

# The Aspect Transition Graph: an Affordance-Based Model

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# Abstract

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Introduces an affordance-based model that is grounded in the robots own action and perception.

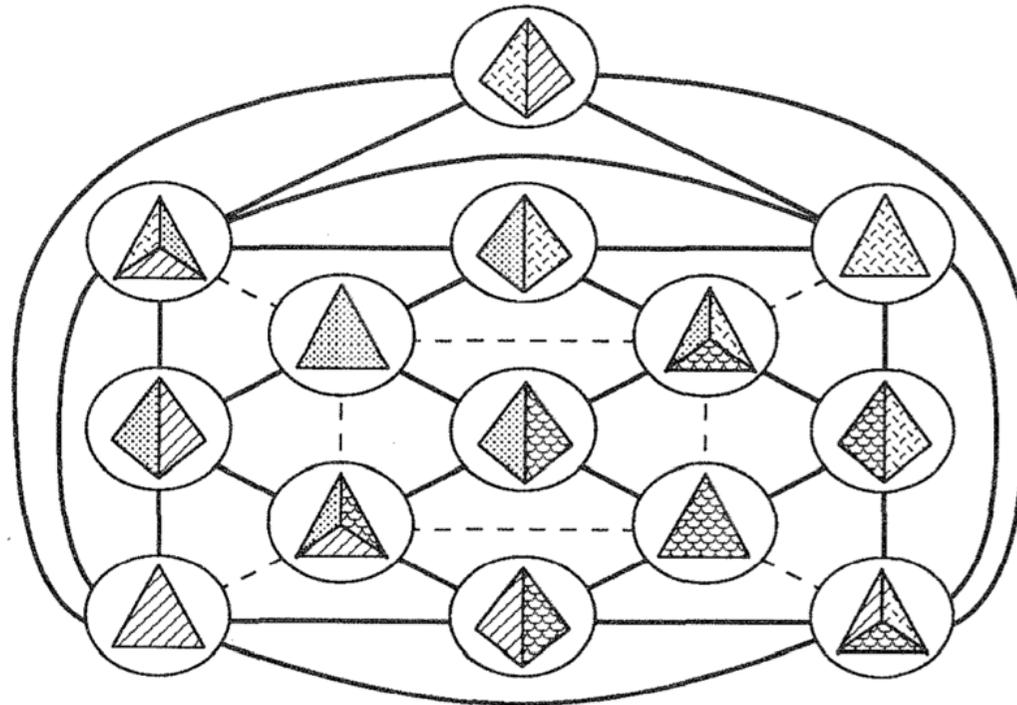
# Defining Affordance

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- “the opportunities for action provided by a particular object or environment.”
- Used to explain how “value’ or “meaning” of things in the environment is perceived.

# Aspect Graph

- Aspect graph represents an object's shape through its topologically distinct views.
- Aspect graph of a tetrahedron:



Eggert, David W., Kevin W. Bowyer, and Charles R. Dyer. "Aspect graphs: State-of-the-art and applications in digital photogrammetry." *Proc. ISPRS 17th Cong.: Int. Archives Photogrammetry Remote Sensing*. 1992.



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# Aspects

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- Views (Visual Aspects) are random processes that depend on the relative viewpoint, the sensors and the object.
- Example: an apartment with a great mountain view.

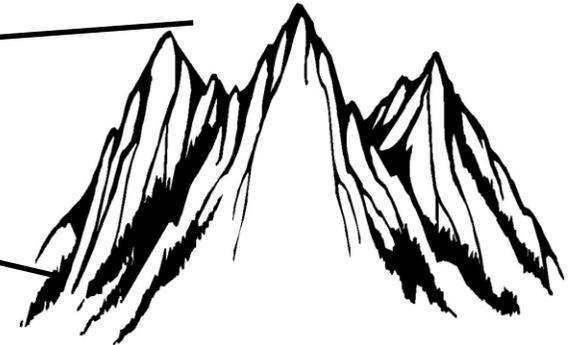
Viewpoint



Sensor



Object



# Definitions

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*Aspect - The features of an object that are measurable given a set of sensors and their geometry relative to the object.*

Examples:

- The visual features of an object that can be observed with an RGB camera from an object-relative viewpoint.
- The tactile features that can be measured on a force sensor at an object-relative contact point.

