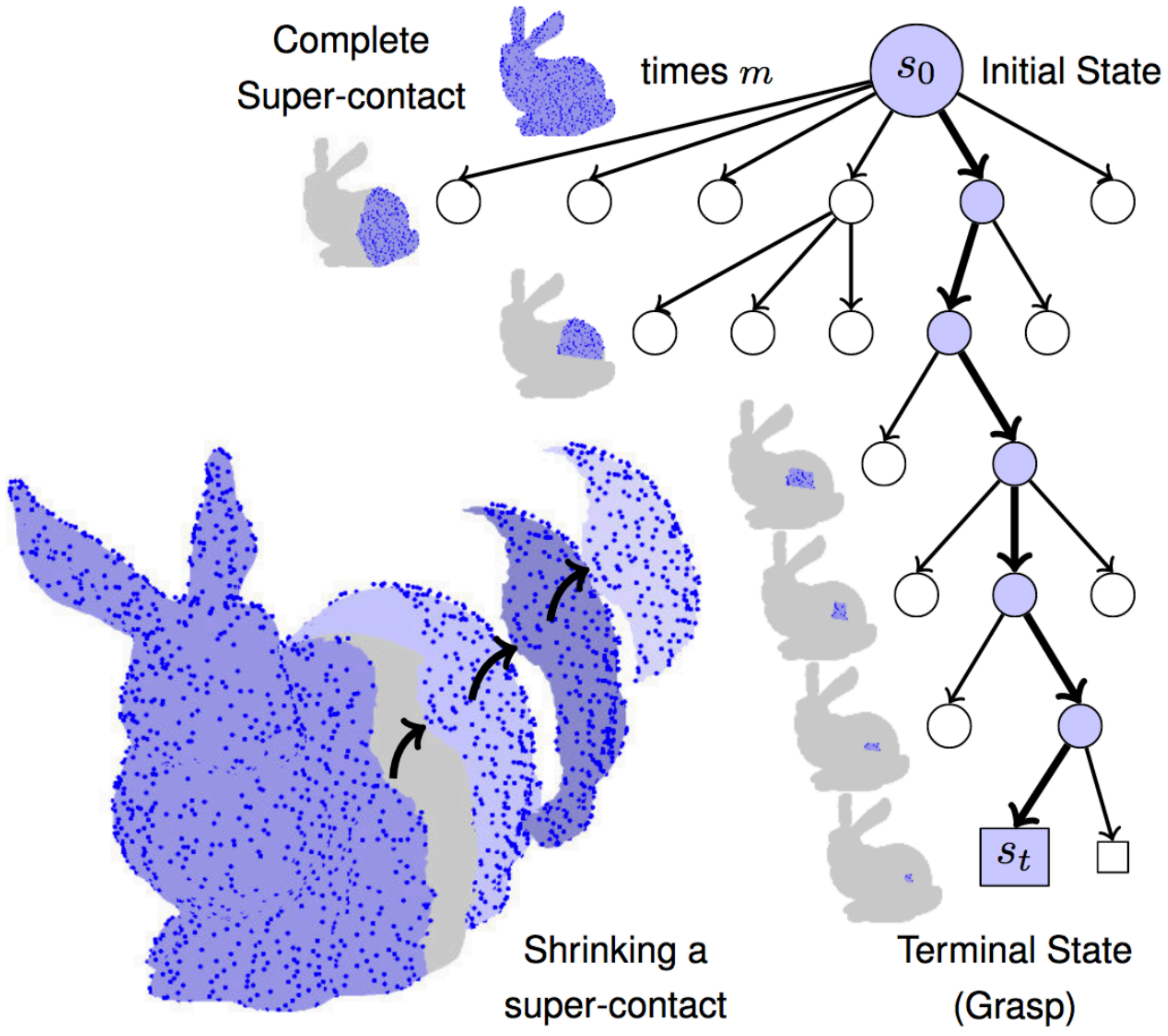
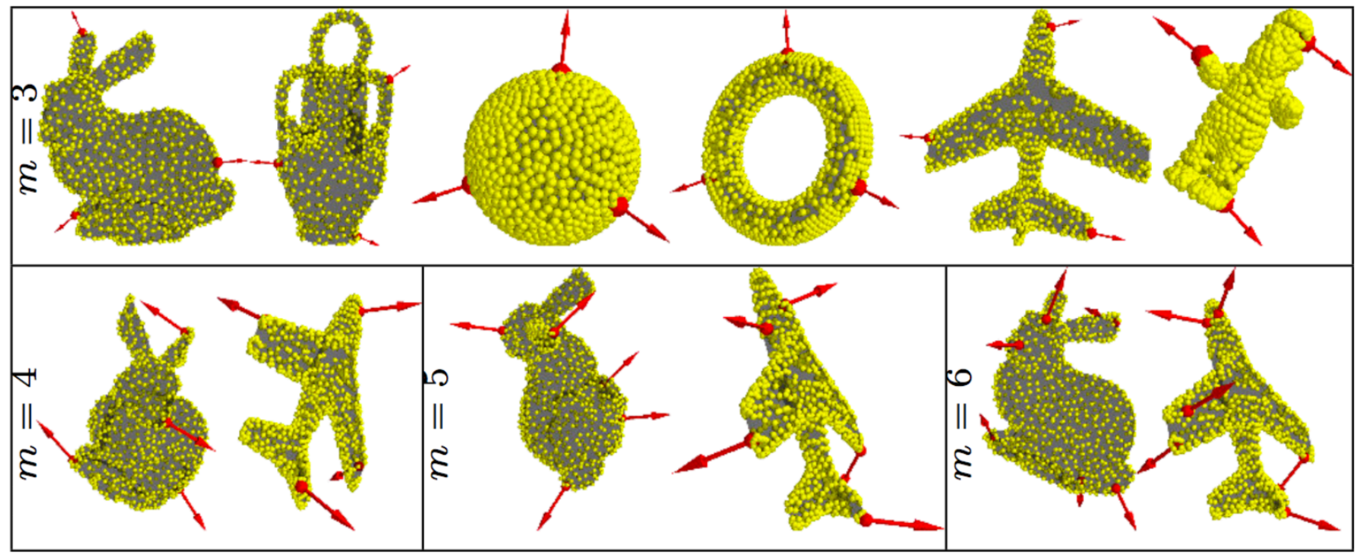
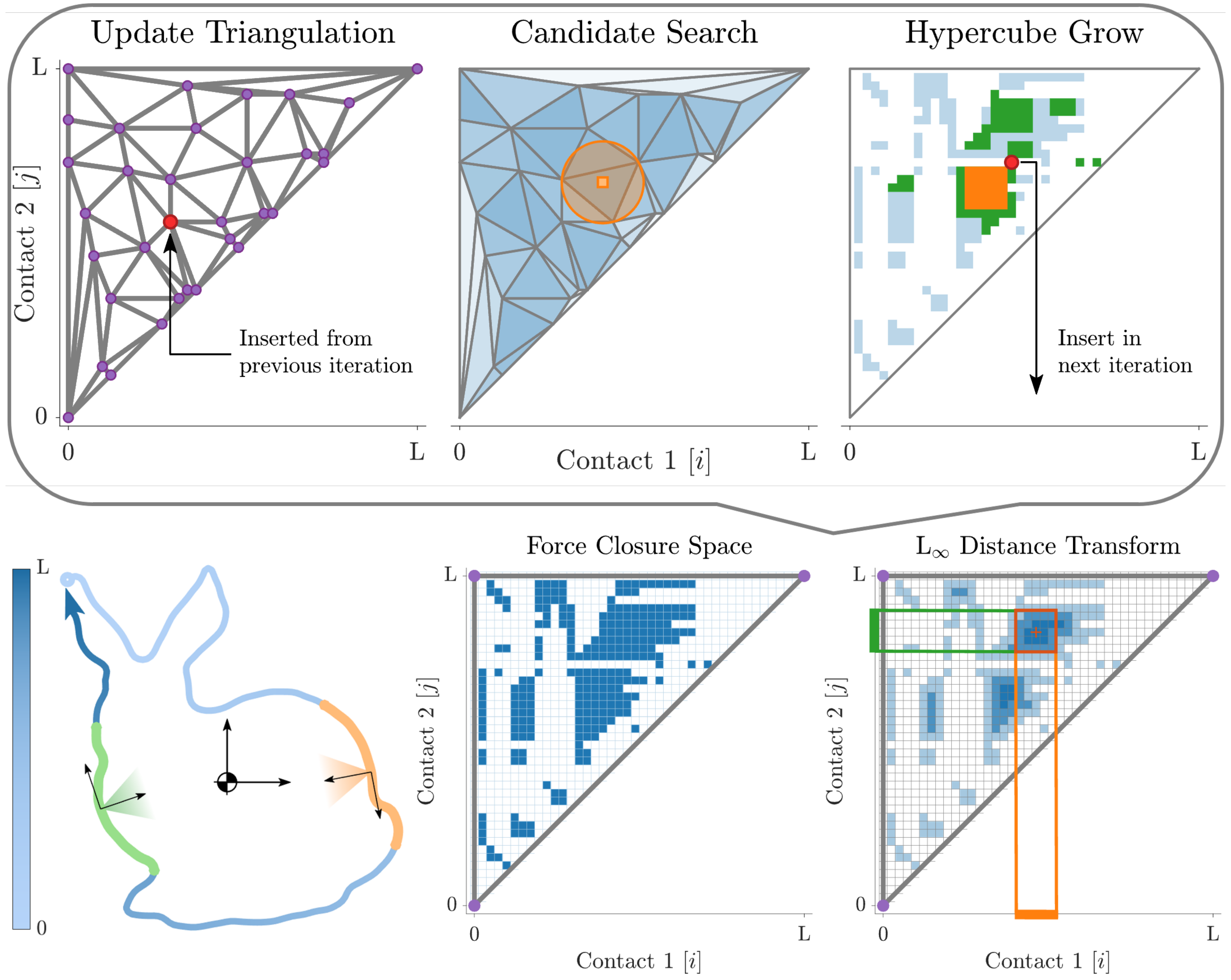
We can combat the curse of dimensionality





