Affordances:

The adventures of an elephant in the land of autonomous robots

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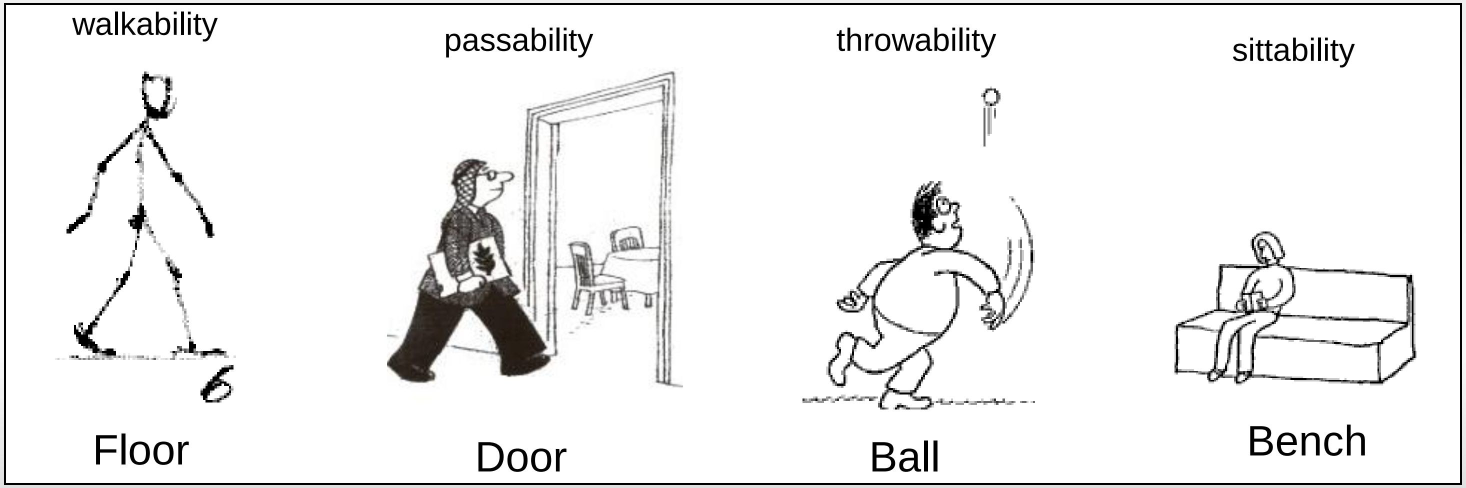
The notion of affordance

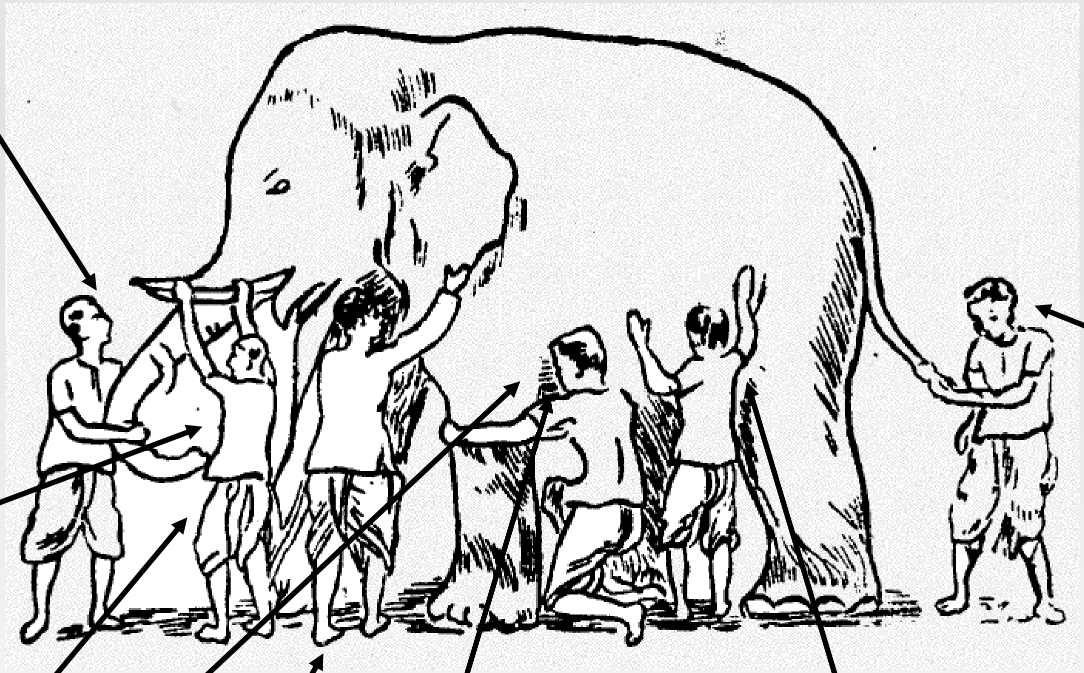
J.J. Gibson (1904–1979)

- Introduced J.J. Gibson to explain
  - how inherent “values” and “meanings” of things in the environment can be directly perceived, and
  - how this information can be linked to the action possibilities offered to the organism by the environment.
- Gibson argued that an organism and its environment complement each other and that studies on the organism should be conducted in its natural environment rather than in isolation



An Elephant called Affordance

J.J.Gibson



Amand & Steedman

MacDorman

Fitzpatrick & Stoytchev

Rizzolatti

E.Gibson

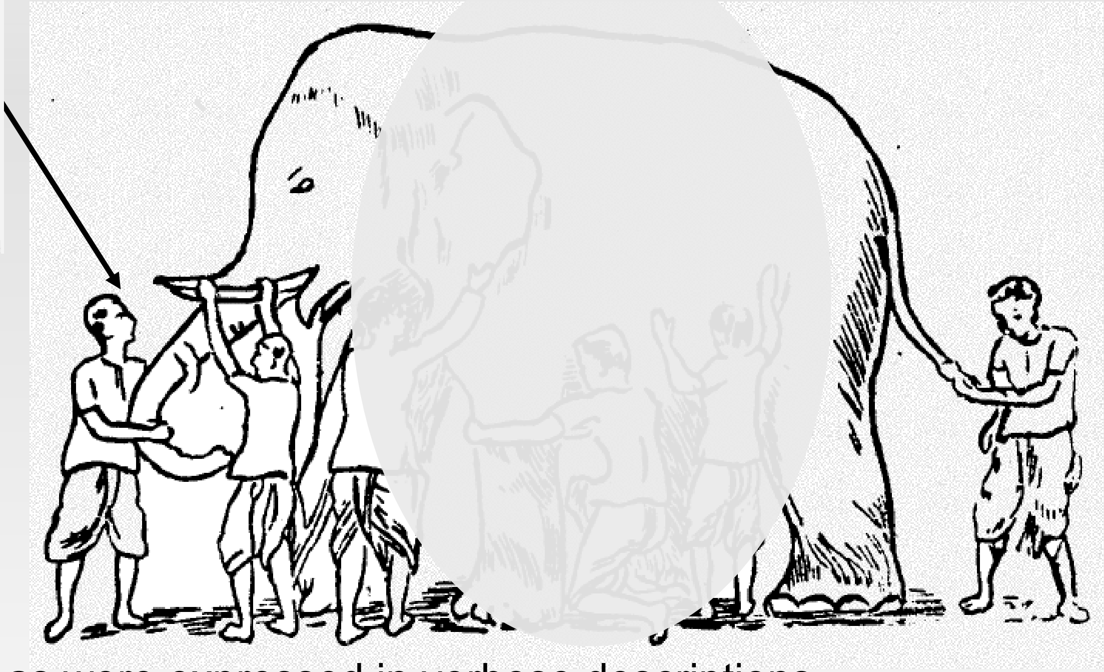
Turvey, Chemero, Stoffregen

Norman & Murphy

An elusive, yet confusing notion that has influenced a wide range of fields ranging from Human-Computer Interaction and Neuroscience, to Robotics

Affordances and Elephants

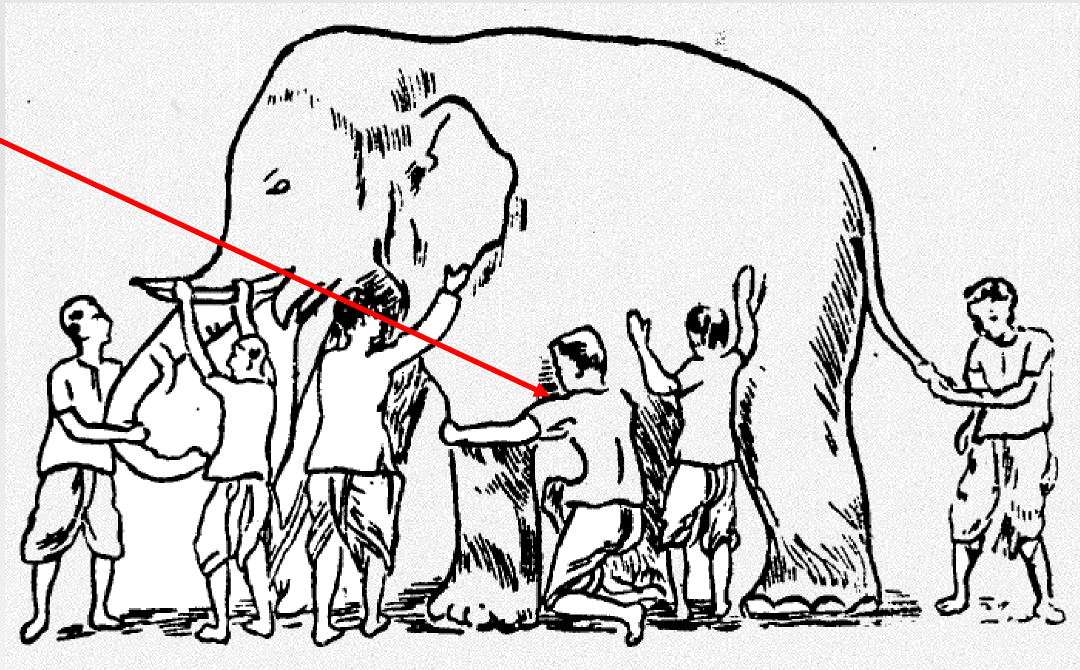
J.J.Gibson



- Gibson’s ideas were expressed in verbose descriptions.
- Gibson’s own understanding evolved over time and were not finalized during his lifetime.
- Gibson’s ideas can be understood only in contrast to the background of contemporary ideas.
- Gibson’s ideas were often blended with his work on visual perception.

Affordances and Elephants
Ecological Psychology

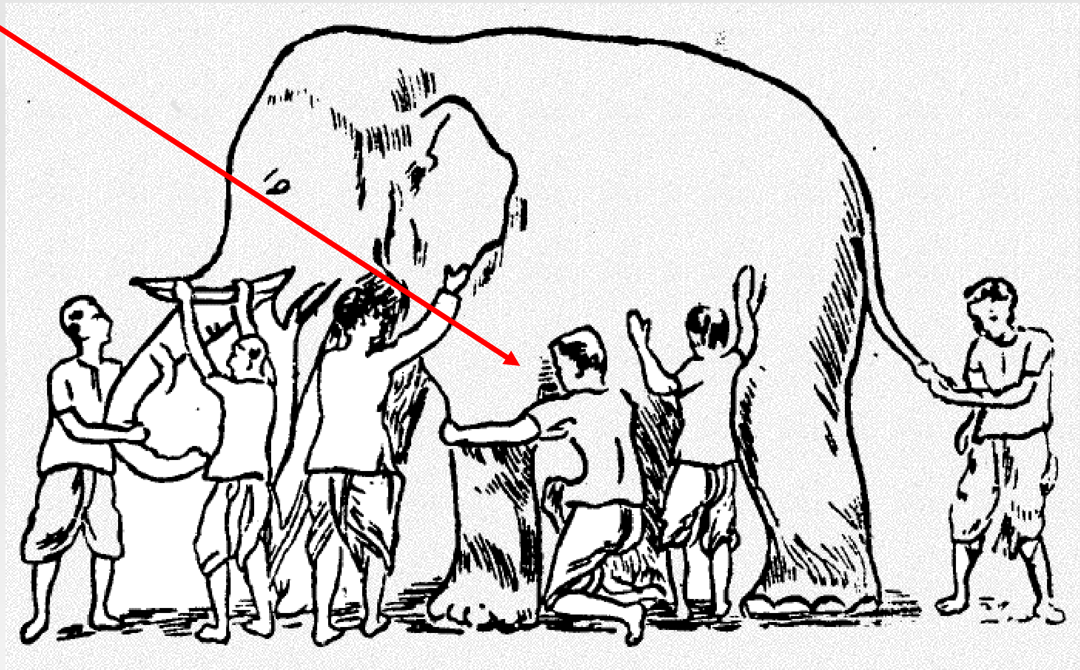
Warren,
Turvey,
Chemero,
Stoffregen



- Affordances are action possibilities that are supported by the environment.
- Organisms tend to perceive the world in terms of body-scaled (intrinsic) metrics not in absolute or global dimensions.
- Affordances exist within the organism-environment system and cannot be attached to the object or to the environment.

