A Knowledge Representation for Planning-Based Story Generation Applied to the Manual and Automatic Encoding of Plot

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Abstract. There have been a range of coding schemes to code story structure. However, few of these coding schemes map directly to expressive formal models of story that also characterize character beliefs or the complexities that arise when mistaken beliefs lead to action failure. We describe HeadCode, a coding scheme motivated by recent work in plan-based story generation.

Keywords: Story generation · coding schemes · Intentional Planning.

1 Introduction and Background

In stories, characters commonly attempt to perform actions that fail. Sequences with action failure are designed in narratives specifically to prompt explanatory and anticipatory inferences on the part of story consumers. Because story consumers act as problem-solvers [4], anticipating the progression of characters' plans and their ultimate success or failure, the design feature of stories where characters perform actions that fail are critical to the experience of a reader.

Thorne and Young [15] [16], developed a knowledge representation, called HeadSpace, that has been used in a generative context to produce story lines that contain these anticipation-prompting elements. In this document, we isolate the knowledge representation (KR) that Thorne and Young developed and describe a methodology for human analysts to employ the KR to encode characters' intentional structures from sample narratives. We call the resulting coding scheme and coding methodology HeadCode.

The motivation for this work comes from a necessity in the current domain: to be able to seamlessly transpose between human-authored narratives and computational narratives. There is an existing corpora of real world stories in various media, and this work is intended to provide a capability for their translation into a representation compatible for computational study.

A number of approaches involving narrative have sought to develop coding schemes for naturally occurring or artificial narratives. For example, work by social scientists exploring interpersonal relationships and health have used talk-aloud protocols to solicit insight into ill patients' perspectives on their own health [14], and coding schemes were developed to obtain structured knowledge from subject-generated personal narratives.

There is narrative psychological research that explores how people represent their lives through telling stories [10]. Narrative psychologists study people's personal stories in a range of contexts (e.g., [6, 13, 8, 7, 12]). These researchers typically use distinct coding schemes that address idiosyncratic questions specific to each research project.

There have been approaches to encode narratives towards generating computational representations as well. Cardona Rivera and his collaborators [1] introduce a computational model to capture information from narratives using the event indexing situation model, a cognitive model of human narrative understanding [17]. Metafor is a system which attempts to create programming constructs for stories [9] and visualize stories as constructs of object-oriented programs. Harmon's work on a narrative encoding framework is aimed at promoting analysis and comparison of narratives with each other [5]. Elson and his collaborators [2] also constructed a tool that supports an encoding process for narratives to be used for acquiring world knowledge in a narrative generation and understanding.

The HeadCode knowledge representation borrows and adapts many of its formal definitions from the HeadSpace planning data structures. For use by annotators, the HeadCode knowledge representation models the actions present in a narrative sequence, the conditions in the world relevant to the actions' success, the set of characters in the world capable of executing actions, and the beliefs, desires and intentions of these characters over time. Formal definitions for all the elements of a HeadSpace plan are provided by Thorne and Young in their original paper [15]. We provide an informal characterization of the HeadSpace elements that are relevant for HeadCode below. Readers should refer to Thorne and Young's work for the complete characterization.

2 Coding Cinematic Plotlines using HeadCode

The coding process using HeadCode requires three passes through the cinematic sequence. Each pass involves the annotator watching the sequence in temporal order from start to finish. With each pass the annotator populates the knowledge representation making reference to elements added in the preceding passes. For brevity, in the remainder of this paper we refer to the human annotator as *Ann*.

First Pass. During the first pass, Ann records the following aspects:

1. Characters. Ann adds unique character identifiers to a *Character List* just when Ann sees an as yet unrecorded character perform an action that *contributes causally* to the cinematic sequence. For example, a background character which is performing a random action in the background would not be added to the Character List unless at least one their actions contributes causally to the plot sequence.

2. Objects. Ann adds a unique object identifier to an *Object List* just when Ann sees an as-yet-unrecorded object that plays some role in an action, either in the action's preconditions or effects.
3. Locations. Ann adds a unique location identifier to a *Locations List* just when Ann sees a distinct as yet unrecorded location where an action takes place.
4. Literals. Ann records a ground literal in the world in a *Literals List* just when Ann sees a condition in the world that plays a role in a precondition to some observed story action. Care must be taken that the literals recorded in the Literals List are consistent in their semantics. That is, Ann should not create two different literals in the Literals list denoting the same condition or its negation. For instance, Ann should not record both `(unloaded gun1)` and `(not (loaded gun1))`.

At the end of the first pass, Ann must check their list to ensure that the list is consistent and has no duplicates. Ann can choose to remove certain elements if they feel at the end of the sequence that they were not necessary for the plot, or add more elements if they seem to have contributed to the plot. Then Ann can move on to the second pass.

Second Pass. During the second pass, Ann re-watches the cinematic sequence, observing the actions performed and their relationship to world states over time. The second pass focuses on the following aspects:

1. Operators. Ann records an operator definition for an action in an *Operators List* just when Ann observes an action being executed that is a) of an as yet unrecorded action type and b) dependent upon or changes the state of some literal in the Literals List.
2. World States. Ann creates a world state record that describes the state of the world currently being viewed just when Ann observes an action occur in the world that changes the truth value or character belief value of a literal in the Literal List. This world state record is added to a *World States List*. A world state record consists of the enumeration of truth values of the literals in the Literal List for each character and the ground truth value for the world and the identifier of the world state record that immediately precedes it in the cinematic sequence.
3. Actions. Ann records a unique action identifier in an *Actions List* just when Ann observes an action that is dependent upon on changes the state of some literal in the Literals List. Part of this recording includes the operator of the action as well as the specification of how elements from the Characters, Objects and Locations Lists play roles in the action's arguments. Finally, the recording indicates which world state record occurs immediately prior to the action.

Third Pass. In the third pass, Ann encodes aspects of the cinematic sequence by building upon the information encoded using the first two passes. Specifically, Ann reasons about *why* characters perform those actions. This involves the following type of annotation:

1. Intention Plans. As the cinematic progresses through each world state noted in the World State List, Ann creates an intention record for each character. The intention record lists Ann's estimation of the character's current goals as well as a partial description of the plans that the character intends to pursue to achieve those goals. Goals are drawn from the Literals List and plans are composed of a partial order of actions instantiated from the Operators List using literals, locations and characters from their respective lists as arguments.
   When creating a new intention record for a new world state, Ann modifies the intention record for the preceding state by a) updating any plans containing the most recently executed action, to indicate that action's successful execution, b) adding any plans and goals that Ann perceives result from a character adopting a new set of intentions and c) removing any plans and associated goals that Ann perceives have just been abandoned by a character due to the character's changing beliefs.

3 Conclusion

Because the HeadCode coding language was designed based on the HeadSpace planning data structures, there is a direct, one-to-one mapping between story plans produced by the HeadSpace planner and the language elements of HeadCode that would be used to code a sample story produced by the HeadSpace planner. In fact, the mapping is so direct that a straightforward process can be followed that produces the mappings without human intervention. Specifically, the mapping takes each element of a HeadSpace plan and produces the identical element in HeadCode. It parallels much of the structure found in the HeadSpace planning system, which itself extends the widely-used STRIPS model of action [3]. Further, HeadCode provides a process by which output from narrative planners can be automatically translated into coding model and by which human annotators can create data from naturally occurring narratives in the same format.

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