Robots with …Memory

PRAXICON:
Towards a Semantic Memory-like Module for Robots

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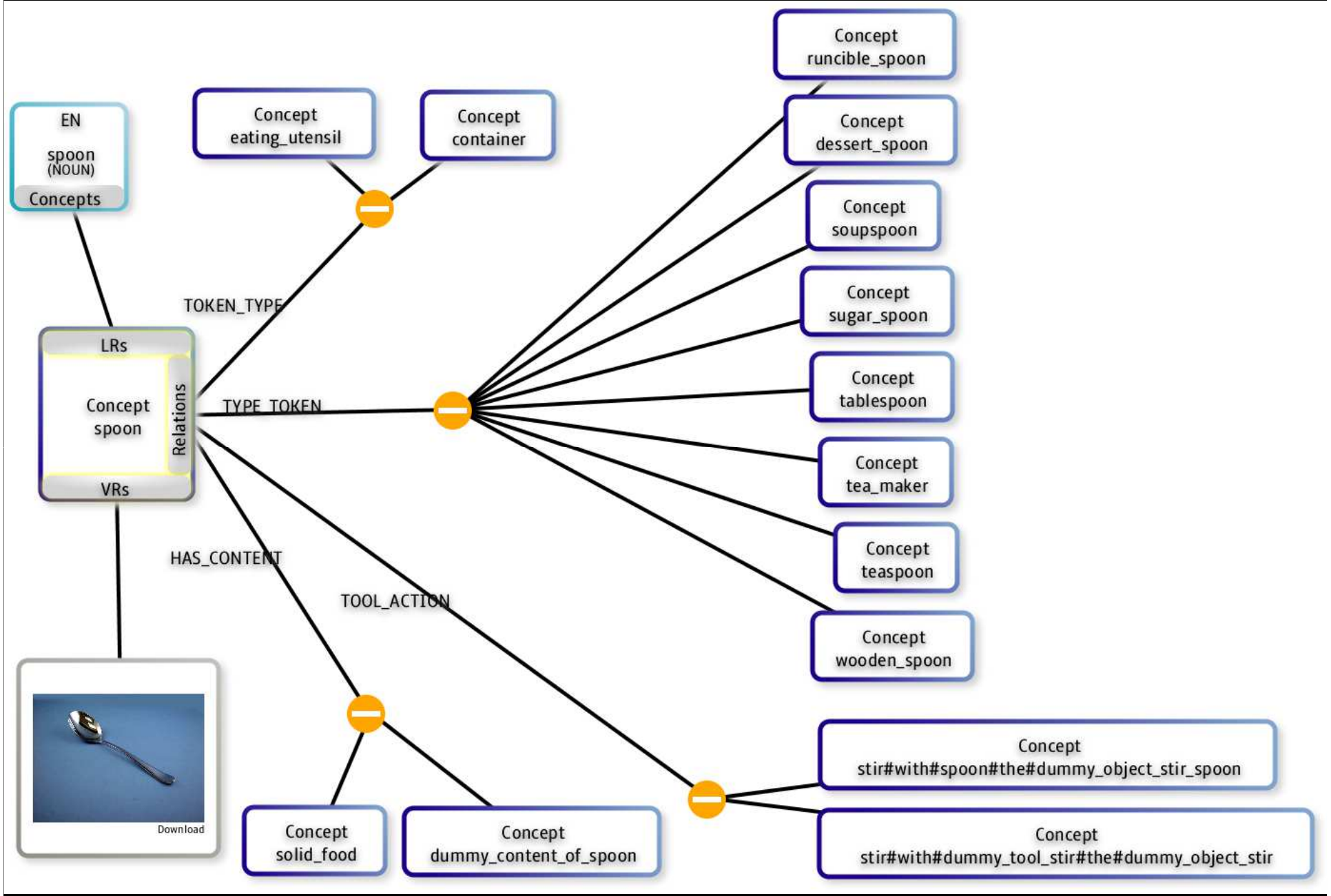
Layout of the talk

- 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
- Examples


EN
spoon
(NOUN)
Concepts
Concept
eating_utensil
Concept
container
Concept
runcible_spoon
Concept
dessert_spoon
Concept
soupspoon
Concept
sugar_spoon
Concept
tablespoon
Concept
tea_maker
Concept
teaspoon
Concept
wooden_spoon
TOKEN_TYPE
LRs
Concept
spoon
Relations
VRs
TYPE_TOKEN
HAS_CONTENT
TOOL_ACTION
Download
Concept
solid_food
Concept
dummy_content_of_spoon
Concept
stir#with#spoon#the#dummy_object_stir_spoon
Concept
stir#with#dummy_tool_stir#the#dummy_object_stir

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 resource) (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

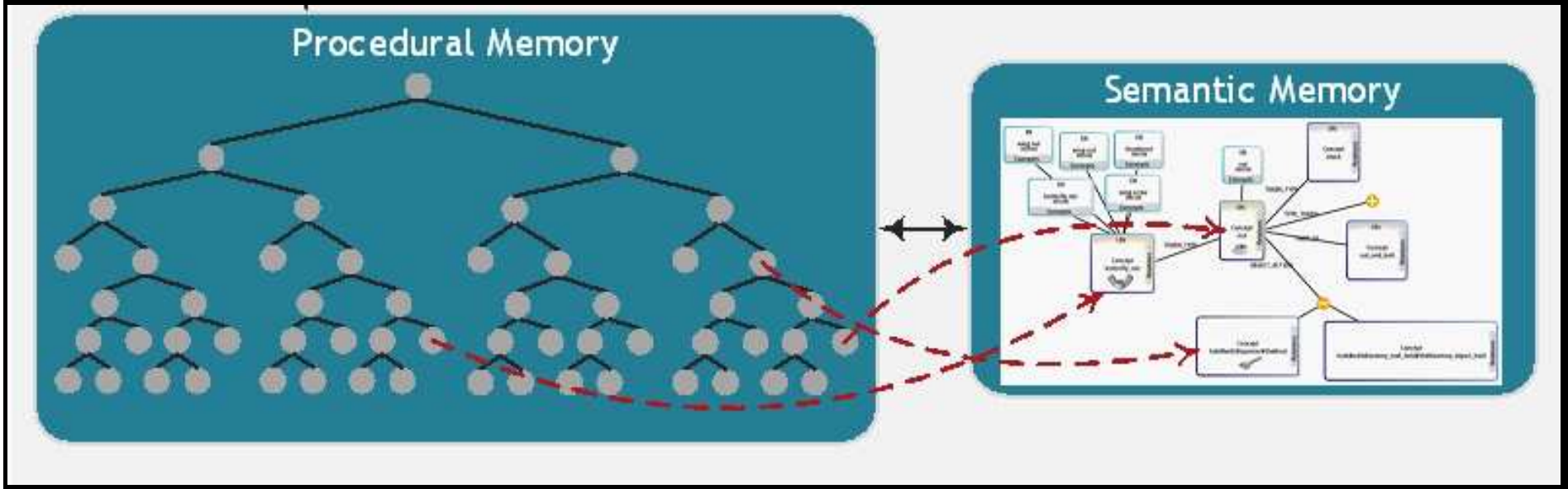
Aka: These modules/resources are NOT embodied, they are tied to language idiosyncrasies and lack structure that will unify language-perception-action.