Affordances and Elephants
Cognitive Science

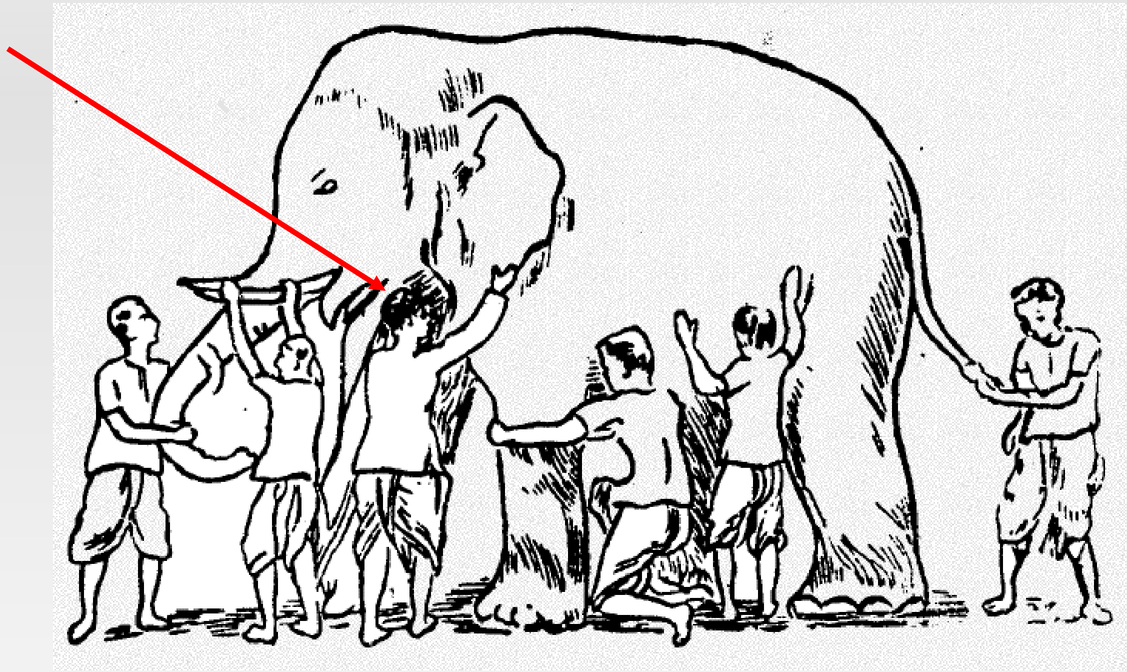
E.J. Gibson



- Learning is "discovering distinctive features and invariant properties of things and events" that specifies an affordance.
- "narrowing down from a vast manifold of (perceptual) information to the minimal, optimal information that specifies the affordance of an event, object, or layout"

Affordances and Elephants
Neurophysiology and Neuropsychology

J.Norman,
Humphreys,
Rizzolatti et
al.
Gallese

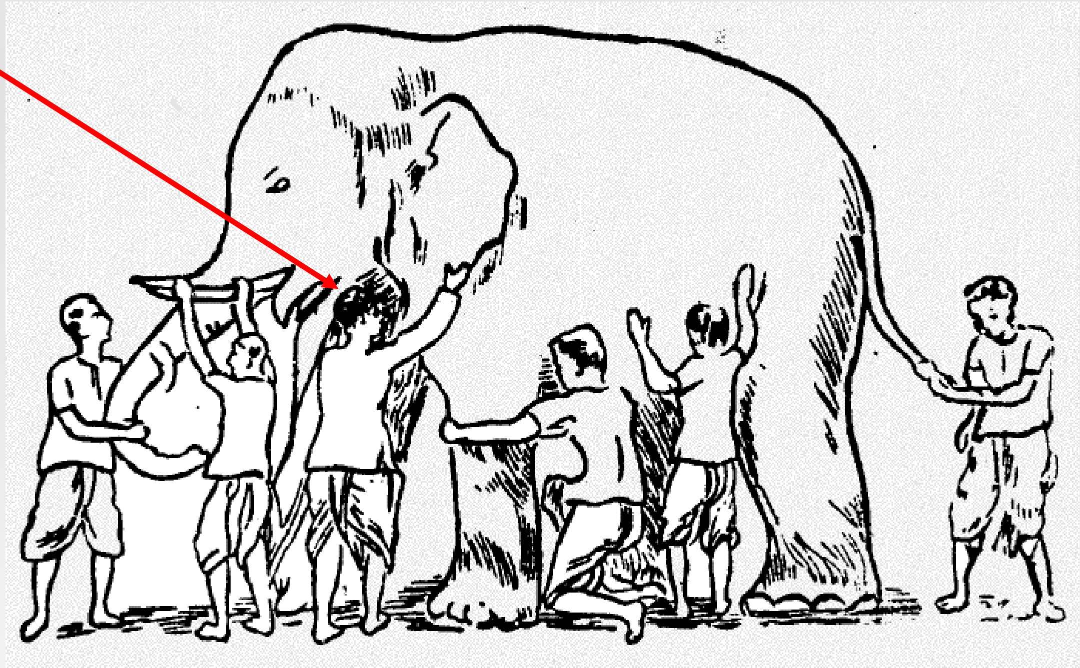


- “the pickup of affordances can be seen as the prime activity of the dorsal system.” (J.Norman;2001)
- Mirror and canonical neurons code both motor and perceptual aspects of the organism.
- “Objects are identified and differentiated in relation to the organism acting in the environment.” (Gallese; 2000)

Affordances and Elephants

Human Computer Interaction

D.A.Norman, McFrenere & Ho



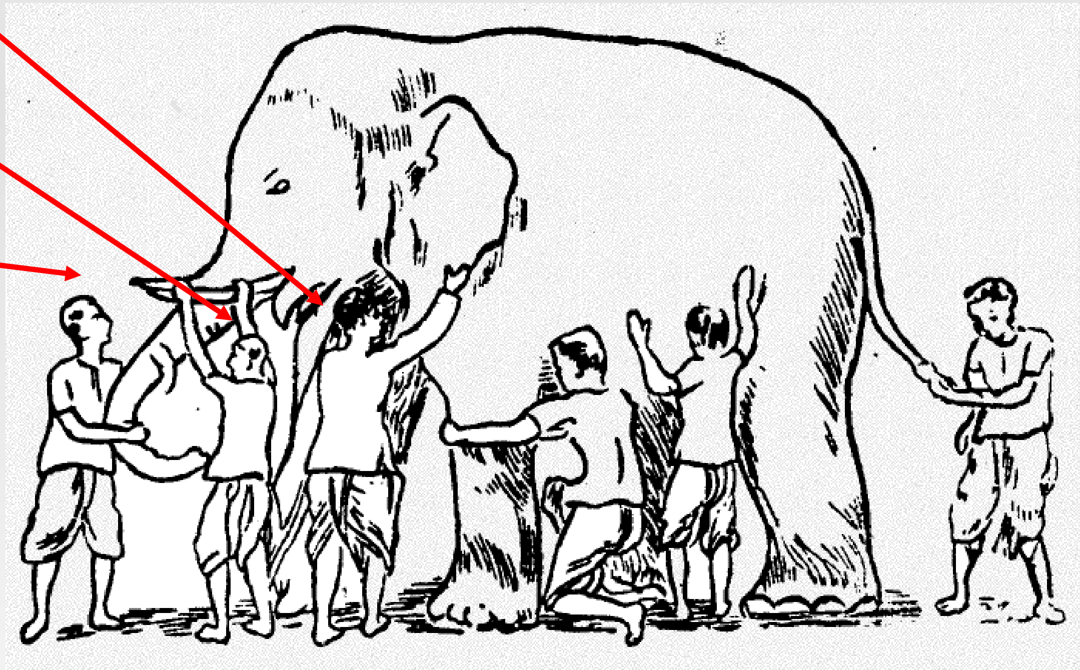
- "…affordance refers to the perceived and actual properties of the thing, primarily those fundamental properties that determine just how the thing could possibly be used."
- "The designer cares more about what actions the user perceives to be possible than what is true." (D.A.Norman; 1988)

Affordances and Elephants
Robotics

Arkin, Murphy, Duchon et al

Fitzpatrick et al, Stoytchev et al,

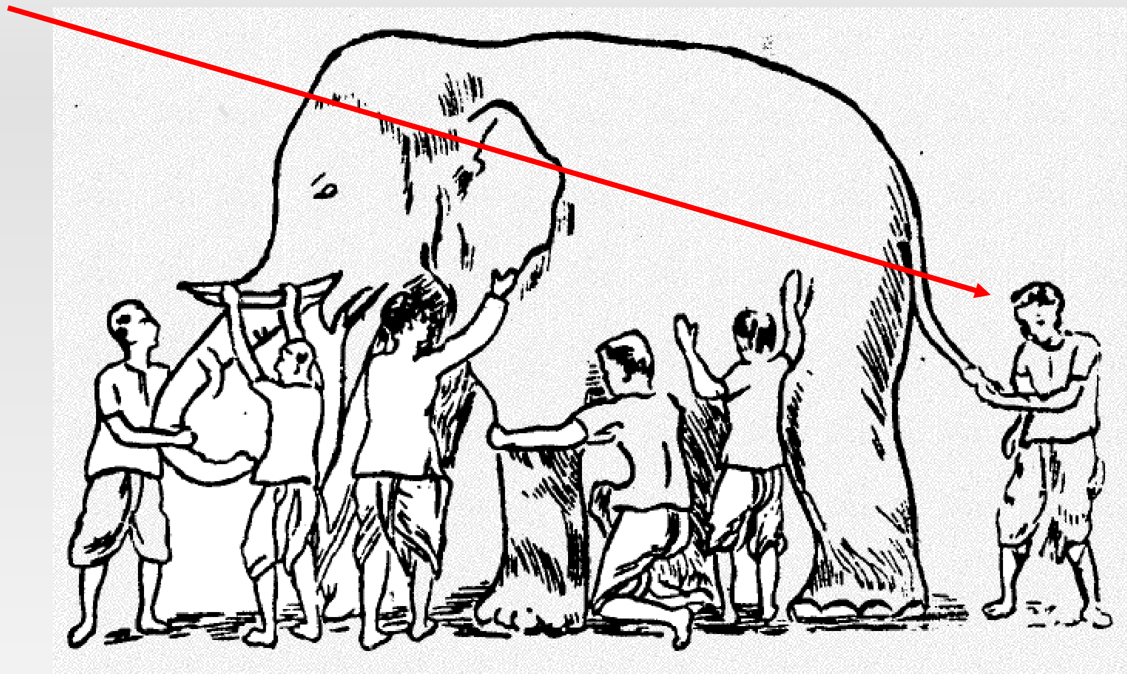
Cos-Aguilera et al, MacDorman



- Can guide the design of behaviors (Arkin, Murphy, Duchon et al.)
- affordance learning is referred to as the learning of the consequences of a certain action in a given situation (Fitzpatrick et al., 2003; Stoytchev, 2005a, 2005b).
- the learning of the invariant properties of environments that afford a certain behavior (Cos-Aguilera et al. 2003, 2004; MacDorman, 2000).