K. Hang, J. A. Stork, N. S. Pollard, and D. Kragic, 2017. A Framework For Optimal Grasp Contact Planning, IEEE RA-L 2017.



Jonathan King, Michael Zhang, and Nancy Pollard, "N-D Delaunay Triangulation for Fast, Iterative Computation of Globally Optimal Independent Contact Regions," work in progress.

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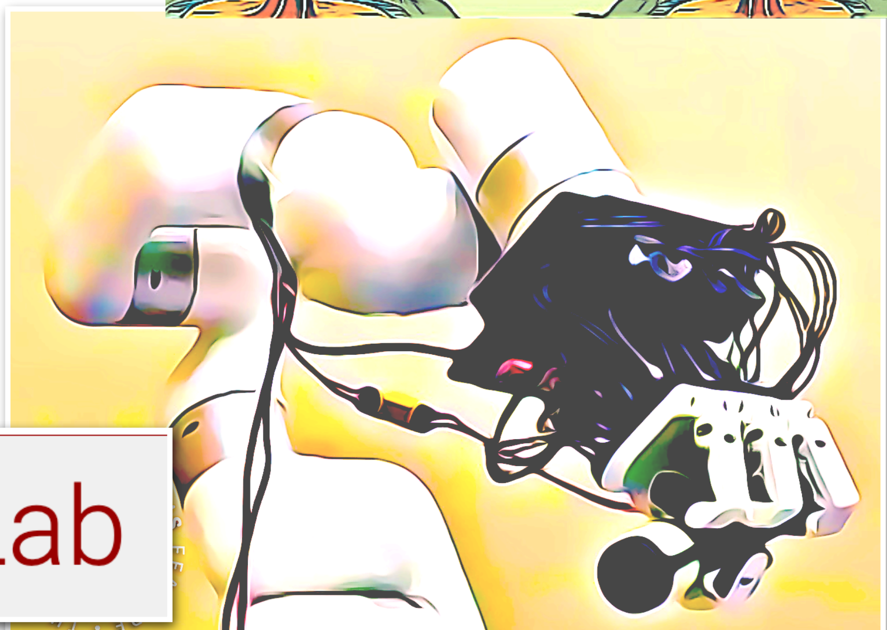
Quality Metrics in Grasping & Manipulation

