A Computational Model of Plan-Based Narrative Conflict at the Fabula Level

STEPHEN G. WARE, R. MICHAEL YOUNG, BRENT HARRISON, DAVID L. ROBERTS

IEEE TRANSACTIONS ON COMPUTATIONAL INTELLIGENCE AND AI IN GAMES (2014)

Conflict in Narrative Planners

- How to introduce conflict into narrative planners?
- Previously, IPOCL bridged the knowledge gap of intention for traditional POCL planners
- Now, CPOCL intends on bridging the gap of conflict for IPOCL

Background

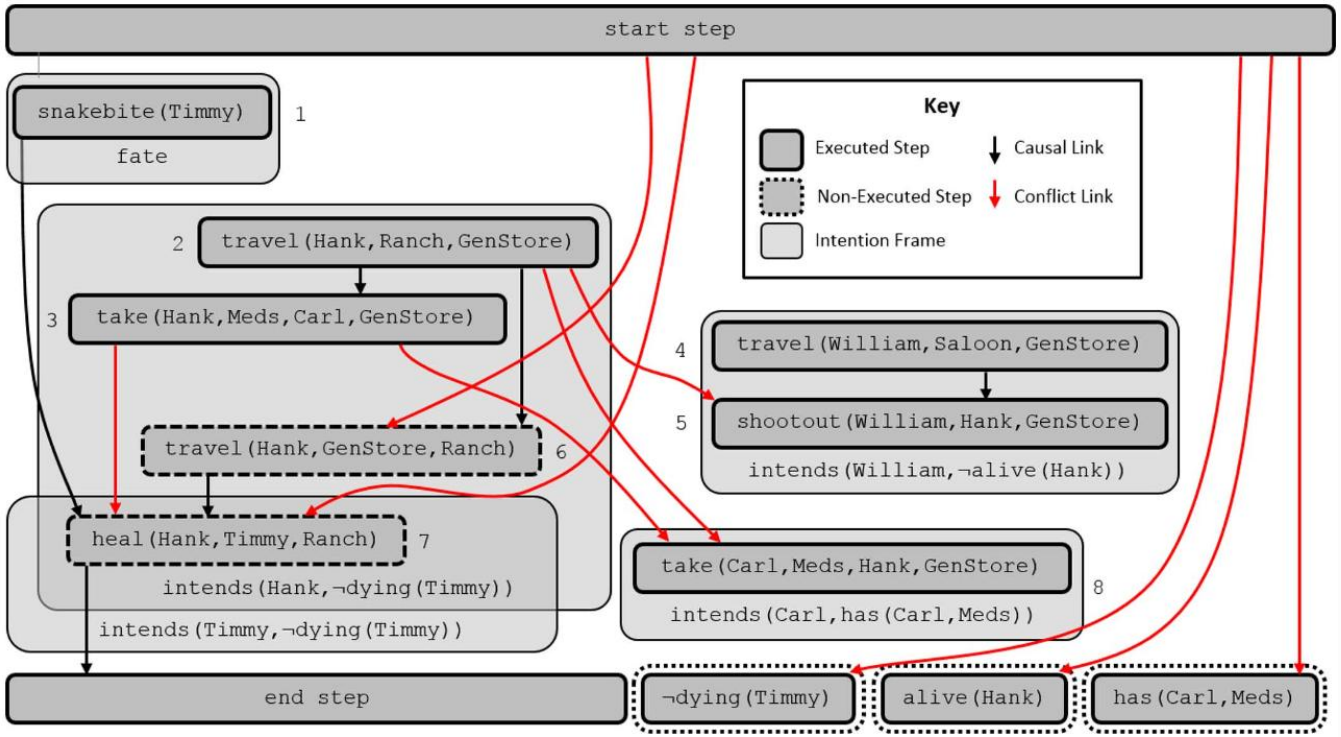
- Narrative justifications for conflict
  1. Conflicts structure the discourse, central conflicts are created early and causes characters to adjust their plans accordingly
  2. Conflict engages the audience because it sets expectations and assumptions of the outcome
- Conflict as defined by the paper:
  - When a character creates a plan that is prevented by another event, or would have been prevented if the event had executed.
- Types of conflict prevention/thwarting:
  1. External conflict – another character prevented
  2. Internal conflict – character prevented itself through conflict of two different goals
  3. Environmental conflict – fate intervened

