Artificial General Intelligence

5. Memory Self-Organization

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Incrementally constructing NARS

- Like NAL, NARS is developed incrementally, and in each stage, the system is revised with
  1) additional Narsese grammar rules to introduce new term and sentence types
  2) additional IL and NAL inference rules to process the new types
  3) revised and augmented system architecture, memory structure, and control mechanism
- The intelligence of NARS is increased in this way

Ideas from set theory

- Narsese came from the attempt of using the language of set theory for representation
- *Set* becomes *concept*: fuzzy boundary, defined by both extension and intension, uncountable
- *Subset* becomes *inheritance*: multi-valued, combined extensional and intensional aspects
- The categorical language of term logic has similar features

Ideas from set theory (2)

- Additional copulas: *similarity*, *instance*, *property*, with different roles in concept hierarchy
- Compound terms: using *extensional/intensional intersection* and *difference* as "term connectors"
- Relational terms: used with term connectors *product* and *image* for empirical relations
- Each copula and term connector is a *logical constant* with corresponding inference rules

Ideas from propositional logic

- Statement: a term that can has a truth-value
- Isomorphism between term-level inference and statement-level inference
- Correspondence between *implication* (as a statement) and *derivation* (as a procedure)
- *Negation* of statement: positive and negative evidence switched
- IL theorems can be used in NAL inference

Ideas from predicate logic

- A *variable* term can name different concepts in different sentences
- Types: *independent* ($), *dependent* (#), *query* (?)
- Rules: *introduction*, *unification*, and *elimination*
- Sample usage: separating the extensional and intensional aspects in *inheritance*
- Adding abstract reasoning and axiomatic subsystems into NARS

NARS for question answering

- Using the logic of NAL-1 to NAL-6, NARS can answer questions using declarative knowledge, comparable to natural languages
- The memory structure is still a graph, but with
  - compound terms as nodes (including statement)
  - compositional relations as links (between a compound and its components)

Relations among terms

Types of relations among terms:

- *Semantic*: expressed by copulas

  e.g., *swan* $\longrightarrow$ *bird*

- *Syntactic*: expressed by constructors

  e.g., between ([*white*] $\cap$ *bird*) and *bird*

- *Empirical*: expressed by relational terms

  e.g., *dissolve, give, friend*

The former two types are innate, the latter is not

Concept model

- The *general meaning* of a term consists of all the existing relations in the concept it identifies
- The *current meaning* of a term involved in the processing of a task consists of all of its accessed relations in the process
- The meaning of a term (and the corresponding concept) depends on history and context
- Meaning is compositional, but not fully reducible

Learning as self-organizing

- All empirical knowledge is learnable: tasks, beliefs, and concepts
- Learning as reasoning: different perspectives of the same process
- Learning is not function approximation, and does not follow any algorithm
- Meta-level knowledge is experience-independent and cannot be learned by the system itself

Suggested Readings

- Wikipedia:
  - Set theory
  - Propositional logic
  - Predicate logic
  - Categorization
  - Learning
- Pei Wang, Non-Axiomatic Logic, Chapter 6-10
- Pei Wang, Rigid Flexibility, Chapter 4, 10-11