Three things we can do to create more focused metrics

- Safety margin compared to a demonstration (X% as good)

- Safety margin for the task

- Safety margin that includes actuator capabilities



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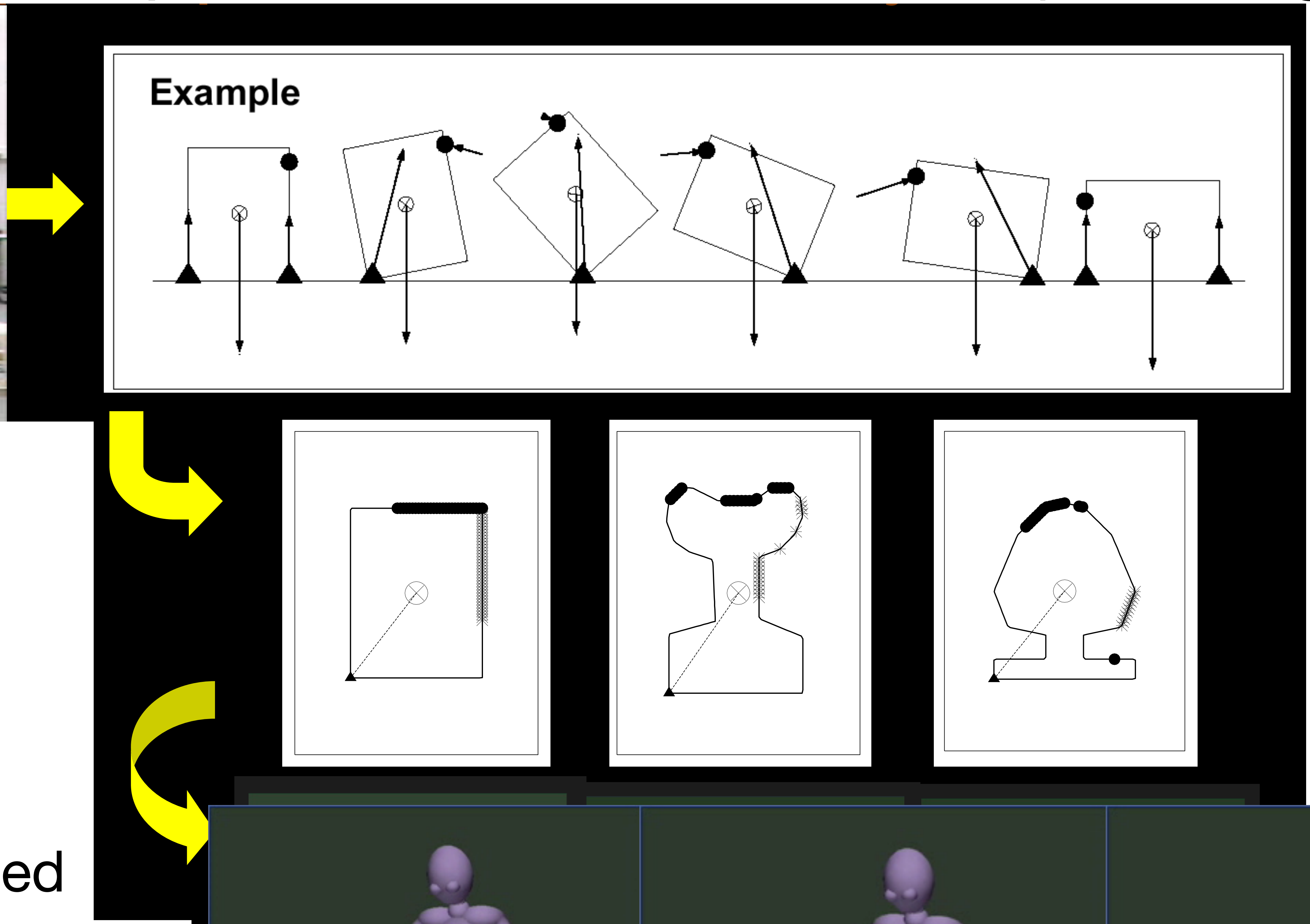
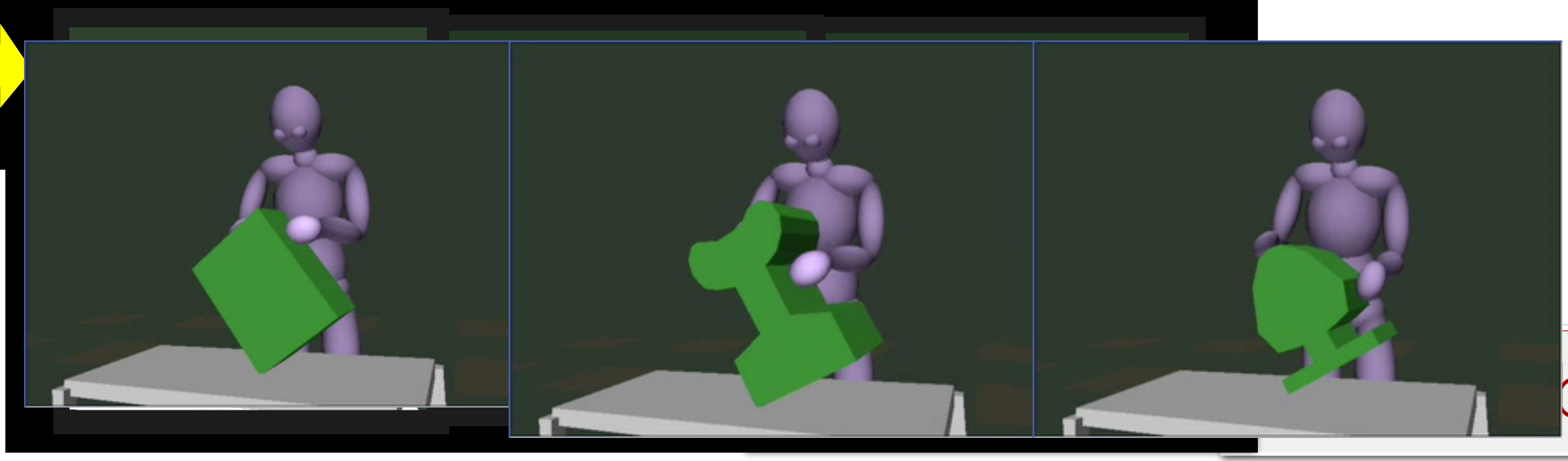
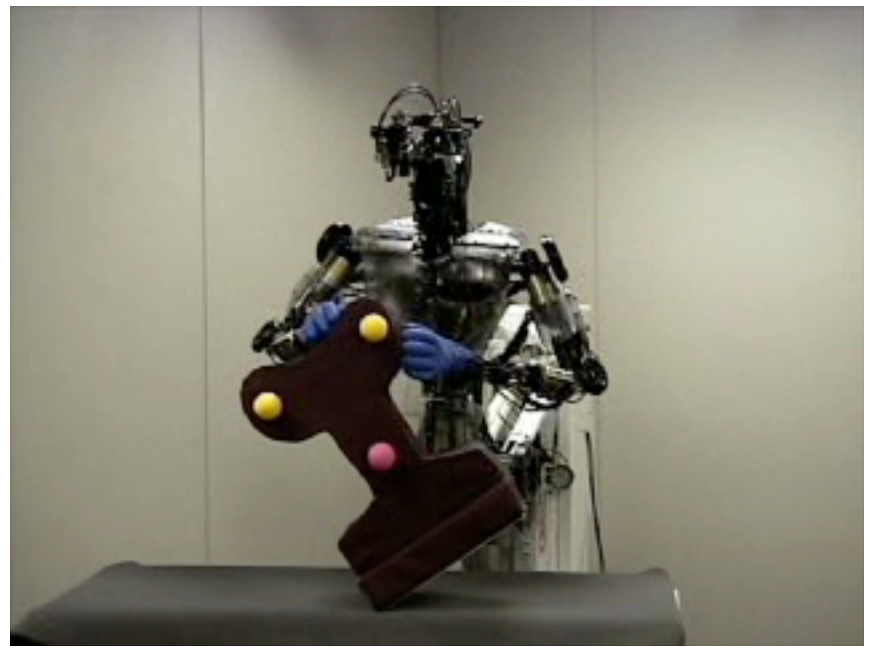


