

# The PRAXICON

*Towards a Semantic Memory-like Module for Robots*



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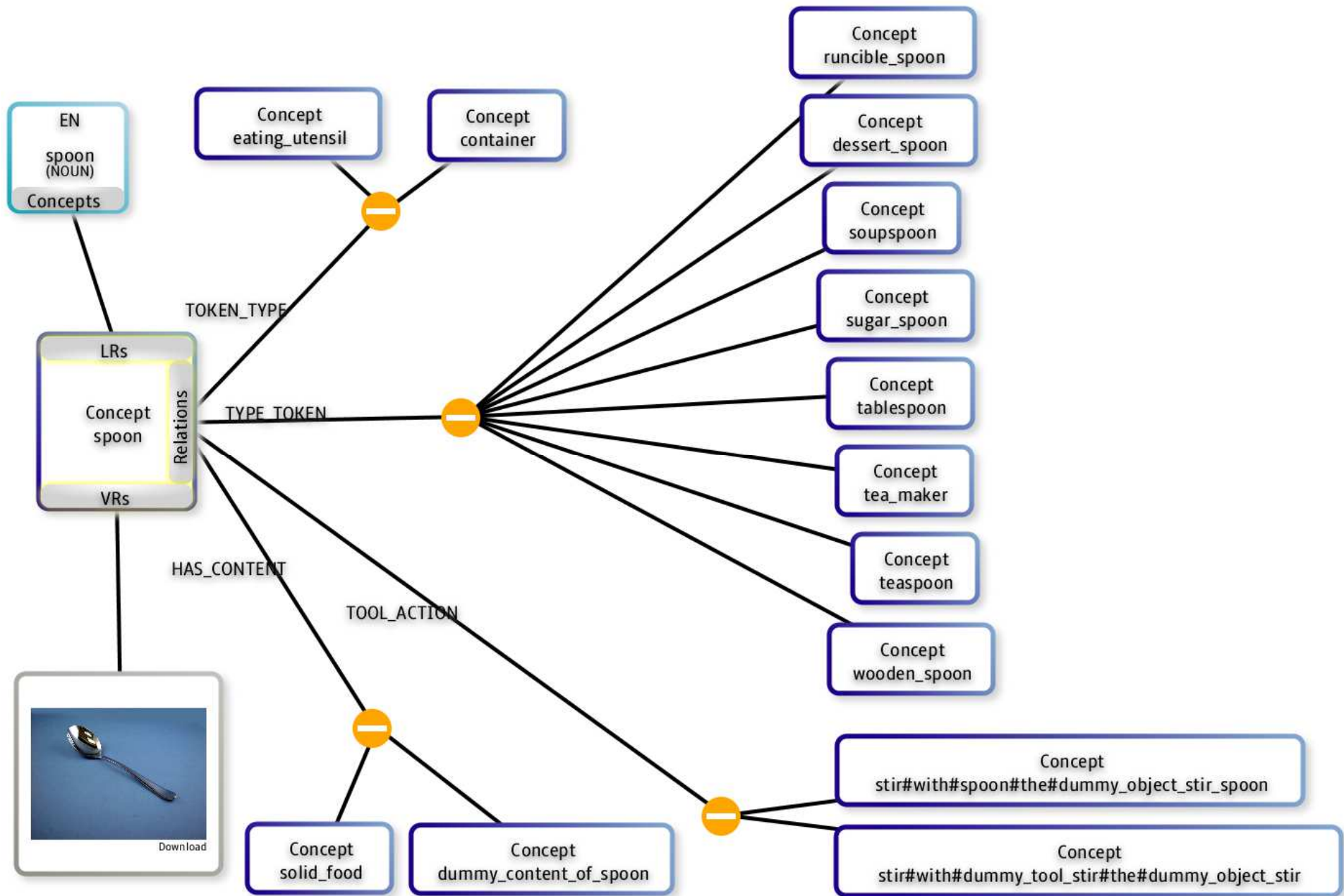
# A tutorial

## PART A:

- What is the PRAXICON – What is a Semantic Memory?
- Do robots need a semantic memory?
- The structure of our PRAXICON
  - Type of information included (Concepts and their characteristics)
  - Relations included

## PART B:

- Using the PRAXICON in different applications (demos & rationale)
- Querying the PRAXICON
- The tool game



# PRAXICON

- PRAXICONS: From Liepman's (1908) input/output motor representations stored in memory, to...
- ...embodied-concept representations of perceptual, motoric and/or linguistic/symbolic nature, perceived and stored in memory for behaviour generation and understanding