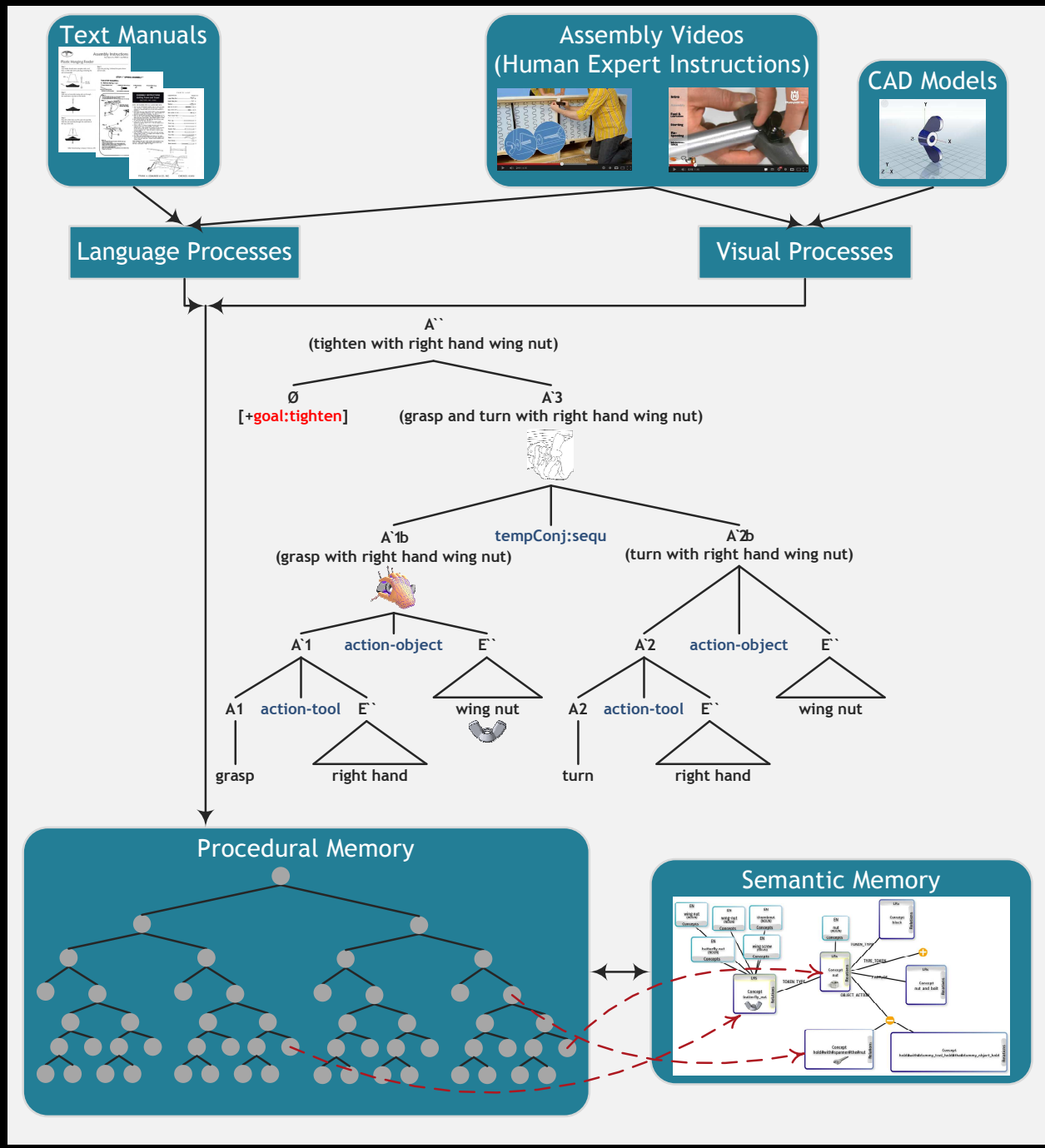
Note: linking robots to the web and interconnecting the knowledge they acquire through a cloud, can only be useful if…

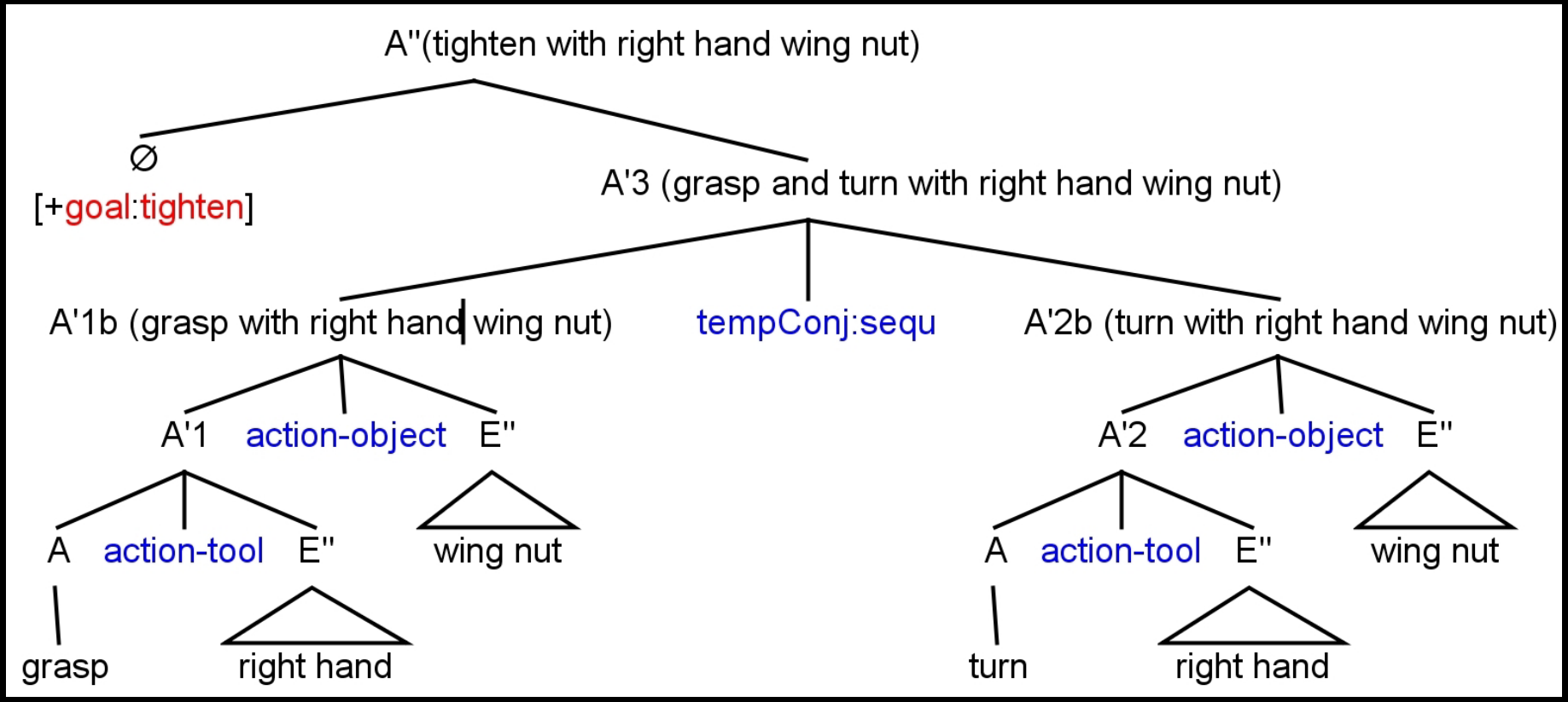
Theories on Semantic Memory (2)