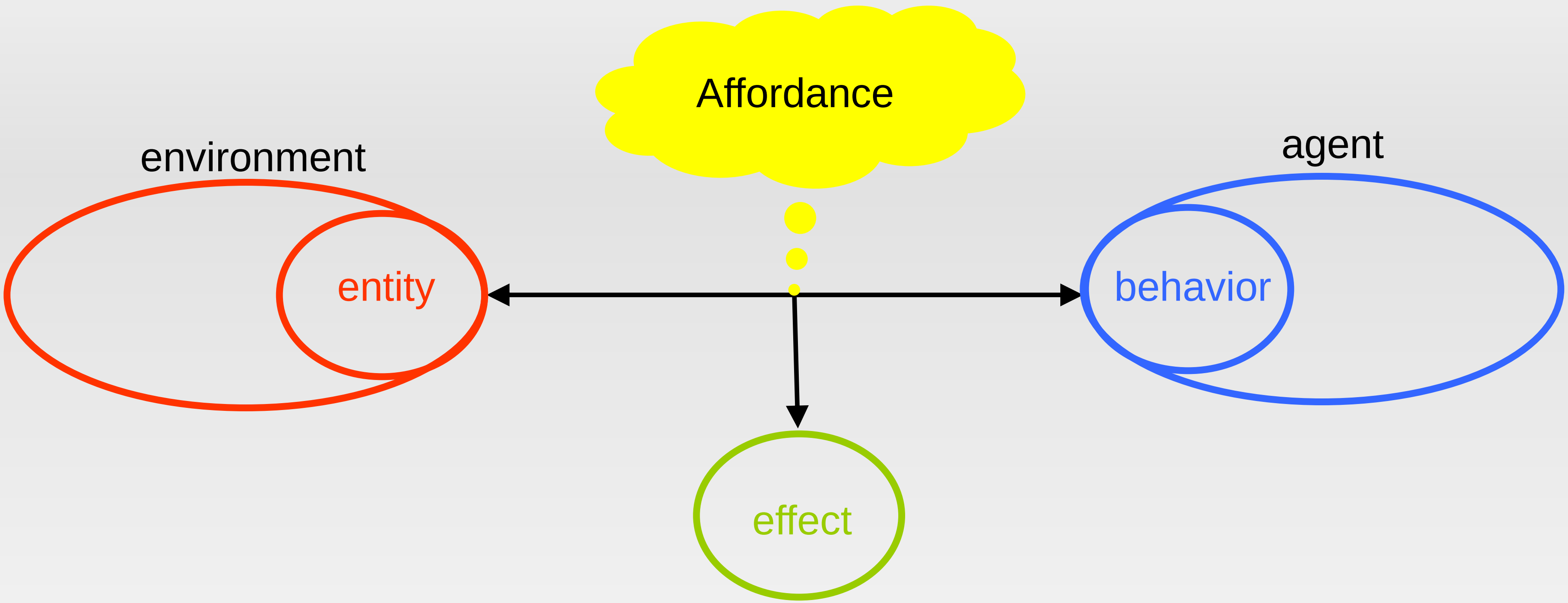
Affordances and Elephants
Planning

Steedman,
Amant



- Affordances are related to planning.
- The different actions that are associated with a particular kind of object constitute the affordance-set
- A door is linked with the actions of “pushing” and “going-through,” and the preconditions and consequences of applying these actions to the door.

Formalizing Affordance for Robotics

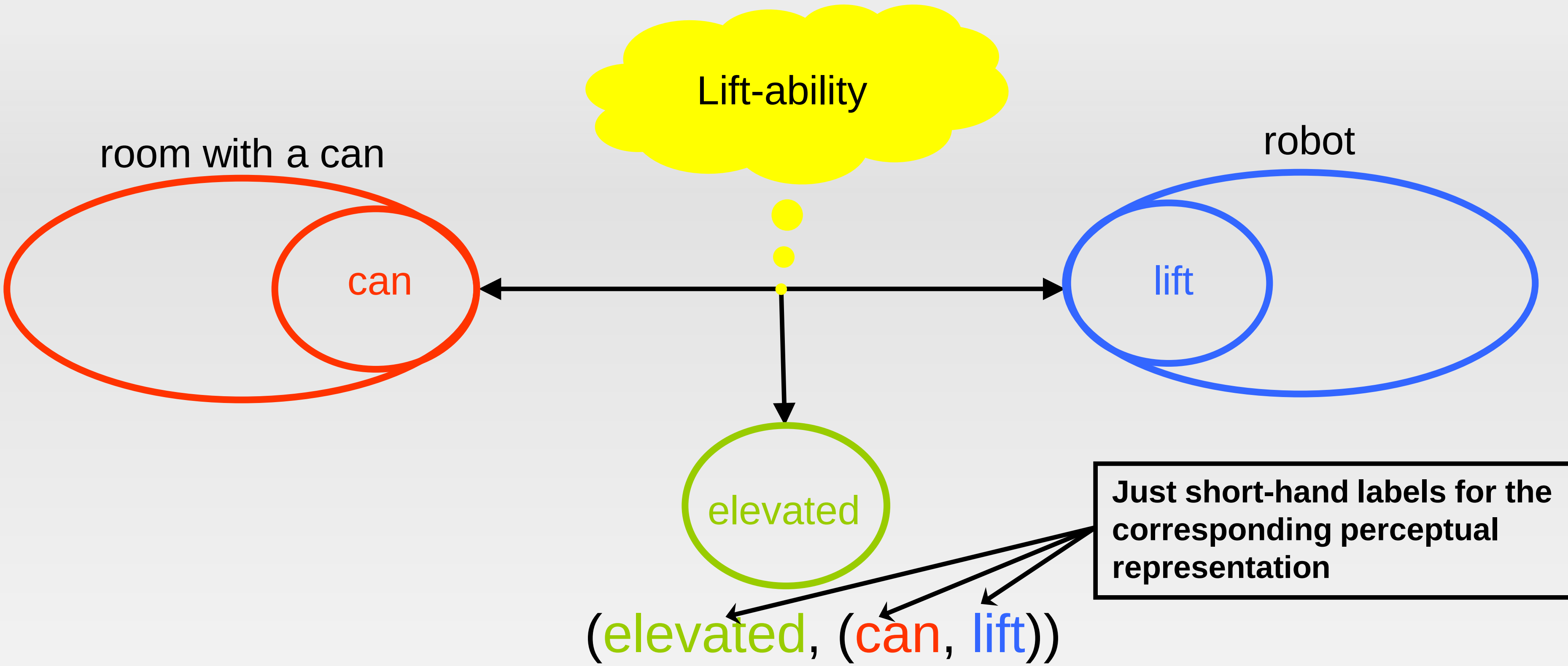


(effect, (entity, behavior))

Definition: An affordance is an acquired relation between a behavior of an agent and an entity in the environment such that the application of the behavior on the entity generates a certain effect.

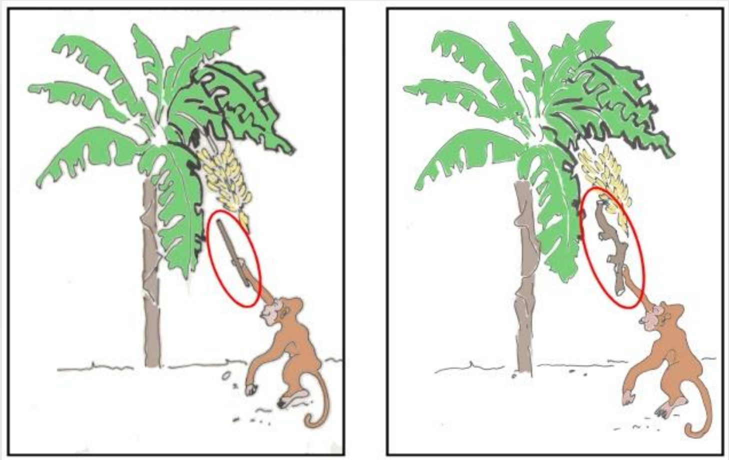
E.Sahin, M.Cakmak, M.R.Dogar and E.Ugur. *To Afford or Not to Afford: A new formalization of Affordances toward Affordance-based Robot Control.* Adaptive Behavior, December 2007.

Cont’d

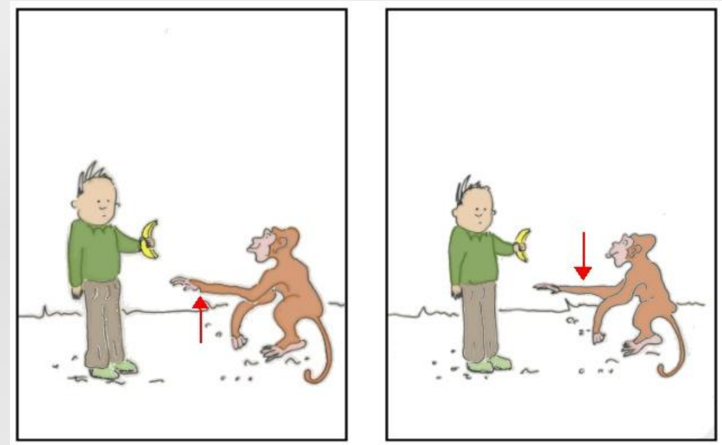


The robot applied its lift behavior on the can and obtained the elevated effect.
Can: The perceptual representation of the can as seen by the robot
Lift: The behavior executed by the robot
Elevated: The effect of the behavior on the environment as perceived by the robot.

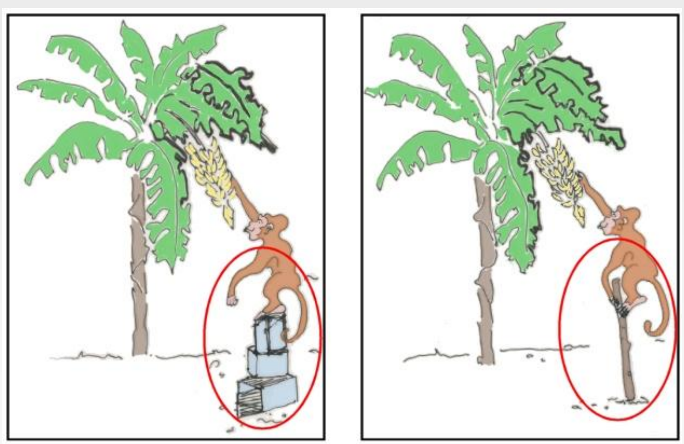
Equivalence Classes



Entity Equivalence
(effect, (<entity>, behavior))



Behavior Equivalence
(effect, (entity, <behavior>))



Affordance Equivalence
(effect, <(entity, behavior)>)

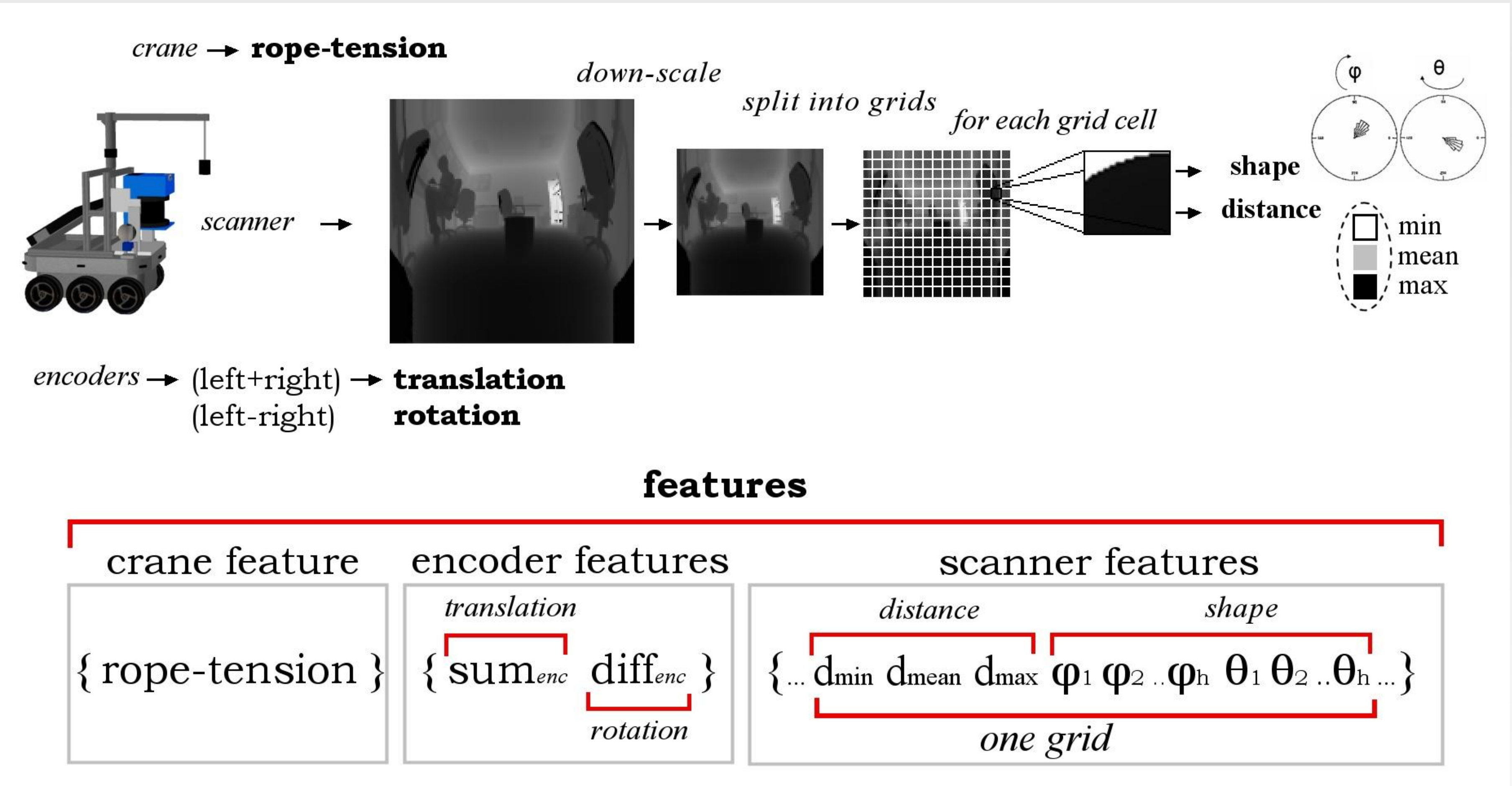
Effect Equivalence

Experimental Setup

- 6 wheel, differential drive
- 3 DOF crane arm with electromagnetic gripper
- 3-D scanning with SICK laser range finder
  - ~0.25° angular resolution
  - 720x720 data points

