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Towards Improving Recall and Comprehension in Automatically Generated Narratives

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Abstract. This paper examines the similarity between cognitive models of narrative comprehension and plan based narrative generation to inform the process of narrative generation for educational applications. The situation model, a key element of narrative discourse comprehension, affects reader inferencing, comprehension, and recall in ways that are predictable and widely observed by cognitive psychologists. Mapping the situation model to the data structures of narrative planning, we seek to create guidelines for the generation of educational narratives by a narrative planning method.

Introduction

Generating narratives that convey information to the reader is an important task that could have significant ramifications for interactive training simulations and educational software. Narratives present a unique vector of approach for teaching, given our natural understanding and affinity for narrative structure. In this paper, we hope to increase learning from generated narratives by increasing readers' levels of inferencing and recall. We examine how cognitive models of narrative understanding have been shown to influence reader recall and comprehension. We relate the discourse structure of the situation model to planning data structures used in narrative generation, resulting in guidelines for automatically generated educational narrative. We center our guidelines on the abstract concept of reader expectation, and from these guidelines, we devise an algorithm intended to increase measures of learning from automatically generated narratives.

1. Elements of Story Comprehension and Recall in Cognitive Psychology.

Cognitive psychologists [10] [26] have identified six levels of discourse structure used in the cognitive processes of narrative comprehension. These are the *surface code*, *textbase*, *situation model*, *thematic point*, *agent perspective*, and *genre.* The situation model is a mental representation of the world state; including items such as the events in the plot, characters, settings, and the many complex relationships between these items [10]. This model contains elements that are most closely related to existing computational models employed by AI researchers when reasoning about action and change. It is constantly updated during reading as new information becomes available, and it is the basis for performing inferences and other reasoning about the story structure. The situation model can be broken down into a time related series of individual models. Zwaan and Radvansky (1998) distinguish the (a) *current* model under construction; the (b) *integrated* model comprising the series of models since the beginning of reading the story; and the (c) *complete* model, which is the last model obtained at the end of the narrative. When a new clause or sentence is read, the current model is altered to enclose this new information. The current model is then incorporated into the integrated model, in a process called *updating*.

Psychologists have identified five dimensions of situation models: *space, time, causation, intentionality,* and *protagonists and objects* [4]. The spatial dimension represents

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the physical layout of the imagined story world. The temporal dimension represents both the timeline in the story and the sequence in which the story is told. The dimension of causation maintains the causes and effects of events in the story, denoting which events cause others and why. The intentionality dimension tracks the goals of the characters in the story. Lastly, the protagonists and objects dimension follows the main character(s), lesser characters, and various items with which the characters come in contact (books, keys, etc.) [26].

Being the most basic of the deeper levels of structure, while still causing direct effects to inference and recall, the situation model serves as a natural embarking point for computational modelling. Furthermore, the situation model is quite close to our current computational models of narrative generation, which allows for straightforward conversion to these models. For these reasons, we choose to focus our analysis the situation model. Other discourse structures would serve as excellent candidates for future work.

2. The Effects of the Situation Model on Recall and Inference

Researchers have found a wide variety of variables affecting reader recall and inference generation in narrative. This section presents how each of the five dimensions of the situation model influences these two measures.

2.1 Space

There is no strong support that readers track spatial information automatically, although they are able to do so on request [26]. When readers do form spatial situation models, they find it easier to recall spatial relationships in the order of vertical, depth, and then horizontal [5]. Readers are also much more concerned with objects and areas that are physically closer to the protagonist [22].

2.2 Time

There has been comparatively little research regarding the aspect of time in situation models. Studies have shown how distancing events in time serves to separate the situation models that contain them, making inferences between events more difficult and time consuming [26].

2.3 Causation

Causation has an interesting relationship to inference generation and recall. Causal relatedness is a measure of how closely connected events are according to the world knowledge of the readers. For instance, pouring a bucket of water on a fire is highly causally related to the fire extinguishing if the events are temporally close and the pouring comes before the extinguishing. However, setting a bucket of water next to a fire is only slightly causally related to the fire extinguishing; in this case, readers will attempt to infer the reason behind the fire going out. Causal relatedness has a curvolinear relationship with recall and inference generation. Low relatedness produces low recall, moderate relatedness produces high recall, and high relatedness produces low recall [14]. Myers et al. (1987) postulated that moderately related pairs both enable and necessitate readers to form inferences about their relations. Active focusing and inferencing improves the reader’s comprehension and recall about these events.