# Memories

- Long term Memory (see Tulvig 1972)
  - **episodic** (tied to specific learning experiences)
  - **semantic** (general knowledge of the world, and related generalisation and reasoning abilities)  
see Quillian 1968, see semantic networks
  - **procedural** (related to single action & action sequence learning, created through repeated learning)

# Memories (2)

- Issues
  - type of knowledge stored
  - structure of memory space
  - use/activations (in memory search, retrieval, decision making)

# Theories on Semantic Memory

Many theoretical accounts on structure & neural basis of SM  
(cf. extensive reviews in Kiefer and Pulvermueller, in press,  
McNorgan et al. 2011, Meteyard et al. in press)

- (1) Concepts are flexible, distributed representations; they comprise modality-specific conceptual features (latter stored in distinct sensorymotor brain areas) [Kiefer and Pulvermueller, in press]
- (2) Much of the semantic memory content is related to perception and action and is represented in a brain region that overlaps with or corresponds to regions responsible for perception and action (Patterson et al. 2007)

# Semantic Memory & Language

Traditional representation of semantic knowledge through:

- **Semantic Networks (hierarchical or non)** (see Collins and Quillian 1969, Collins and Loftus 1975) and/or **Feature Bundles**

**NOTE:**

- all such knowledge is represented through LANGUAGE only, and carries all idiosyncrasies of language...(i.e. the semantic gap to the sensorimotor space lurks behind these resources)



# Semantic Memory & Language (2)

**A number of knowledge bases around (of different types):**

- WordNet (hierarchical lexical database) (Fellbaum 1998)
- Common sense knowledge bases (e.g. ConceptNet, CYC – Lenat et al. 1995) etc.

**A number of cognitive architectures with recently incorporated semantic memory modules:**

- SOAR (Laird et al. 2009)
- ACT-R (Anderson et al. 2004)
- ICARUS (Langley 2009)

# Semantic Memory & Language (3)

Common ASSUMPTION that agents have:

- (a) sensorimotor experiences related directly or indirectly to what the language representations denote, and
- (b) mechanisms for performing such link between language, perception and action

Aka: These modules/resources are NOT embodied, they are tied to language idiosyncrasies and lack structure that will unify language-perception-action.

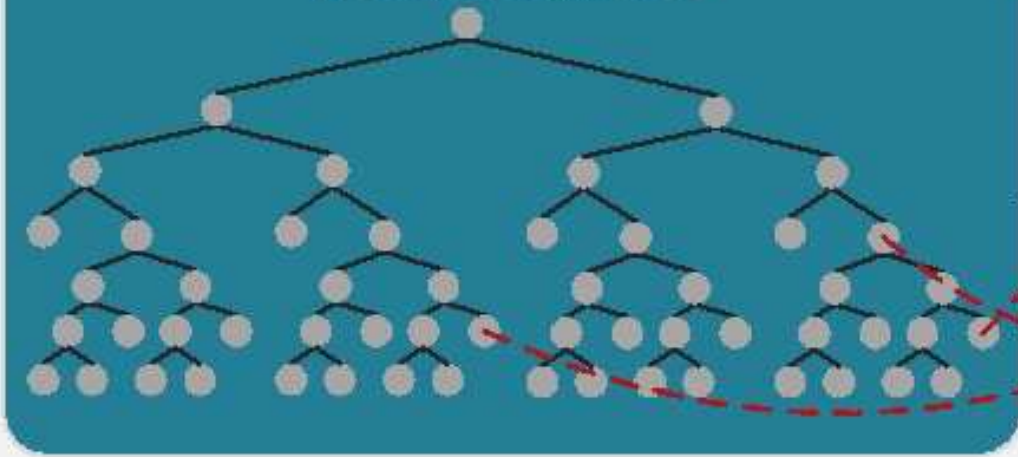
Note: linking robots to the web and interconnecting the knowledge they acquire through a cloud, can only be useful if...

# Theories on Semantic Memory (2)

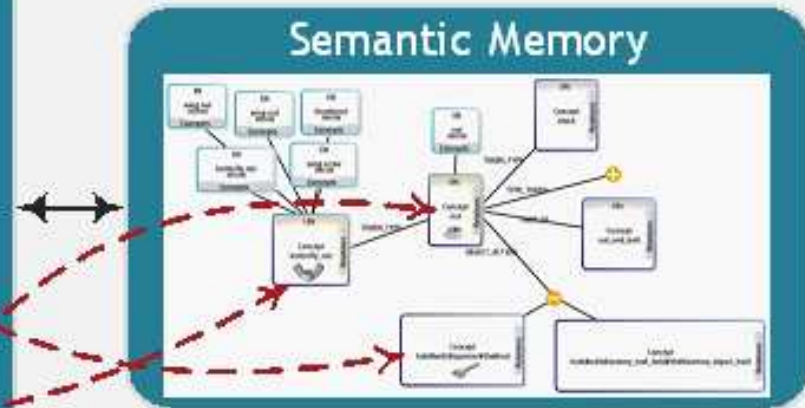
## How could it be implemented?

