ASM Project

NI-DiscoverHistory: Meta-narrative for Explanation Bounding

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Abstract

Long-lived goal reasoning systems that reason over their history confront the bounding problem–the impracticality of reasoning over a large, ever-growing experience-base. This is a problem with some explanation systems that use the history of their observations to inform beliefs about the current state of the world. We propose to apply narrative intelligence (NI), which includes the ability to structure experience into narrative structures, to resolve the bounding problem by regarding the full history as a meta-narrative containing individual narratives that can be used in reasoning. Reasoning over narratives rather than raw data will reduce the problem space and also provide opportunity for future work implementing higher forms of reasoning using the semantics inherent to narrative structures.

1   Introduction & Definitions

We consider the problem of how a goal reasoning agent reasons over experiential knowledge. Reflective experience-based learning, in which past experience can be consulted for present guidance, is challenged by the **bounding problem**: for a goal reasoning agent that will be long-lived, the cumulative bulk of past experience can be so great as to make reasoning over it inefficient and even intractable. How far back should reflection search? What should be the boundaries on the context?

Research on cognition has indicated that one way humans deal with the bounding problem is through use of narratives to segment experience into meaningful chunks [1]; this ability to form experience into narratives is referred to as **narrative intelligence** (NI) [2]. While we here focus on the potential of these chunks for solving the bounding problem, these narrative chunks can also become central units to other forms of narrative cognition such as planning, communication, and event categorization.

Each narrative chunk can be considered a full narrative in its own right; in this case, the full history from whence these narratives come can be considered a meta-narrative. In

complete history explanation systems, then, an approach to addressing the bounding problem is to determine the event-centered narrative constituents of the greater meta-narrative. Our formal definitions for narrative and meta-narrative are discussed in section 1.2.

1.1 Related Work

Like full-history explanation systems, systems and architectures that implement a form of episodic memory may confront the bounding problem as the breadth of experiences grows in size. One way episodic memory systems answer is by implementing forgetting within the system, which is also a major way humans stay in control of ever-increasing experience-bases. A model by Brom et al implemented forgetting according to emotional weight of memories [3]; other theories of forgetting include cue overload [4], temporal trace-decay, retrieval-induced forgetting, and other cue-dependent forgetting mechanism. Subagdja et al provide an extensive overview of these and other forgetting methods [5].

This work on the bounding problem can be seen as a subset of work on event segmentation, which looks over sequential streams of data to find meaningful chunks [6]. This has been researched in the domain of video analysis to locate scenes and story-units [7, 8].

1.2 Narrative and Meta-Narrative

Our formal definition of meta-narrative is designed to be independent of specific definitions of narrative, in order to allow it to accomodate a wide variety of approaches. In this way it can be applied, for instance, to narratives as plans (e.g., Mark Riedl's work [9]). In the context of this work we consider **narratives** as explanations consisting of observations of occurences over time, according to Molineaux's definition of explanations [10].

The concept of meta-narrative stems from structuralist and post-structuralist theories across disciplines in the humanities, where it indicates an over-arching structure that describes history, society, and processess while influencing individual narratives [11]. While the concept of meta-narrative is often ambiguously conflated with normal, vernacular uses of the term "narrative," its use here highlights a distinction between narratives consisting of specific actors, actions, times, and grounded events (henceforth, referred to generally as "narratives"), and those concerning higher-level descriptions of beliefs, goals, roles, and other commonalities that can be seen as formations over constellations of narratives; these we call **meta-narratives**.

Definition: Meta-Narrative   *A tuple $\langle \{N\}, R, O \rangle$ where $\{N\}$ is a set of narratives $\oplus$ meta-narratives, R is a dynamic, non-deterministic membership function for $\{N\}$, and O is a partial-ordering of $\{N\}$.*

This definition of meta-narratives is recursive in that a meta-narrative exists over either narratives or (exclusive-or) meta-narratives. Application of this notion of meta-narrative centers on use of R, which is used for the related tasks of recognizing narratives as members of some meta-narrative, as well as generating narratives that fit into a meta-narrative. Note that meta-narratives are dynamic and are likely to evolve over time. Related to this property is the fact that R is non-deterministic; in the case of explanation narrativizing, explanations N can be expected to be generated with degrees of variation.

An example of narratives and meta-narratives can be seen in a battlefield scenario, such as a small-team scouting mission. In this case considering narratives simply as plans (popular in literature such as [9]), the $n \in N$ include the possible plans of infantry-men, scouts, com

officers, and (in our case) robots in such a scenario. R would include constraints that these narratives include the afore-mentioned roles (scouts, com officers, robots, etc), include general rules for reporting unexpected activity and reaching check points, and include events such as reporting on mission success, reaching the checkpoint, and awaiting orders. O would then be the partial ordering specifying that the order of events should be 1) reach checkpoint 2) report success 3) await orders. Together these constitute a meta-narrative $\langle \{N\}, R, O \rangle$.