CPOCL Plan Properties

- Execution – Boolean flag, indicates whether a step is executed or nonexecuted
  - Executed step – A step that will be executed at a point in the story
  - Nonexecuted step – A step that a character intended to take but wasn't able
- Persistence
  - Slight callback to Plangraphs
  - Characters sometime adopt goals that have been satisfied, but they still want it satisfied at the end
  - Dummy persistence steps allows a character to showcase their intention of keeping a goal true

CPOCL Plan - <S, B, O, L, I>

- S – set of executed and nonexecuted steps
- B – set of binding constraints on free variables in S
- O – partial ordering of steps in S
- L – set of causal links joining steps in S
- I – set of intention frames describing subplans in S



Conflict - $\langle c_1, c_2, s \xrightarrow{p} u, t \rangle$

- c_1 – character 1
- c_2 – character 2 (can be identical to c_1)
- $s \xrightarrow{p} u$ - causal link threatened by t
- t – conflicting step

- Properties:
  - u and t have unique intention frames
  - u and/or t are nonexecuted steps

Conflict Utility Functions

- π(T) – measure of how likely a sequence of actions T is to succeed.
- Utility(c,T) – measures satisfaction of character c after sequence of actions T occurs.
- Utility(c,∅) – character's utility before the conflict begins

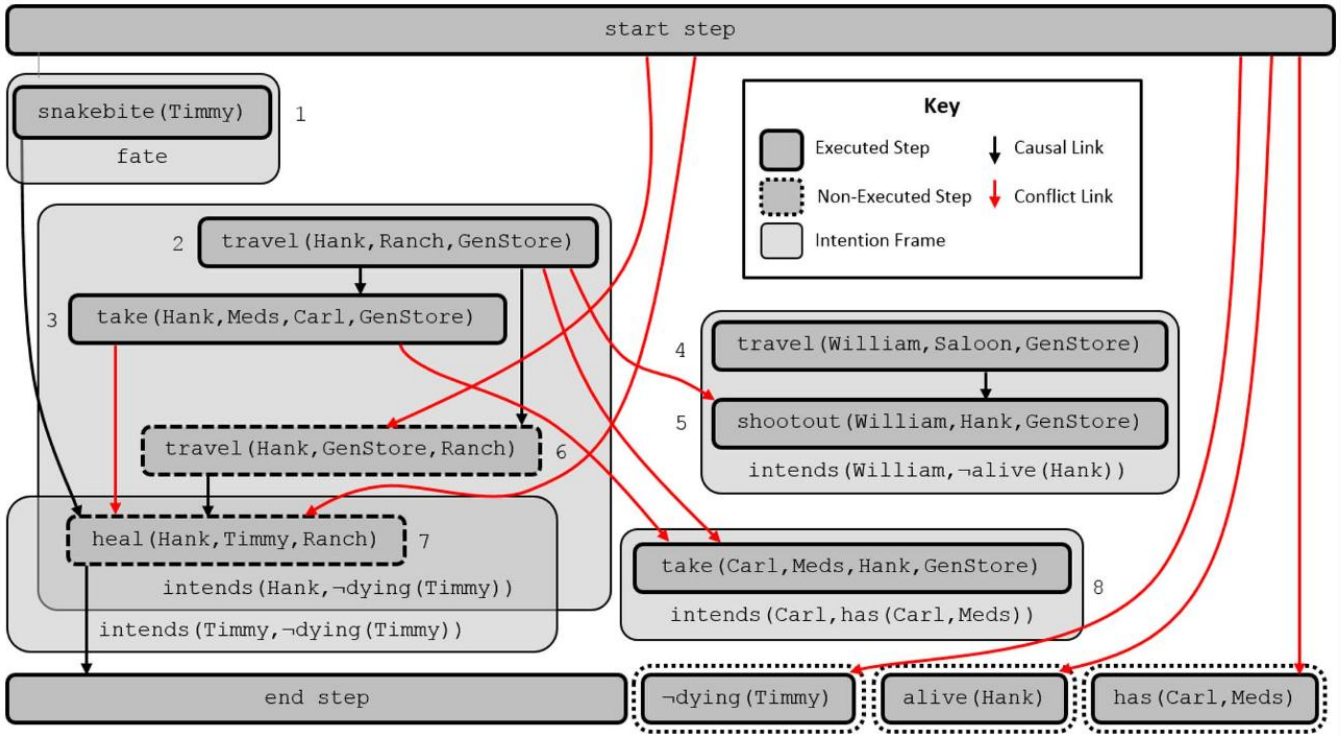
```
utility(?c):
    u = 0;
    if(alive(?c) ∧ ¬dying(?c))
        u += 0.7;
    if(∃?i belongsto(?i,?c))
        if(has(?c,?i))
            u += 0.3;
    else
        u += 0.3;
    if(∃?h parentof(?c,?h))
        u = (0.4 u) + (0.6 utility(?h));
    return u;

π(step):
    if(step.operator = snakebite)
        return 0.05;
    if(step.operator = take)
        if(¬alive(step.?h))
            return 1;
        if(armed(step.?t) ∧ ¬armed(step.?h))
            return 0.8;
        if(¬armed(step.?t) ∧ armed(step.?h))
            return 0.2;
        else
            return 0.5;
    if(step.operator = shootout ∧ armed(step.?p))
        return 0.5;
    return 1;
```