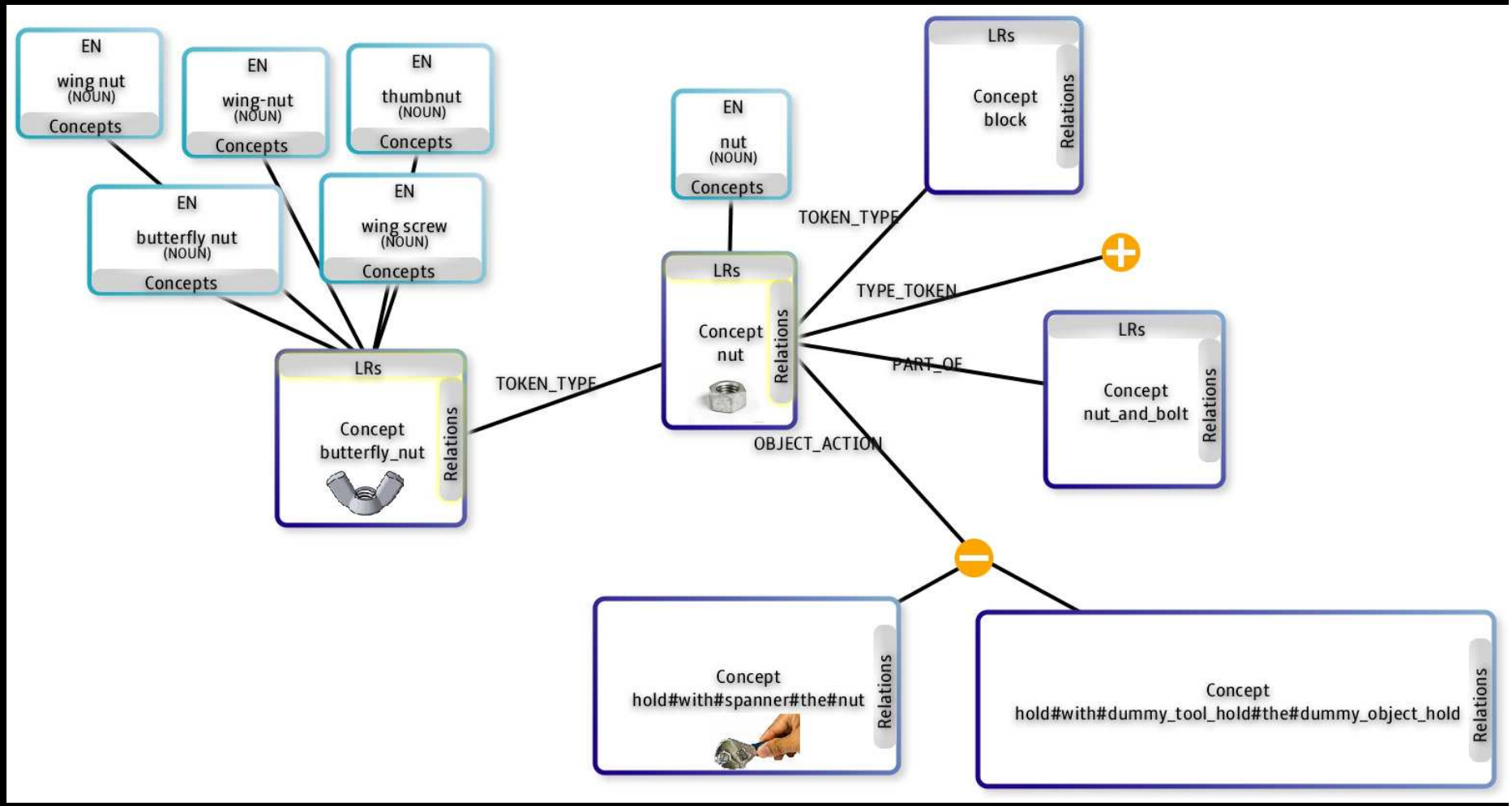
How could it be implemented?

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


Text Manuals
Assembly Videos
(Human Expert Instructions)
CAD Models
Language Processes
Visual Processes
A``
(tighten with right hand wing nut)
Ø
[+goal:tighten]
A`3
(grasp and turn with right hand wing nut)
A`1b
(grasp with right hand wing nut)
tempConj:sequ
A`2b
(turn with right hand wing nut)
A`1
action-object
E``
A1
action-tool
E``
grasp
right hand
wing nut
A`2
action-object
E``
A2
action-tool
E``
turn
right hand
wing nut
Procedural Memory
Semantic Memory


A''(tighten with right hand wing nut)
∅
[+goal:tighten]
A'3 (grasp and turn with right hand wing nut)
A'1b (grasp with right hand wing nut)
tempConj:sequ
A'2b (turn with right hand wing nut)
A'1
action-object
E''
A'2
action-object
E''
A
action-tool
E''
wing nut
A
action-tool
E''
wing nut
grasp
right hand
turn
right hand


EN
wing nut
(NOUN)
Concepts
EN
wing-nut
(NOUN)
Concepts
EN
thumbnut
(NOUN)
Concepts
EN
butterfly nut
(NOUN)
Concepts
EN
wing screw
(NOUN)
Concepts
LRs
Concept
butterfly_nut
Relations
TOKEN_TYPE
EN
nut
(NOUN)
Concepts
LRs
Concept
nut
Relations
TOKEN_TYPE
LRs
Concept
block
Relations
TYPE_TOKEN
PART_OF
LRs
Concept
nut_and_bolt
Relations
OBJECT_ACTION
Concept
hold#with#spanner#the#nut
Relations
Concept
hold#with#dummy_tool_hold#the#dummy_object_hold
Relations

