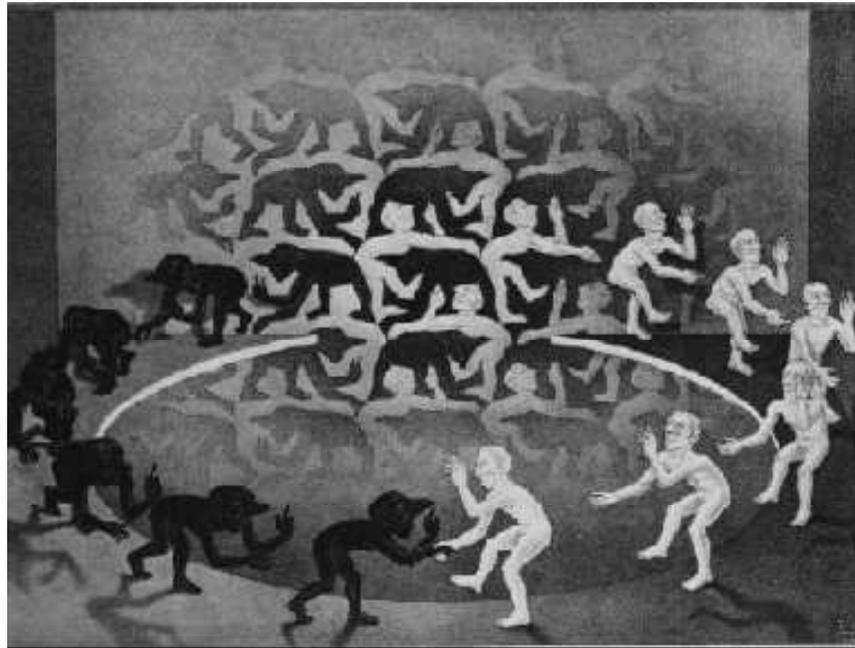
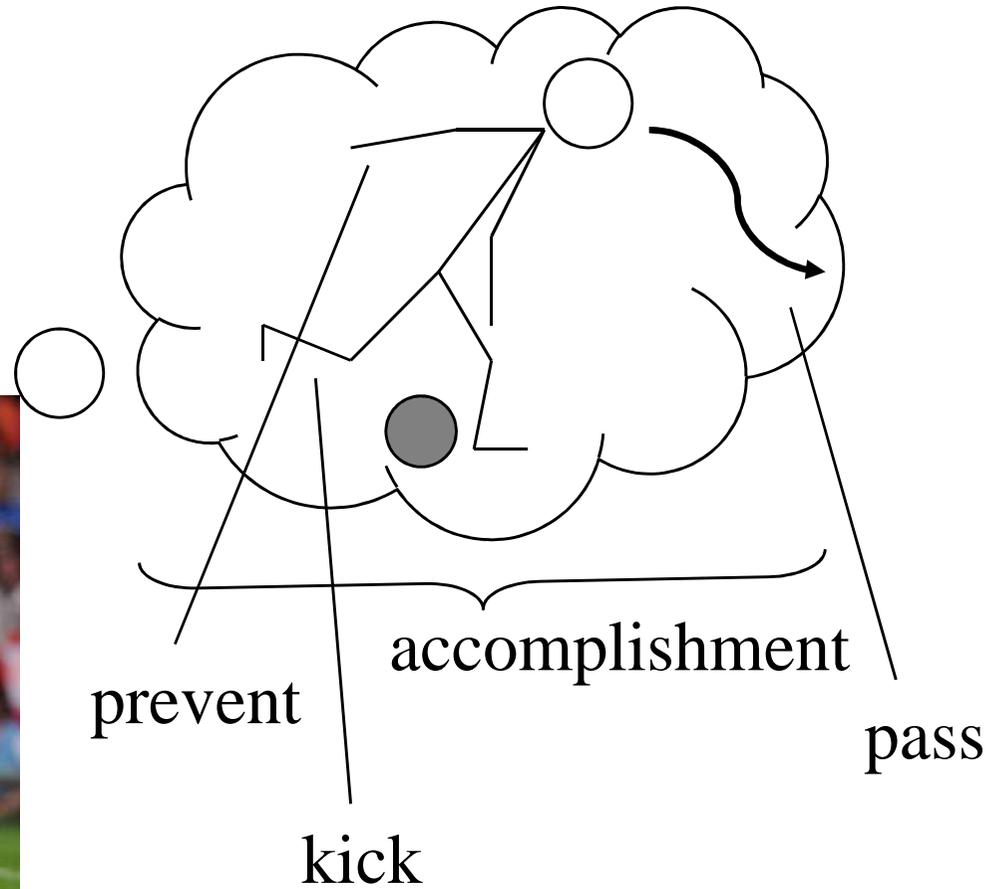


