Goal Reasoning and Narrative Cognition

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Abstract

Narrative cognition is central to how humans reason and make sense of their experiences. We create personal or natural narratives from the events of our lives which become a resource for future knowledge, beliefs, and goal reasoning. This paper is chiefly concerned with natural narrative, as opposed to traditional formal narratives of books, film, or theater. It focuses on the meaning-making functions of cognitive narrative and introduces a model of personal narrative generation from event perception. Several possibilities are elaborated by which the model can contribute to goal reasoning.

1. Introduction

In addition to being the primary content of the media we consume on a daily and hourly basis, narrative plays a key role in our cognition in making sense of our everyday experiences. This *natural narrative* that is a currency of cognition is distinguished from *formal narrative* that is composed and conveyed through media. Unlike many systems which serve intelligence—systems natural and artificial—narrative is definitively general: it is essentially cross-domain and polymorphic (i.e. non-expert). This fact is demonstrated by its ubiquity, by the use of concepts like "genre" which are necessary to distinguish between the breadth of possibilities exhibited by narratives, and by the heavy interaction narratives have with cognitive processes like analogy, upon which traditional narrative forms like allegory and metaphor are based. Although narrative itself is not necessarily goal driven, goal reasoning (GR) within humans is likely to draw significantly from the resources of narrative cognition. Formulations of GR benefit from qualities that are either provided by or shared with narrative cognition. This paper starts by providing a basic introduction to the literature and concepts of narrative cognition and narrative intelligence, followed by a consideration of narrative cognition in conjunction with GR. Related work is presented in which functions related to narrative cognition are applied in GR systems. Next is introduced a model for implementing basic narrative intelligence for long-lived agents, based upon the event segmentation theory for event perception. We conclude with a discussion of applications of this model to goal reasoning and suggestions for future work.

1.1 Narrative Cognition and Narrative Intelligence

Some of the earliest known precedents for narratology started with Aristotle, whose reflections on narrative came part and parcel with his philosophy of the dramatic arts (Butcher et al., 1961).

His work provided a definition of narrative structure as that with a beginning, a middle, and an end. Though this notion has been challenged by more recent literary and artistic movements it remains influential and, honoring the intuitive appeal of that simple definition, is retained as one of the core concepts of narrative in modern cognitive narratology. Within the last century serious philosophies of individual and society have descended from Aristotle's dramatic approach. These include Kenneth Burke's dramatism (Burke, 1969) and Walter Fisher's narrative paradigm (Fisher, 1984), which take literally Shakespeare's "All the world's a stage" and are broadly influential in the fields of social communication. **Narrative cognition** spans all of these and is a categorical term for cognition that applies or specifically works upon narrative.

In more recent years literary critics have also referred to the reality-negotiating importance of narrative. David Herman, one of the leading proponents of the term and field of cognitive narrative, recognized the key role narrative plays in the mind and suggested five core functions narrative plays in human cognition (Herman, 2007; Herman, 2013): 1) sense-making by segmenting experience into useful chunks, 2) causally linking events, 3) typifying phenomena to determine norms, 4) sequencing actions (including planning), and 5) distributing intelligence across time and space, including the function of communication. Although each of these five functions has significant implications for cognition and goal reasoning, and any system exhibiting narrative cognition will contribute to each of these, this work highlights the first function: sense-making of experience.

The ability to interpret experience in narrative is a form of narrative cognition called **narrative intelligence** by Mateas and has been recognized as a particularly desirable aspiration for AI systems (Mateas & Sengers, 1999). Modern AI as a whole owes significant parts of its ancestry to efforts in narrative comprehension (Brewer, 1982; Schank & Abelson, 1977). Work on narrative comprehension includes Schank and Abelson's pioneering AI work and modern systems aiming, for example, at news story and blog summarization (Cullingford, 1978; Mani, 2013; van Erp, Fokkens, & Vossen, 2014). These systems continue to be the focus of considerable research effort; however, less attention has been given to the capability of long-lived agent-based systems to make narrative sense of their experiences in something like the way of humans. As perhaps the most important form of narrative intelligence for us, the ability to negotiate reality by reflecting upon our experiences is the subject of *Living Narrative* (Ochs & Capps, 2009), a hallmark consideration of personal narratives in children and adults as a sense-making tool. As children mature they improve in the selection, complexity, and expressive power of their personal narratives (also explored in (Botvin & Sutton-Smith, 1977) and (Wigglesworth, 1997)). As shall be discussed, the improvement and growing sophistication of these narratives most likely coincides with the accumulation of narrative structures like scripts and schema in semantic memory. The accumulation of experiences into episodic memory provides the basis for the narrative store with which narrative intelligence in children starts (Anderson, 2015).

