Applications of AI Planning: Story Telling

Tarek Saier

July 3, 2015

Seminar: Advanced Topics in AI Planning
Research Group Foundations of Artificial Intelligence
Department of Computer Science
University of Freiburg
Summer semester 2015

1 Introduction

The classic types of problems dealt with in the field of artificial intelligence planning are problem-solving tasks where the length of plans and the time for finding them are to be minimized. This is referred to as "classical planning". AI planning in this traditional sense is already applicable to various practical tasks, such as route planning or logistics. Additional areas of application can be found where the task at hand can be modeled in a way that is structurally similar to classical planning problems. One such area is *story telling*, where AI planning has been applied for well over a decade and currently is the dominant technology in use [1].

For a first intuition of how "story telling by means of planning" can look like, one can consider a story as being modeled as a sequence of actions performed by story characters. Given an initial world state, a goal and a set of characters with certain actions they can perform, a planner can create a coherent story leading from its beginning to the end. This is, of course, just a very basic notion. As will become apparent in the following sections, the inherent differences between classic problem-solving tasks and stories lead to significant deviations from techniques in classical planning and interesting challenges when more sophisticated approaches to narrative generation are considered.

The remainder of this document is a general introduction to story telling as an application area of AI planning. It is structured as follows:

- Section 2, "Story world modeling", discusses ways of translating a story into a planning problem.
- Section 3, "Differences to classical planning", describes what differences arise when dealing with stories instead of classic problem-solving tasks as a basis for planning.
- Section 4, "Concrete approaches", showcases two approaches of using planning for story telling.
- Section 5, "Conclusion", sums up the subject matter with a short discussion.

2 Story world modeling

The notion of a story as a sequence of character actions is easy to understand. However, the actual modeling of a story world as a planning problem can — depending on the level of sophistication of the modeling — be quite involved. As a basic example, consider the following story:

> "In a fictional world with a continent named Westeros, the high-born refugee Viserys sold his younger sister Daenerys to a warlord in exchange for the warlord's army. He used the army to conquer Westeros and become its king."

In order to create a planing problem from this textual representation one has to decide on how to identify predicates and operators. From there, initial and goal states can be defined. Actions can, for example, be acts carried out by characters and predicates can be the character's circumstances. For above example this would yield the predicates $A = \{V\text{-}has\text{-}army, V\text{-}king, D\text{-}sold\}$ and operators $O = \{V\text{-}sell\text{-}D, V\text{-}conquer\text{-}W\}$ where:
$V\text{-}sell\text{-}D = \langle \neg V\text{-}has\text{-}army \wedge \neg D\text{-}sold\ , V\text{-}has\text{-}army \wedge D\text{-}sold \rangle$
$V\text{-}conquer\text{-}W = \langle V\text{-}has\text{-}army \wedge \neg V\text{-}king\ , V\text{-}king \rangle$
Building upon the identified predicates:
$I = \neg V\text{-}has\text{-}army \wedge \neg V\text{-}king \wedge \neg D\text{-}sold$ (initial state)
$\gamma = V\text{-}king$ (goal formula)
$\Pi = \langle A, I, O, \gamma \rangle$ (planning task)

Above example shows how a very minimal story can be modeled as a planning task, but it doesn't really make it clear why this would be useful. The problem is, that it is a mere one-to-one "translation" and solving the planning task results in nothing more than the story which was used a as starting point. Narrative generation becomes useful once its result is something *new*. This is the case when things like story variations or interactivity are introduced or when story structures are "planned" based on fundamental world rules and a set of characters. Taking such approaches is when the modeling process becomes more involved. Chapters 4.2, "Planning a fabula", and 4.3, "Planning a discourse", will describe two instances of such modeling approaches in more detail.

3 Differences to classical planning

Although the process of generating a story can be modeled as a planning task, the underlying nature of a classic planning problem and a narrative is very different (e.g. in terms of intended purpose, key properties, etc.). As a consequence there are similarities at a coarse level and differences once more complex properties are taken into account. An essential similarity on a very simple level: both the solution to a planning problem and a narrative are a sequence of successive steps, leading from a beginning to an end. In contrast, a key difference: a desired quality of a classic planning problem solution is shortness. Qualities sought in narratives, however, are less easily quantifiable aesthetic properties such as "interestingness" and "originality". While there is no obvious solution as to how such properties can be encoded in a planning problem and optimised for, it is easily recognizable that shortness is not an optimum. A basic approach towards generating interesting stories is introducing variation. For a given, rough outline of a story, variation in character actions (within reasonable bounds of the story world) or changes in perspective can make for an interesting narrative.