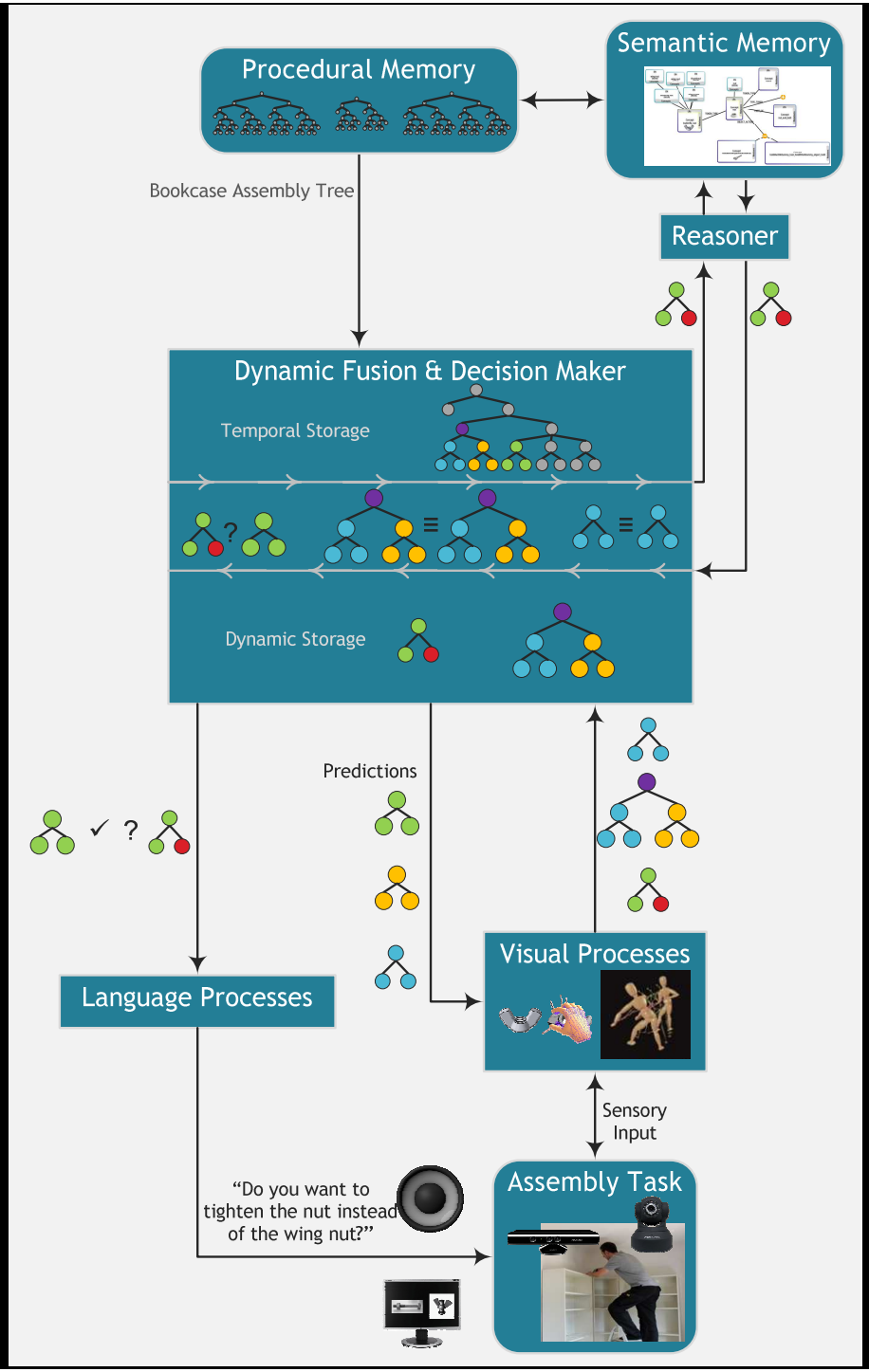
Why Needed in Robots?

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


Procedural Memory
Semantic Memory
Bookcase Assembly Tree
Reasoner
Dynamic Fusion & Decision Maker
Temporal Storage
Dynamic Storage
Predictions
Language Processes
Visual Processes
Sensory Input
"Do you want to tighten the nut instead of the wing nut?"
Assembly Task

PRAXICON Structure (1)

- **Concepts** (nodes – multi-representational)
- **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)

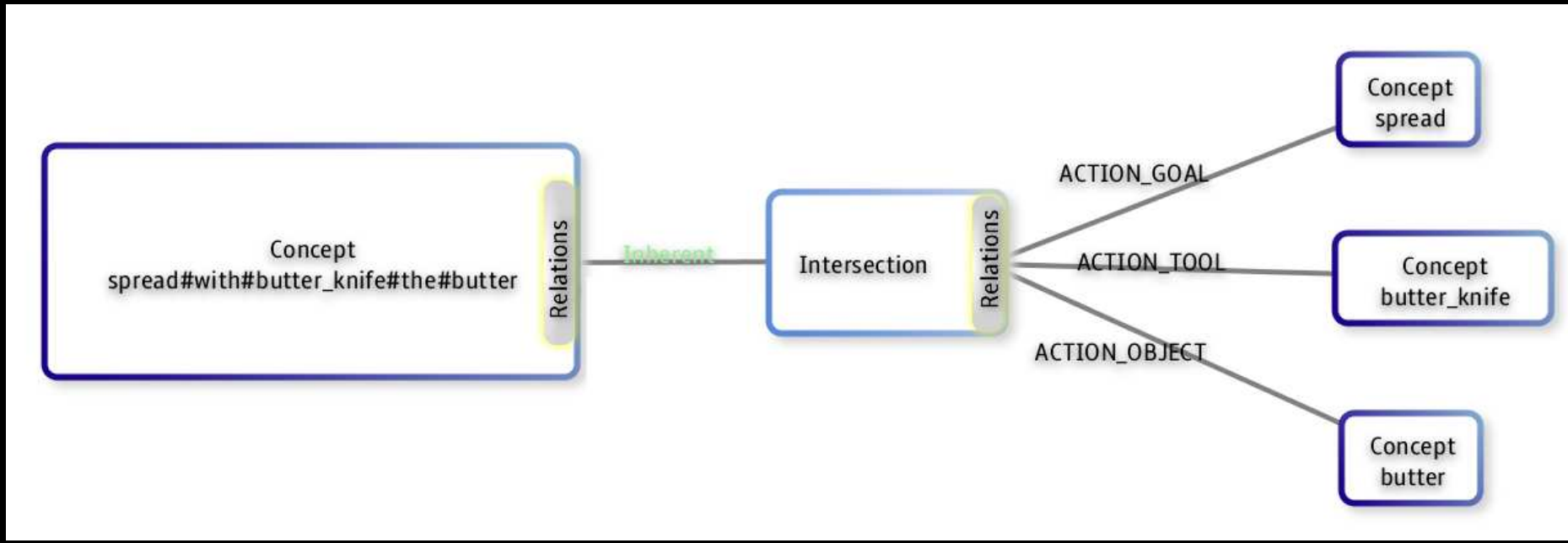
Concepts: Characteristics

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


Concept
spread#with#butter_knife#the#butter
Relations
Inherent
Intersection
Relations
ACTION_GOAL
ACTION_TOOL
ACTION_OBJECT
Concept
spread
Concept
butter_knife
Concept
butter

PRAXICON Structure (2)