# Definitions

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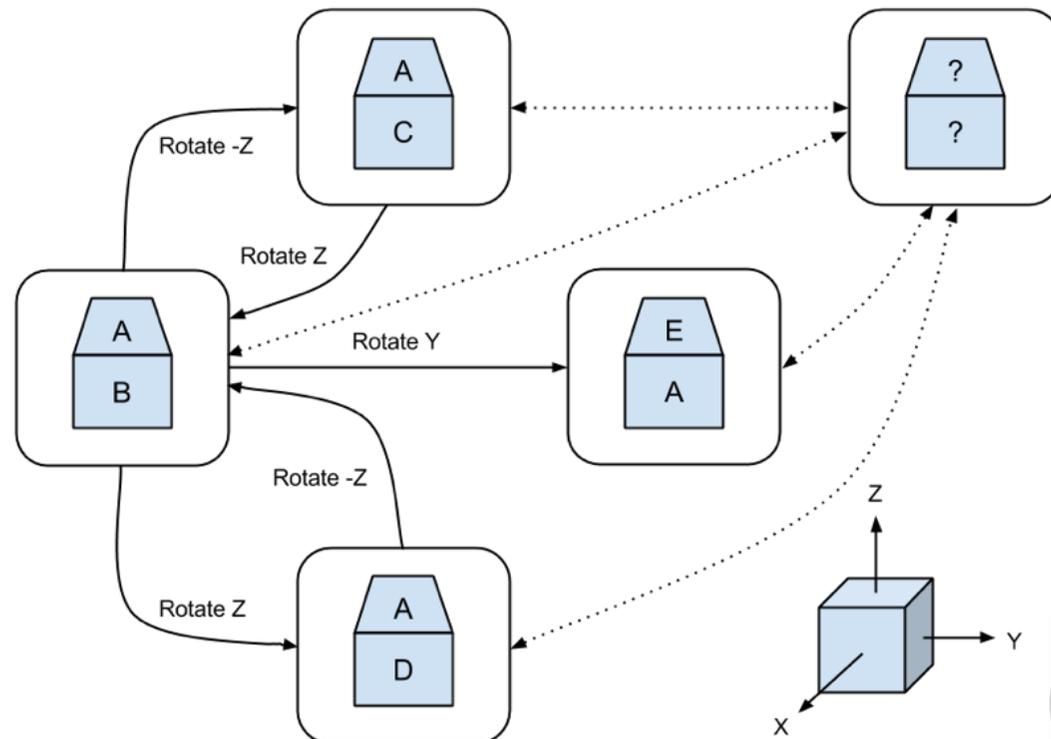
*Action - May change the object or the geometric relationship to the sensor and hence lead to a new aspect.*

Examples:

- Rotating a cube changes the viewpoint of observation leading to a new aspect.
- Squeezing a rubber ball changes the ball leading to a new aspect.

# Aspect Transition Graph (ATG)

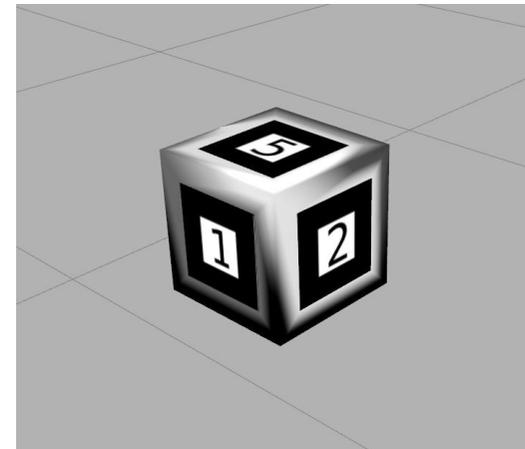
- Summarizes empirical observations of the aspect transitions in the course of interaction.
- Partially observed model



