Towards a Model of Uncertainty in Narrative Planning

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Abstract

Most narrative planners currently lack the ability to model characters believing in multiple different possibilities or actions with different outcomes. By introducing a sense of uncertainty into narrative planning, we can model more realistic human behavior as well as generate new types of stories. In particular, stories surrounding a detective or a mystery require some form of uncertainty for the story to sound reasonable to a reader.

Motivation

Narrative planning is a method of generating stories often used in interactive fiction. Given a domain with characters, their goals, actions they can take, and a desired ending of the story, a narrative planner finds a solution, or list of actions, that achieves the desired ending. Any action taken by a character must be explained, which in many planners means it must bring that character closer to achieving their goal, even if they don't reach it before the end of the story. Narrative planning is particularly interesting as a narrative generation method as it requires every action to be logically possible whenever it is taken, and for every action to be reasonable for the characters that take them. This frequently leads to stories that seem more reasonable than stories generated via other methods.

One of the character traits that many narrative planners (Ware and Siler 2021; Sanghrajka, Young, and Thorne 2022; Teutenberg and Porteous 2013) are unable to model well when generating stories is uncertainty. In the narrative planner Sabre (Ware and Siler 2021), characters can have beliefs about the state of the world, such as where a friend is currently located. A character can have a correct or incorrect belief, or a belief can take on a null value. Likewise, characters can also have beliefs about the world in the narrative planner IMPRACTical (Teutenberg and Porteous 2013), but still these beliefs can only take on one in world value, rather than a list. Neither of these planners has a way for a character to have a list of locations they believe their friend might be and a list of locations where they believe their friend is not. This kind of belief structure could be useful in a range of storytelling domains, such as a detective

story. A detective solving a crime would need to be able to maintain who they believe could be the culprit and who has a valid alibi. A representation of the detectives uncertainty about the identity of the culprit is necessary for them to plan their investigation based on who they still believe could be guilty.

A character's uncertainty can be vital to a story. In the mystery film *Knives Out* (Johnson 2019), the death of Harlan Thrombey is initially labeled a suicide by detectives. Even though there is plenty of evidence to support this theory, the protagonist detective, Benoit Blanc, is uncertain whether this is truly the case and still believes it could have been murder. This leads him to collect more evidence and information from the Thrombey family and eventually (correctly) conclude that the death of Harlan Thrombey was in fact a murder.

For my dissertation, I plan to develop a way to represent uncertainty and non-determinism in stories produced by narrative planners. This would allow for many new features in narrative planning, such as characters believing in multiple possible worlds or actions that have more than one possible non-deterministic outcome. My hope is that these features will expand the domains and stories possible with narrative planning. I also plan to investigate whether these features, particularly uncertainty in character beliefs, more closely model human thinking and produce stories that seem reasonable to readers. Adding uncertainty will increase the computational burden of narrative planning, thus I also plan to explore the tradeoff between the representational richness and computational cost and find an appropriate balance. While I have done work in narrative planning, the inclusion of uncertainty will be a new field of research for me.

Previous Work

Planning under uncertainty is a well-studied topic (Blythe 1999). Scenarios such as Markov Decision Processes have actions with multiple different outcomes, and planning requires reasoning about several possibilities. However, these domains often model the real world, where there is true uncertainty. In narrative planning, our goal is only the reader perceive that characters are uncertain about something. A narrative planner has full control over the environment. Thus, methods for creating plans under uncertainty in planning may serve as an initial foundation, but ultimately,

new methods can be created that can better take advantage of the fully controllable world accessible to the narrative planner and only give an illusion of uncertainty.

The beliefs of a character can be modeled as possible worlds (Shirvani, Ware, and Farrell 2017). In this way, all of the beliefs and knowledge that a character has about the state of the world culminate in a full model of the world that they believe in. My definition of uncertainty would expand this such that a character can believe that multiple possible worlds are possible. For example, if a character believes their friend is either at home or at work, that character believes in two possible worlds: one where their friend is at home, and one where their friend is at work. Assuming their friend's location is the only thing they are uncertain about, this would be the only difference between the possible worlds the character believes in.

Similar work has been done on planning actions that will ultimately fail (Sanghrajka, Young, and Thorne 2022). Actions like this might be unnecessary logically, since they do not accomplish anything, but can be essential to the narrative. My work will build on this concept as it allows for these types of actions that may be necessary to a story, but not logically necessary to a story. For example, imagine a detective who might suspect someone of a crime. There is nothing stopping the detective from immediately arresting the suspect of a crime, but would it not make sense for the detective to investigate first? The investigation doesn't change anything about the world, but it is necessary for the story to make sense to a reader.

One of the applications of uncertainty in narrative planning is detective stories. Murder mysteries, one of the most common forms of detective story, in particular, are seen as difficult to generate (Eger 2020). Eger states that one of the challenges in generating murder mysteries is the difficulty in generating human intuition rather than strict logic (Eger 2020). Many famous murder mysteries have the investigator use at least some intuition to solve a crime, and this intuition can be very open-ended and hard to model. Narrative planning especially sees this flaw, as planning algorithms often use logic to create a valid sequence of actions. While my addition of uncertainty to narrative planning will not immediately solve this problem, it can make it easier to model intuition in the future. When a character believes in multiple possible worlds, a model of the character's intuition would involve them selecting the world or worlds they believe are most likely to be accurate.

Methods

Beyond distinguishing what a character believes possible or impossible, it is also necessary to track constraints among those beliefs. For example, a detective might believe a crime happened either in the kitchen in the morning or in the backyard at night. Their belief about the location of the crime would be either the kitchen or the backyard, and their belief about the time of the crime would be either morning or night. A narrative planner, in addition to these beliefs, would also need to track that the detective only believes two possible scenarios, and does not believe the crime happened in the kitchen at night or the backyard in the morning.