Depending on what properties of a narrative are taken into account, further requirements or constraints have to be considered. These can sometimes be incorporated into the modeling of the story world — such that the resulting planning problem can be solved by an off-the-shelf solver — some efforts, however, make use of custom a solver. An example for such a solver, tailored for narrative planning, is IPOCL [2], which takes causality and character intentionality into account.

Since a common use case for narrative planning is interactive story telling, there is a need for systems capable of replanning in response to changes to the story world introduced by a human element. This is less of a difference between classical and narrative planning in and of themselves but a special requirement for certain narrative planning systems due to forementioned characteristic use case. Section 4.3 will showcase such a system.

4 Concrete approaches

4.1 Narratology excursion

The following two subsections (4.2 and 4.3) will showcase two concrete cases of story telling by application of AI planning. Because they approach the subject matter on different levels a distiction is required. It will be necessary to distinguish between *fabula* (or *story*) on the one hand, and *discourse* (or *plot*) on the other hand.
Chatman writes in [3] (furthermore cited in [4]):

> "In simple terms, the story is the *what* in a narrative that is depicted, discourse is the *how*."
>
> (Note: Since *story* and *plot* are more commonly used in everyday language and might lead to confusion or wrong assumptions the remainder of this document will refer to the two concepts as *fabula* and *discourse*.)

To illustrate the difference with an example: viewers of a movie might be presented with a character A, talking about what a character B has done (assume A's report to be truthful and B's action to be relevant for the movie). On the level of the fabula (the narrative structure), we have B doing something. On the level of the discourse (how this is conveyed to the recipient) we have A talking about it. When watching a movie or reading a book one is presented with a discourse and automatically constructs a fabula in their head.

4.2 Planning a fabula

In [5] Haslum shows how a specific model of story generation proposed for the IPOCL planner [6] can be compiled into a classic planning problem. The model in question is designed to create fabulae and incorporates the notion of character intentions. The following subsection will describe the story world modeling in general. After that aforementioned compilation will be adressed.

4.2.1 Story world modeling

The central building blocks in this apporach are story characters for which certain abilities are defined. For illustration purposes a story world which is loosely based on the tale of Aladdin is used. Characters are humans (Aladdin, Jasmine, king Jafar) and monsters (a genie, a dragon). The characters' abilities are actions which can be divided into intentional actions and happenings. The former are deliberate interactions with the story world or other characters (such as traveling between locations or slaying a monster) while the latter are unintentional effects (e.g. a monster scaring a human because of its appearance or a human falling in love with another).

In order to create coherent, believable fabulae the modeling lays its focus on intentionality. Apart from the desired story outcome (the goal of the overall planning problem) characters can have their own goals which can arise and change through influence by the story world. Intentionality can also be caused by delegation — i.e. a character A evokes a character goal in another character B (for example through a command or persuasion). Most importantly character goals allow for *intentional plans* which characters can pursue. When a character has a goal and carries out an action in order to reach it, the action is said to be performed in a *frame of commitment.* Formally these terms are defined as follows:

> "**Definition 1** An intentional plan is one in which every occurrence of an intentional action is part of some frame of commitment. A frame of commitment is a subset S' of steps (i.e., action occurrences) in the plan, associated with a modal literal (*intends* A g), satisfying four requirements: (1) Character A is an actor of every step in S'. (2) There is a final step $s_{fin} \in S'$ that makes g true. (3) There is a motivating step s_m in the plan, which adds (*intends* A g) and which precedes all steps in S'. We'll say there is a motivational link from s_m to every step in the frame of commitment, S'. Note that s_m is not part of S'. (4) From each step in S' other than s_{fin} there is a path of causal or motivational links to s_{fin}. A complete (fabula) plan is one that is both intentional and valid in the classical sense." [5]

To visually aid the formal definition consider figure 1 on page 6. Arrows are to represent actions and dashed lines an arbitrary sequence of actions not shown. If all blue arrows are actions carried out by character A then the frame of commitment is $S' = \{s_i, s_{i+1}, s_{i+x}, s_{fin}\}$. Note that s_m does not necessarily have to be an action of A since intention can be delegated and that the intentional plan which includes S' may contain an arbitrary number of happenings unrelated to S' or g.