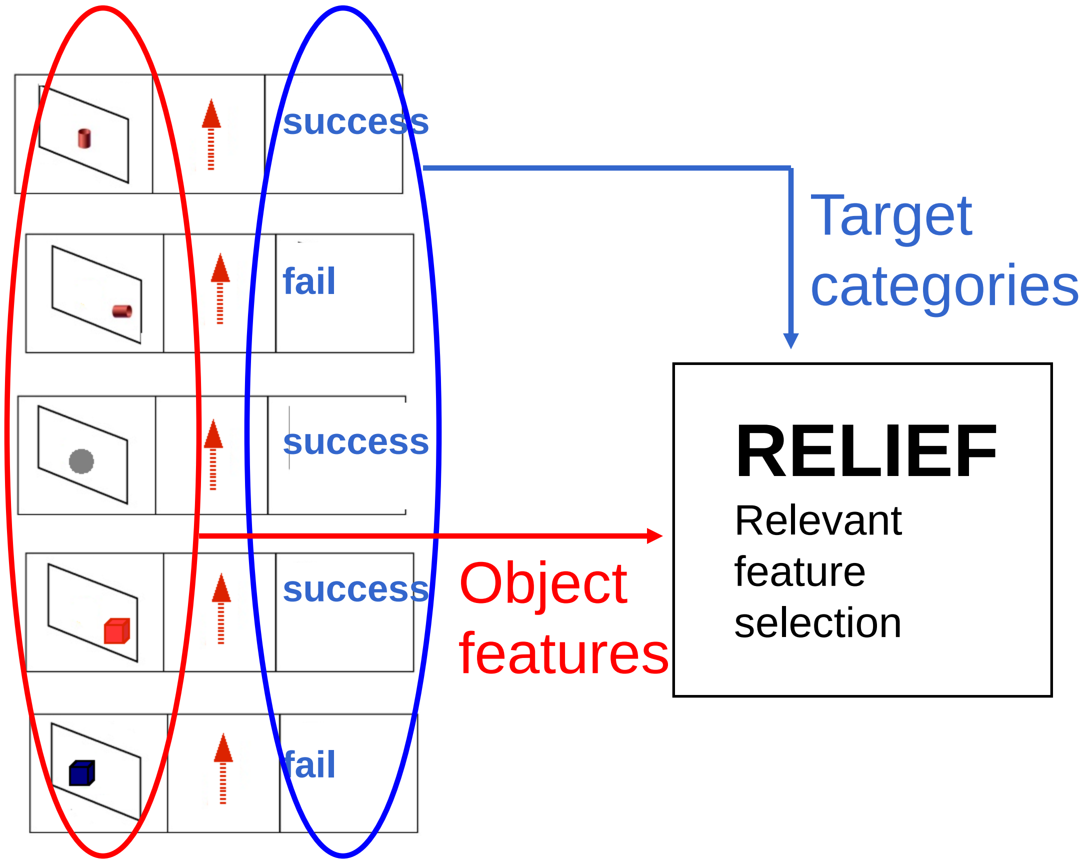
- MACSim : High-fidelity simulation environment
- ODE used as physics engine
- Sensors and actuators are calibrated

Perceptual Features

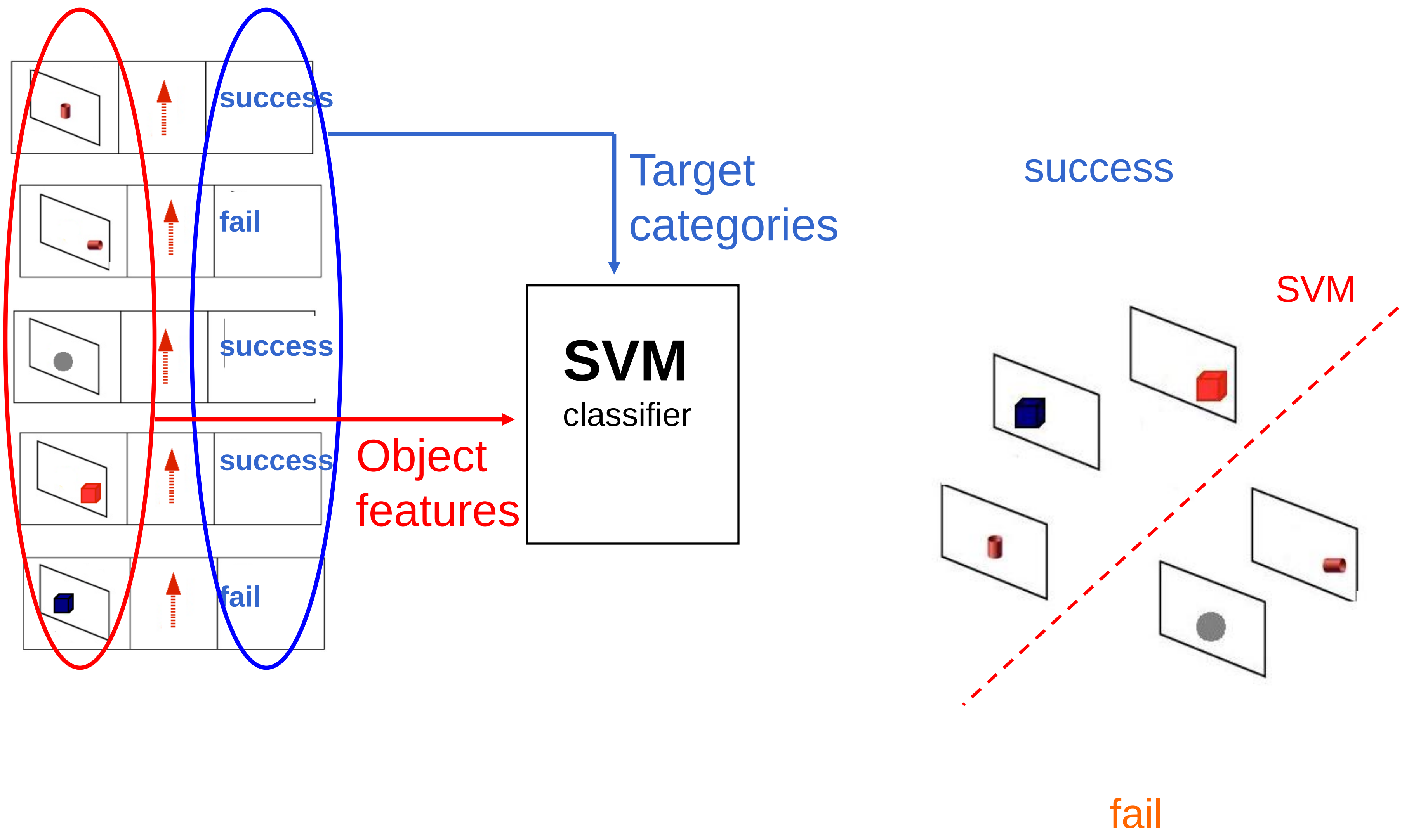


More than 30000 perceptual features!