1.2 Narrative Intelligence and Goal Reasoning

Goal reasoning, as surveyed in breadth in (Vattam et al., 2013), requires architectures with three fundamental features: explicit goals, goal formulation, and goal management. None of these are strictly required in formal narrative; post-modern non-structural approaches to literature and film have specifically explored narratives that offer as little of these as possible. To this extent narrative cannot, of itself, provide the architecture necessary for goal reasoning, nor does it suggest goal reasoning as one of the functions upon which it relies. However, more can be said for the four challenges to traditional planning which motivate GR:

1. Non-deterministic partially observable environments
2. Dynamic environments
3. Incomplete knowledge
4. Knowledge engineering

The first and third points each indicate the kind of incomplete knowledge that drives narrative as well. This is particularly true of personal narratives, the first-person accounts that result from reflection upon experience. As analyzed by Ochs and Kapps the reality-negotiation of personal narratives are driven by the tension "between narrators' yearning for coherence of life experience and their yearning for authenticity" (Ochs & Capps, 2009, p. 24), a product of agents which have incomplete knowledge working in domains that disallow omniscience. One of their examples is of a woman describing and revising the story of her experience of being paid what she thought might be too much by a day-care client while her husband argued that the payment was correct; whether the payment was correct, what were the intentions of the payer, and what moral conclusion to ascribe were all in flux as the personal narrative was refined and revised.

The second point refers to environments which are subject to change, with or without intentional manipulation by the agent. This quality of change echoes the requirements of the theory of narrative cognition to be elaborated below, which suggests that the fundamental building-block of narratives are the product of prediction failures within the environment. Like GR, narratives seem to require dynamic environments.

Finally, point four refers to the real-world constraint imposed by unlimited richness, which is related to the second's point indicating nearly intractable knowledge problems. Humans are undergoing constant internal knowledge engineering via learning, largely via experience. The storage of this experience for analysis and reflection is the evolutionary role of episodic memory (Allen & Fortin, 2013; Tulving, 2002) and narrative intelligence. Implementing and improving narrative intelligence within agents is therefore a method of addressing the challenge of a rich domain.

2. Related Work

Related to the work of generating personal narratives are explanation systems, which perform some form of reasoning over their previous operations to communicate to the user the reasons for decisions or activities. As a form of narrative cognition explanation generation has been found to be a method for improving learning in humans (Fukaya, 2013). Computational explanation generation systems aim to provide users with insight into what is otherwise a black box of reasoning. Such systems face the challenge of distilling from the compiled knowledge of an expert system a sensible and accurate account of reasoning to a human operator, which may require substantial knowledge engineering beyond the knowledge with which the system is performing its tasks (Matheson, Coghill, &

Sripada, 2012). Some approaches almost entirely divorce the explanation from the activities of the system (Wang, 2012). Explanation generation systems differ from human explanation generation, and from human narrative cognition, in that usually the explanations are of no use to the systems themselves, and therefore do not provide the benefits of learning, reflection, or metacognition.

A reasoning method that does seek to benefit the agents is abductive reasoning by which an agent refines its beliefs by reflecting upon the past, deriving explanations for its own benefit. A prime example is DiscoverHistory (Molineaux, Kuter, & Klenk, 2012), which is designed with GR problem domains in mind and is able to ascertain novel facts about its world by detecting errors in prediction. Abductive reasoning in humans can be considered alongside analogy as a primary instrument to be applied in narrative cognition.