Action representations and the semantics of verbs



Matthijs Westera

Introduction



Introduction

- Aims:
 - Model human action representations
 - Use it to explain some linguistic phenomena
 - Manner/Result verbs
 - Grammatical aspect
 - Modal verbs
 - (Try to make the model useful for robotics)

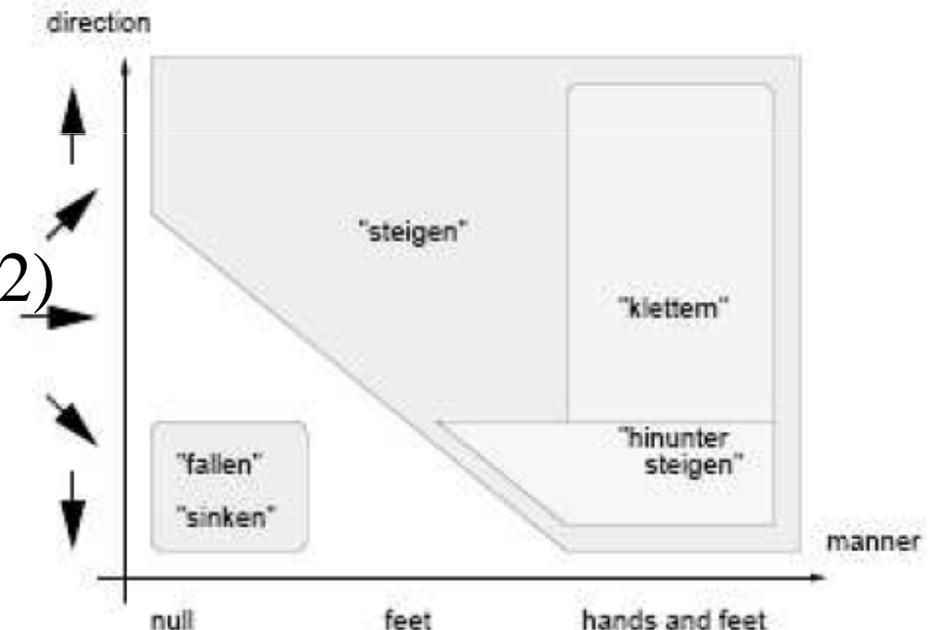
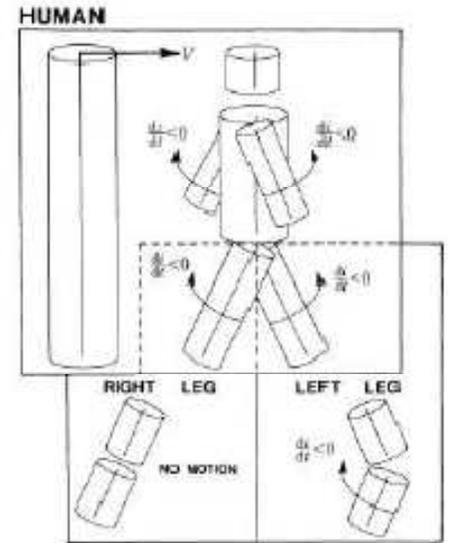
Structure

1. Existing approaches
 - Symbolic/Subsymbolic/Conceptual
2. Towards action space
 - Psychological evidence
 - Creating the conceptual space
3. Linguistic phenomena
 - Manner/result
 - Aspect
 - Modals.
4. Conclusion & Outlook

Existing approaches

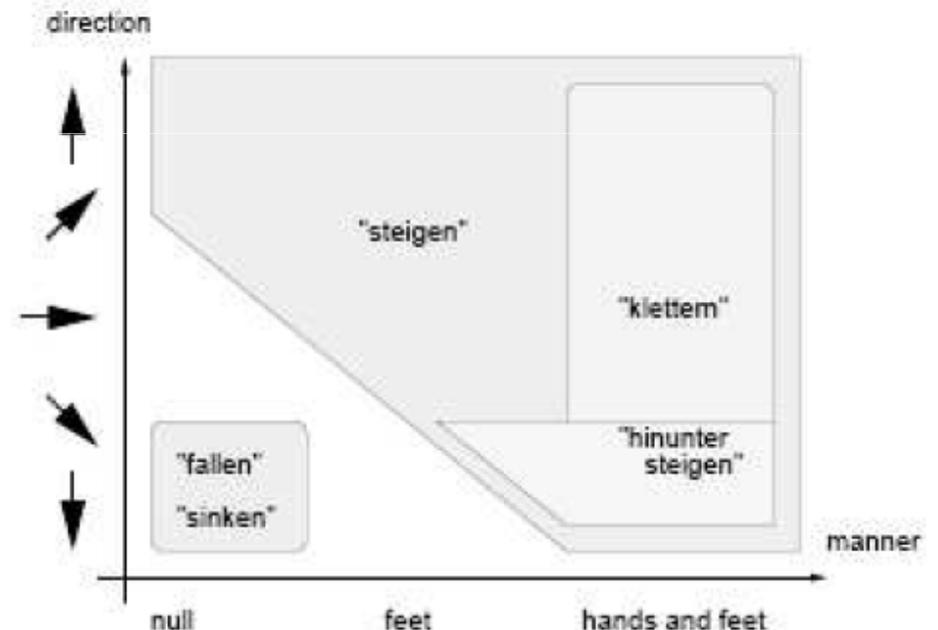
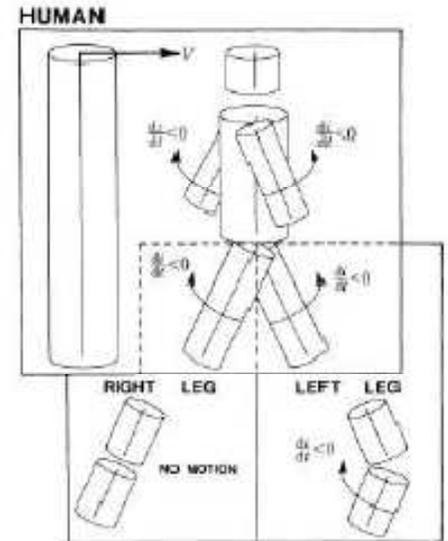
Existing approaches