Dimensions of Conflict

- Seven dimensions defined for conflict

1. Participants
   - Who? The characters involved in conflict
2. Reason
   - Why? The condition that makes two subplans incompatible
3. Duration
   - When? Period of time in which characters inten their incompatible subplans

$$\begin{aligned} \text{start} &= \max(\text{index}(m_1), \text{index}(m_2)) \\ \text{end} &= \min(\text{index}(t), \text{index}(u), \Omega(f_1), \Omega(f_2)) \\ \text{duration} &= \text{end} - \text{start} \end{aligned}$$



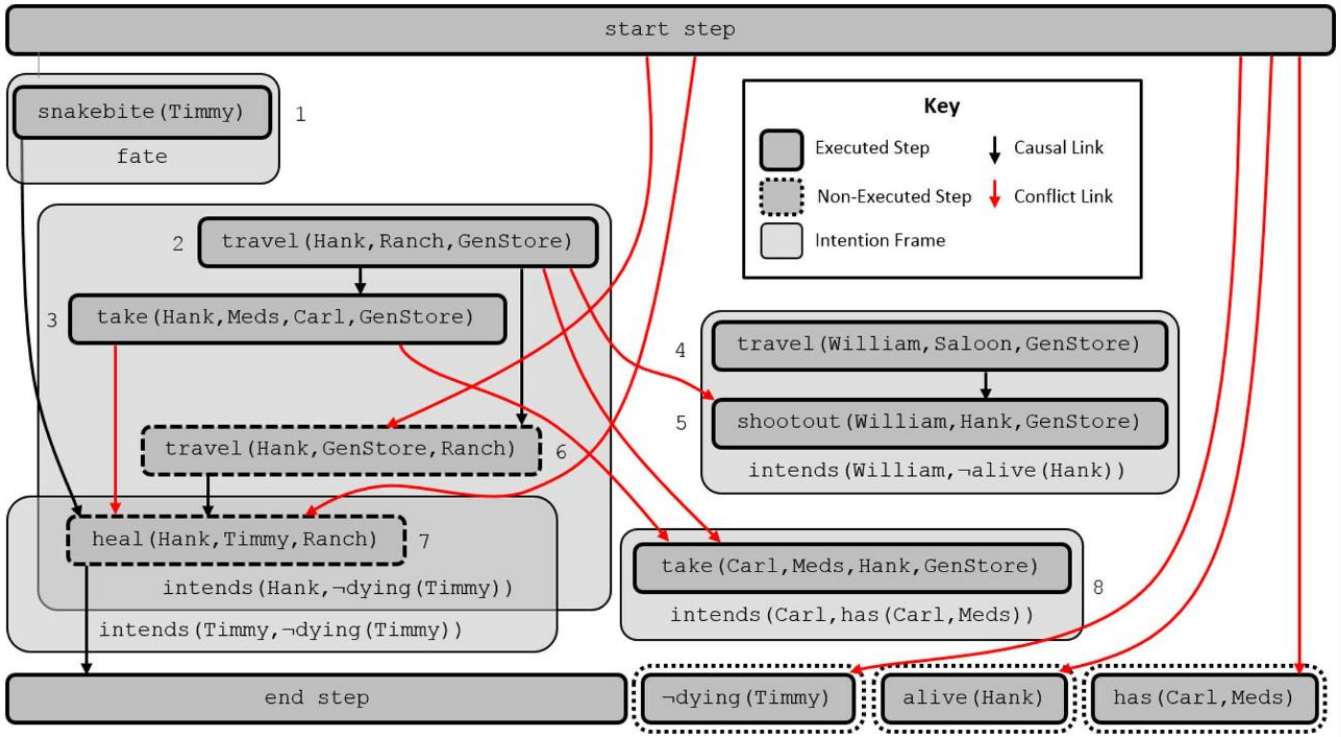
Dimensions of Conflict

4. Balance
