The OpenNARS implementation of the Non-Axiomatic Reasoning System

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0.1 Context

0.2 Learned in this study

0.3 Things to explore

1 Overview

2 1 Introduction

- NARS has a memory, a logic component and a control component
- The logic component consists of inference rules that work on statements, where the statements are goals, questions and beliefs
  - A statement can be eternal (non time-dependent) or events (time-dependent)
  - Beliefs are statements that the system believes to be true to a certain extent
  - An inference task is a statement to be processed, with additional control relevant information
- NAL: Non-Axiomatic Logic
- Narsese: Language for representing statements

3 2 Memory

- 3 primary operations:
  - Return the best ranked belief or goal for inference within concepts (local inference)
  - Provide a pair of contextually relevant and semantically related statements for inference between concepts (general inference)
  - Add statements to memory whilst maintaining constraints on the system
- The main loop:
  - Get a concept from memory
  - Get a task and belief related to the selected concept
  - Derive new tasks from the selected task and belief
  - Put the involved items back into the corresponding bags
  - Put the new tasks into the corresponding bags
- System of metadata (budget and stamp)
  - Used to prevent certain forms of invalid inference such as double counting evidence and cyclic reasoning
  - Abstracts temporal requirements away from the Narsese grammar
  - Provides certain implementation efficiencies
- A budget determines the allocation of system resources (time and space) and is defined as $(p, d, q) \in [0, 1]x(0, 1)x[0, 1]$
  - p: priority

  - d: durability
  - q: quality
- A stamp is defined as $(id, t_{cr}, t_{oc}, C, E) \in \mathbb{N} \times \mathbb{N} \times \mathbb{N} \times \mathcal{P}(\mathbb{N})$
  - id: unique id
  - t_{cr}: creation time
  - t_{oc}: occurrence time
  - C: syntactic complexity (the number of subterms in the associated term)
  - E: an evidential set
- Curve bag is a data structure that supports a probabilistic selection according to the item priority distribution
- The priority value p of the items in the bag maps to their access frequency by a predefined monotonically increasing function
- Called a curve bag because it allows the user to define a custom curve which is highly flexbile and allows emotional parameters and introspective operators to have influence on this selection
- The memory consists of a curve bag of concepts, where a concept is a container for: a concept term, tasklink curve bag, term link curve bag, belief tables and goal tables

4 Logic Module

- Composed of two components: an inference rule domain specific language (Meta Rule DSL) and an inference rule execution unit
- The Meta Rule DSL != NAL grammar rules
- Meta Rule DSL: provides a flexible methodology to quickly experiment with alternate inference rules, to support the goal of creating a literate program, and to substantially improve the quality of the software implementation
- Meta inference rules take the following form:
  $T, B, P_1, ..., P_n \vdash (C1, ..., C_n)$
  - T: the task to be processed
  - B: the belief retrieved for the task
  - $P1, ..., P_n$: logical predicates dependent on $T, B, C_1, ..., C_n$
  - $C_1, ..., C_n$: conclusions in the form (D_i, M_i) where D_i is the term of the derived task the conclusion C_i defines, and M_i provides additional meta-information, such as which truth function will be used to decide the truth or desire of the conclusion, how the temporal information will be processed, or whether backwards inference is allowed
- The inference rule execution unit roles are:
  - Parse the Meta Rule DSL into an efficient and executable representation
  - Select and execute the relevant inference rules

5 4 Temporal Inference Control

- In order to support temporal reasoning, the non-temporal NAL inference rules are extended by adding temporal variants:
  - Temporal window: Events occurring within a specified temporal window will be deemed to have occurred at the same time
  - Temporal chaining: Semantically unrelated events are linked together if they are temporally following one another
  - Interval handling: Events patterns which occur at a given interval from one another can be detected/observed
  - Projection
  - Eternalization
  - Anticipation

6 5 Projection and Eternalization

- When a truth value for a statement is projected in time, its value decreases according to the following function:
- $c_{new} = (1 - k_c) \times c_{old}$
  - c_{new}: new confidence value the belief
  - c_{old}: old confidence value the belief
  - k_c: confidence decay
- $k_c = \frac{|t_B - t_T|}{|t_B - t_C| + |t_T - t_C|}$
  - k_c: confidence decay
  - t_B: original occurrence time of the belief
  - t_T: projected occurrence time of the belief
  - t_C: current time
- In eternalization, the occurrence time is dropped, so the conclusion is about the general situation
- $c_{new} = \frac{1}{k + c_{old}}$
  - c_{new}: new confidence value the belief
  - c_{old}: old confidence value the belief
  - k: a global evidence horizon personality parameter

7 6 Anticipation

- Based on the observation of an antecedent and behavior, a consequent is excepted (anticipated)
- In the event that an antecedent and behavior is observed, and the consequent is also observed, nothing special needs to be done
- In the opposite case, then the system needs to recognize that the prediction may not be 100% appropriate. Such event will have a high budget and will significantly influence the attention of the system (in order to rectify the situation)

8 7 Evidence Tracking

- The truth value of a statement is a (w_+, w_-) pair, where w_+ represents positive evidence and w_- represents negative evidence
- Can alternatively be represented as a confidence and frequency tuple, where
  - $c = \frac{w_+ + w_-}{k + w_+ + w_-}$
  - $f = \frac{w_+}{w_+ + w_-}$
  - k: global personality parameter that indicates a global evidential horizon
- Evidence follows the following principles:
  - Evidence can only be used once for each statement
  - A record of evidence used in each derivation must be maintained, although given AIKR (assumption of insufficient knowledge and resources), this is only a partial record, which is not an issue in practice
  - There can be positive and negative evidence for the same statement
  - Evidence is not only the key factor to determine truth, but also the key to judge the independence of the premises in a step of inference

9 8 Processing of New and Derived Tasks

- Temporal chaining
- Ranking
- Adding to belief/desire table
- Selecting belief for inference
- Revision

- Decision

10 9 Attentional Control

- 3 phases process:
  - Select contextually relevant and semantically related tasks for inference
  - Create or update budget values based on user requirements and/or inference results
  - Update memory with results of the updated task and concepts
- Phase 1: Premises for inference are selected according to the following scheme
  - Select a concept from memory
  - Select a tasklink from this concept
  - Select a termlink from this concept
  - Select a belief from the concept the termlink points to ranked by the task
- Phase 2: Formation of new statements (tasks), with new metadata, from the derivations.
- Phase 3: Process the new tasks and insert them into memory.

11 See also

12 References

- Paper: The OpenNARS implementation of the Non-Axiomatic Reasoning System (4th Draft for Comment)