- Symbolic
 - Situation calculus (McCarthy & Hayes 1969)
 - Marr and Vaina (1981)
- Subsymbolic
 - Giese and Poggio (2002)
 - Motion recognition
- Conceptual
 - Geuder and Weisgerber (2002)
 - Chella et al. (2000)
 - Gärdenfors (2007)

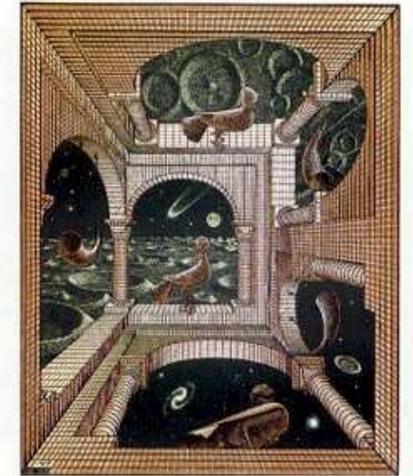


Existing approaches

- Symbolic
 - Frame problem
 - Lack of ‘true’ meaning
 - Not psychologically realistic
- Subsymbolic
 - Bonini’s paradox
 - Training data required
- Conceptual
 - Psychologically realistic
 - Insightful
 - Computable



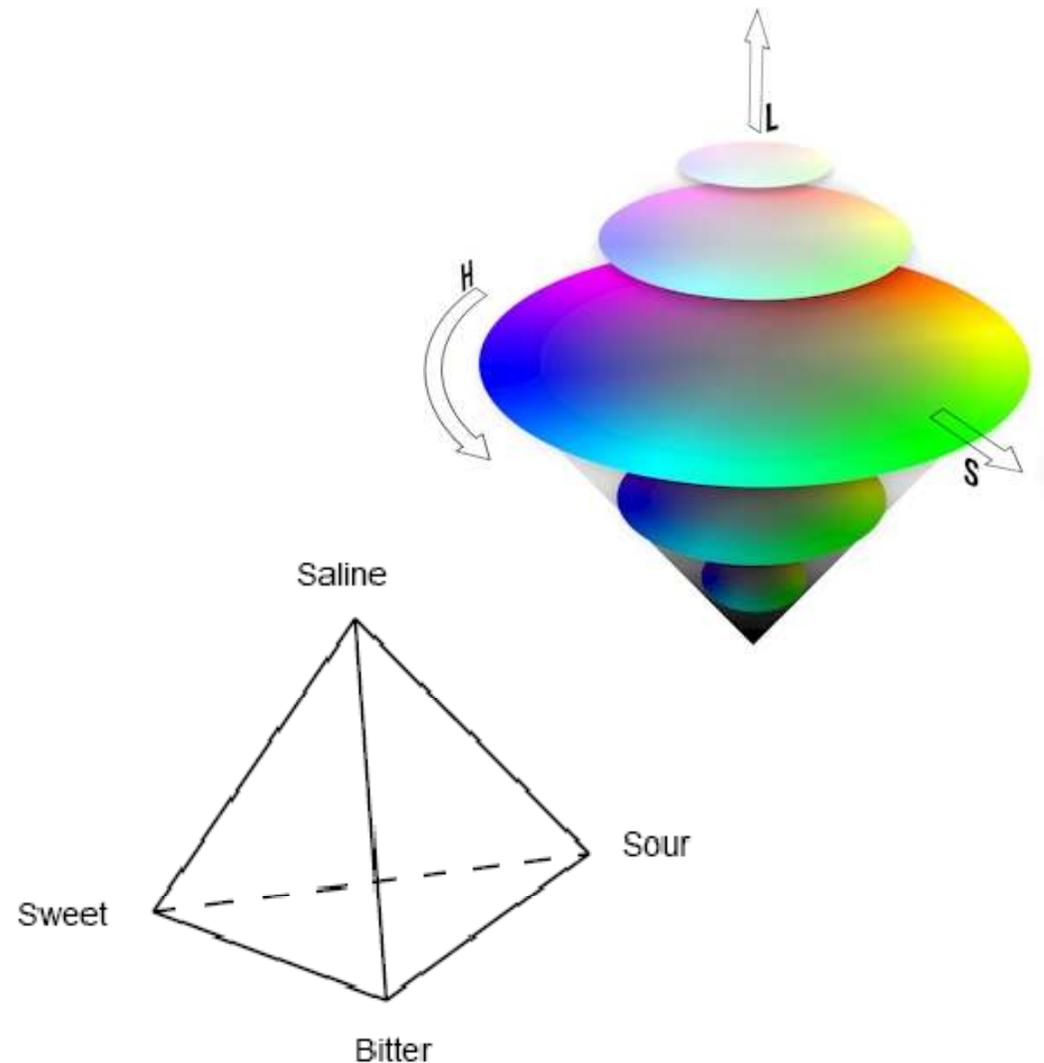
Conceptual spaces



- Gärdenfors (2000)
- Geometric space
 - Quality dimensions (e.g. hue, saturation, brightness)
 - Similarity measure (e.g. $1/\text{Euclidian distance}$)
- Concepts
 - Regions in this space
 - Centered around prototypes

Conceptual spaces

- Examples:
 - Color space
 - Taste space
 - Vowel space
 - Shell space
 - Action space?



Towards action space

Action representation ingredients

- Recognition
 - Force patterns (Runesson 1994, Wolff 2006)
 - Intentions (Tomasello 2005)
- Generation
 - Motor patterns (McKay 1987)
 - Plans (McKay 1987)
- Representation = recognition + generation
 - Mirror neurons (Rizzolatti 1996)
 - Motor cortex itself (Feldman & Narayanan 2004)

Action representation ingredients

- Motor patterns
 - Force-patterns
 - Joints and effector systems
 - Effector-independent
- Goals
 - Trajectory/Endstate based (Abrams 1994)
 - Causal chains
 - Effector-independent (Cisek 2003)