   - Conflict fairness, measure of which participant is more likely to succeed in a conflict. Ranges from [0,1].

$$\text{balance}(c_1) = \frac{\pi(T_1')}{\pi(T_1') + \pi(T_2')}.$$

5. Directness
   - Proximity of characters, in this domain physical and family closeness is measured. Ranges from [0,1].

$$\text{directness}(c_1) = \frac{\sum_{i=1}^{n} \text{closeness}_i(c_1, c_2)}{n}.$$



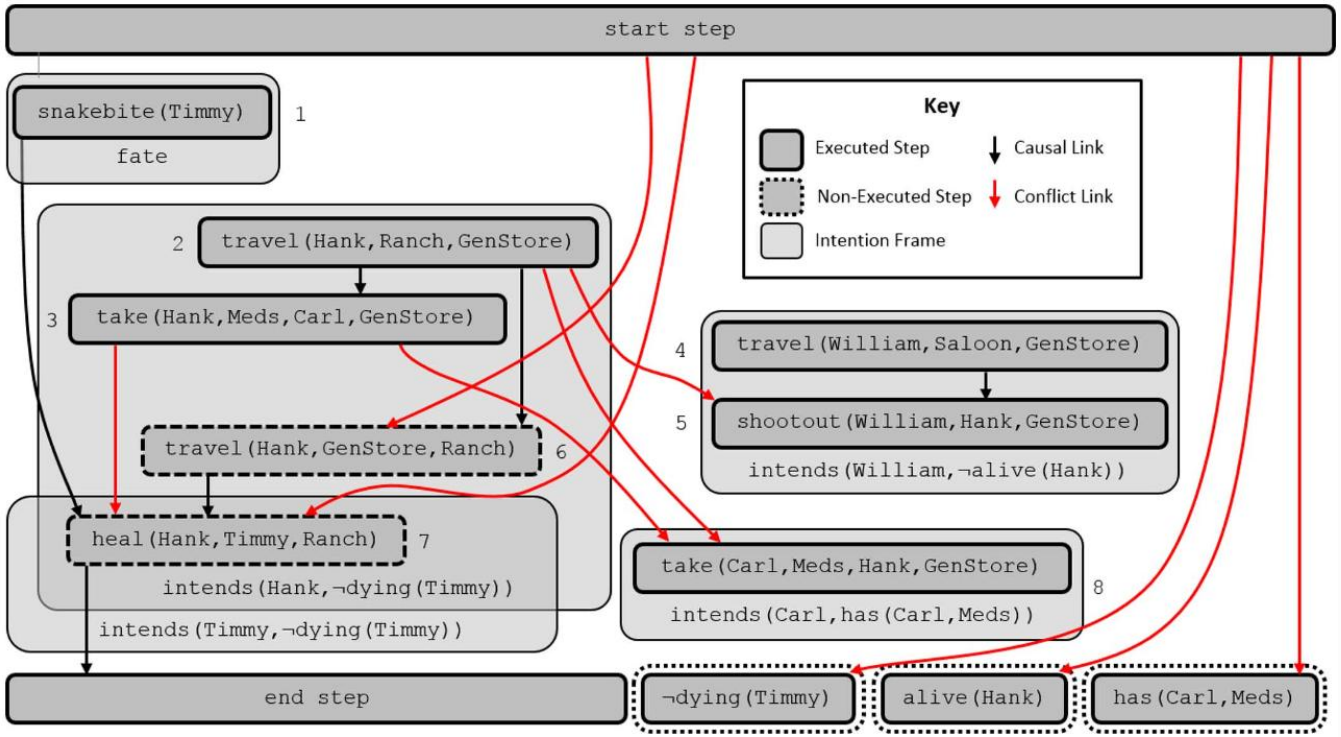
Dimensions of Conflict

6. Stakes
   - Importance of prevailing. The difference b/t best and worst outcome. Ranges from [0,1].

$$\text{stakes}(c_1) = |\text{utility}(c_1, T_1') - \text{utility}(c_1, T_2')|.$$