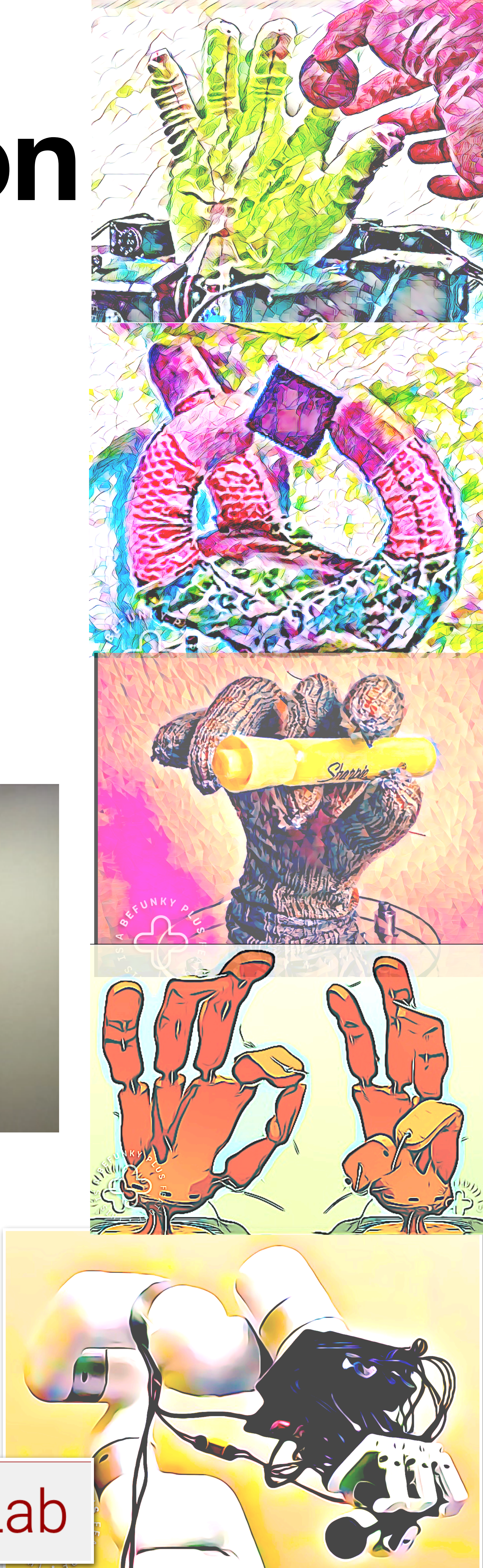
Similar contact forces

Force magnitudes < 2X example

Example forces do not need to be measured







Pollard, Nancy S. "Closure and quality equivalence for efficient synthesis of grasps from examples." IJRR 2004