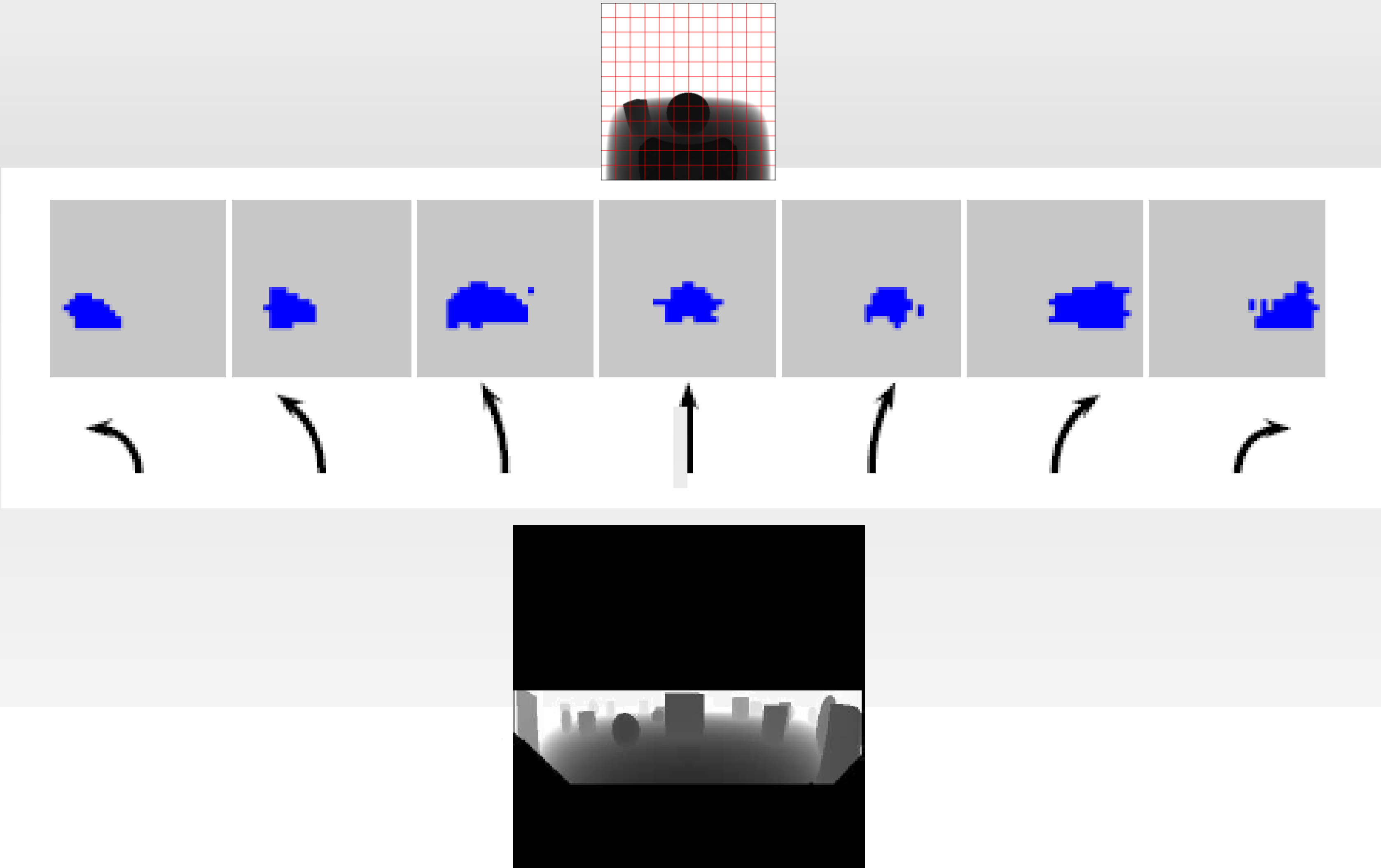
Learning invariant features



Learning Entity equivalence classes

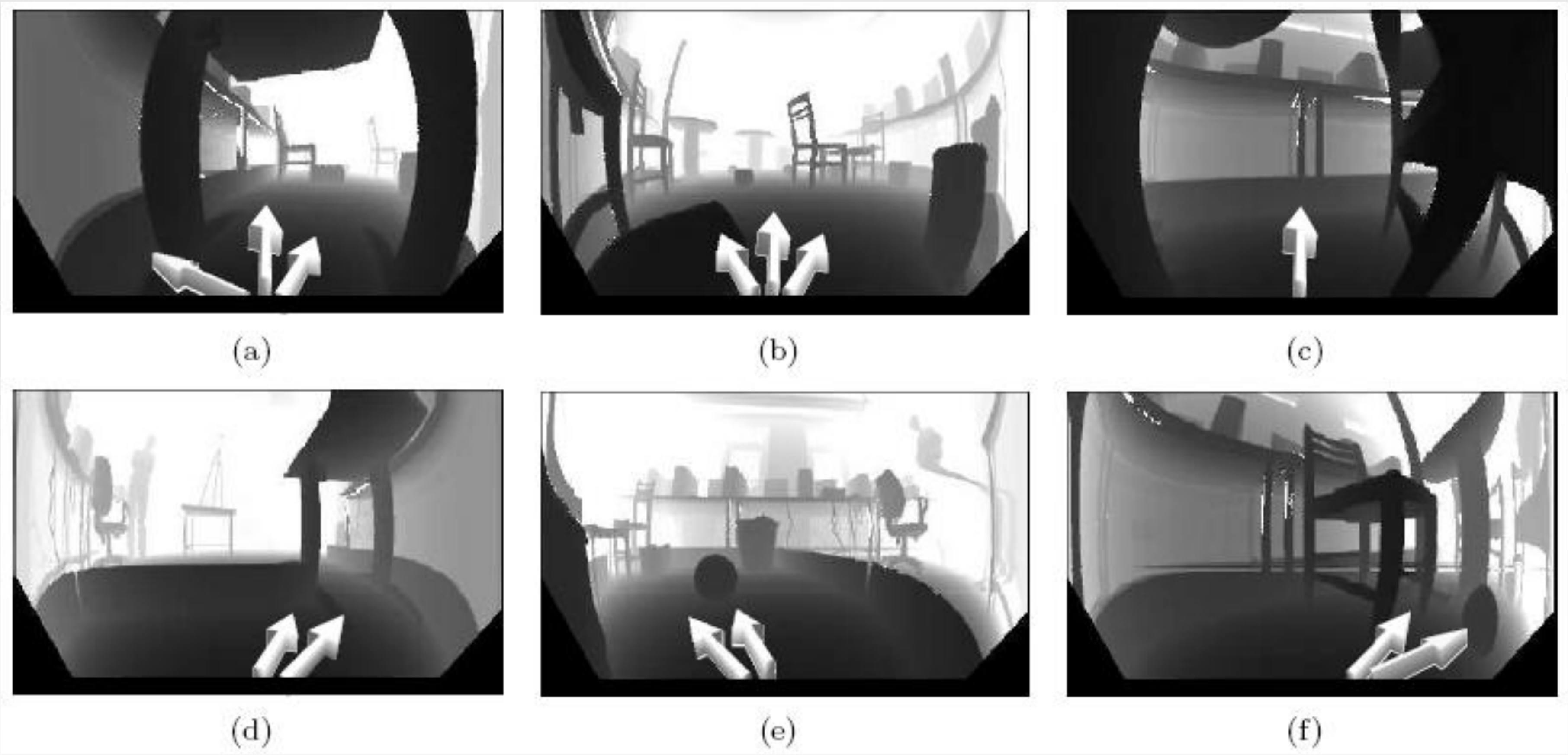


Perceptual Economy



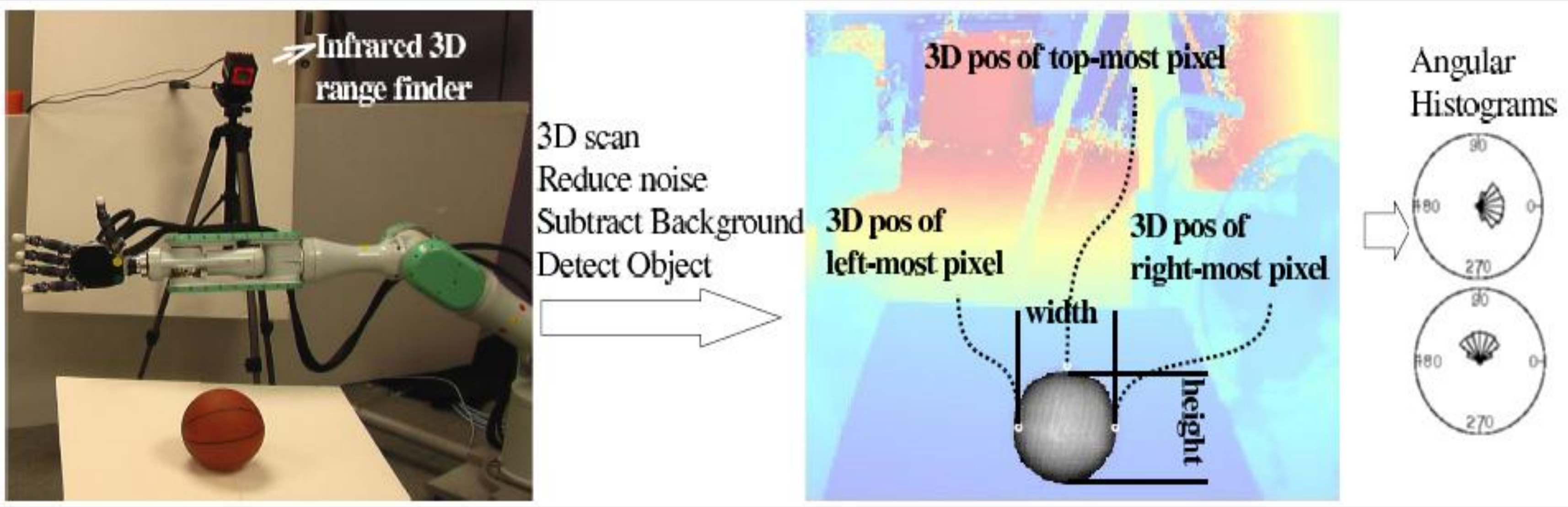
Only 1% of the features are relevant!

Generalization



(a) (b) (c) (d) (e) (f)

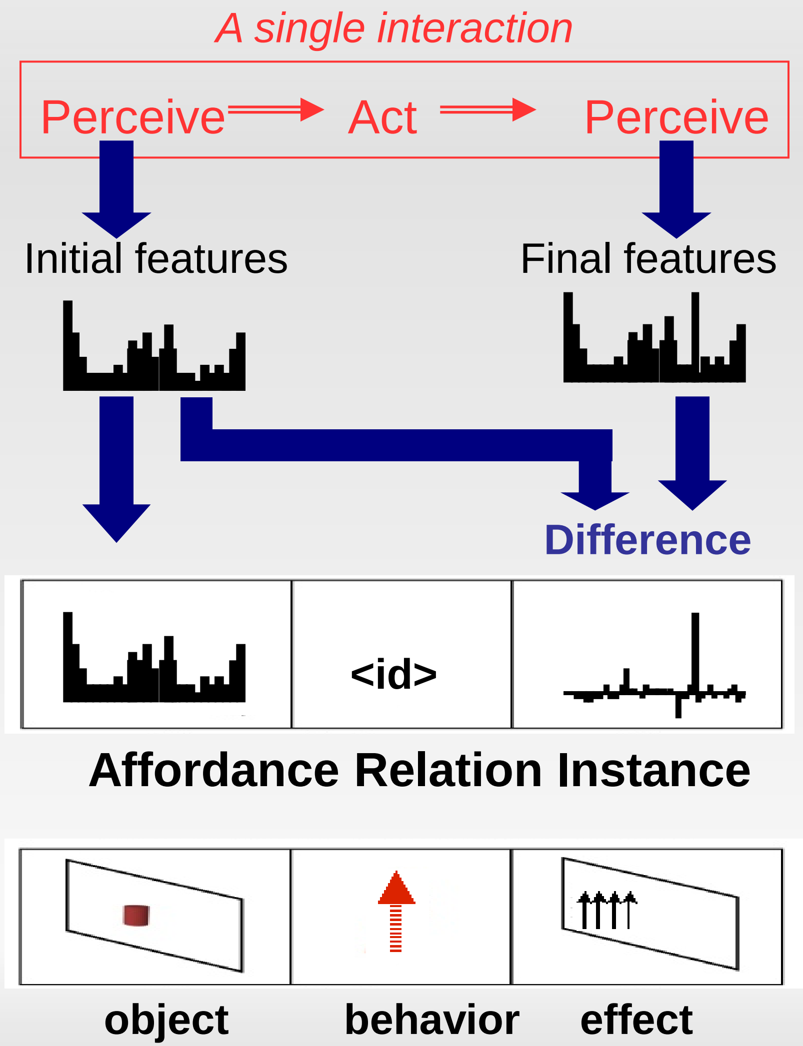
Perception



Feature vector for an object includes:

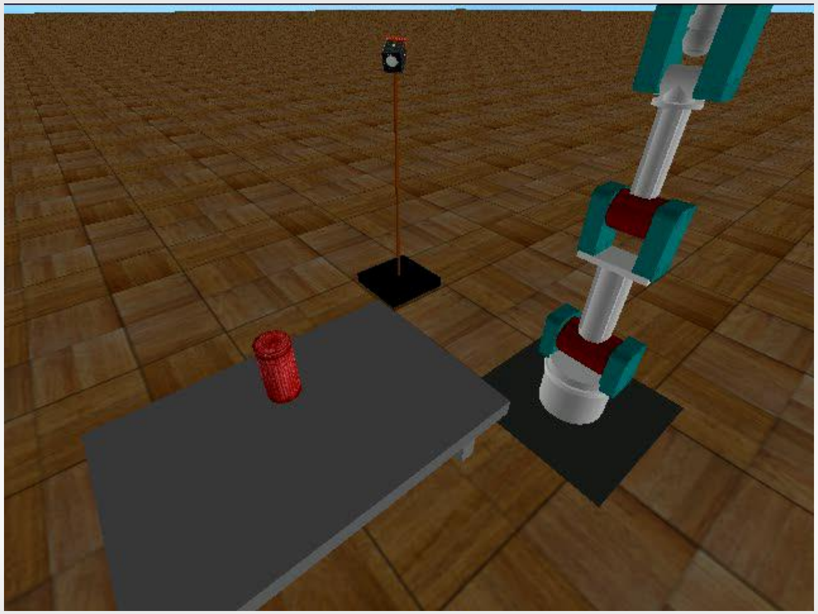
- **1 object visibility** feature
- **36 shape** related features (frequency values of angular histograms of normal vectors)
- **1 distance** related: avg. distance
- **4x3 position** related: boundary coordinates of region
- **3 size** related: width, height, and depth