7. Resolution
   - Measures utility of a character following a conflict. E represents actual steps taken between T'_1 and T'_2. Ranges from [-1,1]

$$\text{resolution}(c_1) = \text{utility}(c_1, E) - \text{utility}(c_1, \emptyset).$$



Algorithm

- Extension of classic POCL algorithm
- Integrates intentional planning from IPOCL algorithm

Algorithm 1 The CPOCL (Conflict Partial Order Causal Link) Planning Algorithm

CPOCL ($\Pi = \langle S, B, O, L, I \rangle$, Λ, F)

Π is a plan, initially the null plan, with steps S, variable bindings B, ordering constraints O, causal links L, and intention frames I; Λ a set of operators; F a set of flaws, initially open precondition flaws for unsatisfied preconditions of the end step and unsatisfied intention frame flaws for start step effects like $intends(c, g)$.

Termination: If B or O is inconsistent, fail. If $F = \emptyset$ and Π has no orphans, return Π. If orphans exist, fail.
Plan Refinement: Choose a flaw $f \in F$. Let $F' = F - \{f\}$.
    Goal Planning: If f is open precondition flaw $f = \langle s_{need}, p \rangle$, let s_{add} be a step $\langle P, E, C \rangle$ such that $p \in E$.
        Choose s_{add} in one of two ways:
            Reuse: Choose s_{add} from S.
            New Step: Create s_{add} from an operator in Λ with effect p. Let $S' = S + \{s_{add}\}$.
                For each precondition pre of s_{add}, add new open precondition flaw $\langle s_{add}, pre \rangle$ to F'.
                Mark s_{add} as non-executed.
        Link: Create causal link $l = s_{add} \xrightarrow{p} s_{need}$. Let $L' = L + \{l\}$, $B' = B \cup \text{MGU}(e, p)$, $O' = O + \{s_{add} < s_{need}\}$.
        Execution Marking: If s_{need} is executed, mark s_{add} and all its causal ancestors as executed.
        Happening Frame: If $P = \emptyset$, create new intention frame $r = \langle fate, \emptyset, s_{add}, s_{add}, \{s_{add}\} \rangle$. Let $I' = I + \{r\}$.
        New Frames: For each effect of s_{add} like $intends(c, g)$:
            Create new intention frame $r = \langle c, g, s_{add}, \emptyset, \emptyset \rangle$. Let $I' = I + \{r\}$.
            Add new unsatisfied intention frame flaw $\langle r \rangle$ to F'.
        Intent Flaws: For each intention frame $r = \langle c, g, \sigma, m, T \rangle \in I'$:
            If $s_{add} \notin T$ and $s_{need} \in T$ and $c \in C$ for s_{add}, add new intent flaw $\langle s_{add}, r \rangle$ to F'.
    Threat Resolution: If f is threatened causal link flaw $f = \left\langle s \xrightarrow{p} u, t \right\rangle$, choose how to prevent the threat:
        Promotion: Let $O' = O' + \{t < s\}$.
        Demotion: Let $O' = O' + \{u < t\}$.
        Restriction: Add bindings to B' which cause the threatening effect of t not to unify with p.
    Satisfaction: If f is unsatisfied intention frame flaw $f = \langle r = \langle c, g, m, \emptyset, T \rangle \rangle$, let s_{sat} be a step with effect g.
        Choose s_{sat} the way s_{add} is chosen (**Reuse** or **New Step**) or by **Persistence**.
            Persistence: Make a persistence step $s_{sat} = \langle \{g\}, \{g\}, \{c\}, false \rangle$. Let $O' = O + \{s_{sat} = s_{end}\}$.
        Let $T' = T + \{s_{sat}\}$. Let $r' = \langle c, g, m, s_{sat}, T' \rangle$. Let $I' = I - \{r\} + \{r'\}$.
    Intent Planning: If f is an intent flaw $f = \langle s_{orphan}, r = \langle c, g, m, \sigma, T \rangle \rangle$, choose how to handle s_{orphan}:
        Inclusion: Let $T' = T + \{s_{orphan}\}$. Let $r' = \langle c, g, m, \sigma, T' \rangle$, $I' = I - \{r\} + \{r'\}$, $O' = O + \{m < s_{orphan}\}$.
            For each causal link $s \xrightarrow{p} s_{orphan} \in L$, if $c \in C$ for s, add new intent flaw $\langle s, r' \rangle$ to F'.
        Exclusion: Do nothing.
Threat Detection: If any casual link $l \in L'$ is threatened by step $\theta \in S'$ and l is not a conflict link,
    Add new threatened causal link flaw $\langle l, \theta \rangle$ to F'.
Recursive Invocation: Call CPOCL ($\Pi' = \langle S', B', O', L', I' \rangle$, F', Λ).