# Experiment Settings

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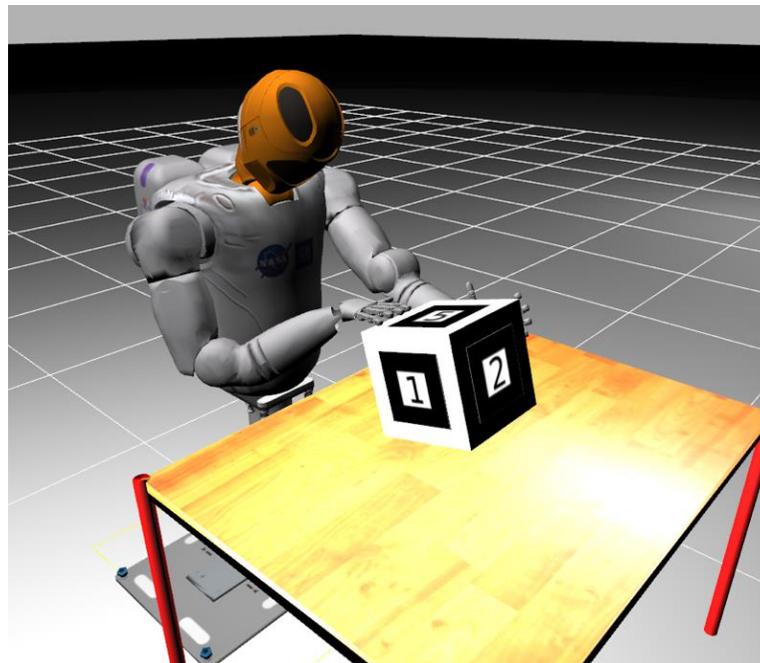
- NASA Robonaut 2 simulator
- 100 unique ARcubes in simulation
- 3 different rotation actions



# Learning Object Models

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- A random object is given to the robot for each trial.
- The robot plays with the object and builds its ATG model.
- The new ATG model is added to the robot memory if the object is novel.



# Identify Novel Objects

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- Posteriors of aspects are updated through Bayes filter algorithm.
- The probability that a given object is novel can be calculated by assuming the robot knows how many objects are in the world.

$$\begin{aligned} & p(O_T \notin \mathcal{S}_{T-1} | z_{1:t}, a_{1:t}, \mathcal{M}) \\ &= \sum_{o_i \notin \mathcal{S}_{T-1}} p(O_T = o_i | z_{1:t}, a_{1:t}, \mathcal{M}) \\ &= \sum_{o_i \notin \mathcal{S}_{T-1}} \sum_{x_t \in \mathcal{X}_i} p(x_t | z_{1:t}, a_{1:t}). \end{aligned}$$

# Two Important Challenges

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- Acquire object models
- Recognize object identities