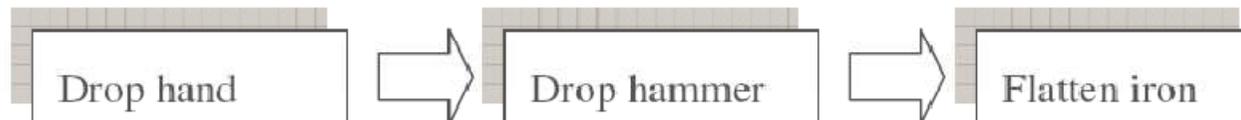
a) Cognitive Neuroscience

b) Cognitive Neuroscience

c) Cognitive Neuroscience

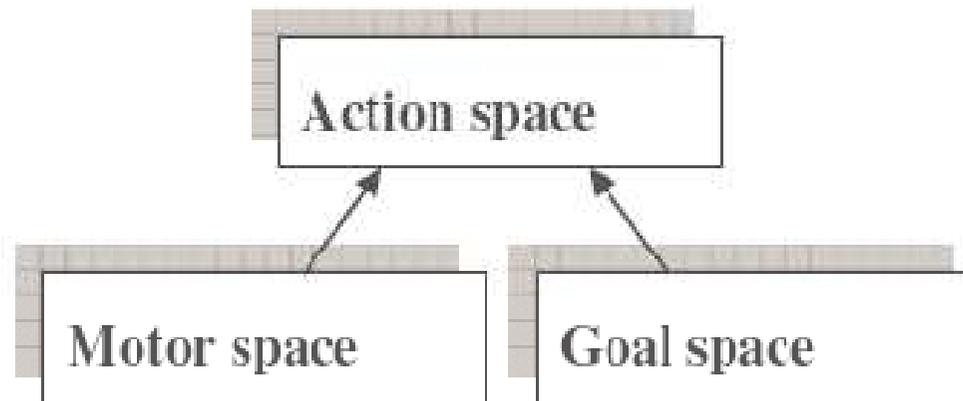
d) Cognitive Neuroscience

e) Cognitive Neuroscience