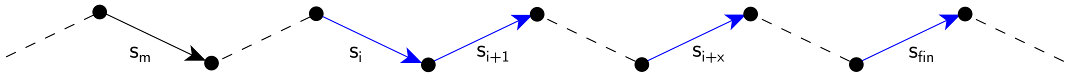

Figure 1: Visual example of a frame of commitment.

Ensuring that character goals are pursued by means of intentional plans is referred to as *explicit justification tracking*. In Riedl and Young's approach [6] this is performed by the IPOCL planner but in Haslum's paper [5] it is incorporated into the planning problem. This is accomplished by the main compilation described in Haslum's paper [5] and will be briefly discussed in the following subsection.

4.2.2 Compilation

The original story generation model includes modal literals in the form of (*intends A g*) in order to handle intentionality. For the compilation into a classic planning problem predicates are introduced for intention, delegation and justification. Intention literals are used as preconditions for intentional actions, which allows the modeling of frames of commitment — e.g. (*intends-dead Aladdin Dragon*) as a precondition for every action in Aladdins frame of commitment to slay the dragon including s_{fin} (him achieving his goal). Delegation and justification literals, on the other hand, are used for justification tracking. They are true in the initial state, required to be true at the goal, made false by certain intentional actions and then set up in a way such that only if motivational link as described in Definition 1 are adhered to will they become true again.

Description and discussion of this compilation's precise nature take up most of [5] and can therefore not be covered here. To get an intuition of a possible output consider below example of a monster slaying action in PPDL-like syntax.

```
(:action slay-1-because-intends-dead
    :parameters (?knight - knight ?monster - monster ?where - place)
    :precondition (and (alive ?knight) (at ?knight ?where)
                       (alive ?monster) (at ?monster ?where)
                       (intends ?knight (dead ?monster))
```

```
6                 (not (exists (?c) (and (not (= ?c ?knight))
7                                       (delegated ?c (dead ?monster))))))
8     :effect (and (not (alive ?monster)) (dead ?monster)
9         (justified (at ?knight ?where) (intends ?knight (dead ?monster)))
10        (justified (at ?monster ?where) (intends ?knight (dead ?monster)))
11        (not (delegated ?knight (dead ?monster)))))
```

A notable restriction of the compilation is that a delegated goal can only be achieved by the character it has been delegated to. In case of above monster slaying example this can be seen in lines 6 and 7. The monster may only be slain if there exists no other knight to whom the death of the monster has already been delegated.

4.2.3 Result

As already mentioned the story generation model at hand is designed to create fabulae. The result a planner produces therefore is a story *structure*. (TODO: Fig. 1 from Haslum paper in appendix or just mention?)

4.3 Planning a discourse

In [1] Porteous, Cavazza, and Charles present an approach to narrative generation on the level of discourse. The main focus of the proposed system is generating variation and being suitable for *interactive* story telling. Both aspects are realized through the way the story world is modeled and therefore will be part of the following subsection.

4.3.1 Story world modeling

For illustration purposes Porteous et al. [1] employ the *pound of flesh* subplot of Shakespeare's *The Merchant of Venice*, which revolves around a loan agreement between Antonio, a wealthy Christian merchant and Shylock, a Jewish moneylender. Primary aspects of the story world modeling are the concepts of narrative control knowledge and decomposition as well as the usage of character PoV (point of view). The purpose of narrative control knowledge and decomposition is to allow interactivity and generated variation (i.e. deviation introduced by a non deterministic element) whilst adhering to a predefined baseline plot. PoV is used to generate variation. The modeling process that implements these constructs is illustrated in figure 2 on page 8 and will be explained in the following.