2.4 Intentionality

Intentionality has been shown to be a focal point for readers of narrative. Some researchers have even argued that comprehension of narrative is centered on the tracking of characters' intentionality. Significant evidence indicates that goal-related information is more salient in the mind of the reader, especially before relevant goals are realized [26] [19]. Goals are often left implicit in the text; in these cases, readers attempt to make the necessary inferences to determine the intention behind actions. Readers also remember goal related information better and tend to structure retellings of a story around character goals [20].

Intentions see the same curvolinear relationship to recall as causation. Actions or objects are remembered more readily when they play a role in more intentions. The effect persists up to the point of knowledge saturation, where readers stop making inferences due to mental load and thus recall and comprehension suffers [14].

2.5 Protagonists and Objects

Protagonists and objects feature prominently in the situation model. The protagonist is closely tied to the intentionality dimension, and benefits from the same focusing effect by the reader. As we've seen, the other dimensions' effects of inference generation are increased with proximity to the protagonist. Researchers have found direct evidence to support the claim that readers not only actively draw inferences on protagonists, but also the information related to them [1].

3. Expectation

The effects listed in Section 2 can be summarized by the high level concept of expectation. Due to the structure of narrative and the conventions of genre and culture, readers approach narratives with a collection of expectations about each aspect of the experience. We argue that making and breaking these expectations drive the inferencing process. This effect can most easily be seen in the causation dimension. Returning to the fire and bucket of water example, readers expect that pouring the water on the fire will extinguish the fire, but they do not expect that placing the bucket next to the fire will extinguish fire. This expectation arises from the reader's general world knowledge about the causal relatedness of the two events. If the reader is presented with only these facts related to the fire, the reader will attempt to draw inferences about why the fire was extinguished. Perhaps the bucket had holes it, or maybe the bucket was tipped over at a later point in time.

The expectation is more intense when centered on the main focal points of the reader. As we saw before, more inferences are generated when objects are closer to the protagonist spatially or when they affect the protagonist directly. Also, steps along the main causal chain leading to the narrative resolution also are recalled better and generate more inferences. For example, if the hero of our story has the goal to extinguish a signal fire and he places a 'special' bucket of water next to it, should the fire suddenly extinguish the readers of our story will be intensively involved in making inferences about what this special bucket could be. Because of these inferences they will recall this story event better, and demonstrate better comprehension related to this event. The reader's expectation about the fire was broken, and the reader was both enabled and necessitated to draw inferences. These effects would be lessened if the fire was inconsequential to the protagonist or the story's outcome.

4. From Cognitive Models to Computational Models of Discourse Structure

In order to use cognitive models of narrative comprehension to inform the narrative generation process, we must be able to relate the cognitive models to our computational models of discourse structure. Our approach to narrative generation and execution, known as the Mimesis architecture, employs a decompositional partial-order causal link (DPOCL) planning algorithm [24] [25]. The DPOCL plan is a story and author centric approach that maps particularly well to cognitive models of narrative comprehension [7]. This section provides a high level analysis of the similarities between the situation model and the various elements and improvements of the DPOCL plan.

The spatial dimension of the situation model corresponds to the discourse level planning that must be done to generate 3d virtual environments [23]. Given the interactive quality of our narrative, the spatial dimension is also highly determined by the user's actions at runtime. It is the job of the camera planner to focus and constrain the spatial inferences generated by the user.

The temporal dimension relates to the story planning that determines the sequence and spacing of events as they are presented to the user. Each event must be either included or excluded by the story planner, and the planner must also decide the temporal distance between events. Certainly, this planning is key to maintaining user interest and story coherence.

The dimension of causation is best represented by the DPOCL algorithm, as it explicitly manipulates the causal structure of events in the story. In fact, this activity is the sole purpose of classical planners. This direct mapping is a major advantage in using a plan based approach to model story comprehension.