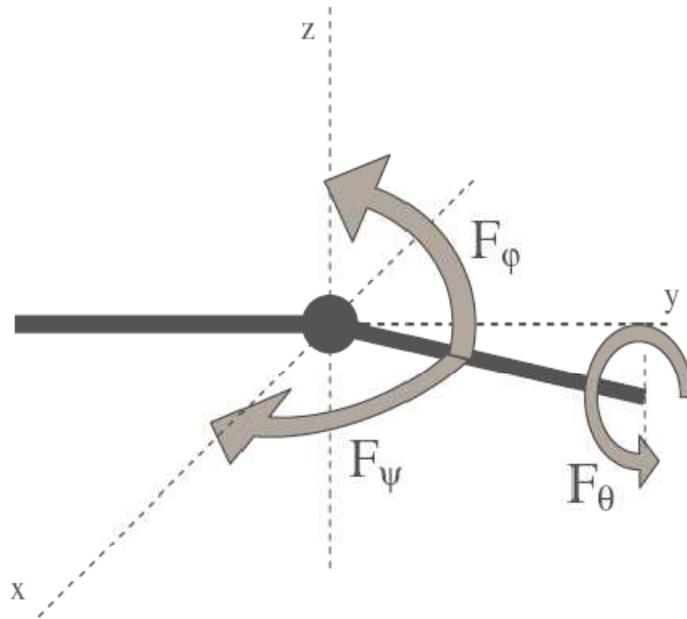
Action space

- Modular approach (Geurder & Weisgerber 2005)
- Action = Motor patterns + Goals:

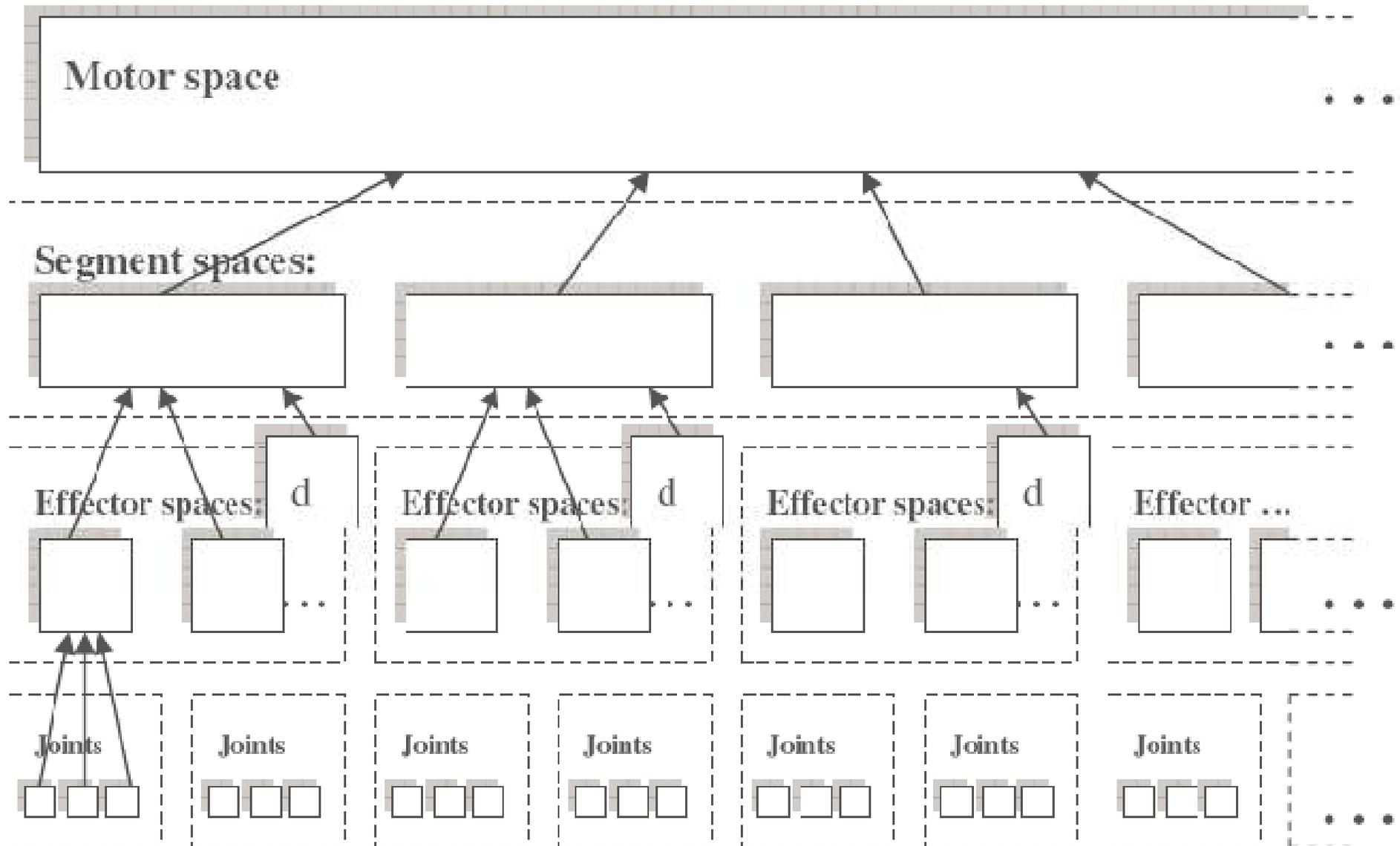


Motor space

- Building blocks: forces on joints.