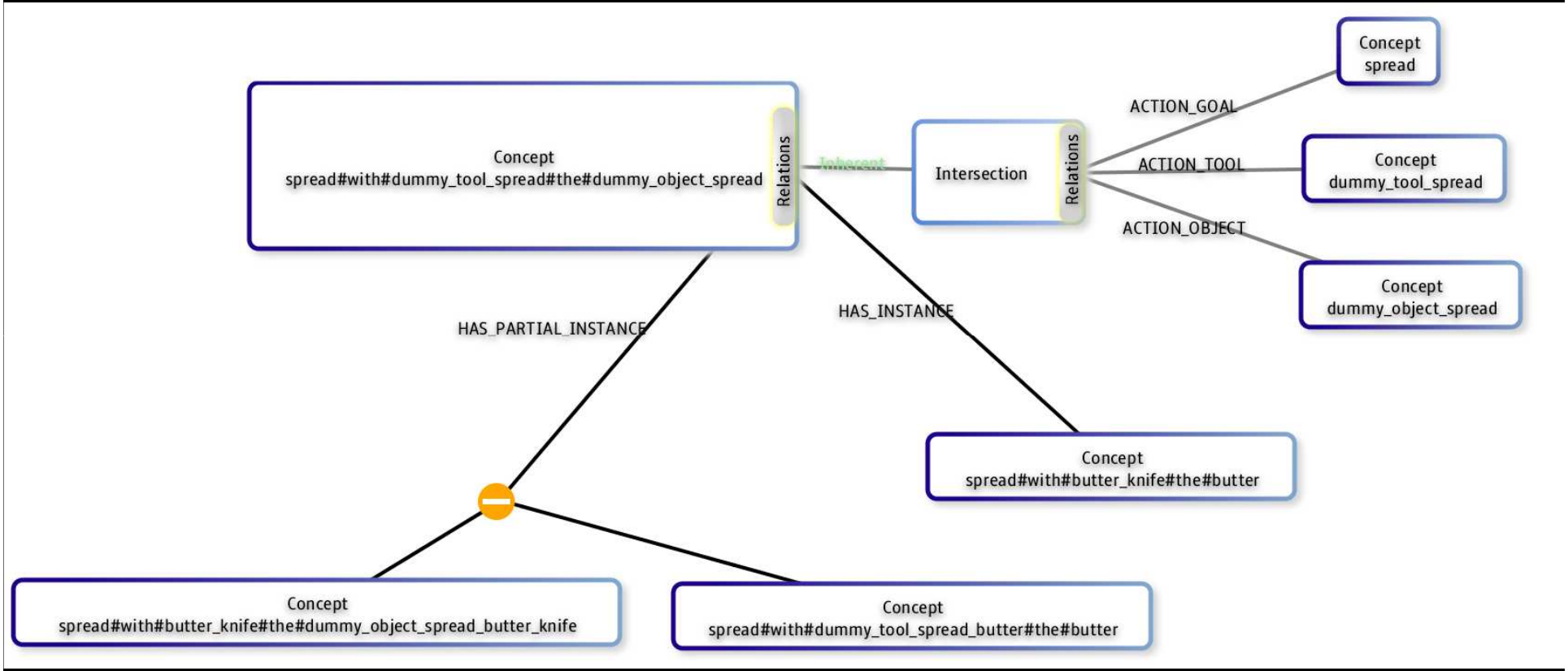
Relations: a finite set

ACTION_AGENT
ACTION_GOAL
ACTION_OBJECT
ACTION_RESULT
ACTION_TOOL
ASPECT_CONCEPT
COMPARED_WITH
ENABLES

MORE
LESS
METAPHOR_OF
PRODUCER_OF
TYPE_TOKEN

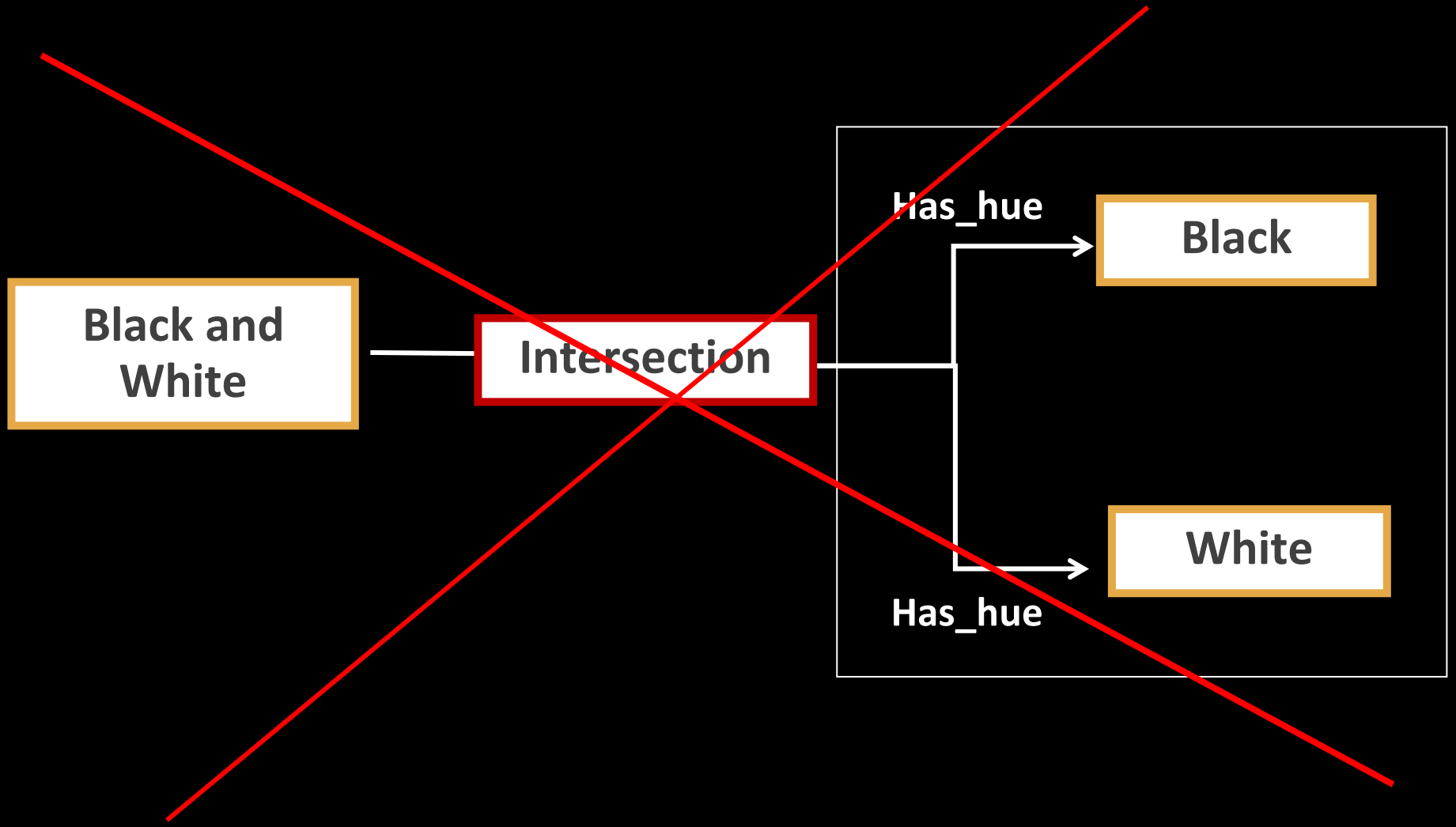
HAS_ANTHROPOGENIC_EFFECT
HAS_COLOUR
HAS_CONDITION
HAS_CONTENT
HAS_DEPTH
HAS_FORCE
HAS_HEIGHT
HAS_HUE
HAS_INSTANCE
HAS_INTENSITY
HAS_LENGTH
HAS_LOCATION
HAS_LUMINANCE
HAS_MATERIAL