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Quality Metrics in Grasping & Manipulation

Three things we can do to create more focused metrics

- Safety margin for the task

maximal wrench that can be applied in the task direction

$$Q = \min_i \frac{||w_{i,max}||}{||t_i||}, i = 1, ..., t$$

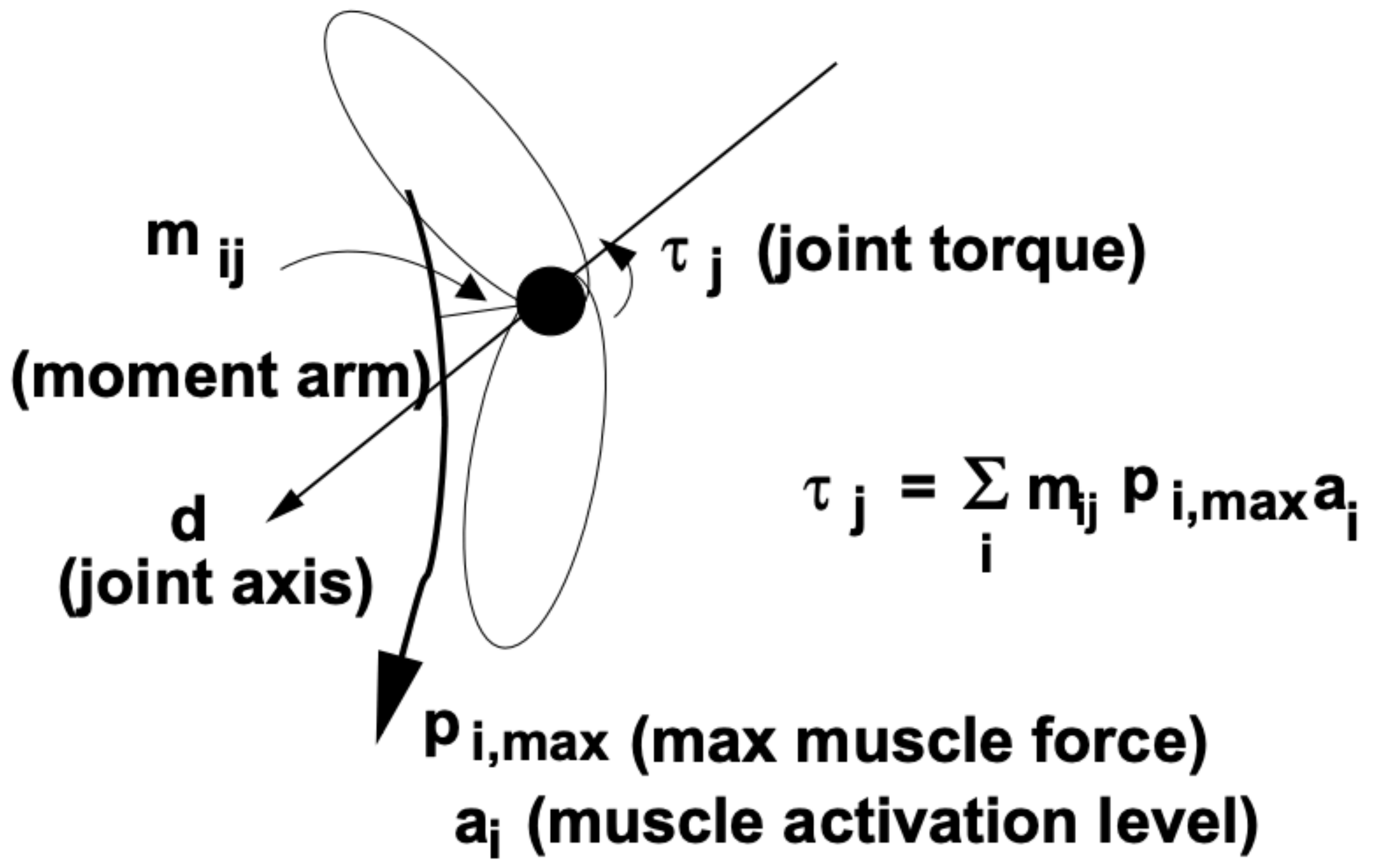
task wrench *i*

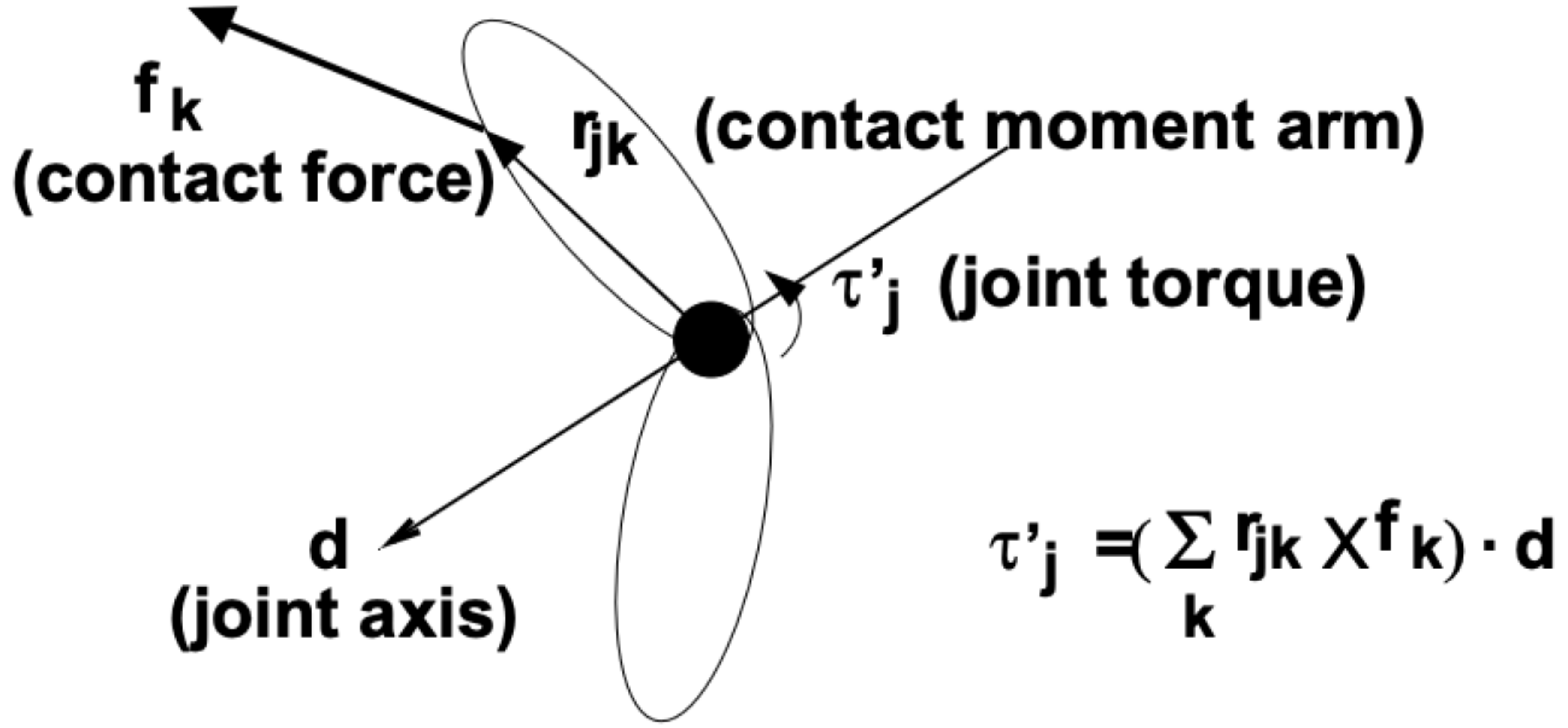
Li, Ying, Jiaxin L. Fu, and Nancy S. Pollard. "Data-driven grasp synthesis using shape matching and task-based pruning." IEEE Transactions on visualization and computer graphics 2007.

Quality Metrics in Grasping & Manipulation

Three things we can do to create more focused metrics

- Safety margin that includes actuator capabilities





actuator torque = torque explained by contact