Algorithm – Open Precondition Flaws

- Add step or reuse step
- New steps are initially nonexecuted
- If causal link is from nonexecuted step to executed step, then all causal ancestors of tail become executed
- Happening actions need individual intention frames with a Fate actor.
- New steps with intend effects must create a new intention frame
- Create new intent flaws

Goal Planning: If f is open precondition flaw $f = \langle s_{need}, p \rangle$, let s_{add} be a step $\langle P, E, C \rangle$ such that $p \in E$.
Choose s_{add} in one of two ways:
Reuse: Choose s_{add} from S.
New Step: Create s_{add} from an operator in Λ with effect p. Let $S' = S + \{s_{add}\}$.
For each precondition pre of s_{add}, add new open precondition flaw $\langle s_{add}, pre \rangle$ to F'.
Mark s_{add} as non-executed.
Link: Create causal link $l = s_{add} \xrightarrow{p} s_{need}$. Let $L' = L + \{l\}$, $B' = B \cup \text{MGU}(e, p)$, $O' = O + \{s_{add} < s_{need}\}$.
Execution Marking: If s_{need} is executed, mark s_{add} and all its causal ancestors as executed.
Happening Frame: If $P = \emptyset$, create new intention frame $r = \langle fate, \emptyset, s_{add}, s_{add}, \{s_{add}\} \rangle$. Let $I' = I + \{r\}$.
New Frames: For each effect of s_{add} like $intends(c, g)$:
Create new intention frame $r = \langle c, g, s_{add}, \emptyset, \emptyset \rangle$. Let $I' = I + \{r\}$.
Add new unsatisfied intention frame flaw $\langle r \rangle$ to F'.
Intent Flaws: For each intention frame $r = \langle c, g, \sigma, m, T \rangle \in I'$:
If $s_{add} \notin T$ and $s_{need} \in T$ and $c \in C$ for s_{add}, add new intent flaw $\langle s_{add}, r \rangle$ to F'.

Algorithm – Threatened Causal Link Flaw

Threat Resolution: If f is threatened causal link flaw $f = \left\langle s \xrightarrow{p} u, t \right\rangle$, choose how to prevent the threat:

Promotion: Let $O' = O' + \{t < s\}$.

Demotion: Let $O' = O' + \{u < t\}$.

Restriction: Add bindings to B' which cause the threatening effect of t not to unify with p.

- Mostly identical to traditional POCL threatened causal link flaw resolution

Algorithm – Unsat Intention Frame Flaw

21: **Satisfaction:** If f is unsatisfied intention frame flaw $f = \langle r = \langle c, g, m, \emptyset, T \rangle \rangle$, let s_{sat} be a step with effect g.
22: Choose s_{sat} the way s_{add} is chosen (**Reuse** or **New Step**) or by **Persistence**.
23: **Persistence:** Make a persistence step $s_{sat} = \langle \{g\}, \{g\}, \{c\}, false \rangle$. Let $O' = O + \{s_{sat} = s_{end}\}$.
24: Let $T' = T + \{s_{sat}\}$. Let $r' = \langle c, g, m, s_{sat}, T' \rangle$. Let $I' = I - \{r\} + \{r'\}$.