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


Concept
spread#with#dummy_tool_spread#the#dummy_object_spread
Relations
Inherent
Intersection
Relations
ACTION_GOAL
ACTION_TOOL
ACTION_OBJECT
Concept
spread
Concept
dummy_tool_spread
Concept
dummy_object_spread
HAS_PARTIAL_INSTANCE
HAS_INSTANCE
Concept
spread#with#butter_knife#the#butter
Concept
spread#with#butter_knife#the#dummy_object_spread_butter_knife
Concept
spread#with#dummy_tool_spread_butter#the#butter

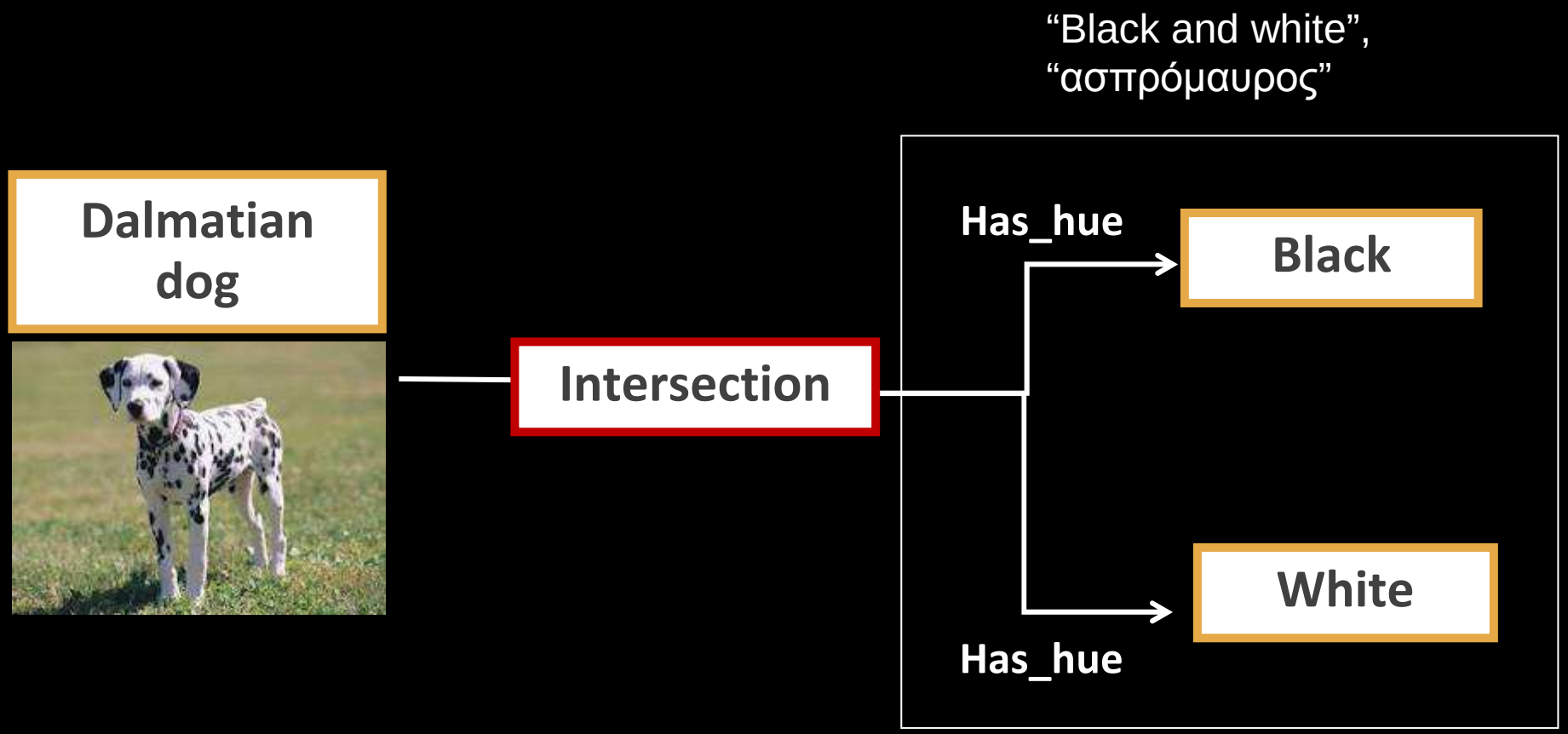
PRAXICON Structure (3)

Relations: Intersection



PRAXICON Structure (3b)

Relations: Intersection

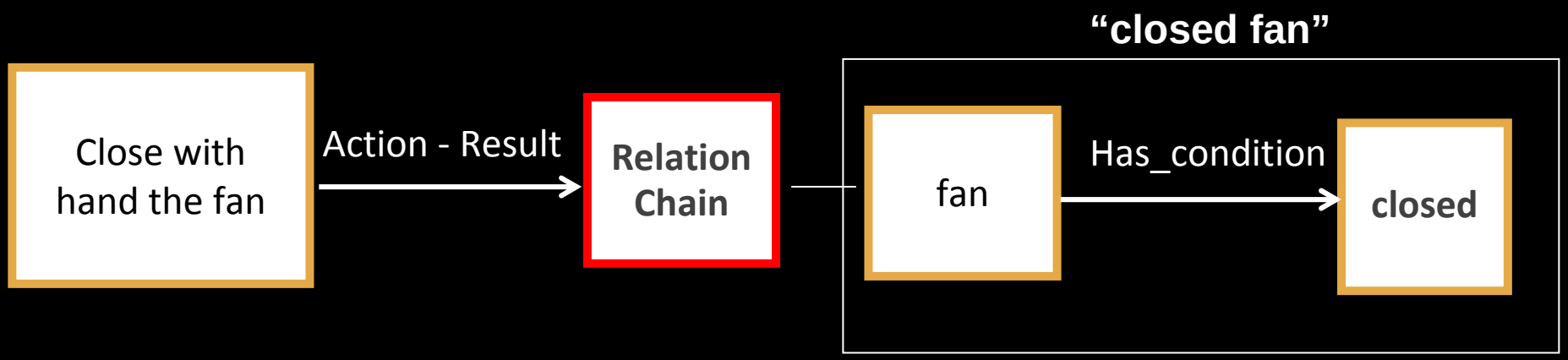


Compare "black and white" vs. "red", "black"….