Motor space



Example

- The tennis serve: the hit

$$DROP_{effector} = \left[joint : [\psi : \mathbb{R}_-] \right]$$

$$SLAM_{effector} = \left[\begin{array}{l} joint : [F_\phi : \mathbb{R}_-] \\ joint : [F_\phi : \mathbb{R}_+] \end{array} \right]$$

$$SERVE_HIT_{segment} = \left[\begin{array}{l} effector : SLAM \\ effector : DROP \\ duration : VERYSHORT \end{array} \right]$$

Example

- The preparation:

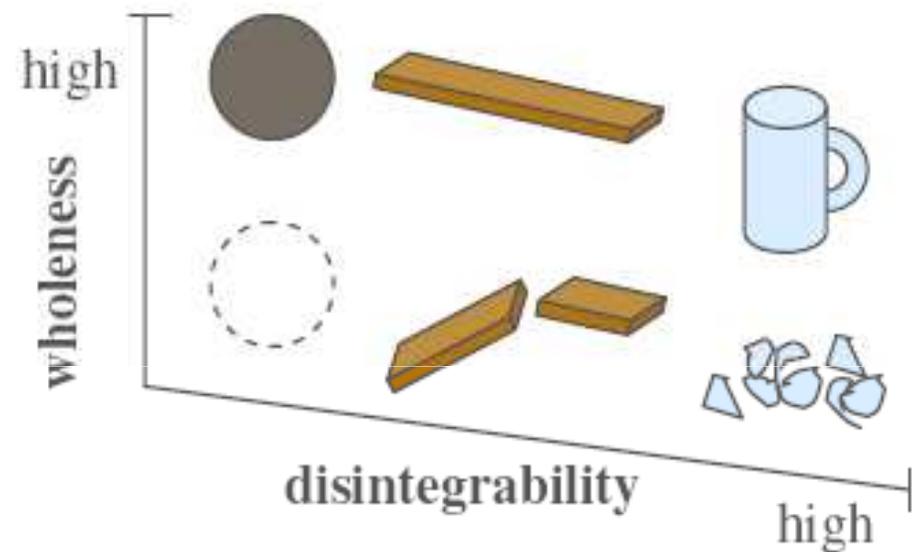
$$SERVE_PREPARE_{segment} = \left[\begin{array}{l} \text{effector : RAISE \& BEND} \\ \text{effector : LIFT} \\ \text{duration : SHORT} \end{array} \right]$$

- The entire motor-representation of the serve, *applied to a human body*, is:

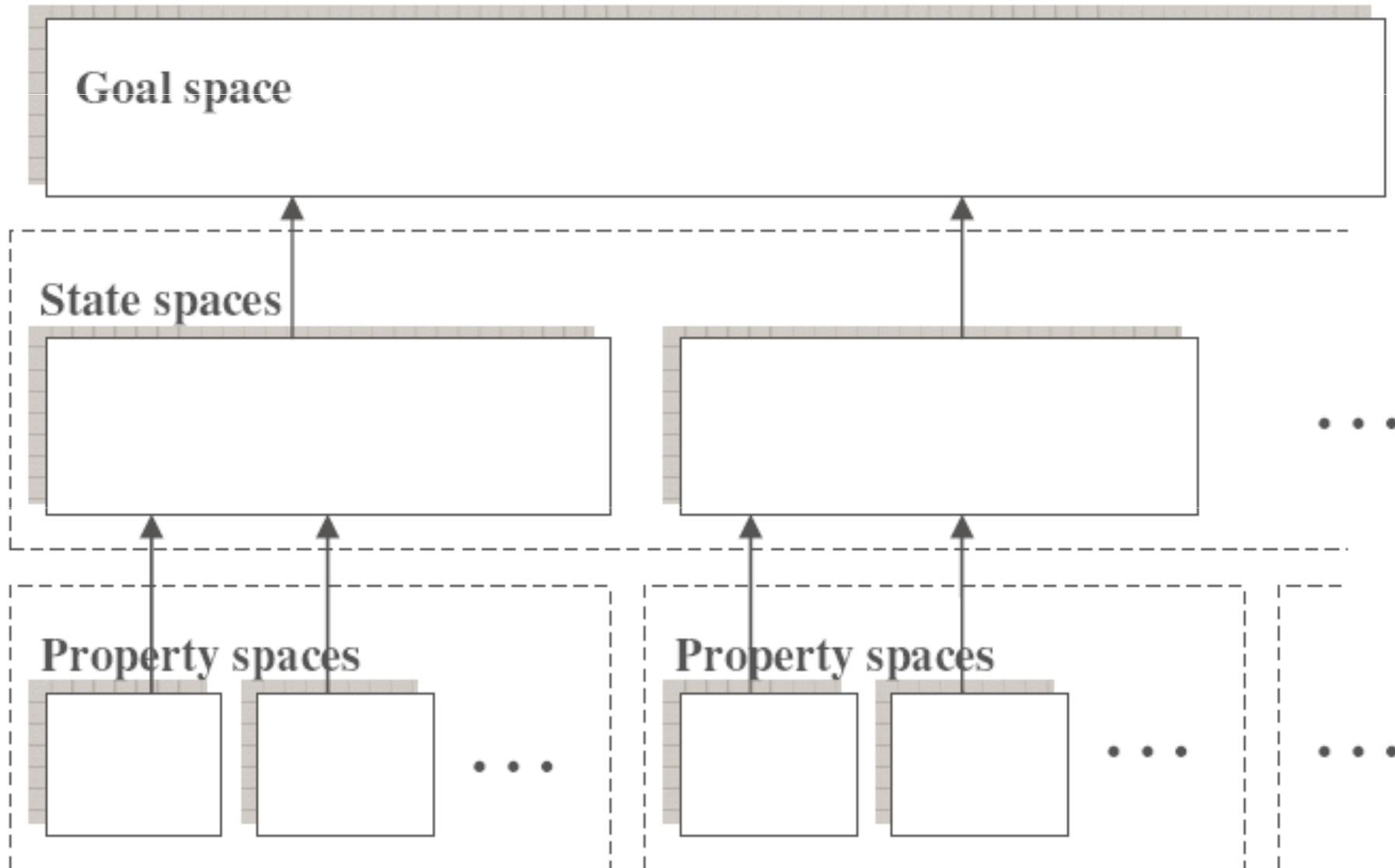
$$SERVE_{motor}(human) = \left[\begin{array}{l} \text{segment : SERVE_PREPARE}(human) \\ \text{segment : SERVE_HIT}(human) \end{array} \right]$$