The dimension of intentionality is loosely maintained by the plan's goal state. The goal state describes the exact configuration of the world when the narrative is completed. However, this state does not describe the moment to moment goals that are formed and then discarded by each character in the story. Riedl and Young (2004) have extended the DPOCL algorithm to include the intentionality of characters. This intent-driven partial order causal link (IPOCL) planner creates intentions for each action or sequence of actions performed in the story. With this added information, the mapping to the cognitive model becomes much more straight forward.

The protagonists and objects dimension is represented by the objects bound to parameters in the planning process. The movement and actions of the main protagonist can be abstracted from the plan by choosing only the plan steps that bind to the protagonist's object. Ordinary objects in the story world can be tracked in the same manner. Recent work to bring a stronger notion of character to narrative planning [17] [16] increases the amount of character level information available to the planner.

5. Generating Educational Narratives Using Expectation

Our current work exploits the mapping from situation model to our plan-based computational model to generate narrative sequences that meet or violate user expectations, depending upon the learning context. The narrative's structure exploits the narrative comprehension process to increase inferencing and improve recall regarding key content in the story world. Through these effects, we hope to indirectly increase overall comprehension and learning. To determine likely user expectations, we integrate the plan construction process with a model of plan recognition; the technique used to combine these two elements is sketched here.

Plan recognition is the process of inferring the plan or plan's of an agent via observing that agent's actions [3]. Given a sequence of agent actions, a plan recognizer will produce a set of possible goals and candidate plans that complete those goals. Candidate plans can then be ranked to select the plan that the agent is most likely executing. Plan recognition has been used in the past for intelligent tutoring systems and also for story understanding [2] [6]; in our approach, it serves as a functional model of the elements of story comprehension and situation model construction.

In order to determine the expectation of the reader, a plan recognizer is used to generate candidate plans that naturally follow from the current situation model according to the five dimensions. When the plan recognizer identifies a plan or plans with sufficient certainty, these candidate plans represent the expectation of the reader at the current point in the story. Deviations from these plans should result in the violation of the reader's expectation. The

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output of this process suggests how alternate plans for completing the story may violate these expectations, thus affecting inference and recall focused around the violations.

Each of the five dimensions of the situation model is accounted for by the likeliness rating of the plan recognizer. For the spatial dimension, the plan recognizer uses objects and settings that are nearby the protagonist in projected plan steps. For the temporal dimension, the plan recognizer groups related events closely in time. For the causal dimension, the plan recognizer uses specified domain knowledge to determine the causal relatedness of events and chooses the sequences which are highly causally related. For the intentionality dimension, the plan recognizer first determines the intentions of the characters and then predicts their actions along these intentions. The intentions of the characters are accessible by performing plan recognition on the characters themselves, similar to the two level approach by Boella and Lesmo (1999). Finally, for the protagonist and objects dimension, the plan recognizer assumes the consistency of the protagonist and the relevance of objects which obtain the focus. The heuristic also takes into account the saturation effect whereby readers are overloaded with the amount of inferencing that must be done and thus decrease the quantity of inferences made.

Our process for narrative generation proceeds as follows. First, the story planner creates a story plan in the usual fashion [25] using the plan recognizer as part of its heuristic.

1. The planner selects both a plan along the fringe and a flaw to fix in this plan based off the plan rankings.
2. The planner generates all of the children nodes and sends them to be evaluated by the heuristic.
3. The plan recognizer evaluates the children nodes based upon how the new addition affects the expectation.
    - 3a. If the expectation about the task material is broken but the plan recognizer is both enabled and necessitated to construct a new plan containing this new information, then the ranking of this plan is increased. This is the case where the reader draws inferences about the task material and comprehension and recall is increased.
    - 3b. If the expectation about the task material is broken but the plan recognizer cannot create a new plan to incorporate this information, then the plan has lost coherency and the ranking is decreased.
    - 3c. Otherwise there is no effect on the ranking.
4. If the plan is without flaws, return the plan, otherwise go back to 1.

This algorithm selects, at each step, the story plan that causes the most inferencing on the part of the reader, according to the plan recognizer.

Consider the following text that grounds the notion of expectation and learning in a narrative. The text is taken from the Star Wars novel Shatterpoint [18]. In the story, Mace Windu, Jedi knight, has spent his first few hours on a strange planet in a detention cell, being interrogated by Major Gepton, planetary security officer. Upon release, he's been followed down a blind alley by two assassins, who level their blasters and attack.