It's a label/adjective that does not correspond to a single feature concept but instead to a whole intersection structure between concepts

PRAXICON Structure (4)

Relations: Relation Chain

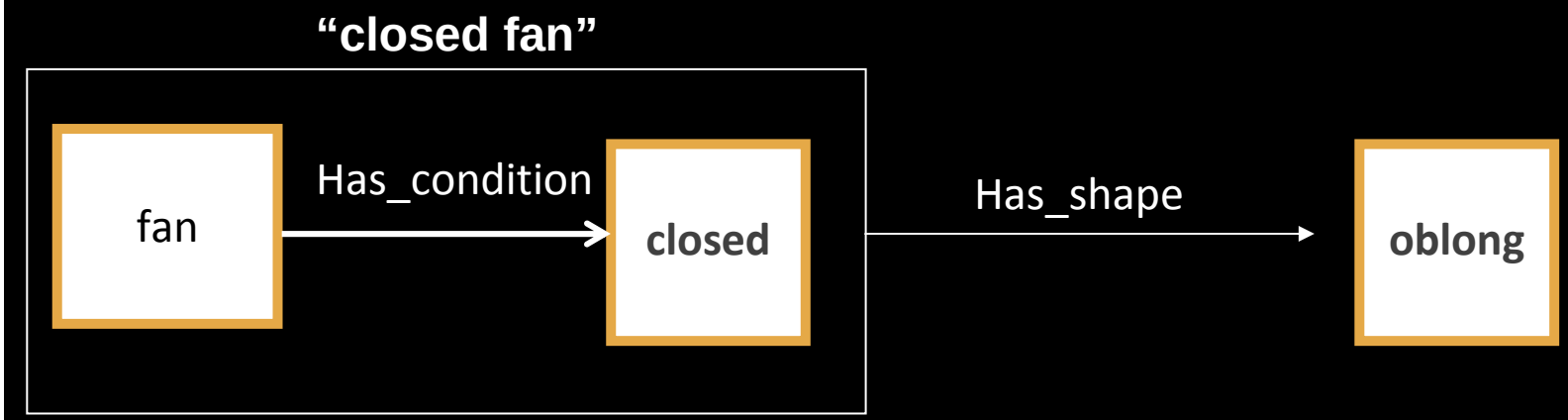


Why is such representation important?

Consider: "the fan is oblong"

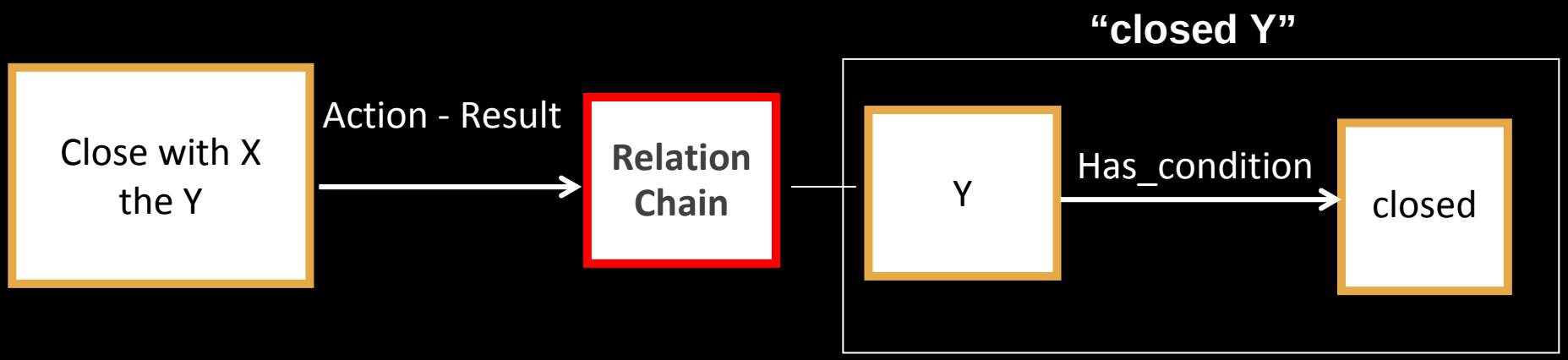
PRAXICON Structure (4b)

Relations: Relation Chain



PRAXICON Structure (4c)