To track how multiple beliefs interact with each other, I have devised two different ways to represent a character's beliefs. A character's beliefs can be used to generate many possible believed states. For example, the detective from the previous scenario believes there are two different possible states, one where the crime was in the kitchen in the morning and one where it was in the backyard at night. Thus, the full extent of the detective's beliefs could be represented as a list containing these two states. The second way is to have each belief represented as a set of possible values, with a list of constraints also included. In this method, the detectives' belief in the location of the crime would include the kitchen and the backyard, and their belief in the time would include morning and nighttime. Then the list of constraints would include the location as the kitchen if and only if the time was the morning, likewise for the backyard and nighttime.

Uncertainty doesn't just have to be added to character beliefs. It can be added to multiple aspects of a storytelling domain, particularly the actions. The outcome, or effects, of an action can be non-deterministic. For example, if a domain included an attack action, most narrative planners would have to describe a deterministic outcome for the action. But with uncertainty, the action could possibly have an outcome of the form "the attacker dies or the victim dies". Characters also need not fully understand the outcomes of the actions they take. An attacker might believe that their attacks will always be successful, even if that is not the case. Planning with uncertainty is usually done to model actions that in the real world may have stochastic outcomes. However, in virtual worlds, any action that has multiple outcomes would allow the narrative planner to choose the outcome that is convenient for the story. Counterintuitively, reasoning only about the possible world that is best for the story may speed up some aspects of narrative planning.

The plans that might be considered interesting stories to a reader in planning with uncertainty can look a little different from regular narrative planning. Imagine a scenario where a detective needs to arrest one of ten suspects for a crime. Since the detective from the beginning believes that the true criminal is possibly the one who committed the crime, the narrative planner may immediately have the detective arrest the criminal. But this is far from an interesting story. On the other hand, a story where the detective investigates every possible suspect before finally narrowing it down to the correct culprit might be too lengthy. One of the goals for planning with uncertainty is that a reader would detect that a character feels uncertain about some fact or facts about the world and plans accordingly. In addition, they should also feel that characters learn as they continue to take actions, not just exhausting every possibility. Thus, one of the biggest areas for my investigation will be finding a balance between using incorrect and correct possibilities within a character's beliefs to create interesting and engaging stories. This is closely related to the need for human intuition in murder mysteries (Eger 2020). During moments in the story where a detective has many options to choose from, the choice that might make the most sense to a person intuitively may be the correct choice to have the story make sense to a reader.

One of the more powerful tools uncertainty allows for is

modal logic, the logic of what is possible and what is necessary. It would allow a detective character to differentiate between "I believe it is possible this person is the criminal" and "It is necessary this person is the criminal". Modal logic allows for stories that start with a character believing many things are possible, and eventually concluding that only one thing is necessarily true. This type of story would be difficult to model in many current narrative planners.

In addition to uncertainty about the current state, we could also model uncertainty about the past or future. A character might believe that there are multiple different outcomes to an action or series of actions. They might also believe that there are multiple possible ways that the current state was reached. A detective would need this kind of temporal reasoning, especially about the past actions that lead to the evidence they have collected. In this situation, their belief of what actions happened may serve as a basis for an accusation of who the culprit is.

However, modal logic introduces some new difficulties in generating explanations for character actions. Depending on the story, it may not make sense for a character to plan based on a possible world they might believe in, without being certain. For example, a detective would not want to arrest a suspect solely based on the possibility that they might have performed the crime; they would want to be certain first.

Research Questions

Uncertainty can quickly make the number of possible states in a planning domain very large, which severely increases computation time. However, as mentioned earlier, it is not necessary to fully implement this into narrative planning, only to give the illusion of it for the reader. Thus, one of the major things I plan to investigate is how to model uncertainty in narrative planning without increasing computation cost by an unfeasible amount. A good model of uncertainty using non-determinism may take beyond a reasonable amount of computation time to produce a plan.

The definition for an explanation will change with the introduction of uncertainty, and especially modal logic. One of the goals of creating explanations for characters is to make them appear to a reader as a reasonable action for a character to take if that character wants to achieve their goal. So with the addition of uncertainty, I plan to investigate how to modify the definition and creation of action explanations while maintaining the reasonability that they provide in other narrative planners.

Evaluation

There are many new possibilities that come from the addition of uncertainty, and I am particularly interested in the new types of stories that can be told. I intend to evaluate and show that domains and stories that were not possible with previous narrative planners are now possible with the addition of uncertainty.

To test this new belief system, I plan to design a new domain for storytelling. Many already existing storytelling domains (Ware and Farrell 2023) do not account for the possibility of characters believing in multiple worlds in the possible actions or the initial beliefs of characters. All of the actions, initial beliefs, and goals can be achieved without any degree of uncertainty. This new domain will follow a detective solving a crime. This activity will require the detective to be uncertain about which character is the criminal, and potentially other aspects such as the location or time of day of the crime. To achieve the author's goal or raise their utility, the detective will need to be certain about the correct details of the crime and arrest the culprit.

My goal with uncertainty in narrative planning is to model human uncertainty. In doing so, I believe that the stories generated will closely model human behavior and thus appear as realistic to readers. I propose two possible ways to evaluate this claim. First, test participants can be shown a partially generated story from a narrative planner that involves uncertainty in a character's beliefs. After reading it, they can be asked what they think the character believes, and this can be compared to what the planner actually had as the character's beliefs. The hope is that they will be similar, showing that my system closely reflects what readers expect in stories. The second method would involve developing an interactive murder mystery game and having participants play it, and rate whether they think the actions other characters took were realistic. This would also test the potential for using uncertainty in interactive narrative.

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