2 Goal Reasoning

Narrative intelligence has considerable overlap with goal reasoning (GR) and can facilitate GR in several ways.

2.1 Discover History

Discover History [10] is an algorithm developed by Matthew Molineaux to generate explanations that are used to reason about the state of the world and generate expectations for partially-observed domains. It is implemented in the ARTUE system for Goal Driven Autonomy, a method instantiating Goal Reasoning, and has been shown to significantly improve performance in these domains.

One of the limitations of Discover History is that its working explanation at any given time works over the beliefs and observations spanning the course of the entire life of the agent, which introduces a bounding problem that is an obstacle if the algorithm is to be applied in long-lived agents. Applying a meta-narrative decomposition of a current life-length explanation is a promising method of addressing the bounding problem.

Discover History and ARTUE are key components of the ASM project and represent a specific instantiation of GR and goal driven autonomy (GDA). By factoring a form of narrative intelligence into the Discover History algorithm the ASM bot will be able to better-perform as a long-lived goal-reasoning agent.

2.2 Goal Reasoning and Meta-narrative

In addition to addressing the bounding problem in long-lived agents, meta-narratives can directly or indirectly constrain candidate goal sets. Because goals can be components of both $n \in \{N\}$ and R in a meta-narrative $\langle \{N\}, R, O \rangle$, reasoning for recognition or decision upon meta-narratives is a form of goal reasoning.

2.3 Goal Lifecycle

The goal lifecycle introduced by Roberts et al [12], illustrated in figure 1, frames goal reasoning as a refinement process where a goal may pass through a set of modes via strategies toward accomplishment. For meta-narrative this process can be used to arrive at the "best" or "most likely" narrative. Providing that a meta-narrative has been selected/identified as currently applicable, the formulation process can be strongly informed by the goals of this meta-narrative. Selection, expansion, and evaluation are likewise in a position to be benefited by the contextual information contained in a meta-narrative and its subsumed narratives. If we consider narratives as expansions (as when represented by plans), they can also be the products and/or arguments of the commit, dispatch, monitor, and repair functions.
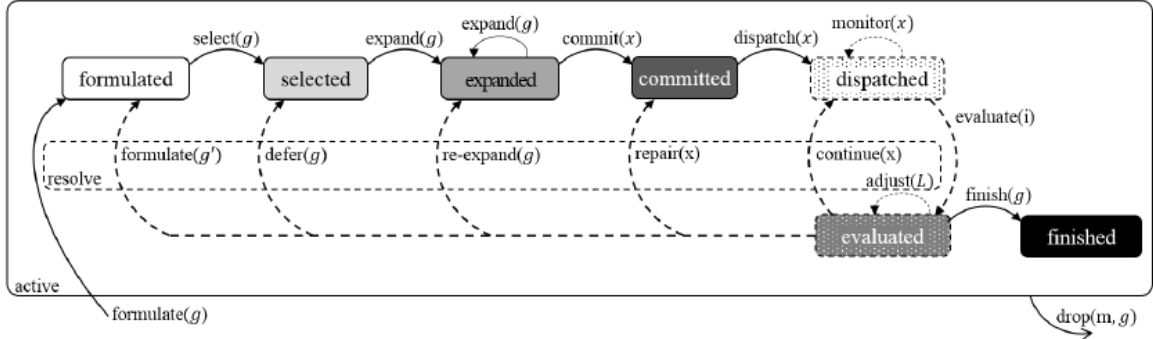
Figure 1: The goal lifecycle [12]

3 Narrative Intelligence Approach to the Bounding Problem

The narrative intelligence (NI) approach to the bounding problem being here suggested differs from approaches using forgetting in that it centers more on what is remembered than what is forgotten: by remembering narratives, we change the space over which reasoning about history is occuring. Because the NI space consists of clustered sequences of occurences it is much less dense than a full episodic history. Further, unlike raw episodes, narratives necessarily include semantic information that should be useful to reasoning such as goals, other agent information, and–in the context of meta-narratives–information on other narratives.

4 Evaluation

The Discover History algorithm has previously been applied within the ARTUE system where it improved planning and goal achievement in domains including satellites, and rovers [10]. These evaluation methods are the basis for our evaluation. A three-step evaluation procedure will be followed:

1. A preliminary evaluation will test the previous system in increasingly lengthy lifetimes to determine its rate of decline in performance: as agent lifetime increases the decline in performance-time and, if applicable, goal-achievement efficiency will be measured.

2. An ablative study of the NI-augmented system against the benchmark of Discover History's previous performance will test that performance is not worsened by working over a set of explanations (narratives) rather than a single, complete history: if agent lifetime remains at base-line, goal-achievement efficiency and performance-time should not be worse.

3. A repeat of evaluation 1, comparing the narrative intelligent system against the baseline Discover History agent for a test of significance: as agent lifetime increases does the NI system outperform the original system in performance-time and/or goal-achievement efficiency?

Acknowledgements

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