Narrative generation, which is a function of narrative cognition when it occurs in a cognitive system, is a major trend in AI, often for computer games; this work can bring to bear analogy (Zhu, 2011), planning (Riedl & Young, 2006; Riedl & Young, 2010), and other dramatic and theoretical creativity-based approaches (e.g. (Gervás, 2009; Pita, Magerko, & Brodie, 2007; O'Neill & Riedl, 2011)). Several of the leading systems in narrative generation employ planners to generate their narratives. These plausibly define a narrative as a causal sequence of events that can be represented as a partially ordered plan. Systems have been developed to specialize typical planning algorithms to the added tasks of coherence necessary for narrative (Riedl & Young, 2004; Riedl & Young, 2010). Planning is one of the functions of narrative cognition; however, conventional narrative generation approaches are not cognitively oriented and are primarily concerned with fiction generation, and as such require a controlled set of inputs. They do not directly provide the potential for learning or internal reasoning.

3. Towards a Model of Narrative Intelligence

The model for narrative cognition to be elaborated takes a simple concept of narrative similar to those used by narrative generation approaches: that a narrative consists of a sequence of one or more causally related events. These events can be provided by the experience of the agent, in which case they are stored in some form of episodic memory. After reviewing some computational implementations of episodic memory we introduce Zacks' event segmentation theory, which provides the basis for segmenting events from the perceptual stream. We then consider the generation of narratives from the events that have been generated.

3.1 Semantic and Episodic Memory

Tulving introduced the terms *semantic memory* and *episodic memory* to distinguish between distinct memory systems in our declarative memory (also called "explicit memory," storing contents that can be consciously recalled) (Tulving, 1972). Semantic memory stores general facts which are not dependent upon location or time, while episodic memory encodes experiences.

Both semantic memory and episodic memory play key roles in narrative cognition. Narrative structures, particularly scripts and schema, are stored in semantic memory. The evidence of children's narratives improving with age indicates that the acquisition of these structures is a key product

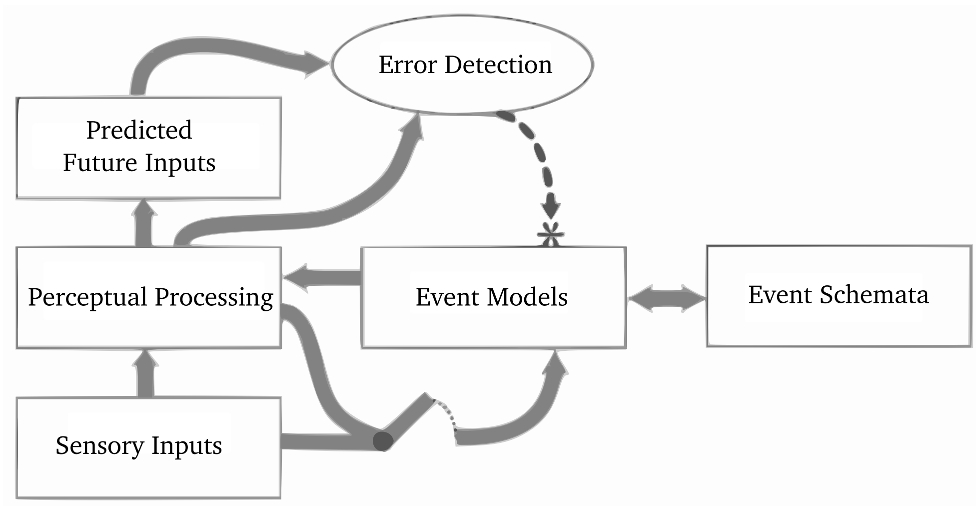

Figure 1. A high-level view of EST, image from (Zacks et al., 2007). Information flows along gray arrows and error detection leads to resetting of event models, which is the only time sensory input is gated to them.

of experience (Ochs & Capps, 2009, ch. 2). These structures are learned as episodic memory grows with experience, and influence human reconstruction of memories (Bartlett, 1932).

Episodic memory has received significant attention from researchers in recent years. It is believed to be the storage place for temporally contextualized data, including personal experiences, attended experiences (experiences depicted in stories), and prospective memory (Schacter, Addis, & Buckner, 2007; Tulving, 2002). Distinctions have been made including autobiographical memory, a subset of episodic memory that is specifically concerned with personal memories exhibiting autonoetic consciousness (Wheeler, 2000).

Computational systems often overlook episodic memory, and implementations of episodic memory are usually simplistic. For example, the Soar cognitive architecture (Laird, 2012) only recently implemented episodic memory, and is one of the only cognitive architectures to support episodic memory. In Soar, similar to most systems that do have a form of episodic memory, the implementation consists of time-stamping of recorded states from the operation of the system. This differs from the concept of narrative earlier given in a significant detail: while sequentiality is preserved, such time line recordings provide no concept of "event." Such episodic sequences are nondilineated streams of external perception and/or internal state.