# Action Selection Strategy

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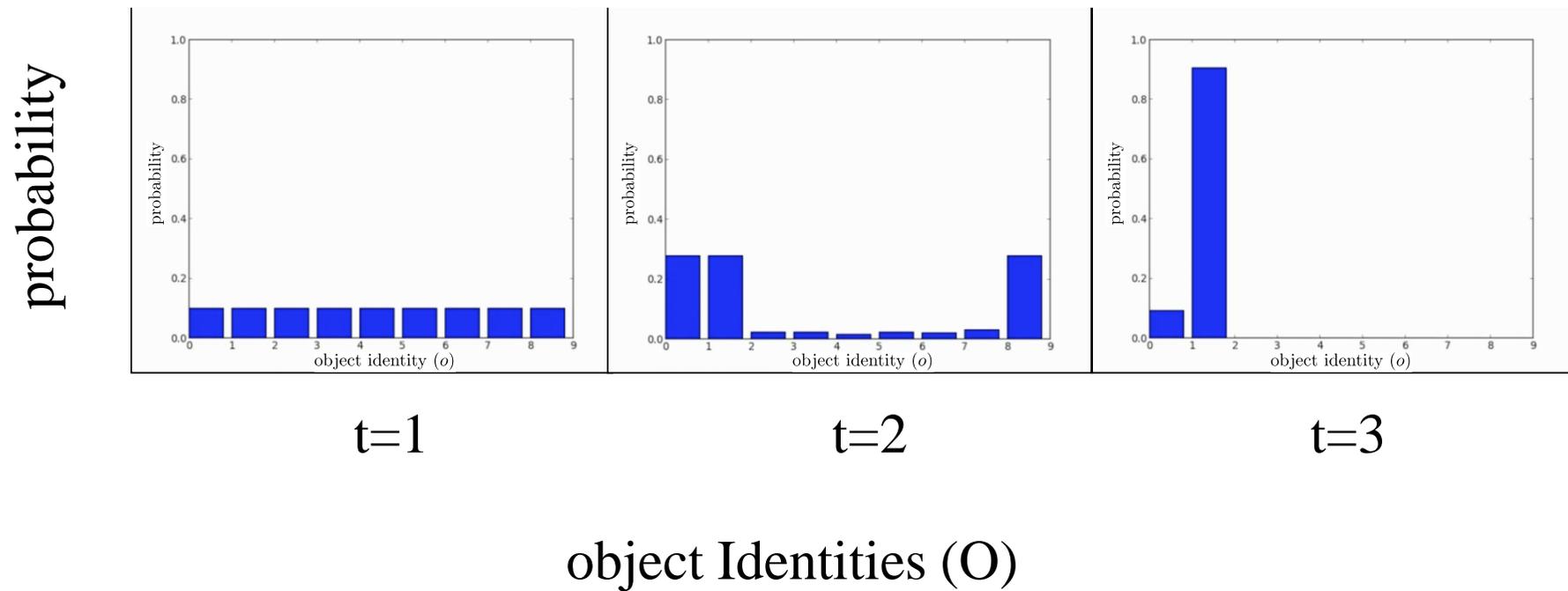
- Minimizes the expected entropy on object/model identity for the next step,

$$\begin{aligned} & \operatorname{argmin}_{a_t} E(H(O_T | z_{t+1}, a_t, z_{1:t}, a_{1:t-1})) \\ &= \operatorname{argmin}_{a_t} \sum_{z_{t+1}} H(O_T | z_{t+1}, a_t, z_{1:t}, a_{1:t-1}) \times \\ & \quad p(z_{t+1} | a_t, z_{1:t}, a_{1:t-1}). \end{aligned}$$

- Future observation can be estimated through models learned in the past.