Li, Ying, Jiaxin L. Fu, and Nancy S. Pollard. "Data-driven grasp synthesis using shape matching and task-based pruning." IEEE Transactions on visualization and computer graphics 2007.

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Quality Metrics in Grasping & Manipulation

Three things we can do to create more focused metrics

- Safety margin that includes actuator capabilities

$$\alpha_i = \|w_{i,max}\|$$

$$s_i = \frac{t_i}{\|t_i\|}$$

$$\text{maximize } (\alpha_i)$$

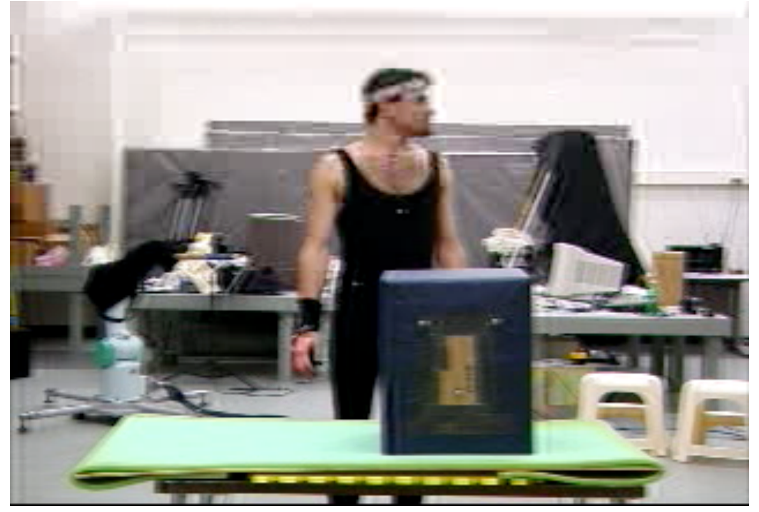
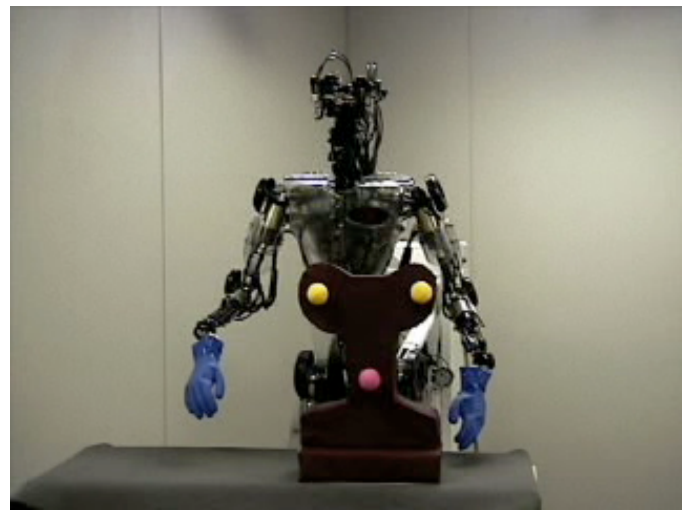
$$\begin{pmatrix} -s_i & G & 0 \\ 0 & J^T & -MP \end{pmatrix} \begin{pmatrix} \alpha_i \\ f \\ a \end{pmatrix} = 0$$

Li, Ying, Jiaxin L. Fu, and Nancy S. Pollard. "Data-driven grasp synthesis using shape matching and task-based pruning." IEEE Transactions on visualization and computer graphics 2007.