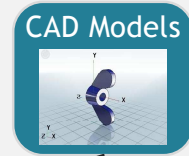
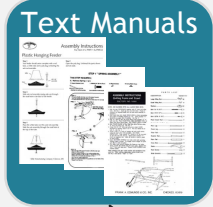
McClelland → neuroscience evidence suggests SM to be implemented as a separate memory not subsumed to episodic memory. Suggestion that hippocampal formation and the neocortex form complementary learning system. Former facilitates auto and hetero-associative learning which is used to reinstate and consolidate gradually learned info in the neocortex.

## Procedural Memory



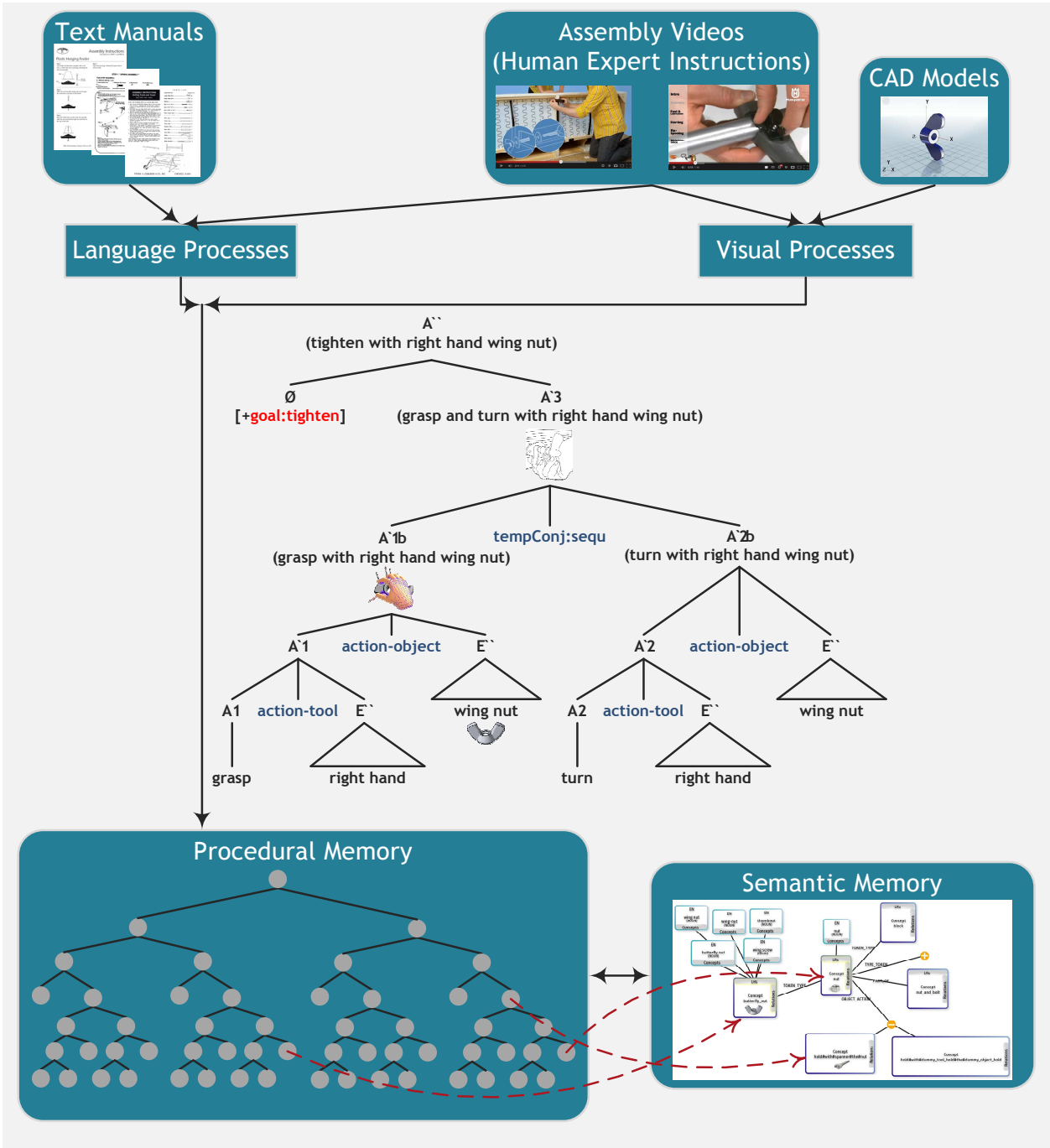
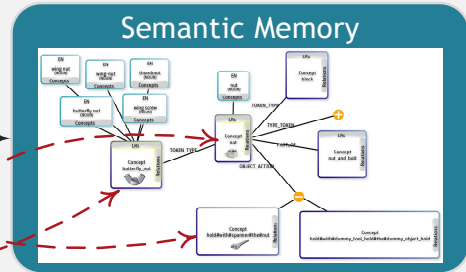
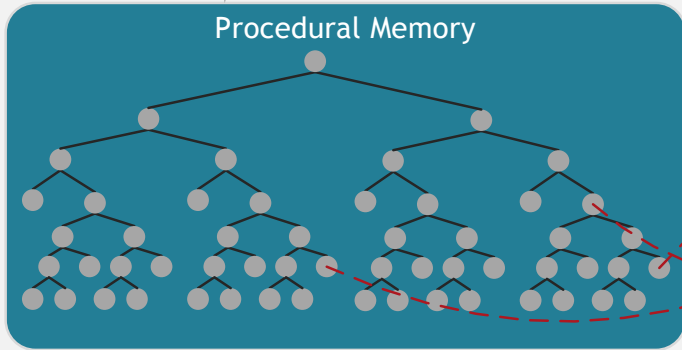
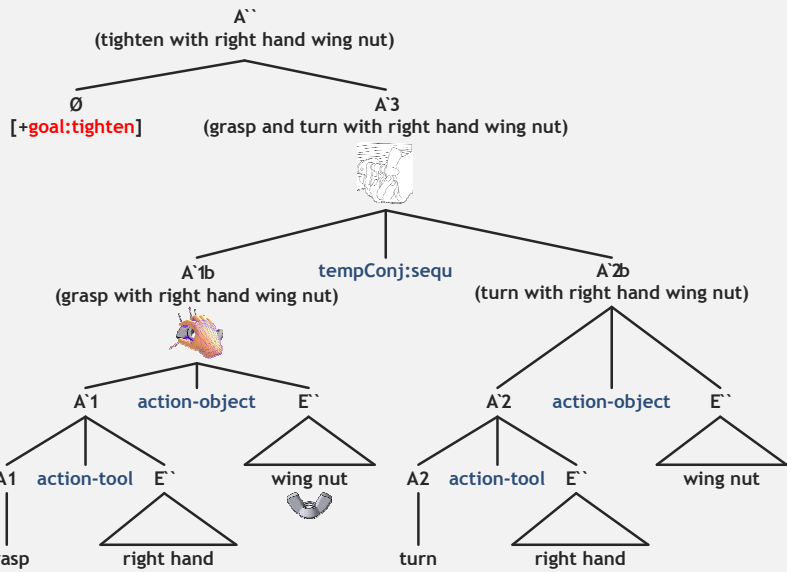
## Semantic Memory