Exploration Phase

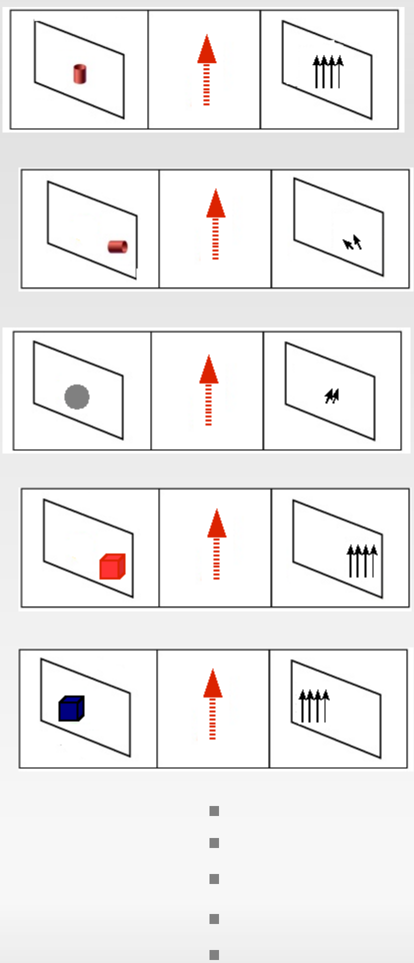


- Random orientation
- Random position

- 1000 different interactions for each push and lift behavior

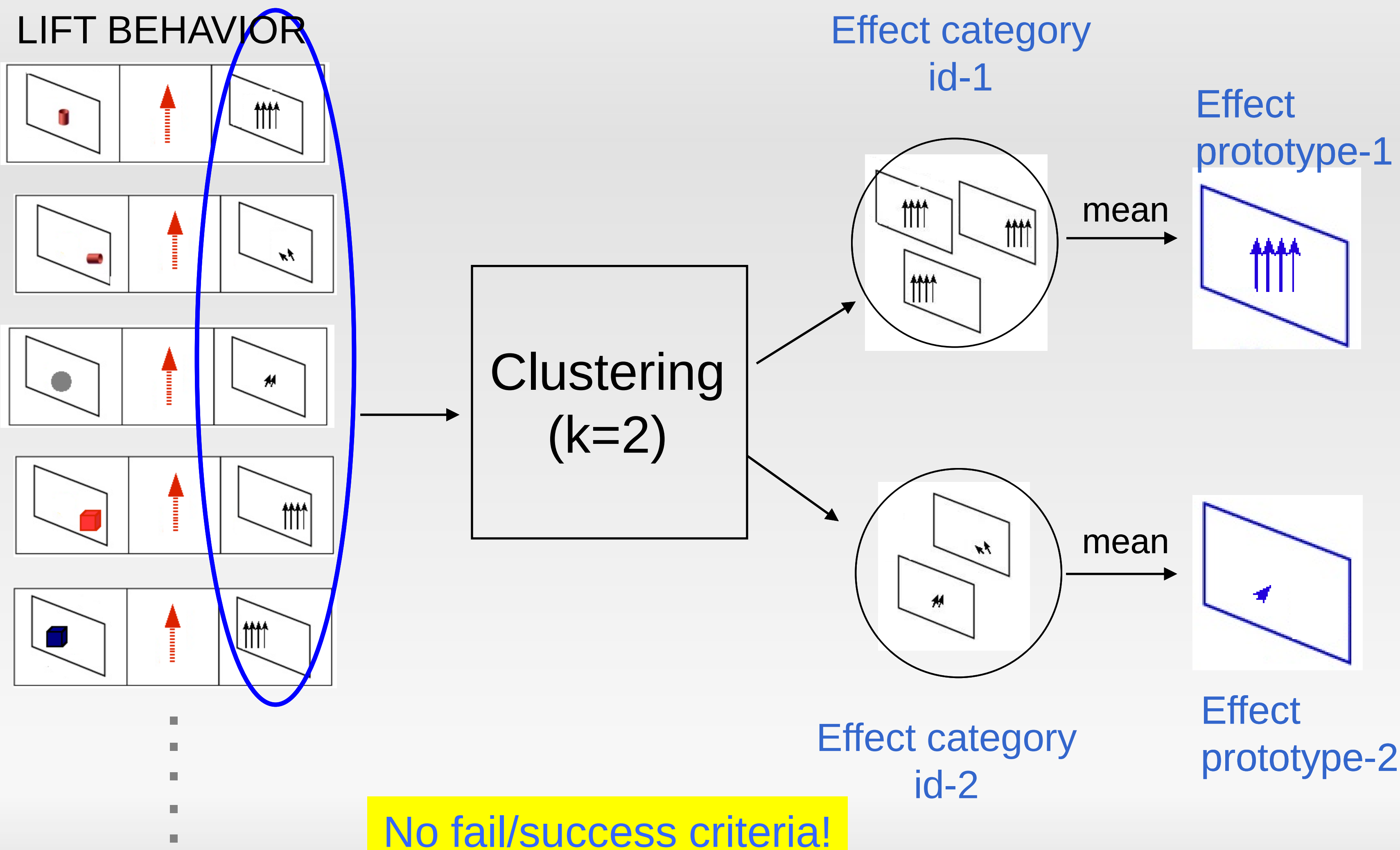


Find Effect Categories



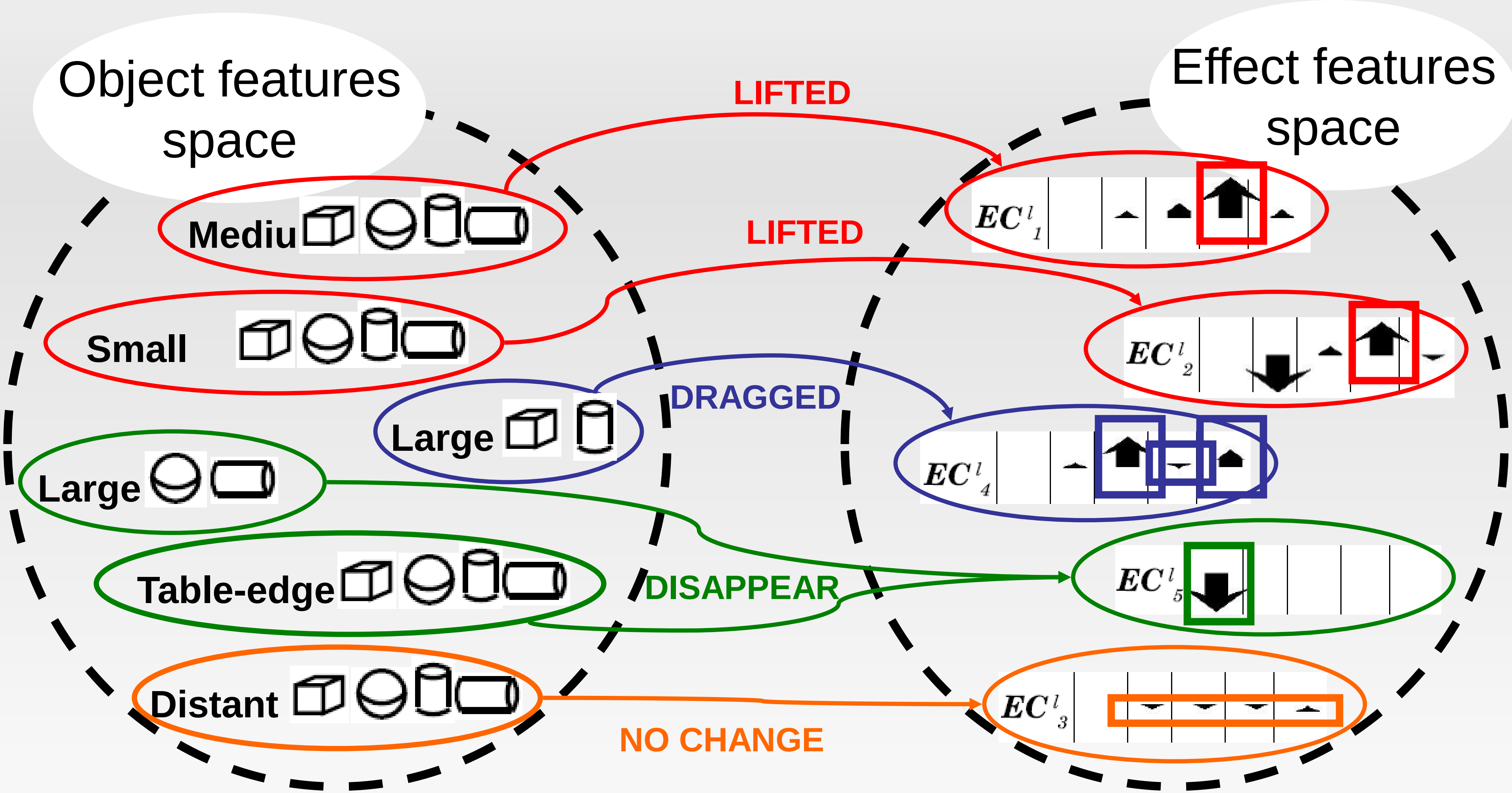
- Each behavior creates a number of qualitatively distinct effects
- Corresponds to different affordances
  - Grasp-ability, lift-ability
  - Push-ability, roll-ability, fall-ability
  - Reach-ability
- Effect categories: clustering in effect space

Find Effect Categories



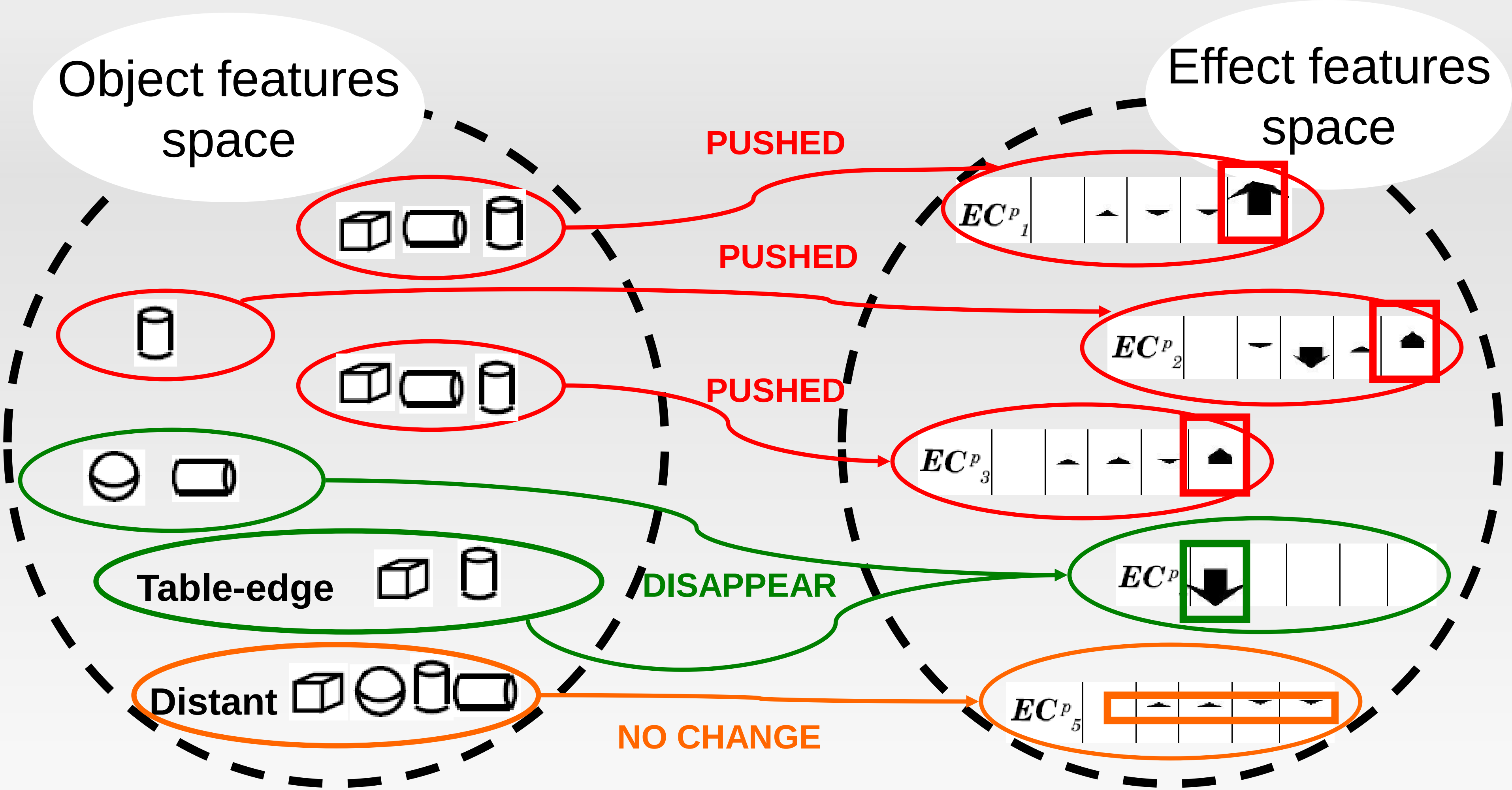
No fail/success criteria!