> By the time the blaster bolts were a quarter of the way there, Mace had whirled, the speed of his spin opening his vest. By the time the bolts were half way there, the force had snapped his light sabre into his palm. At three quarters, his blade extended, and when the blaster bolts reached him, they met not flesh and bone, but a meter-long continuous cascade of vivid purple power.
>
> Mace reflexively slapped the bolts back at the shooters. But instead of rebounding from his blade, the bolts splattered through it and grazed his ribs and burst against the trash bin behind him… he noticed that his blade cast a peculiarly pale light. Much too pale. Even as he stood there starring drop-jawed into the paling shaft, it faded, flickered and winked out. His light sabre was out of charge.
>
> That's not possible, he snarled. That's not.
>
> With a lurch in his guts, he got it. Gepton. Mace had under-estimated him. Corrupt and greedy, yes. Stupid? Obviously not.

When Mace powers up his light sabre, our expectation is that he'll use the weapon to reflect the blaster bolts away from his body and remain unharmed. This expectation is violated with the bolts pass through the blade and weapon powers off, out of power. The explanation for this event that must be inferred, with the help of the discourse, is that the corrupt police chief had drained the power pack while Mace was being interrogated. We suggest that the inferencing that was required to determine how and why the battery could have been drained results in effective learning by the reader of that requirement for light sabre operation. The causal connections involving the draining of the battery fall along the main causal chain of the story and directly affected the protagonist.

Figures 1(a) through 1(b) illustrate the projected planning process for this example. Figure 1(a) shows the partial plan representing the story as told to the reader immediately prior to the occurrence of the exception. This plan is used by the plan recognizer to generate Figure 1(b), the expected plan. When the system plans out Figure 1(c), the actual plan, it makes note of the disconnect between the actual and expected plans, and increases the ranking of the actual plan, since, in this plan, the expectation will be violated but the sequence will still be coherent.

6. Discussion

The techniques presented here have yet to be implemented, and they stand upon their theoretical foundation only. Certainly, we've glossed over many of the finer details concerning the exact implementation of the plan recognizer, the heuristic function, and the method of tracking expectations throughout the planning process. We view these problems as potential future topics of research, with a complete design and implementation being the next step toward validation. Instead, this work presents a general guideline for using the situation model as leverage for learning in narrative planning.

The concepts detailed in section 2, by their nature, must also generalize to other forms of narrative generation. Mapping to other story and author centric systems would be much the same as our mapping above, which is fairly straightforward for the spatial, temporal, causal, and protagonists dimensions while requiring extra steps to represent the intentionality dimension. However, the mapping to character centric systems will most likely have difficulty with the causal dimension, as there is no explicit causal representation in these systems, while handling the intentionality dimension in a straightforward manner. Regardless of the type of narrative generation system, we believe that using cognitive models of narrative as a guide to narrative generation is important for making these narratives more targeted and effective learning tools.

7. Summary

We have examined how cognitive models of narrative understanding have been shown to influence inferencing, recall, comprehension, and learning. Focusing on the situation model, we have related this model to computational models of narrative planning. Using what we know about inferencing and recall in the cognitive models, we have proposed an algorithm for generating educational narratives using plan recognition as a heuristic for expectation and sketched an example of our algorithm in action.

The next step in this research is the complete design and implementation of the described system. Beyond this step is the inclusion of other levels of discourse structure and other cognitive models that influence recall and comprehension. We may consider incorporating additional approaches such as the event indexing model [26] or the constructionist model [10]; this subsequent work may provide additional data about the nature and predictive power of these theories.