# Condensing Belief

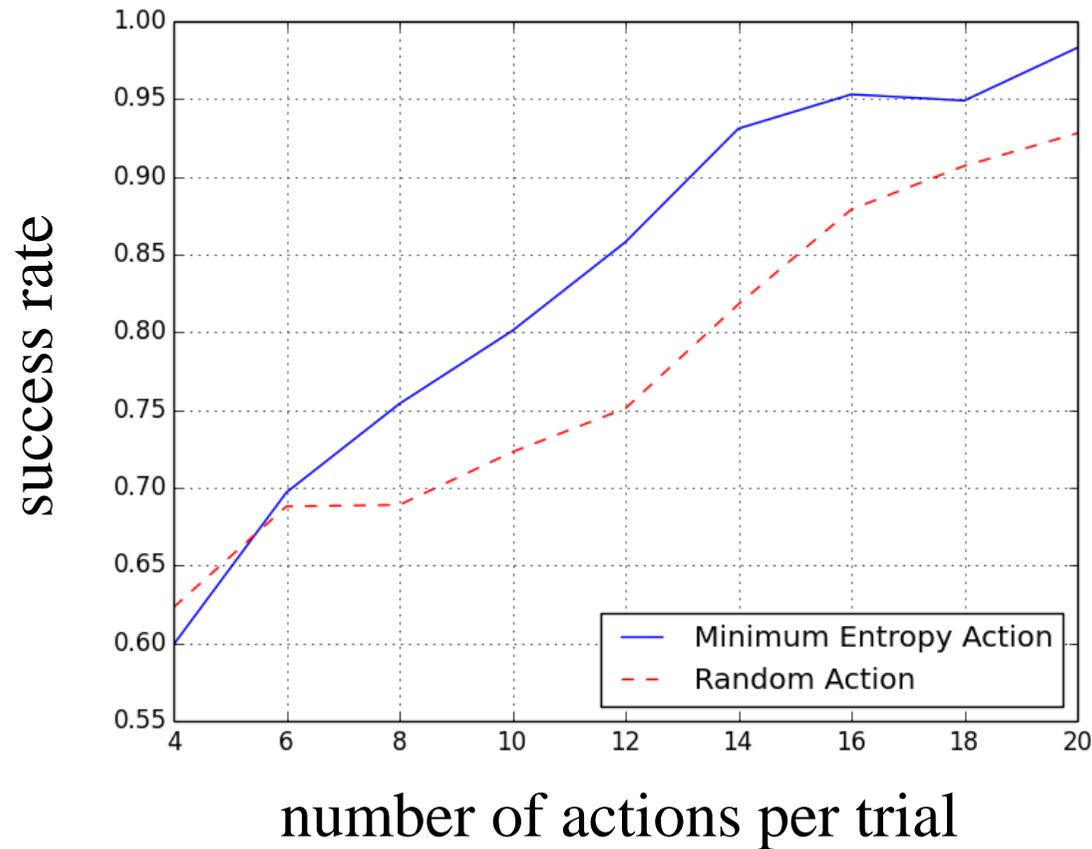
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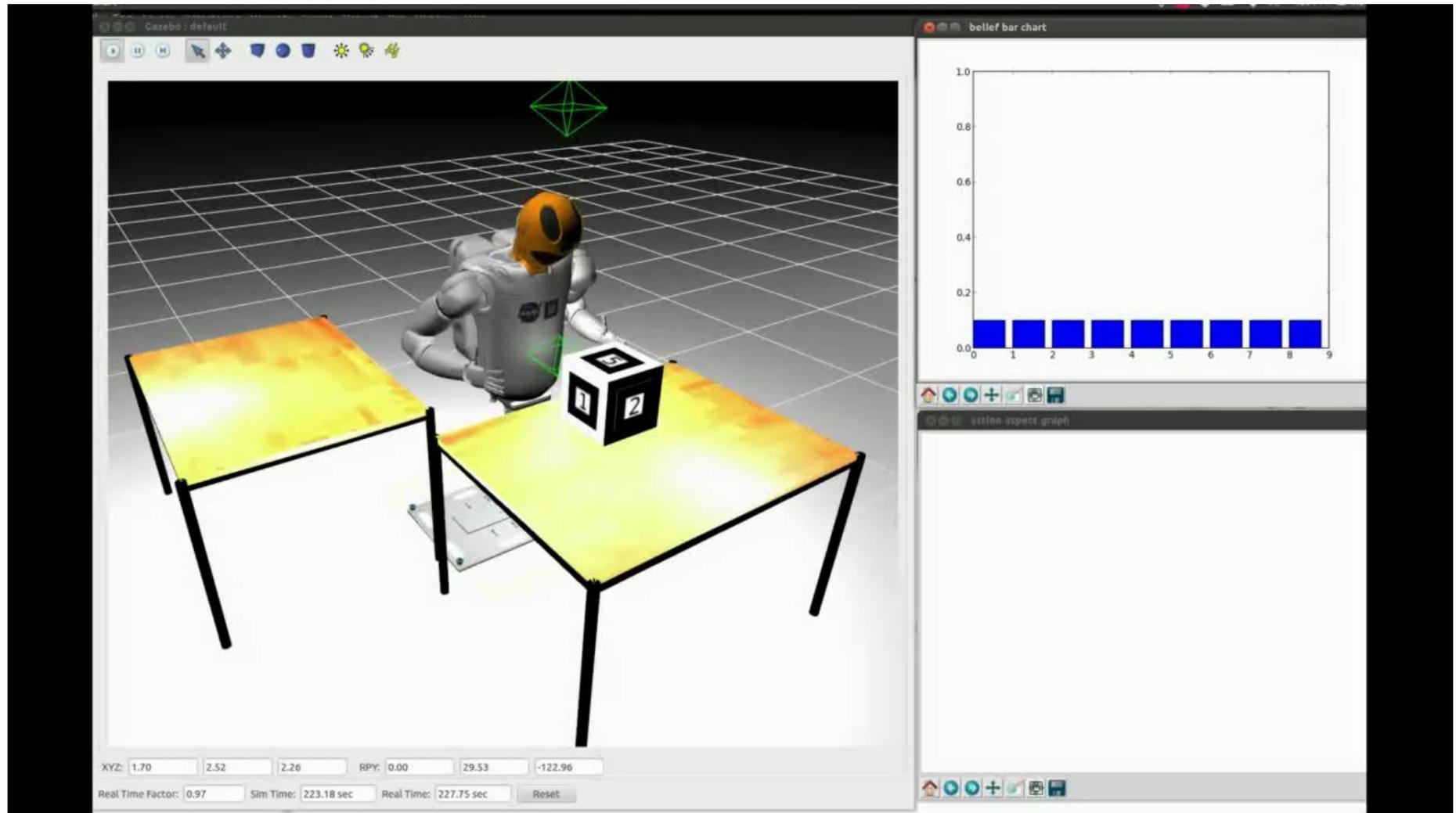
# Experiment Results

