

# Planning with a Theory of Mind

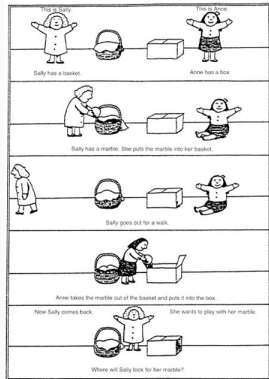
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ICAPS Tutorial: Narrative Planning

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# Planning with a Theory of Mind

- *Theory of Mind*: the capacity to understand others have a mind of their own, and reason about what goes on in it.
- To be believable, characters must behave consistently with what an audience believes is in their minds.
- Characters may need to reason about what other characters want, believe, and intend.



(Baron-Cohen, Leslie and Frith 1985)  
[https://en.wikipedia.org/wiki/Sally%E2%80%93Anne\\_test](https://en.wikipedia.org/wiki/Sally%E2%80%93Anne_test)

- Planning from the author's perspective:
  - Must reason about what characters want, believe and plan, to preserve the illusion that characters are planning and acting of their own will.
  - May reason about what characters believe or assume about what other characters want, believe and plan (because that is what we do)
  - May reason about what the audience believes, to create dramatic effect.
- Planning from a character's perspective:
  - Must work from the beliefs and goals the character has (or is intended or perceived to have).
  - May reason about what other characters want, believe and plan, to predict or manipulate their actions.

- Riedl & Young (2010) distinguish *intentional* actions, performed by one or more characters (its *actors*), from non-volitional events.
- A plan is *intentional* iff every intentional action contributes, directly or indirectly, to achieve an intention (goal) of the character(s) who perform it.
- Characters can acquire intentions as an effect of events or other characters' actions, depending on their character traits.

- Formalised by Riedl & Young in the context of POCL plans.
- A *frame of commitment* is a subset  $S'$  of plan steps such that:
  - character  $A$  is an actor of every step in  $S'$ ;
  - there is a *final step*  $s_{fin} \in S'$  that adds  $g$ ;
  - there is a *motivating step*  $s_m$  that adds (intends  $A$   $g$ ) and that precedes all steps in  $S'$ ; and
  - for each step in  $S'$  other than  $s_{fin}$  there is a path of causal and/or motivational links to  $s_{fin}$ .
- A plan is *intentional* iff every intentional action with actor  $A$  belongs to a frame of commitment of  $A$ .

# Conflict

- Riedl & Young's definition does not allow plans in which characters *fail*, either because
  - they planned from mistaken beliefs; or
  - another character's actions thwarted their plan.
- Ware & Young (2011) amend the definition of intentional plans to allow for plans with inter-character *conflict*, by allowing characters' plan, while complete, to be only partially executed.
- Formally, they distinguish between *executed* and *non-executed* steps in the plan:
  - both executed and non-executed steps may be used to complete a frame of commitment; but
  - only executed steps are subject to normal plan validity.

- Representing character *beliefs* about the world state means representing a potentially different state for each character.
- Character's beliefs can change as a consequence of
  - their actions (failure uncovers false belief);
  - other character's actions (telling or revealing); and
  - non-volitional events (observation).
- Formalised (e.g., Teutenberg & Porteous 2015; Christensen et al. 2020):
  - Character's plans (frames of intention) must be complete with respect to the facts that the character believes.
  - Requires modelling the effects of a character attempting an action whose preconditions are in fact not true.

- Although properties like intentionality, conflict, belief are often formalised in the context of (extended) POCL plans, planners achieving them can be *implemented* in many ways, *e.g.*:
  - By modification/extension of classical POCL algorithms (Riedl & Young 2010; Ware & Young 2011).
  - By modification/extension of (heuristic) state-space search planners (Ware 2012; Ware & Young 2014; Sanghrajka et al. 2022).
  - Through multi-agent planning (Brenner 2010; Teutenberg & Porteous 2013, 2015; Porteous & Lindsay 2019).
  - By reformulation/compilation (Haslum 2012; Christensen et al. 2020).



# Planner as an Audience Model

- A planner, using the facts of the story narrated so far, can be used as a model of the audience's expectations:
  - If there are few or unlikely plans in which the story's protagonist is successful from the current state, then the state is *suspenseful* (O'Neill & Riedl 2014; Cheong & Young, 2015).
  - If the story diverges from the plan generated by the audience model, then the story is *surprising* (Bae & Young, 2014).
- Can also incorporate reasoning about the audience's likely inferences from narrated facts (*e.g.*, Arinbjarnar 2008; Chieppe et al. 2022).

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