Effect Categories for Lift



5 different effect categories are found by X-means

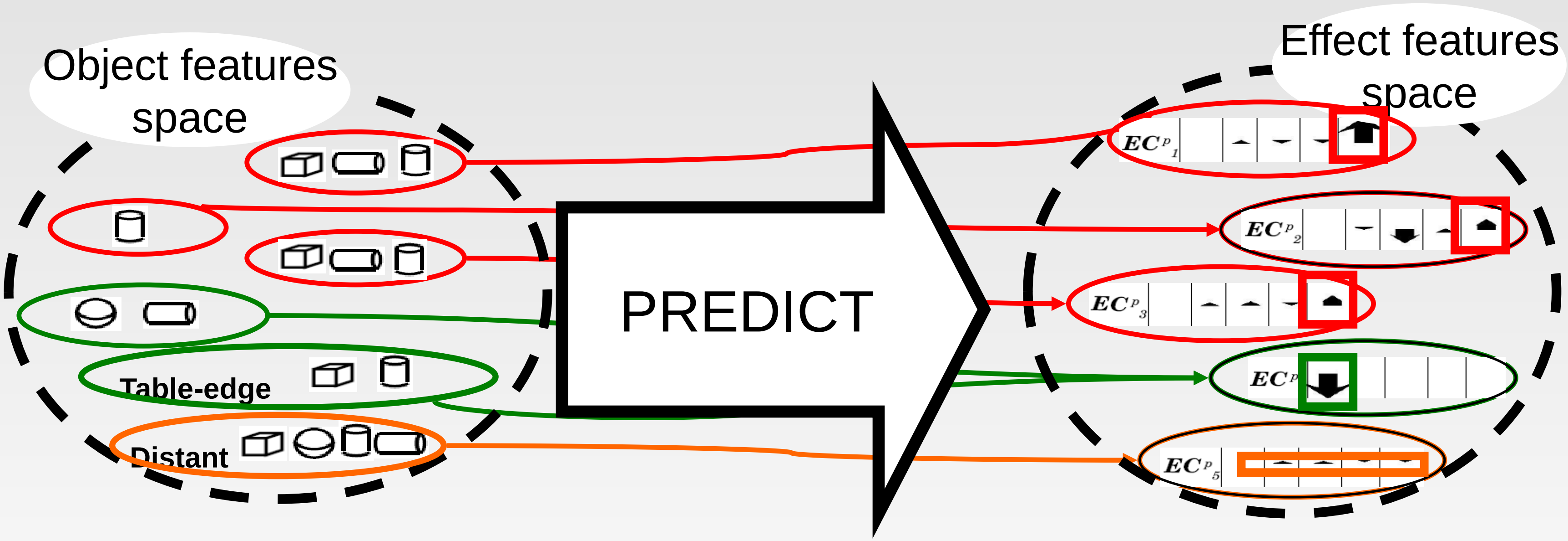
Effect Categories for Push



5 different effect categories are found by X-means

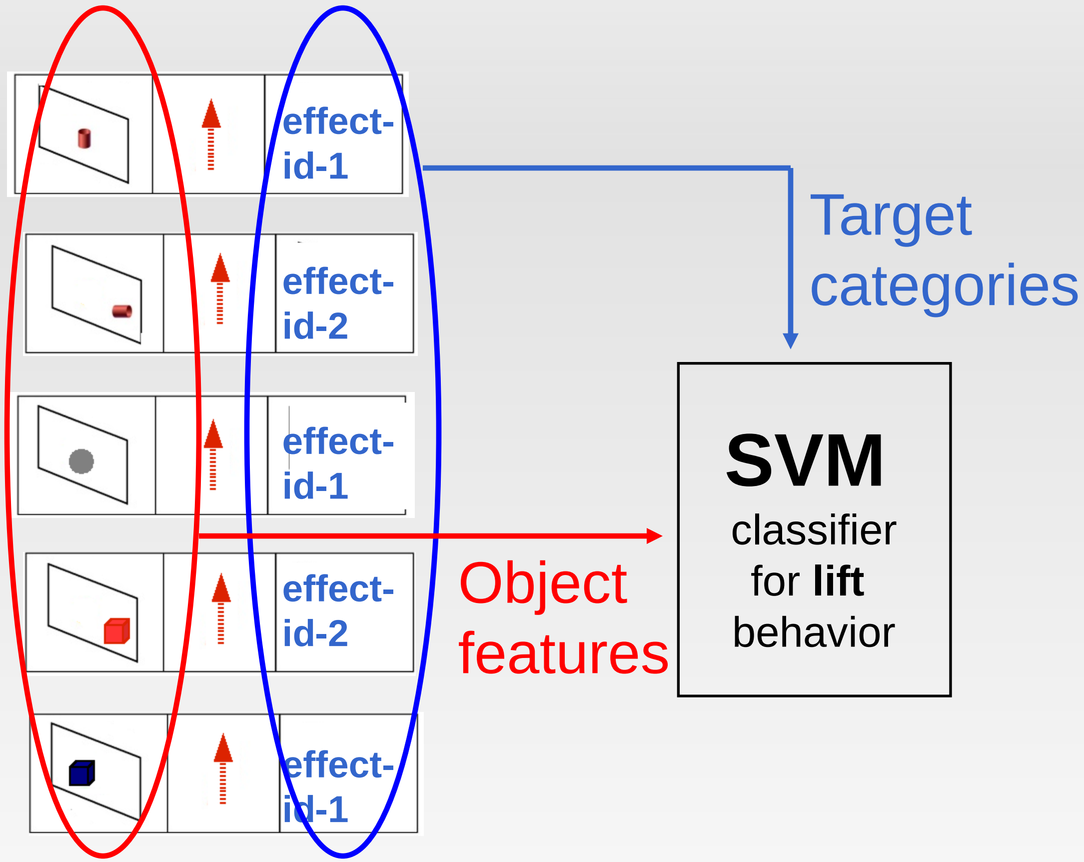
Prediction is required for planning

- Given object features & behavior
  →Predict effect category

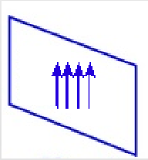


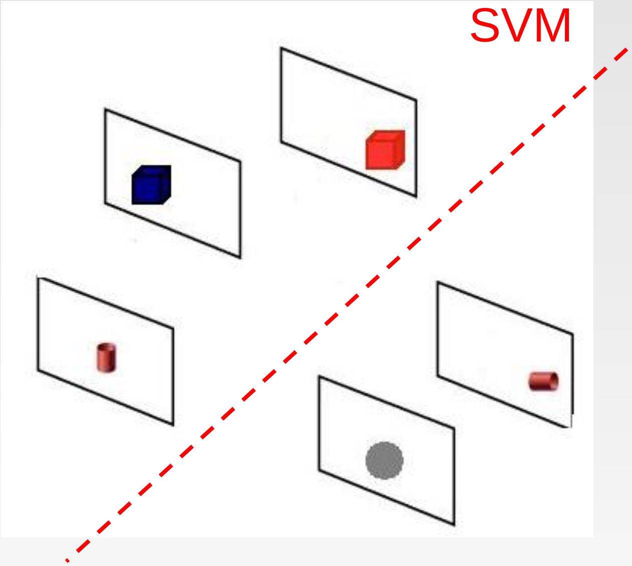
- Train a classifier for each behavior

Prediction of effect categories

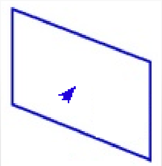


Effect prototype for **effect-id-1**:

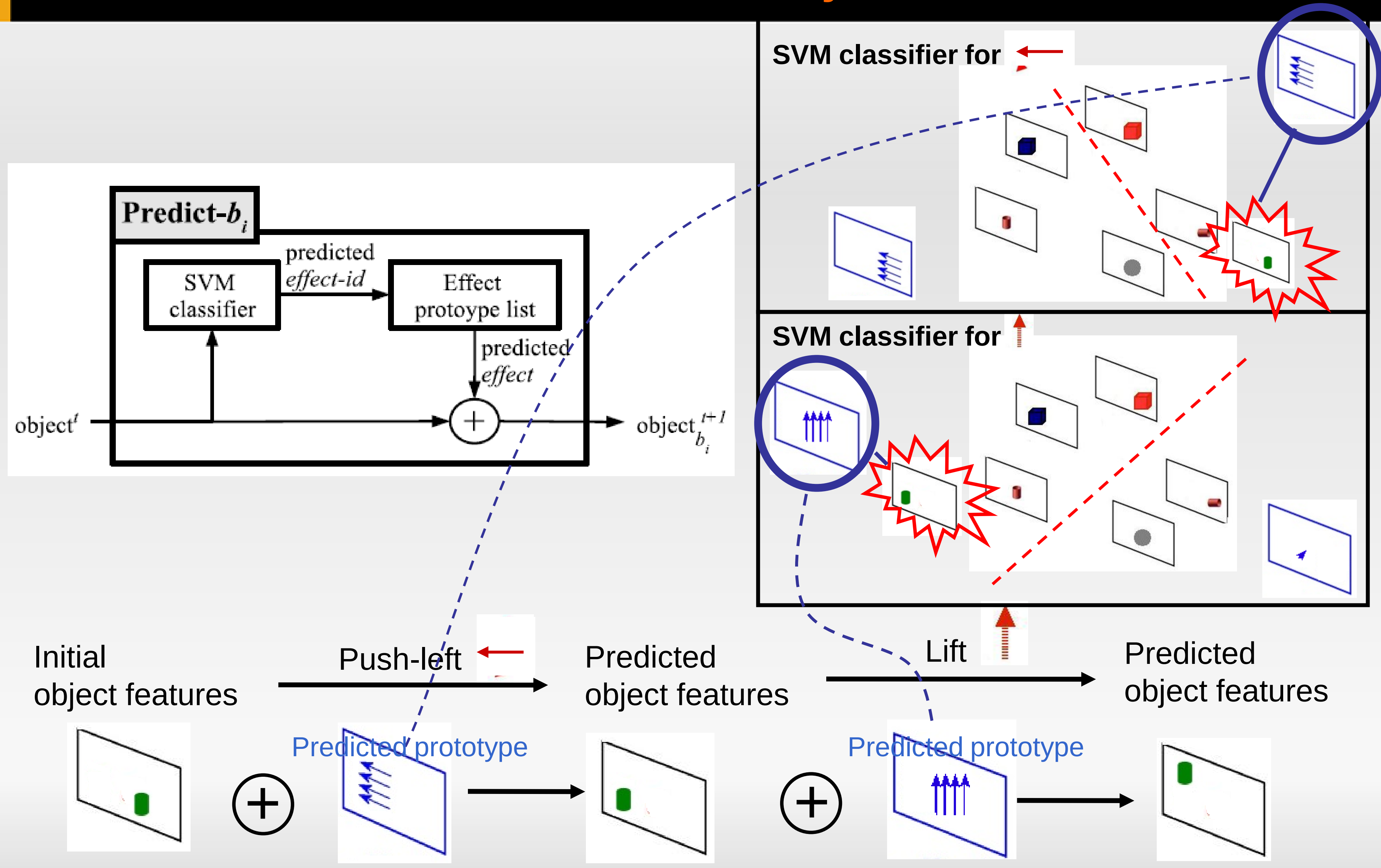




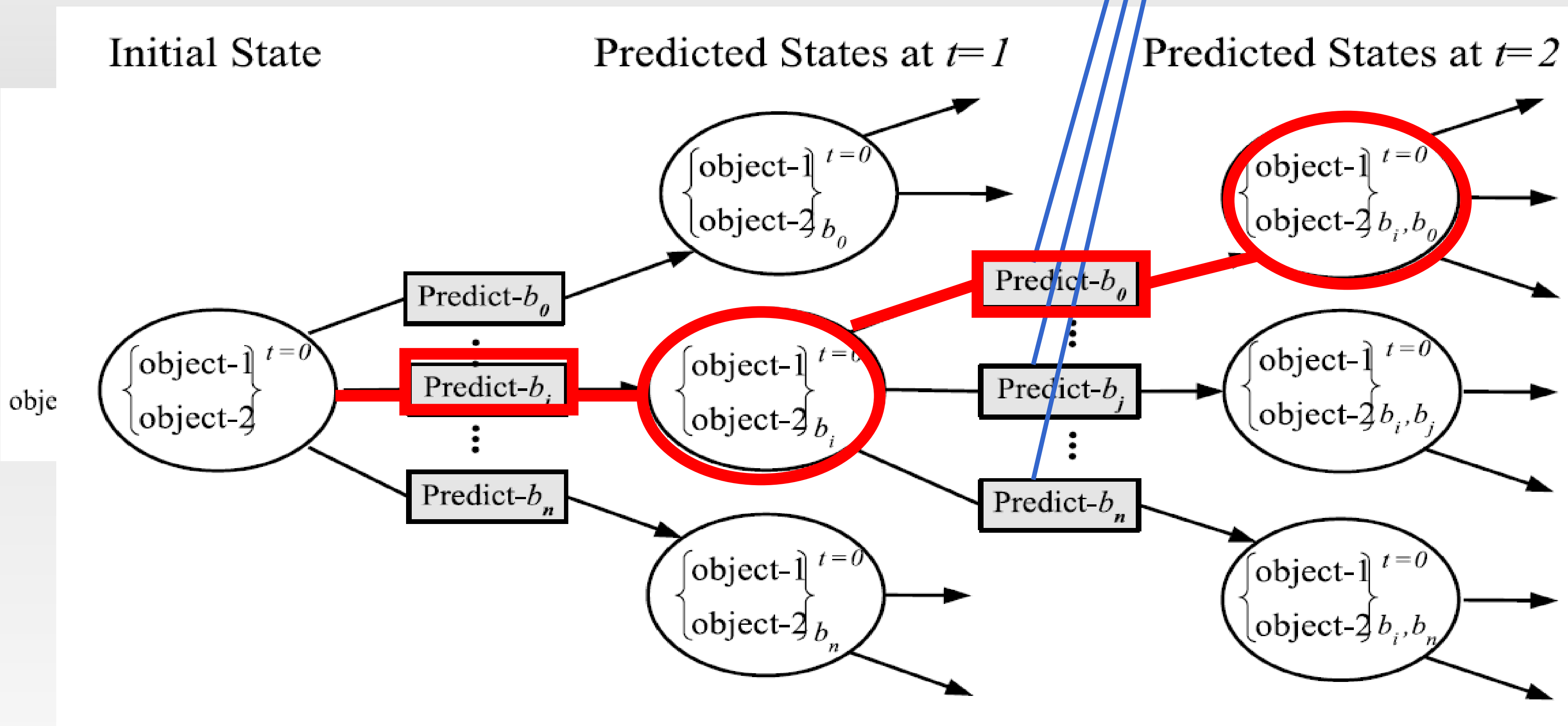
Effect prototype for **effect-id-2**:



Prediction of Future Object Features



Forward chaining with

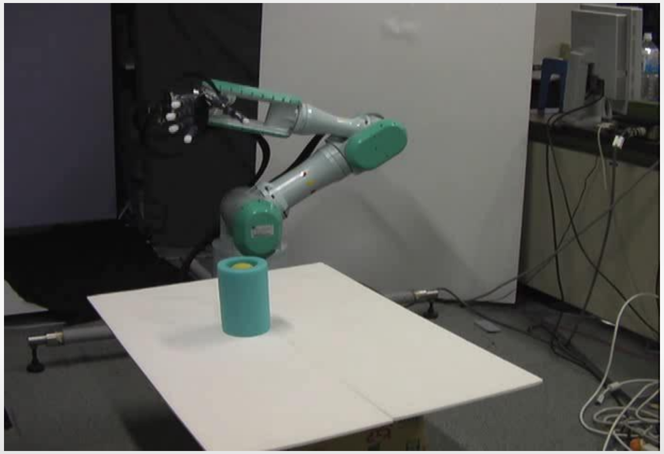


$$S^t_{\{b^1 \ldots b^{t-1}\}} = [\boldsymbol{p}^t_{o_1,\{b^1 \ldots b^{t-1}\}} \cdots \boldsymbol{p}^t_{o_m,\{b^1 \ldots b^{t-1}\}}]$$