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- Compared with a random planner.
- 100 trials per test, starts with empty memory.



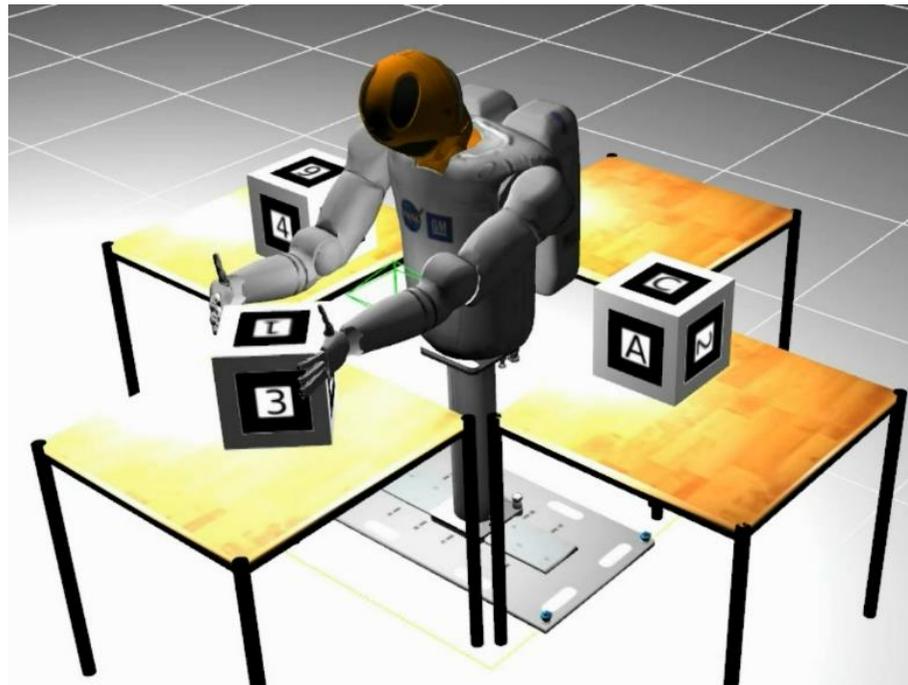
# Demo Video



# Exploiting the Model: Reaching Goal Aspects

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- Example: Spelling words with ARcubes.
- Once an object is recognized, execute the actions on the shortest path from the current aspect to the goal aspect.



# Extending to More Realistic Situations

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- Switch to more realistic objects and more general features.
- Determine new aspects.
- Handle noisy actions with continuous parameters.
- Incorporate haptic sensors.

# Conclusion

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- Introduce the Aspect Transition Graph, an affordance based model that captures the relationship between observations and actions.
- Demonstrate how the model can be learned through exploration and used for inference and reaching goal states.

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Thank You