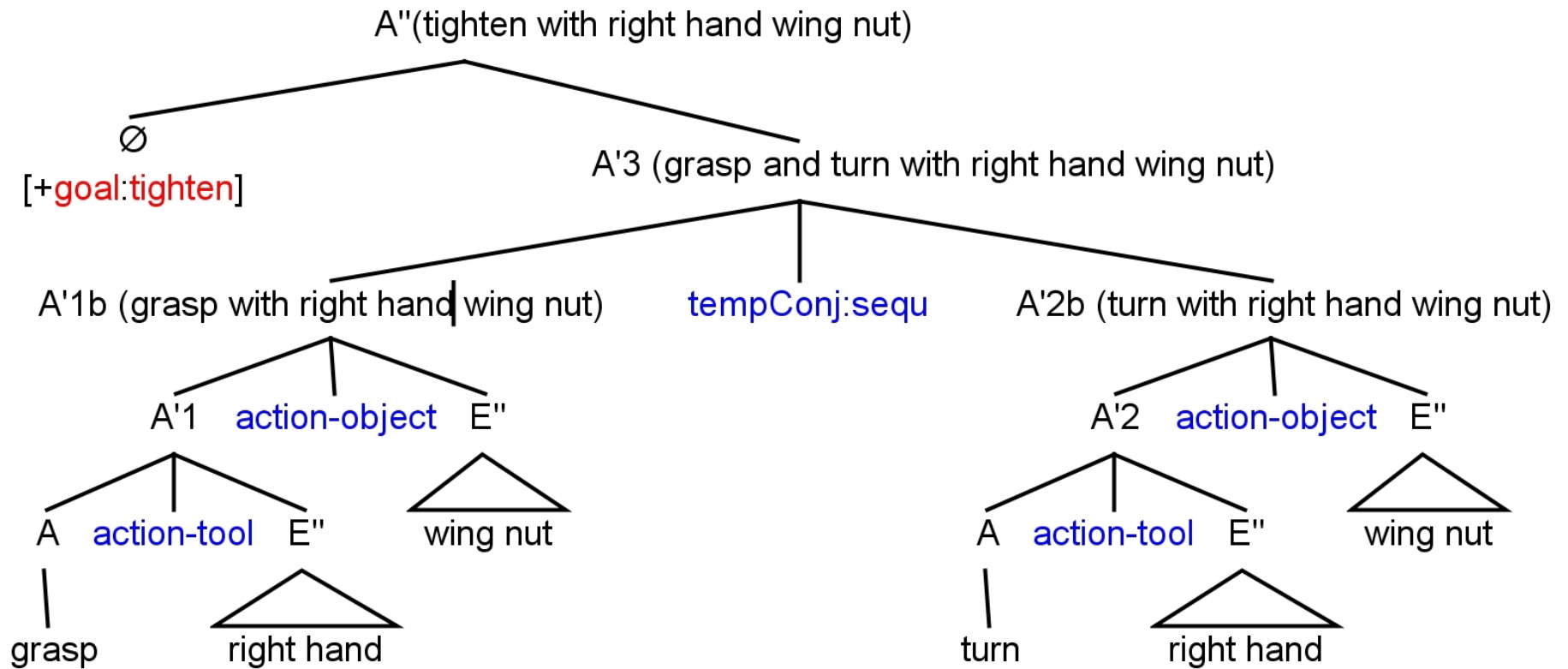


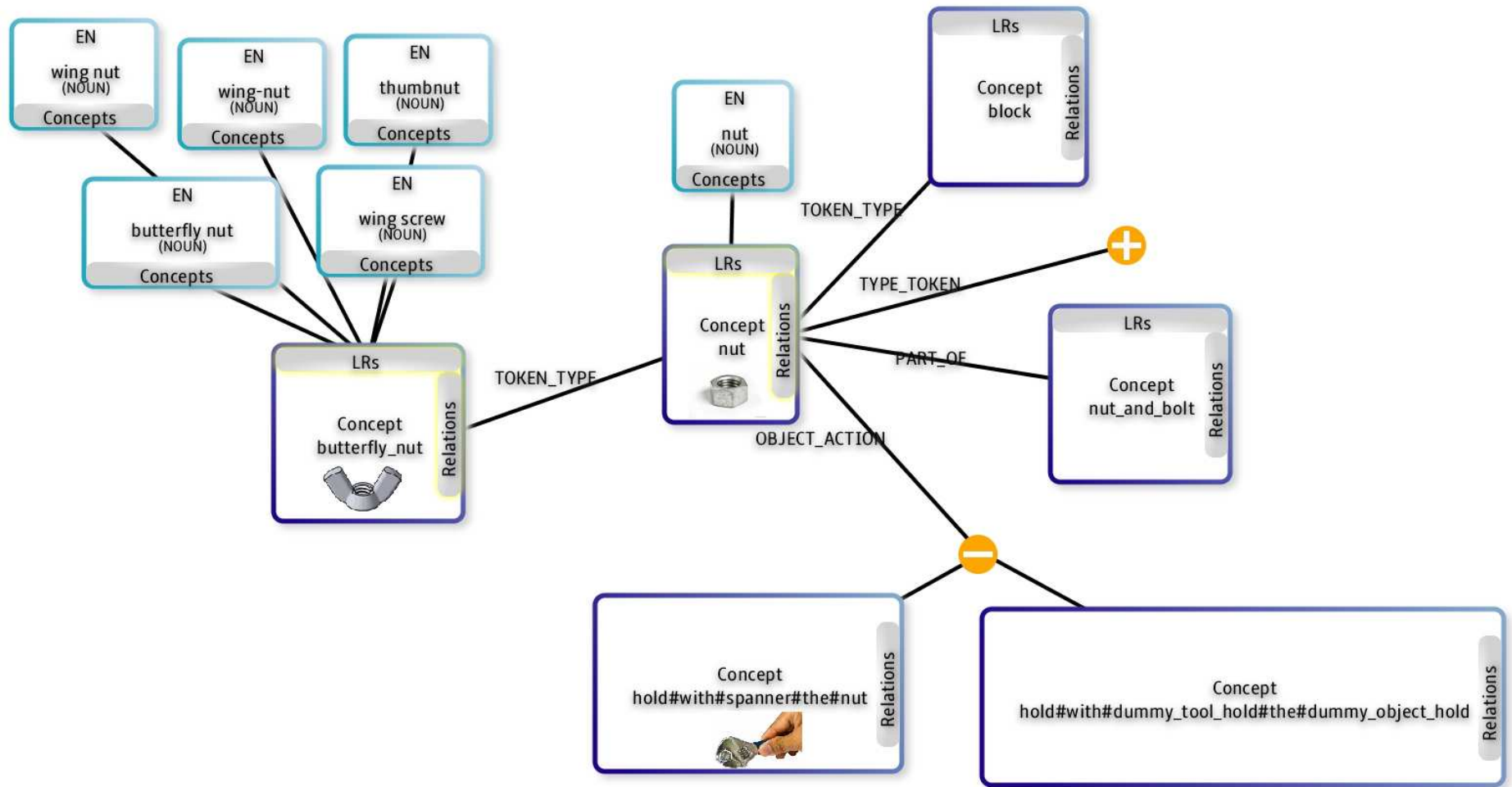


Language Processes

Visual Processes







# Why Needed in Robots?

Currently, our robots have  
episodic and procedural memory ONLY

ONE SHOT learning ← need for Generalisation

- Semantic memories (SM) in Robots usually generated directly by perceptual systems (for object/action recognition) ← reasoning?
- Sometimes indirectly present through association strength information in episodic memory

**We envision:** Self-exploration models for gathering information, input to episodic/procedural memory, and then updating of Semantic Memory → generalization



# PRAXICON Structure (1)

- **Concepts** (nodes - multirepresentational)