1st Task: Keep table clean

- Goal: A future object feature vector where *object-visible* feature is predicted to be 0 (false).

push-right **push-left** **push-right**



1. Push-left ?
2. Push-left ?
3. Push-left ?

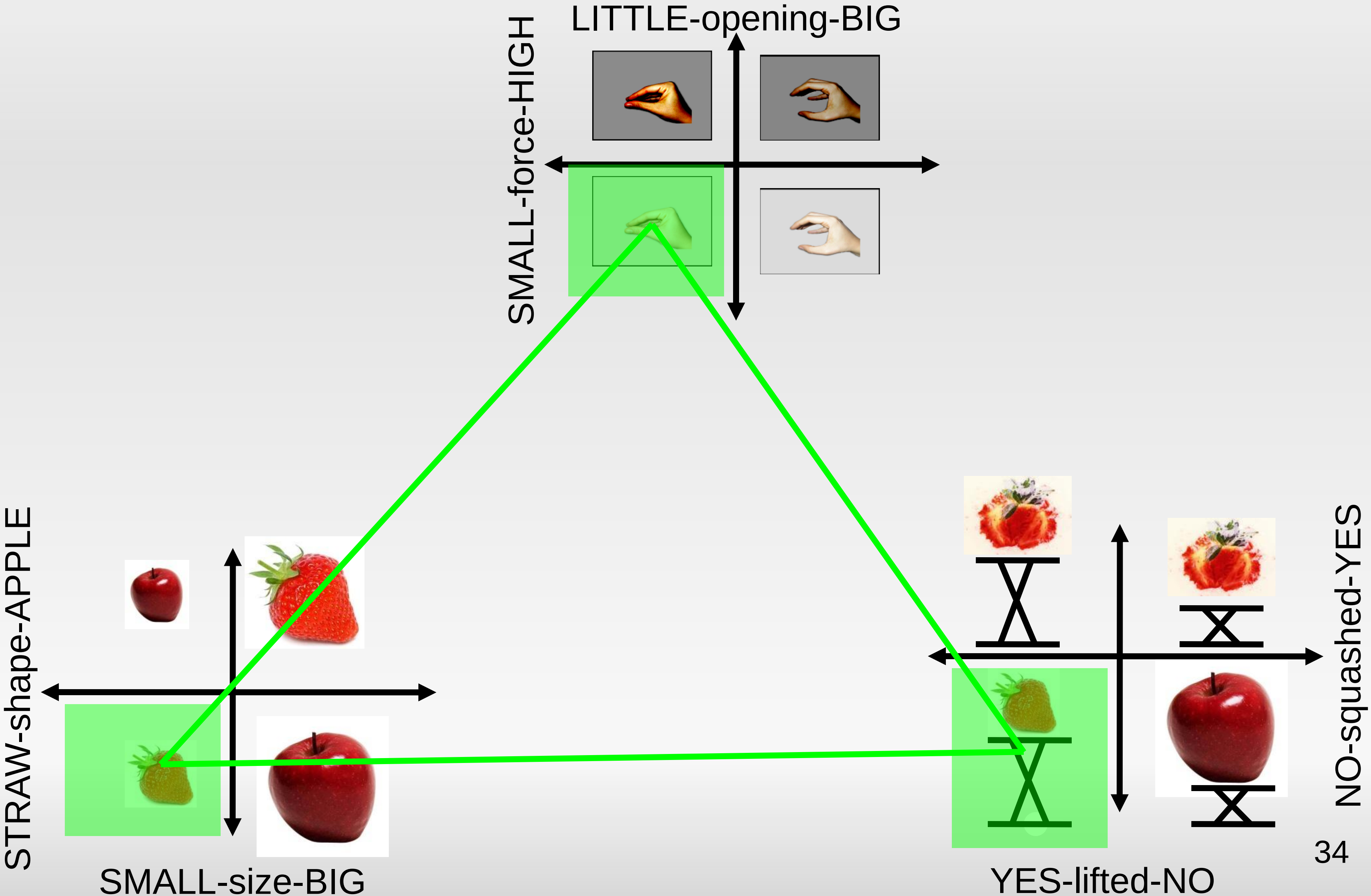
1. Lift
2. Push-forward

<u>Release</u> behavior emerges !

2nd Task: Bring the object to a target position

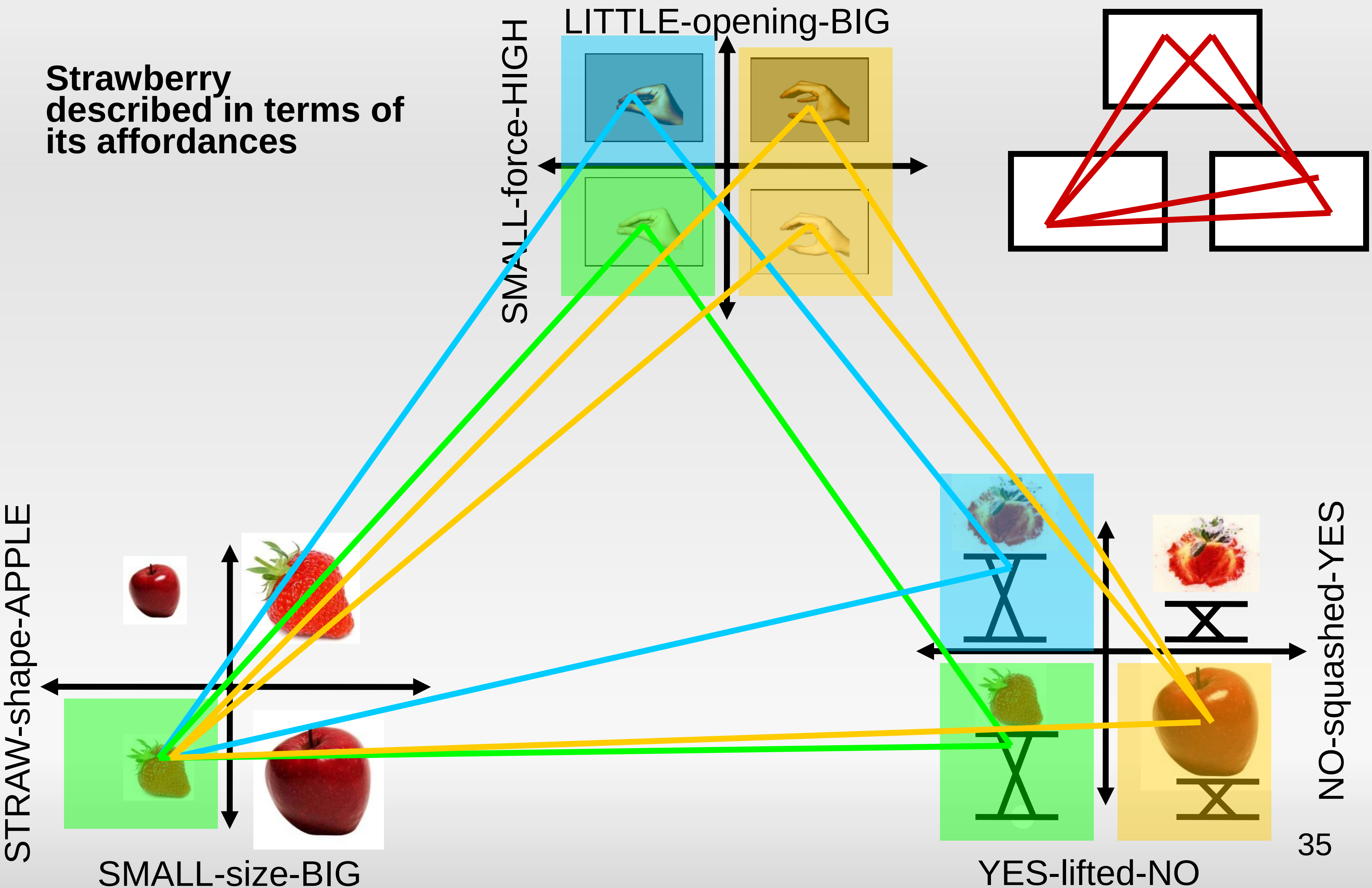
- Goal: A future object feature vector where *object-pos* feature is predicted to be in a certain range.

Affordances as relations



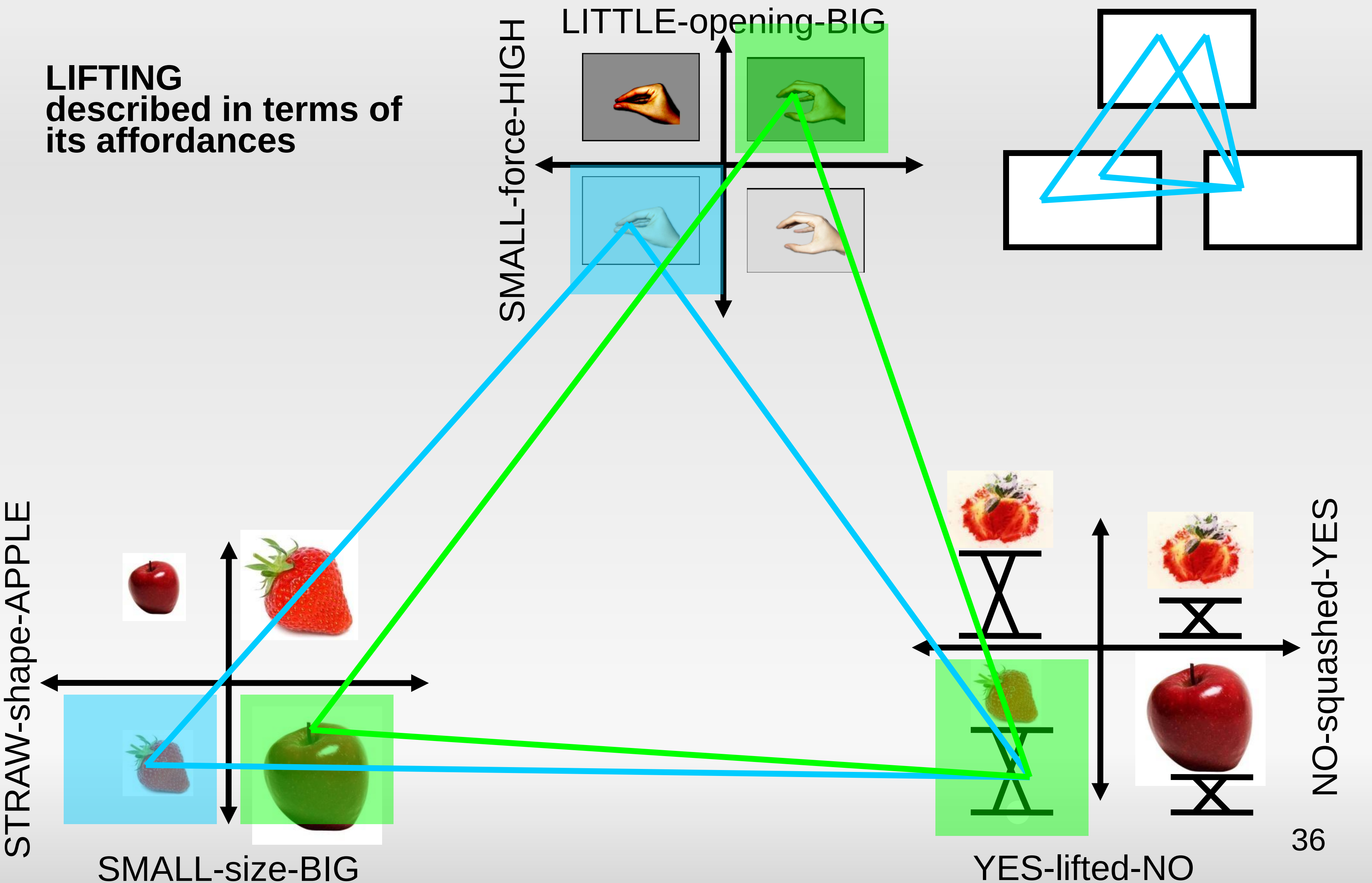
The concept of a strawberry

Strawberry described in terms of its affordances



The concept of lifting

LIFTING
described in terms of its affordances



Acknowledgements

ROSSI

Emergence of communication in RObots through Sensorimotor and Social Interaction

COGNITIVE SYSTEMS ROBOTICS

SEVENTH FRAMEWORK PROGRAMME

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NICT ATR METU

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