Quality Metrics in Grasping & Manipulation

Three things we can do to create more focused metrics

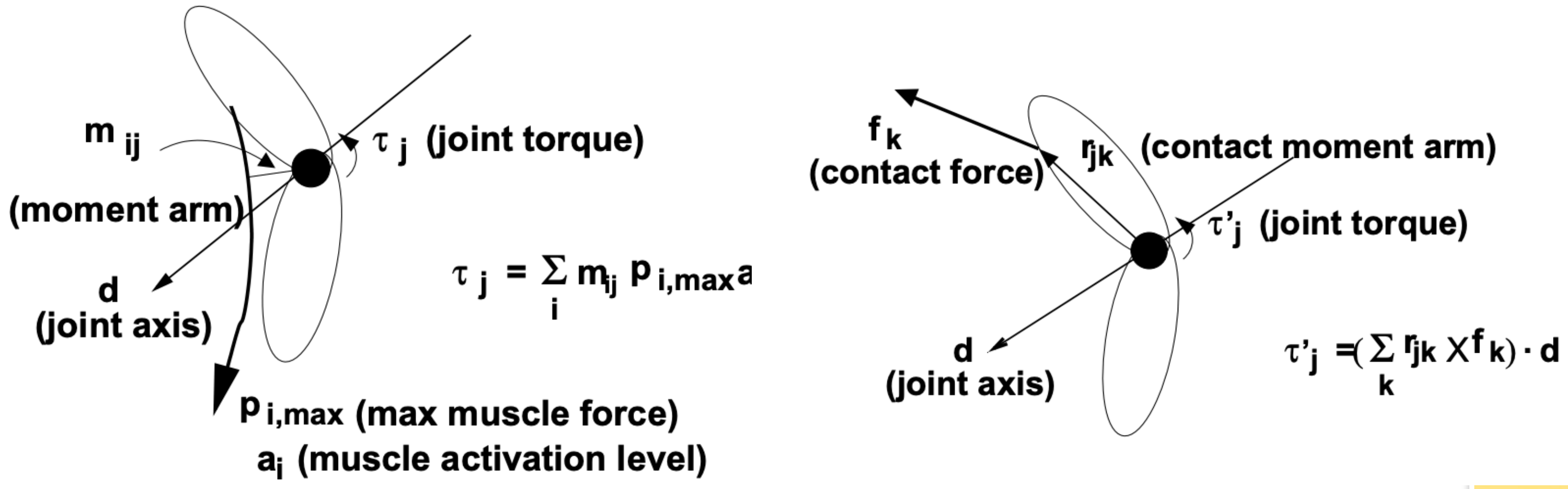
- Safety margin compared to a demonstration (X% as good)
  - *no need to know task / robot*

- Safety margin for the task
  - *need a set of task wrenches*

$$Q = \min_i \frac{\|w_{i,max}\|}{\|t_i\|}, i = 1, ..., t$$

- Safety margin that includes actuator capabilities
  - *need task / robot specifications*



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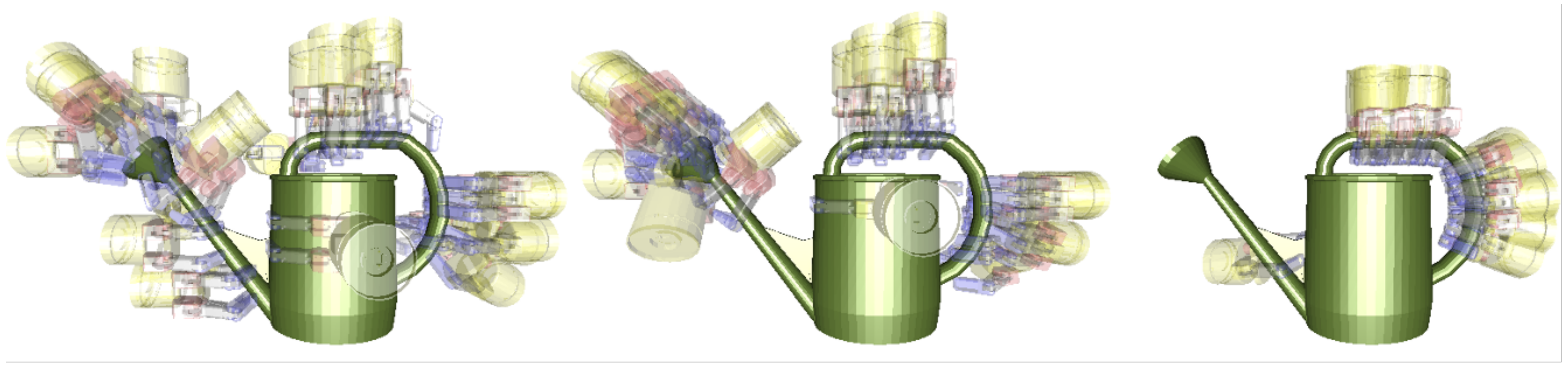
Uncertainty