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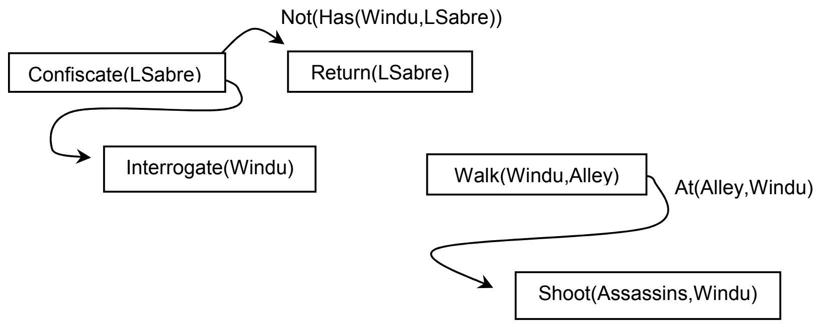
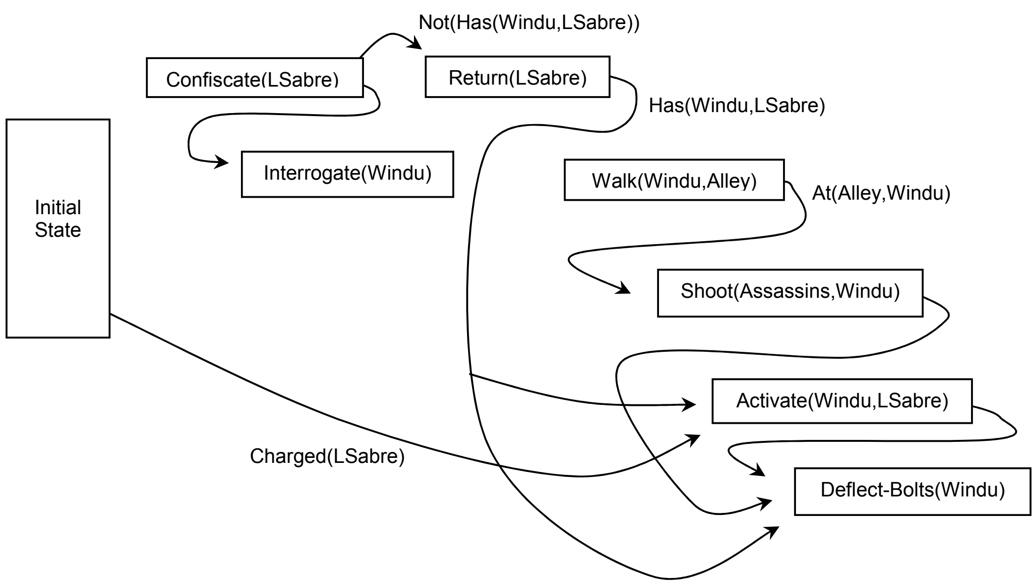
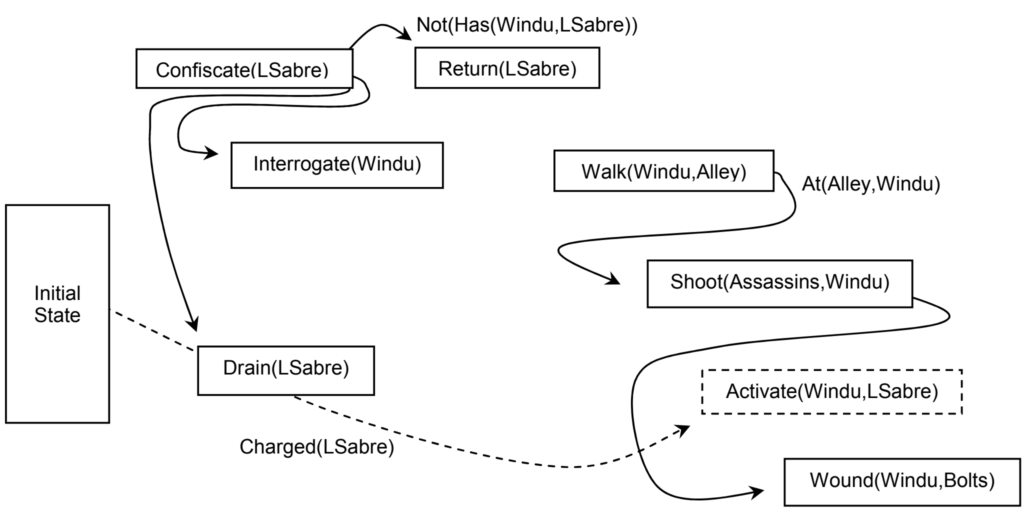


(a). The story as experienced so far.



(b). The expected story.



(c). The story as it unfolds

Figure 1. *Shatterpoint* story plans. Rectangles represent actions, arcs indicate causal connections between actions and are labeled with thecorresponding conditions in the story world.

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