  - **Relations** (edges – labeled, mostly bidirectional)
- One concept may have many relations to many concepts  
BUT there is only one relation linking two specific concepts
- Some relations are more important for a concept than others;  
they are denoted as '**inherent**' relations

# PRAXICON Structure (2)

Concepts: **Characteristics**

**TYPE:** **entity, movement, feature, abstract**

**STATUS:** **constant, variable, template**

**PRAGMATIC STATUS:** **literal, figurative**

*Abstract concepts – compare:*

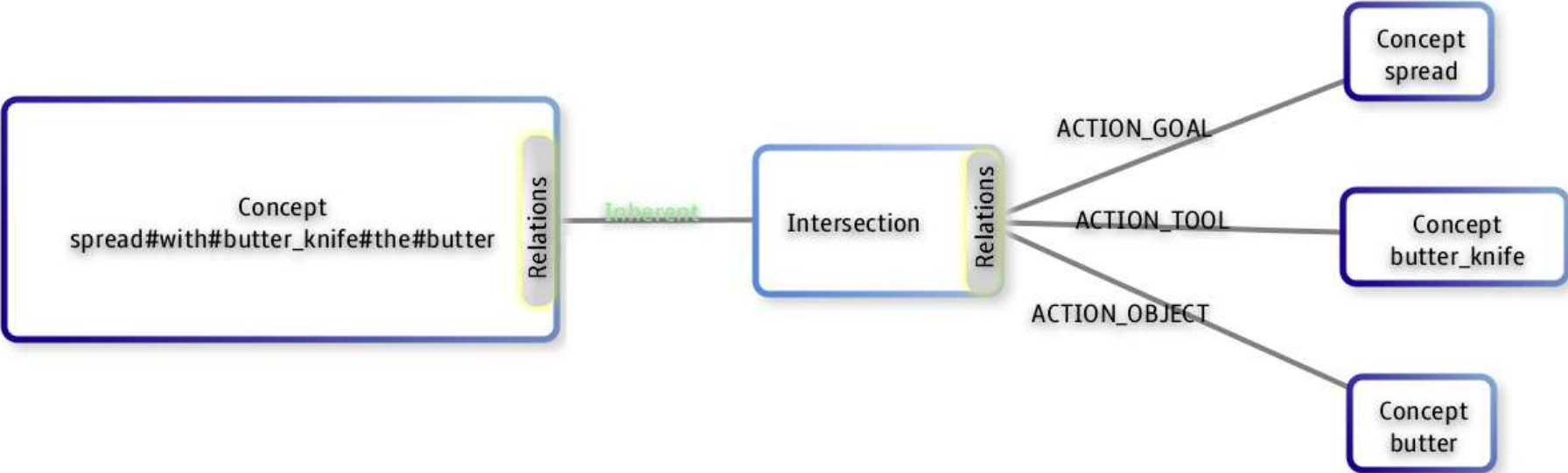
Poverty vs. Cutlery

Cutting instrument vs. knife vs. butterknife

Abstract concepts have 2 more characteristics:

**ORIGIN:** entity, movement, feature

**Basic Level** indication: yes/no



# PRAXICON Structure (2)

## Relations: a finite set

ACTION\_AGENT

ACTION\_GOAL

ACTION\_OBJECT

ACTION\_RESULT

ACTION\_TOOL

ASPECT\_CONCEPT

COMPARED\_WITH

ENABLES

MORE

LESS

METAPHOR\_OF

PRODUCER\_OF

TYPE\_TOKEN

HAS\_ANTHROPOGENIC\_EFFECT

HAS\_COLOUR

HAS\_CONDITION

HAS\_CONTENT

HAS\_DEPTH

HAS\_FORCE

HAS\_HEIGHT

HAS\_HUE

HAS\_INSTANCE

HAS\_INTENSITY

HAS\_LENGTH

HAS\_LOCATION

HAS\_LUMINANCE

HAS\_MATERIAL

HAS\_MEASUREMENT\_UNIT

HAS\_MEASUREMENT\_VALUE

HAS\_MEMBER

HAS\_NATURAL\_EFFECT

HAS\_PART

HAS\_PARTIAL\_INSTANCE

HAS\_SHAPE

HAS\_SIZE

HAS\_SPEED\_RATE

HAS\_STEP

HAS\_TEMPERATURE

HAS\_TEXTURE

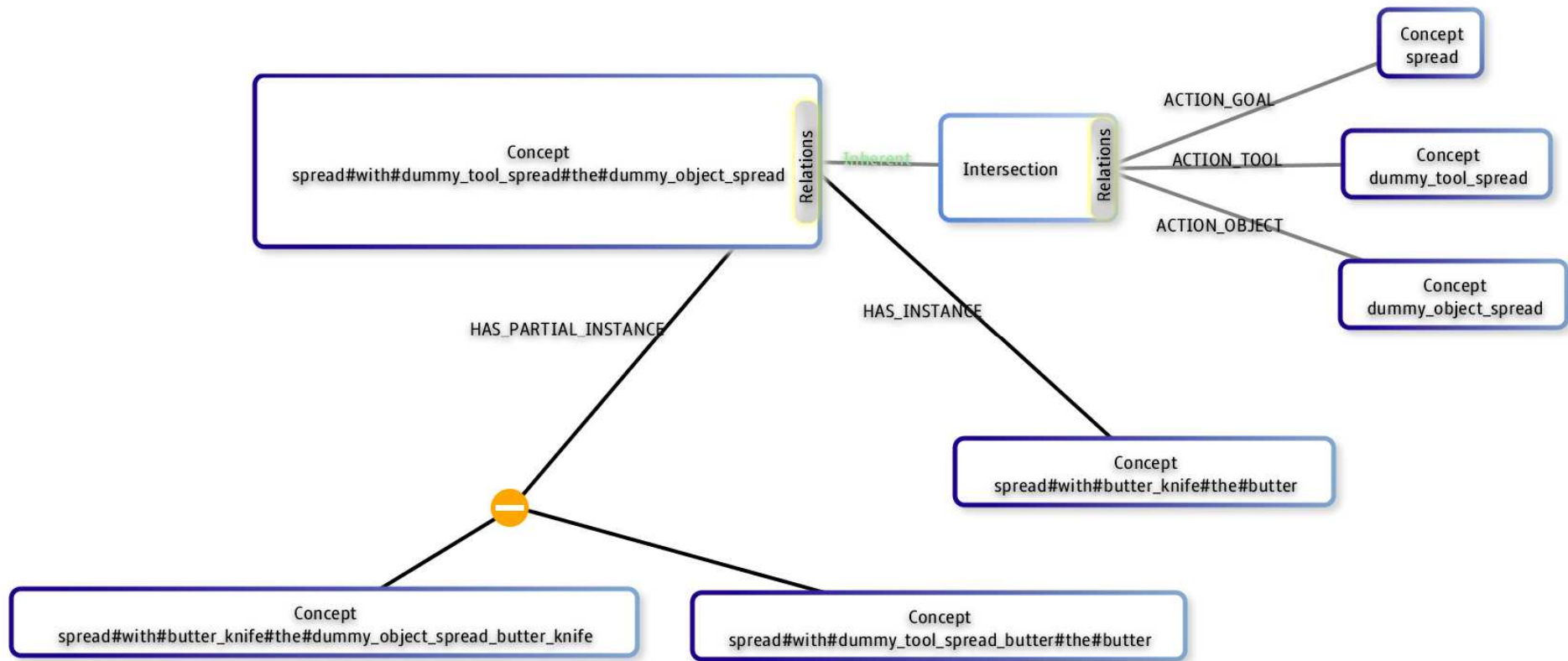
HAS\_TIME\_PERIOD

HAS\_VISUAL\_PATTERN