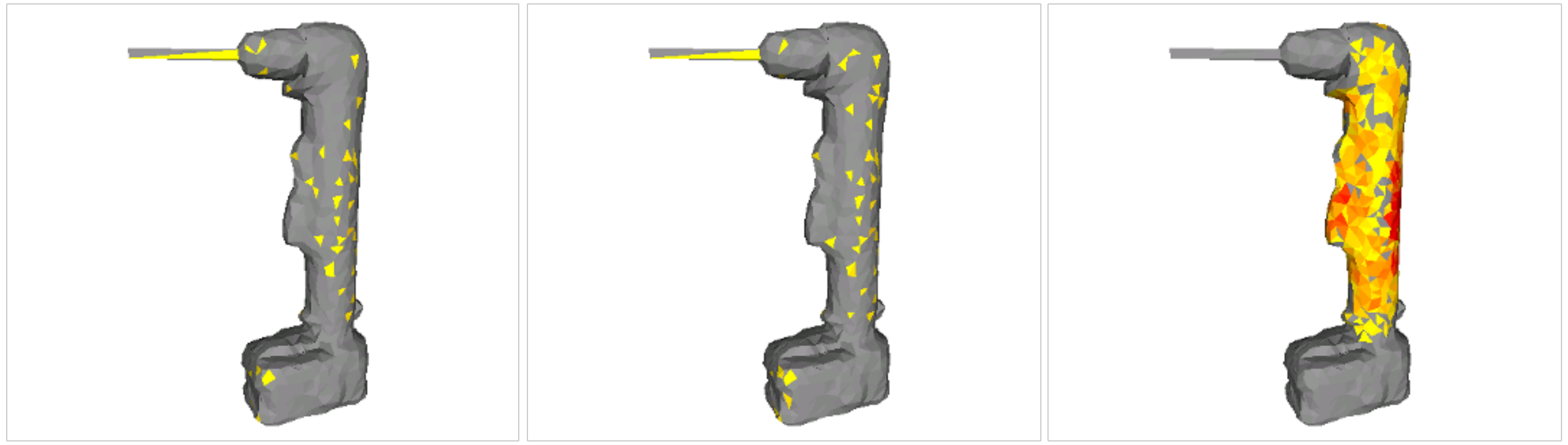
The real world is dynamic and uncertain

Uncertainty

Including Dynamics + Uncertainty with simulation rollouts dramatically improves realism



Existing method (kinematic grasping + force-closure) | Existing method + uncertainty | Dynamics + uncertainty

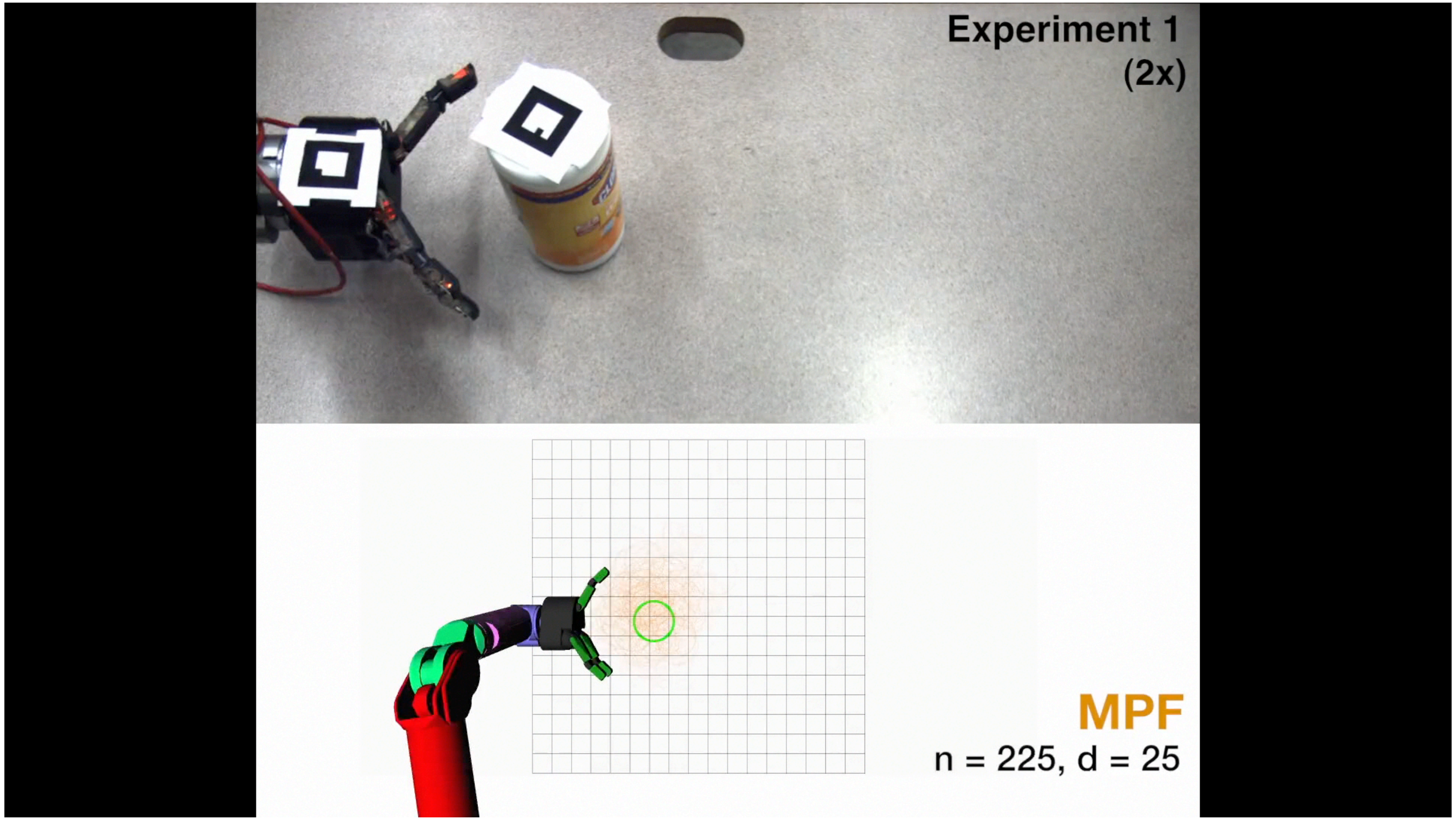


Existing method (kinematic grasping + force-closure) | Existing method + uncertainty | Dynamics + uncertainty

Kim, Junggon, Kunihiro Iwamoto, James J. Kuffner, Yasuhiro Ota, and Nancy S. Pollard. "Physically based grasp quality evaluation under pose uncertainty." IEEE Transactions on Robotics 2013.

Uncertainty

We can further use rollouts to plan actions that actively seek sensor information to shrink a belief state



Koval, Michael C., Nancy S. Pollard, and Siddhartha S. Srinivasa. "Pose estimation for planar contact manipulation with manifold particle filters." The International Journal of Robotics Research 2015