Goal space

- The building blocks: properties
 - Position
 - Orientation
 - Global shape
 - Material structure →
 - Temperature



Goal space



Example

$$DROP_{\overline{pos}} = \begin{bmatrix} x:5 \\ y:0 \\ z:-10 \end{bmatrix} \quad TURN_{\overline{or}} = \begin{bmatrix} \alpha:0 \\ \beta:-10 \\ \gamma:0 \end{bmatrix}$$

$$HIT_{\overline{state}} = \begin{bmatrix} \overline{pos}: DROP \\ \overline{or}: TURN \end{bmatrix}$$

$$FLATTEN_{\overline{state}} = \left[\overline{gs}: \left[a_y : \mathbb{R}_- \right] \right]$$

$$FLATTENIRON_{\overline{goal}}(smith) = \begin{bmatrix} \overline{state}: HIT(righthand) \\ \overline{state}: HIT(hammer) \\ \overline{state}: FLATTEN(iron) \end{bmatrix}$$

Action space

- Action space should be treated as a regular space.
- Distance measure:

$$\sigma_{A \cap B}(\varphi_A, \psi_B) = w_1 \cdot \sigma_{D_1}(D_1(\varphi_A), D_1(\psi_B)) \otimes \dots \otimes w_n \cdot \sigma_{D_n}(D_n(\varphi_A), D_n(\psi_B))$$

- Weights denote each domain's importance
- What is the role of these weights?
 - Further research...

Linguistic phenomena

Manner/Result

- Manner-result dichotomy in verb meaning

1. The boy broke the window

The window broke

2. The boy hit the window

*The window hit

- Generalizes to:

	Means/Manner Verbs	vs.	Result Verbs
— Verbs of Damaging:	<i>hit</i>	vs.	<i>break</i>
— Verbs of Removal:	<i>shovel</i>	vs.	<i>empty</i>
— Verbs of Putting — 2-dim:	<i>smear</i>	vs.	<i>cover</i>
— Verbs of Putting — 3-dim:	<i>pour</i>	vs.	<i>fill</i>
— Verbs of Combining:	<i>shake</i>	vs.	<i>combine</i>
— Verbs of Killing:	<i>stab</i>	vs.	<i>kill</i>

Manner/Result

- Manner ~ Motor space
- Result ~ Goal space

$$HIT_{action} = \begin{bmatrix} motor : DROPFAST \\ goal : \top \end{bmatrix} \quad BREAK_{action} = \begin{bmatrix} motor : \top \\ goal : BREAKOBJECT \end{bmatrix}$$

$$SMASH_{action} = HIT_{action} \times BREAK_{action} = \begin{bmatrix} motor : DROPFAST \\ goal : BREAKOBJECT \end{bmatrix}$$

Aspect

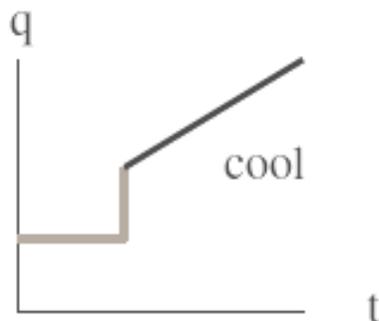
- Grammatical aspect:

	Dynamic	Telic	Durative
State			X
Activity	X		X
Achievement	X	X	
Accomplishment	X	X	X

- Croft (to appear):

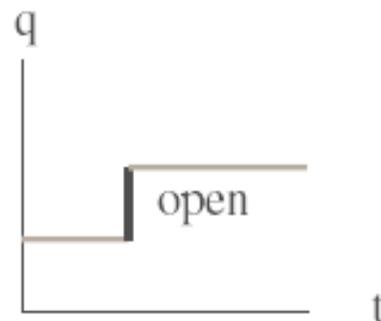
Activity

Mary is cooling the soup.



