DNF Models of Spatial Language Behaviors

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DNF Approach to Cognitive Behaviors

- cognition emerging from sensori-motor processes
- simulation for reasoning
- uses metric representations over perceptual spaces (compare e.g. Barsalou 1999, 2008)

contrast to symbolic processing:
- separate processes and representations for perception and cognition
- cognition based on amodal symbol systems
Relational spatial language

„Where is the green flashlight relative to the blue box cutter?“

Why are we interested in spatial language?

- provides a natural means to communicate about objects and locations
  ⇒ relevant for interactive robotic scenarios
- forms a junction point between metric spatial representations and symbolic verbal descriptions
  ⇒ relevant for understanding spatial cognition
Relational spatial language

According to Logan & Sadler (1996):

1. Spatial Indexing: Locate target and reference item

2. Reference frame alignment

3. Mapping spatial relations onto reference frame

4. Assessment of fit and response selection

„To the left!“
Color-space associations

- Input image
- Color nodes
- Color extraction (algorithmically)
- Color-space fields
- Target/reference field
Color-space associations

- Color-space fields
- Target/reference field
- Input image
- Color extraction (algorithmically)
- Color nodes
- Specific color input
- \( \Sigma \)
Color-space associations

- Color nodes
- Specific color input
- Global boost

Input image

Color extraction (algorithmically)

Color-space fields

Target/reference field
Color-space associations

- Color-space fields
- Color nodes
- Color extraction (algorithmically)
- Target/reference field
- Input image
DNF model of spatial language behaviors

color-space association

„red“  „green“  „blue“
color term nodes
color-space fields

target field  reference field

spatial term nodes  spt. relation nodes
„left“  „right“  „above“  „below“

mapping to spatial terms

transformation field

object-centered field

coordinate transformation
Spatial Transformation for Spatial Language (1D)
Spatial Transformation for Spatial Language

target field

reference field

object-centered field
Spatial Transformation for Spatial Language

Reference field

Target field

Object-centered field

Reference field

Target field

Object-centered field
Spatial Transformation for Spatial Language

- Target field
- Reference field
- Object-centered field
Spatial Transformation for Spatial Language

target field

reference field

object-centered field
Spatial Transformation for Spatial Language
Q: Where is the green flashlight relative to the red tape dispenser?

A: To the right.

Q: What is above the blue deodorant stick?

A: The red box cutter.

Q: Where is the green highlighter?

A: To the left of the blue stack of blocks OR to the right of the red stack of blocks.
Simulation Results

% salient object selected

- LG
- LA
- LA/DG
- LG/DA
- LA/DA
- LG/DB
- LA/DB₁
- LA/DB₂

![Bar chart showing % salient object selected for different conditions.](chart.png)

- **LG** = Carlson & Hill, 2008
- **LA** = Simulations

[Lipinski, Schneegans, Sandamirskaya, Spencer, Schöner 2012]
Strengths and Limitations of the Model

Strengths:
- general and flexible system
- neural process model (contrast e.g. to AVS)

Limitations:
- behavioral flexibility induced by fixed sequence of external inputs
- verbal representations largely outside of the model
- limited autonomy
Extended Architecture for Autonomous Behavior
Extended Architecture for Autonomous Behavior
conjunctive coding (content + semantic role) for task representation
Concept Nodes

meaning of concepts encoded in projections to fields
Behavior Organization
Grounding Spatial Expressions

„the red item to the left of the green item“
Hypothesis Testing

„the red item to the left of the green item“
Hypothesis Testing

„the red item to the left of the green item“
Overview and Outlook

- symbolic representation for verbal task, but processing in modal, metric representations
- autonomy through dynamic behavior organization
- sequential processing to solve binding problem, consistent with human behavior (Logan 1994; Franconeri 2012)

future work:
- combination with DNF model of scene representation: building mental models from verbal descriptions, reasoning through simulation
- relate to human data (e.g. Knauff 2013)