HAS\_VOLUME

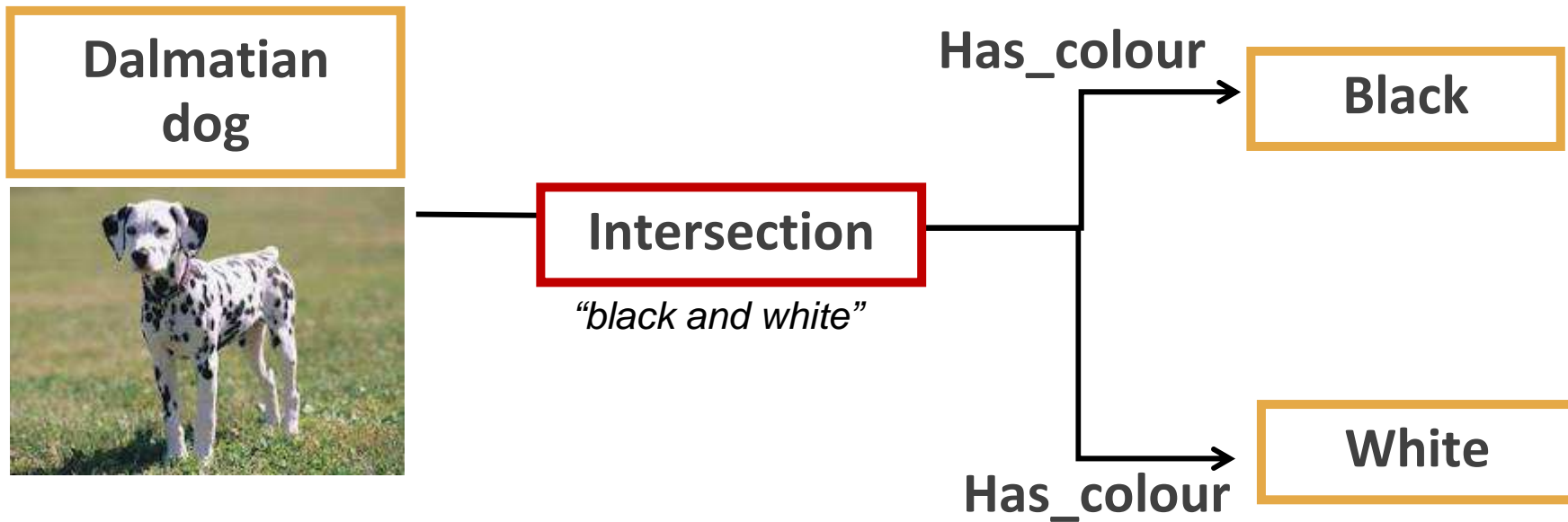
HAS\_WEIGHT

HAS\_WIDTH



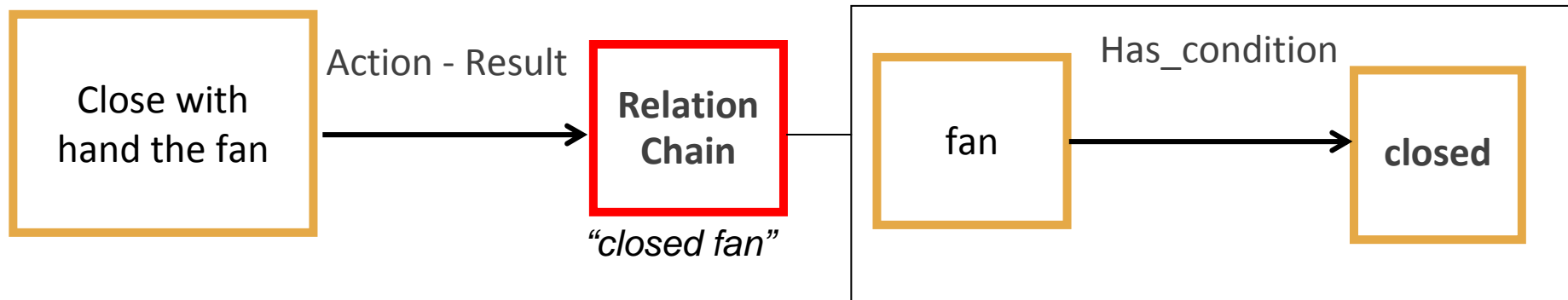
# PRAXICON Structure (3)

Relations: **Intersection**



# PRAXICON Structure (4)

## Relations: Relation Chain



Why is such representation important?

Consider: "the fan is oblong"



# PRAXICON suite of resources and tools

The PRAXICON Semantic Memory, its visual exploration interface (GUI) and the integrated language analysis and reasoning tools

In two forms:

- as a web service (database and game)
- as a downloadable, standalone application for local installation.

Contents:

- Embodied WordNet Lexical Database (more than 100K concepts and relations) Cognitive Experiments (5K)
- Corresponding visual representations from the ImageNet database.