3.2 Event Segmentation Theory

Event Segmentation Theory (EST) (Zacks et al., 2007; Kurby & Zacks, 2008; Radvansky & Zacks, 2014) suggests an approach to the problem of dividing a non-delineated sequence of states into events that could become the constituents of narratives. In humans, event segmentation is an ongoing process occurring simultaneously at multiple time/action granularities. According to EST, event segmentation occurs as an effect of ongoing perceptual prediction. During the process of perception two structures participate in parsing the situation and forming predictions: long-term knowledge is brought to bear in the form of event schemata, which are similar to Schanks' and Abelson's scripts (Schank & Abelson, 1977) and represent the way actions or events normally unfold in similar situations; and working-memory is brought to bear by event models, which are an interpretation of the specific situation at hand. In addition, behavioral models may be used so that predictions can be made based on the presumed goals of the actors in a situation, and world models that account for physical expectations (e.g. the trajectory of an object in free motion). The interplay between the semantic and episodic long-term memory systems in this process is cyclical: semantic memory provides the structures and models to help make episodes from experience, while these episodes are committed to episodic memory where, over time, they help distill further knowledge of semantic structures.

As perception occurs, a cognitive system selects from its knowledge of usual event schemas and uses assumptions about the goals and processes at work in the attended situation to generate expectations of what will happen next. As long as these predictions are mostly fulfilled, the current event model is assumed to continue and no segmentation occurs. However, when the predictions are wrong by some margin of significance, the current event is considered to end and a new event to begin in the process of selecting or generating a new event model. These explanations of event segmentation have been supported by evidence from studies of segmentation of event boundaries in written and video narratives (Zacks et al., 2007). Narratives are constructed as segmentation occurs at broader granularities over episodic memory, to the point of eventually contributing to production of the life-long autobiographical memories that "make up our own personal narrative of who we are and what we have experienced" (Radvansky & Zacks, 2014, ch. 8).

3.3 Generating Personal Narratives

The events produced by EST can be seen as constituting the fundamental building blocks of a narrative, a sequence of events. Narratives can be produced at either of two times: at storage time, useful for short-term reasoning that will operate in conjunction with working memory and is primarily dependent upon the narrative structures provided by semantic memory, and at reflection time. We consider production time narratives to be *first-order narratives*. The latter we call *meta-narratives*, which are of particular interest for meta-cognition and for the development of a life story or narrative identity (King, 2000), as well as for broad understanding of situations that draw upon constellations of narratives over time. In parsimony with the hierarchical nature of perception, personal narrative is hierarchical and recursive such that repeated reflection can produce increasingly complex compounds of narratives. This process, in which the recognizable and (in humans) presumably interesting narratives are formed, occurs on-demand. In particular, meta-narratives are formed when narrative cognition is called upon to fulfill one of the duties elaborated by Herman, such as casually linking events or sense-making (generating a new event model after prediction error).

4. Conclusion

Although narrative as a whole is not primarily goal directed it is essentially concerned with the same problems that necessitate GR. This collocation of interests also underscores the potential of narrative to provide the environment or resources in which goal reasoning can occur, potentially contributing functions of narrative cognition that have developed for the purpose of addressing the challenges previously mentioned.

Goal Reasoning and narrative cognition are collocated in dynamically rich, under-specified, limited-information domains. Within these domains narrative cognition performs a number of functions that serve to increase knowledge and generate predictions capable of informing GR processes. A particular affordance of a system performing narrative intelligence via EST is concurrent goal reasoning. Models of GR share with EST the use of prediction errors to cue activities. Running in parallel goal reasoning can itself become a producer of events over which narrative cognition can work.

In addition, goal reasoning itself constitutes a sequential process, for example as imaged by the goal life cycle of (Roberts et al., 2014). Applied to such a goal-reasoning process narratives of goal reasoning itself could be generated. Imagined verbally these narratives would resemble the internal dialogues we sometimes have with ourselves as we struggle with decisions, and the application of functions of narrative cognition to these processes offer a promising avenue for future work.

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