Narrative control knowledge makes it possible to control the shape of a narrative. It's concrete use in the modeling approach at hand is to guide the narrative along a predetermined baseline plot. This is done by identifying key components of the plot structure and formulating state trajectory constraints, which are based on story world predicates. An example for the *pound of flesh* sub-plot would be the predicate (*sealed-bond-over-load shylock antonio*). These constraints are then implemented by PDDL3.0's modal operators *sometime-before* and *sometime*, the former of which is used for constraints where its relative order with respect to other events is important while the latter is used for things that are allowed to happen at any time during the story. Interesting to note is, that for a given generated story not all identified constraints are used. Only choosing a subset for each generation process is a way to introduce variation.

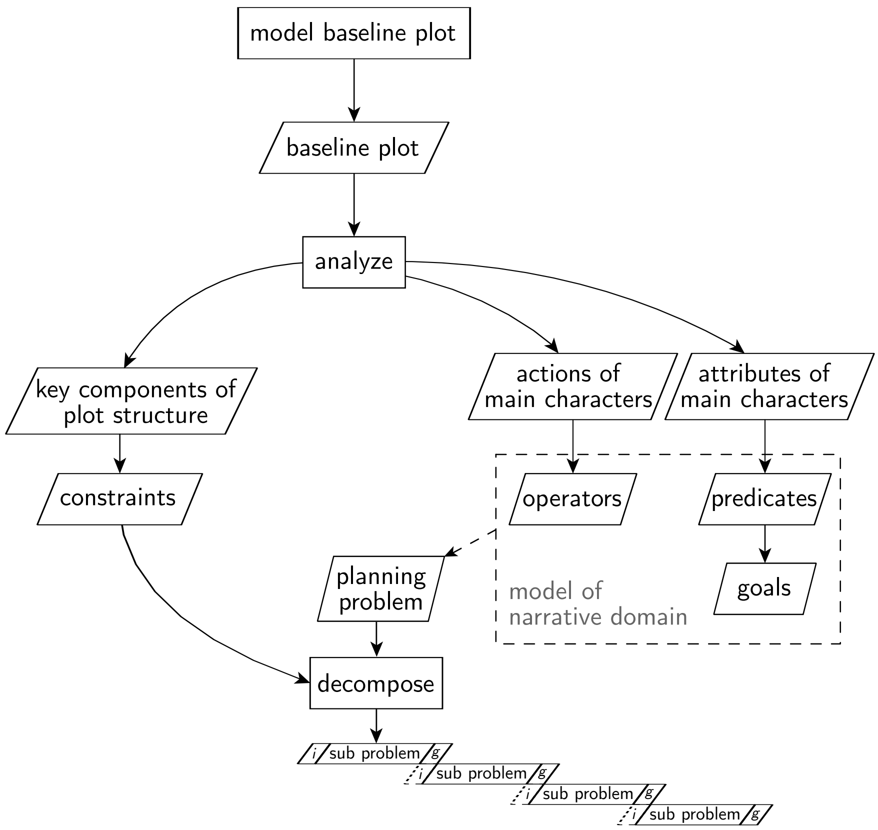

Figure 2: Visualization of the modeling process.

Similar to the story world modeling in section 4.2 attributes and actions of characters are translated into predicates and operators. Together with the goal built upon predicates this forms the model of narrative domain which leads to the initial planning problem. The chosen subset of constraints is then used to decompose the planning problem into several sub problems where the goal of a problem n is the initial state of the problem $n + 1$. This practice of decomposition accomplishes two things. First, since the constraints used are always different it leads to variation in the output; second, it allows for quick replanning which is necessary in the event of intervention — i.e. when the system is used for interactive story planning.

The remaining key aspect, that is not visible in figure 2, is PoV. It is another device for introducing variation to the story and works as follows. As one would excpect from the name, a character's *point of view* renders the story from their perspective. In addition to that PoV is used to define a character's standpoint or disposition with regard to certain story events. To illustrate both aspects consider the following example: the sealing of the bond over the loan in the *pound of flesh* sub-plot can be presented from the perspective of either of the involved characters, Shylock or Antonio. Furthermore let each character have two possible dispositions concerning the event. In [1] the four resulting PoVs are described as follows:

PoV	Action
(*pov antonio-risk-taker*)	Antonio, carfree risk taker, borrows money with no heed to the consequences.
(*pov antonio-victim*)	Antonio, a loyal friend, borrows money from Shylock, fully aware of the risks.
(*pov shylock-victim*)	Shylock, a patient victim, extends a favour to Antonio by lending him money.
(*pov shylock-ruthless*)	Shylock, intent on revenge, lends money to Antonio anticipating the forfeit.