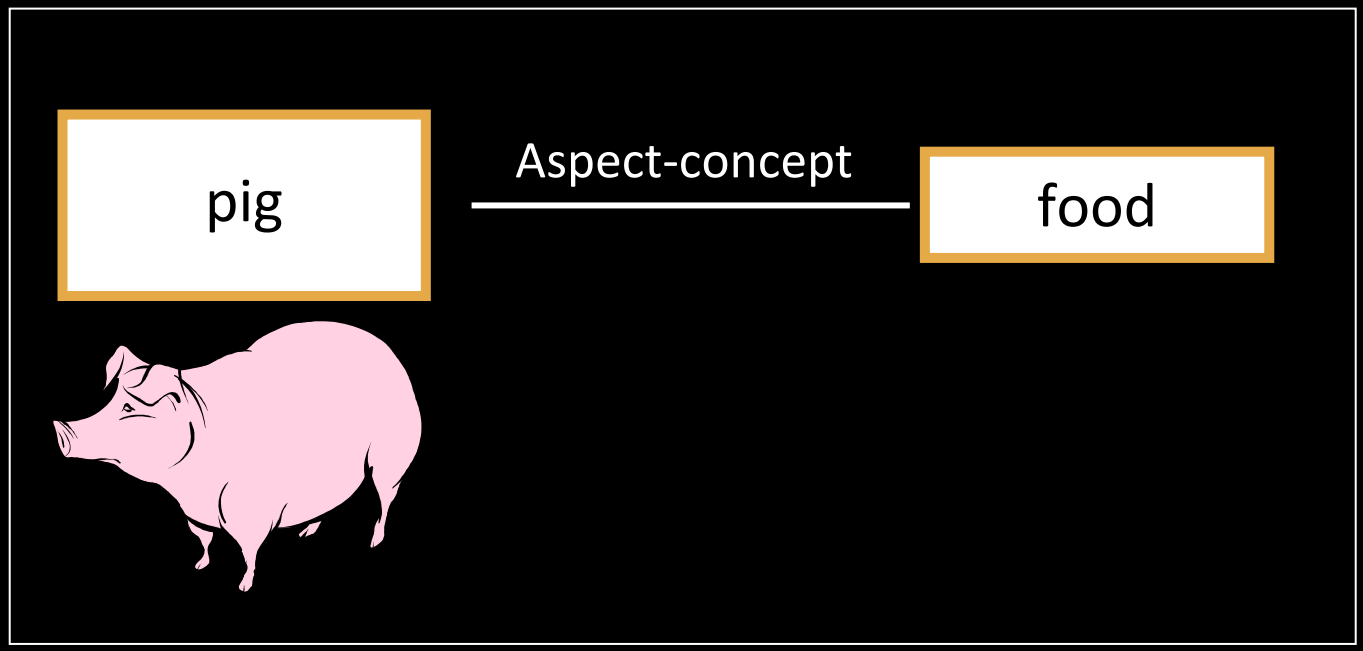
Relations: Relation Chain



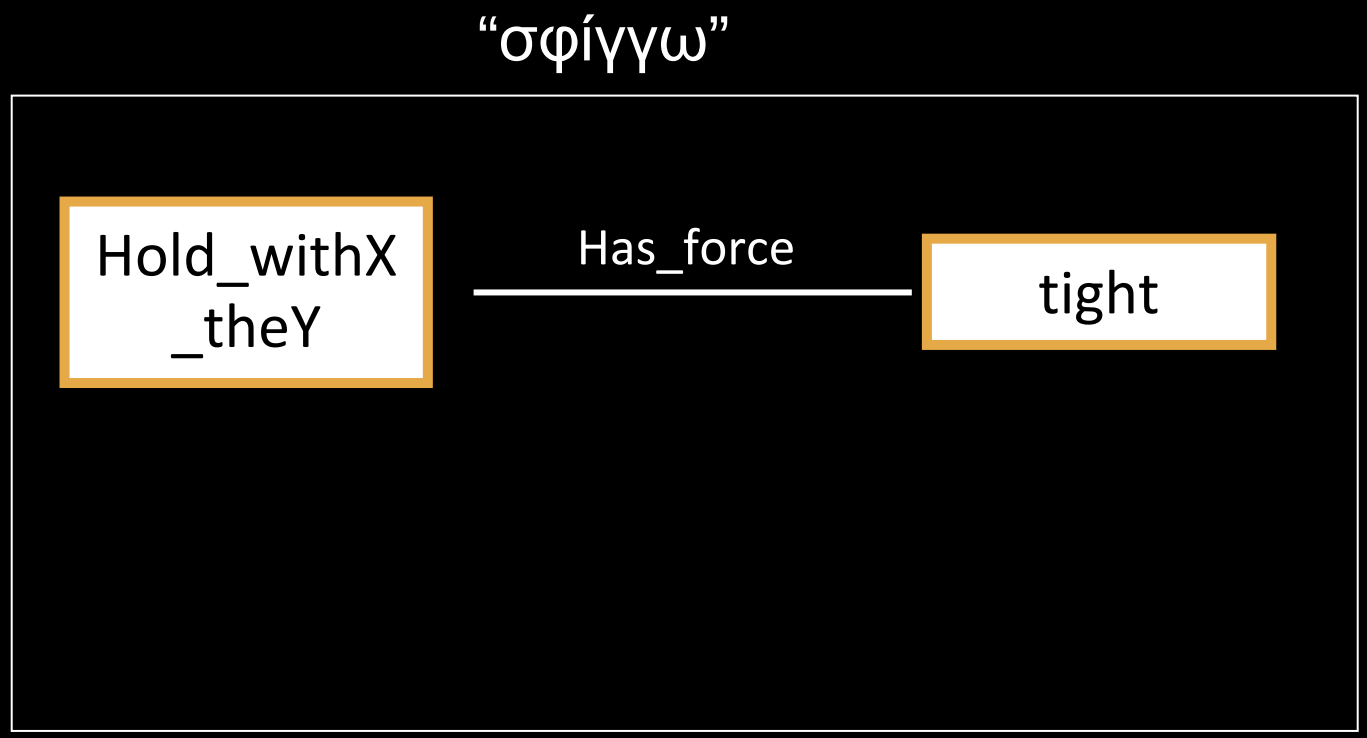
So, passive participles lexicalize systematically relation chain structures

PRAXICON Structure (5)

“pork”, “χοιρινό”



PRAXICON Structure (5)

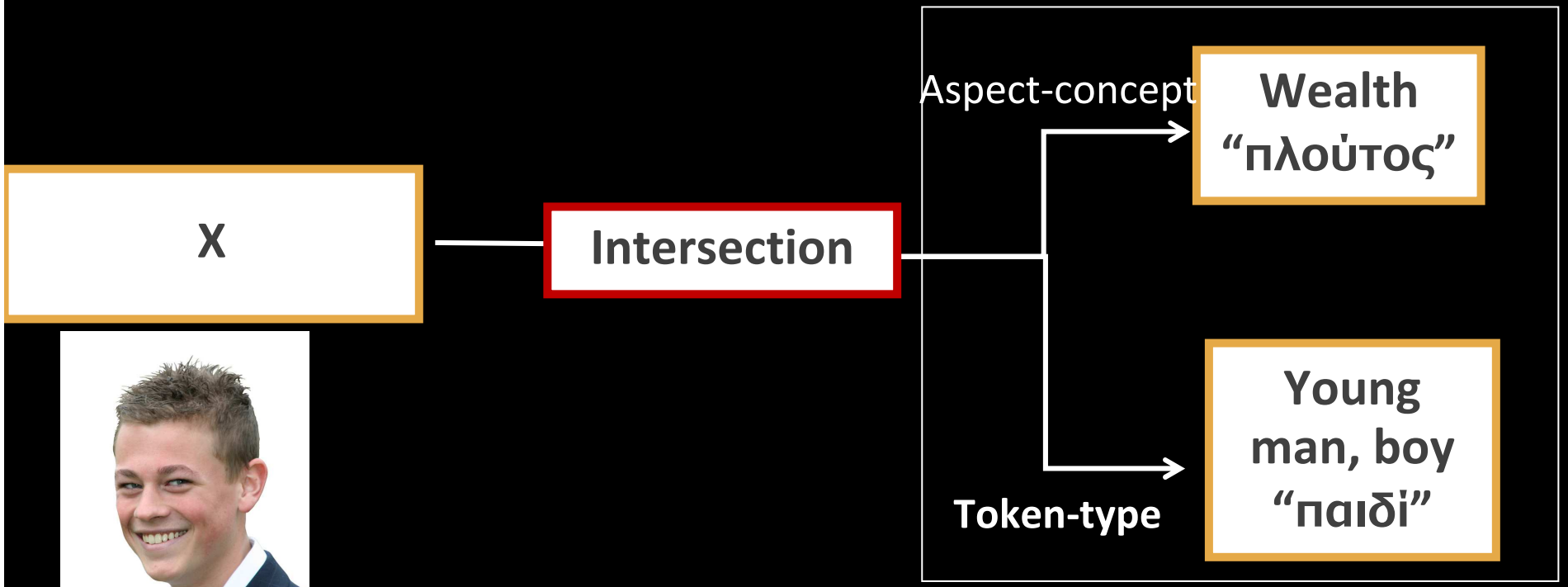


This could correspond to ‘clench’, ‘grip’, ‘tighten’ etc.

PRAXICON Structure (5)

Relations: Intersection

«πλουσιόπαιδο», “rich boy”



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.