A Knowledge Representation that Models Memory in Narrative Comprehension

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Abstract

We present work toward computationally defining a model of narrative comprehension vis-à-vis memory of narrative events, via an automated planning knowledge representation, capable of being used in a narrative generation context.

There has been much recent research on computationally analyzing and generating narratives (e.g. Mani 2012). Key to these efforts is the modeling of the mind as it makes sense of stories. As people perceive narrative, their story comprehension faculties are active in the projection of a fictional world (Gerrig 2013), such that the story context in which they are embedded plays a key role in how they expect the future of the narrative to unfold. Authors accordingly design stories to affect their audience in specific ways (Bordwell 1989). A generative computational model of narrative must go beyond story structure, because the fundamental design criteria for a narrative artifact rest in the cognitive and affective responses they prompt in their human consumers. In this paper, we present work toward a computational model of narrative, which begins to account for the human consumer by modeling the person's memory for previously experienced narrative events relative to the most recently experienced event of the same narrative.

Prior Work

Early approaches to computationally modeling narratives focused primarily on the structural properties of stories, e.g. as a collection of forward-chained scripts (Schank and Abelson 1975). Automated Planning has enjoyed success in supporting narrative content generation, due to its flexibility in representing the causal, and temporal structures typically present in structural analyses of narrative plot (Young 1999). For example, Riedl and Young's (2010) FABULIST system modeled narrative through an extended partial-order causal link (POCL) planning paradigm, capable of modeling the intentional nature of story characters.

There has recently been a call to go beyond story structure and account for the effect of stories on the minds of their consumers (Szilas 2010; Brenner 2010). Advances in systems that account for the cognitive effects of stories have extended the aforementioned structural approaches to model individual psychonarratological phenomena, such as suspense (O'Neill 2013), or inference-making (Niehaus and Young 2010).

Narrative memory in the INDEXTER model

The work we present here is the start of both a unification of the work on modeling psychonarratological phenomena, and an extension of structural approaches to narrative generation: we expand a POCL planning knowledge representation with information that allows us to compute the relative *recallability* between steps in the plan. The recallability of a narrative event indicates how recallable the event is in a person's mind, and correspondingly, the event's availability for cognitive processing. An author's manipulation of the recallability of events during a narrative experience is a key means used to affect a reader's comprehension of the story's structure (Cardona-Rivera et al. 2012). Recallability prompts expectations about upcoming action, and a generative model of narrative that accounts for recallability could target derivative psychonarratological phenomena.

The Knowledge Representation

We adopt a STRIPS-like (Fikes and Nilsson 1971) first-order predicate logic model of a story's actions, with each action identified by a unique label, an action type (e.g. PICK-UP), a set of preconditions (literals which must be true prior to action execution) and a set of effects (literals made true by action execution). We use least-commitment style (Weld 1994) POCL planning, in which causal links record precondition dependencies between actions, and actions are explicitly ordered only when the plan requires two actions to be performed in sequence. We extend the POCL representation defined by Riedl and Young (2010) with data structures derived from a cognitive model of narrative comprehension (Zwaan and Radvansky 1998), the *Event-Indexing Model* (EIM), which posits that as narratives are perceived, they are discretized into their constituent events, which themselves are tagged with information along the following dimensions: 1) the *time* the event took place, 2) the *space* in which it took place, 3) the event's *causal status* with regards to prior events, 4) the event's relatedness to the *intentions* of characters, and 5) the main *entities* for the event itself. In our model, events are isomorphic to plan steps, and thus plan steps are augmented with situation model index value data.

As defined, Riedl and Young's representation captures many of the features needed to represent EIM structures, and we extended the representation in a model we call INDEXTER (Cardona-Rivera et al. 2012). Here we introduce data structures to the INDEXTER model, and illustrate how these structures are used to determine what events are expected to be recallable. Firstly, we model the person's beliefs about a story at its onset using a *domain model*.

Definition 1 (Domain Model) *A* domain model $\mathcal{D}$ *is a tuple* $\langle \mathcal{I}, \Lambda, \mathcal{G} \rangle$ *where* $\mathcal{I}$ *is a set of terms describing a person's beliefs regarding the initial state of the narrative,* Λ *describes a person's beliefs regarding the set of action operators available in the world, and* $\mathcal{G}$ *describes the set of goals that the person believes bring about the successful completion of the narrative.*

$\mathcal{G}$ represents the *author's goals* with respect to the form of the narrative arc. A person will also accumulate new beliefs about the actions that have occurred since the start of story. We represent these new beliefs as a *chronology*.

Definition 2 (Chronology) *A* chronology *is a tuple* $\langle \mathcal{D}, S, B, O, L, I \rangle$*, where* $\mathcal{D}$ *is a domain model,* S *is a set of steps,* B *is a set of variable binding constraints for the free variables in the steps in* S*,* O *is a set of pairwise ordering constraints over elements of* S*,* L *is a set of causal links between elements of* S*, and* I *is a set of frames of commitment (Riedl and Young 2010), which represent a group of intentional actions that agents in a narrative adopt toward the fulfillment of some goal.*

A chronology is *consistent* just when a) no variable is bound to more than one object constant, and b) no step required to come before (or after) another may also come after (or before) that same step. A chronology is *complete* when all preconditions of all steps are satisfied by causal links, no causal links are threatened by other steps that undo their causal conditions, and all plan steps belong to some frame of commitment. It is possible (or even likely) that people will hold inconsistent models of a narrative world at times, but we defer the representation of explicitly inconsistent models for future work.

The INDEXTER Memory Model

The subsequent equation assumes we can determine situation model index values for all events in question. in question. Succinctly, the recallability of an event e_i^* given the chronology C with memory cue q, is the ratio of the number of index values shared between e_i^* and q to the total number of shared index values between q and all events $e_i \in C$ presented to the human consumer.

$$recallability(e_i^*, q, C) = \frac{overlap(e_i^*, q)}{\sum_{e_i \in C} overlap(e_i, q)} \quad (1)$$

$$overlap(e_x, e_y) = \text{\# of index values shared by } e_x \text{ and } e_y \quad (2)$$

We consider recallability as a dimensionless quantity, which only makes sense in the context of other narrative events and a specific memory cue. Future work will validate the INDEXTER model using data collected during the construction of the EIM cognitive conceptual model, with the goal of using INDEXTER to generate narratives designed to achieve a particular mental (memory) configuration.

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