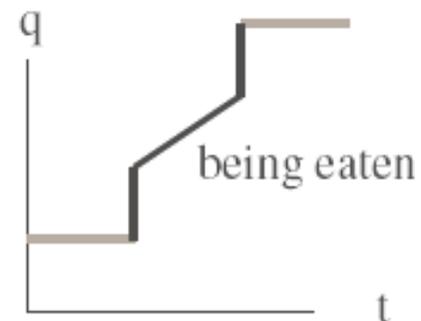
Achievement

Peter opened the door.



Accomplishment

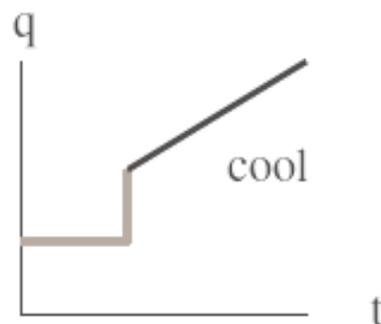
Alice ate the whole thing.



Aspect

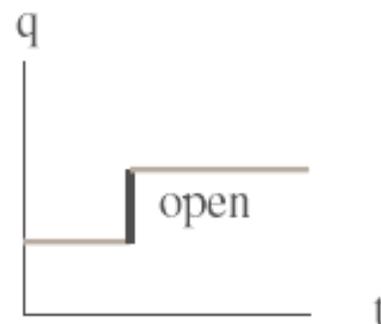
Activity

Mary is cooling the soup.



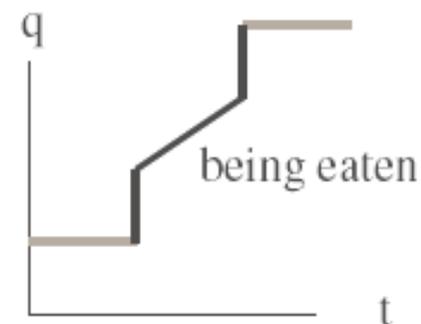
Achievement

Peter opened the door.



Accomplishment

Alice ate the whole thing.



$$COOL_{goal} = \left[\overrightarrow{state} : \left[\overrightarrow{tmp} : [t : \mathbb{R}_-] \right] \right]$$

$$OPEN_{goal} = \left[state : \left[or : [\alpha : \pi] \right] \right]$$

$$EATWHOLE_{goal} = \left[\begin{array}{l} state : [ms : [w : 0]] \\ state : [ms : [w : \mathbb{R}_-]] \end{array} \right]$$

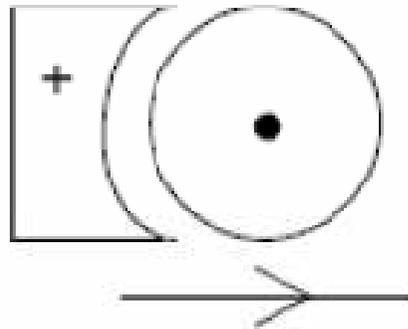
Aspect

- These q/t diagrams are like properties in goal space!
- Differences in diagrams correspond to goal space structure: endstate/trajectory.

	Dynamic	Telic	Durative	Endstate	Trajectory
Activity	X		X		X
Achievement	X	X		X	
Accomplishment	X	X	X	X	X

Modals

- Modal verbs
 - Can, want, should, keep, help, cause, let...
 - Agonist, antagonist, tendency, resultant (Talmy 2000):



The ball kept rolling because of the wind blowing on it.

- Such meanings reside in a double action space:
“Interaction space”

Conclusions & outlook

Conclusions

- Aims:
 - Model human action representations (quite expressive)
 - Use it to explain some linguistic phenomena
 - (Try to make the model useful for robotics)
- Succeeded, apart from some details, e.g.:
 - No ordering of segments in motor space.
 - Goal space conflates causal and aspectual structure.
 - How plausible is it, really?

Further research

- Now that we have a space, many things can be investigated, e.g.:
 - Are action concepts convex? Or just connected?
 - How are action concepts ‘applied’ to objects?
 - Can we represent ‘affordances’ in action space?
 - What are the weights of the similarity measure?
 - And what do they tell us?

Questions?