With these the sealing of the bond can be shown in 4 different ways. As a consequence the action of sealing the bond (i.e. the operation which will be part of the resulting "story plan") has to be defined in 4 different ways. In PDDL3.0 these are (shortened):

```
(:action borrow-money-confident-repay antonio shylock venice-rialto) ...
    :precondition   (and (pov antonio-risk-taker) ...)
    :effect         (and (sealed-bond-over-loan shylock antonio)
                    (unconcerned-over-forfeit antonio) ... ))
(:action borrow-money-wary-of-risk antonio shylock venice-rialto) ...
    :precondition   (and (pov antonio-victim) ...)
    :effect         (and (sealed-bond-over-loan shylock antonio)
                    (concerned-over-forfeit antonio) ...))
```

```
(:action lend-money-as-favour shylock antonio venice-rialto) ...
    :precondition   (and (pov shylock-victim) ... )
    :effect         (and (sealed-bond-over-loan shylock antonio) ...))
(:action (lend-money-intent-on-revenge shylock antonio venice-rialto) ...
    :precondition   (and (pov shylock-ruthless) ...)
    :effect         (and (sealed-bond-over-loan shylock antonio) ...))
```

It can be seen that (*sealed-bond-hover-loan shylock antonio*) is always an effect while other, varying effects may also be present. Furthermore PoVs are used as preconditions, ensuring that each represenation of the action is only used in plans where the corresponding PoV has been chosen.

4.3.2 Result

Clearly evident due to the inclusion of PoV this approach to narrative generation produces a discourse as a result — that is, a solution to a planning problem representing what a viewer of the play that seved as an example might see. (TODO: Fig. 7 from Porteous paper in appendix or just mention? Mention run-time performance results?)

5 Conclusion

This seminar report gave a brief introduction into story telling or narrative generation as an application area for AI planning. On a *very* basic level stories can intuitively be described in a way that is structurally similar to classic planning problems. Sophisticated approaches, however, quickly reveal challenges that arise due to the difference of classic planning problems and narratives. In order to deal with those, specialized planners can be used, but it is also possible to include nontrivial aspects of narratives into the modeling of the planning problem such that a classical planner can be applied. Futhermore, stories themselves can be approached on different levels. Story structures (*fabulae*) as well as story presenations (*discourses*) can be generated by means of planning.

Interactive story telling requires temporally bound narrative (re-)generation due to non deterministic intervention. AI planning has been applied in this field for well over a decade and currently is the dominant technology in use[1]. This shows that planning can be the first choice approach even in areas that are, at first glance, quite different from classic problem-solving tasks.

References

[1] Julie Porteous, Marc Cavazza, and Fred Charles. Applying planning to interactive storytelling: Narrative control using state constraints. *ACM Trans. Intell. Syst. Technol.*, 1(2):10:1–10:21, 2010.

[2] M.O. Riedl and R.M. Young. An intent-driven planner for multi-agent story generation. In *Autonomous Agents and Multiagent Systems, 2004. AAMAS 2004. Proceedings of the Third International Joint Conference on*, pages 186–193, July 2004.

[3] S.B. Chatman. *Story and Discourse: Narrative Structure in Fiction and Film*. Cornell Paperbacks. Cornell University Press, 1980.

[4] D. Herman, M. Jahn, and M.L. Ryan. *Routledge Encyclopedia of Narrative Theory*. Taylor & Francis, 2010.

[5] Patrik Haslum. Narrative planning: Compilations to classical planning. *Journal of Artificial Intelligence Research*, 44:383–395, 2012.

[6] Mark O. Riedl and R. Michael Young. Narrative planning: Balancing plot and character. *Journal of Artificial Intelligence Research*, 39(1):217–268, September 2010.