- A satisfying step hasn't been selected for a specific intention frame
- Satisfying step chosen through reuse, adding a new step, or by persisting a goal.
- Once a step is chosen then all steps taken in pursuit of that goal must be added to the intention frame

Algorithm – Intent Flaw

Intent Planning: If f is an intent flaw $f = \langle s_{orphan}, r = \langle c, g, m, \sigma, T \rangle \rangle$, choose how to handle s_{orphan}:

Inclusion: Let $T' = T + \{s_{orphan}\}$. Let $r' = \langle c, g, m, \sigma, T' \rangle$, $I' = I - \{r\} + \{r'\}$, $O' = O + \{m < s_{orphan}\}$.

For each causal link $s \xrightarrow{p} s_{orphan} \in L$, if $c \in C$ for s, add new intent flaw $\langle s, r' \rangle$ to F'.

Exclusion: Do nothing.

- Intent flaws were identified earlier in open precondition flaw resolution
- Occur when the two ends of a causal link don't share an intention frame
- Solved in two ways:
  - Add a step to the frame, nullifying the condition of the flaw
  - Ignore the flaw (necessary to ensure valid plans, can create orphans)

Solution Space

- All narrative planners are searching the space of partial plans
- POCL planners find plans that reach the goal from the initial state
- IPOCL planners restrict the POCL plan space by enforcing that nonhappening actions are intentional
- CPOCL planners loosen the IPOCL plan space by allowing characters to fail in their plans to achieve a goal

1st Experiment

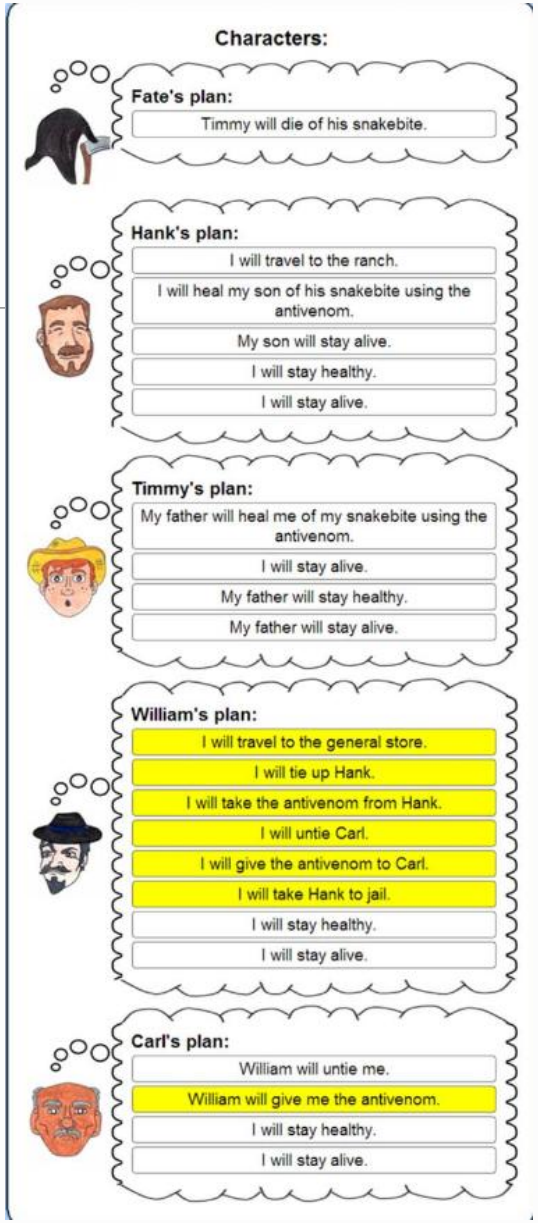
- Validation:
  - Plan-based structure for narrative
  - Participants, reason, and duration
- Gauge how good CPOCL is at determining conflict with participant, reason, and duration with respect to human annotation
- Minimum threshold of participants found that maiximized average accuracy of subjects

TABLE II
THRESHOLD VALUES FOR EACH STORY

Story	min θ	max θ	Average Accuracy
Western	12 (48%)	19 (76%)	80%
Fantasy	8 (33%)	21 (88%)	81%
Space	4 (16%)	16 (64%)	80%

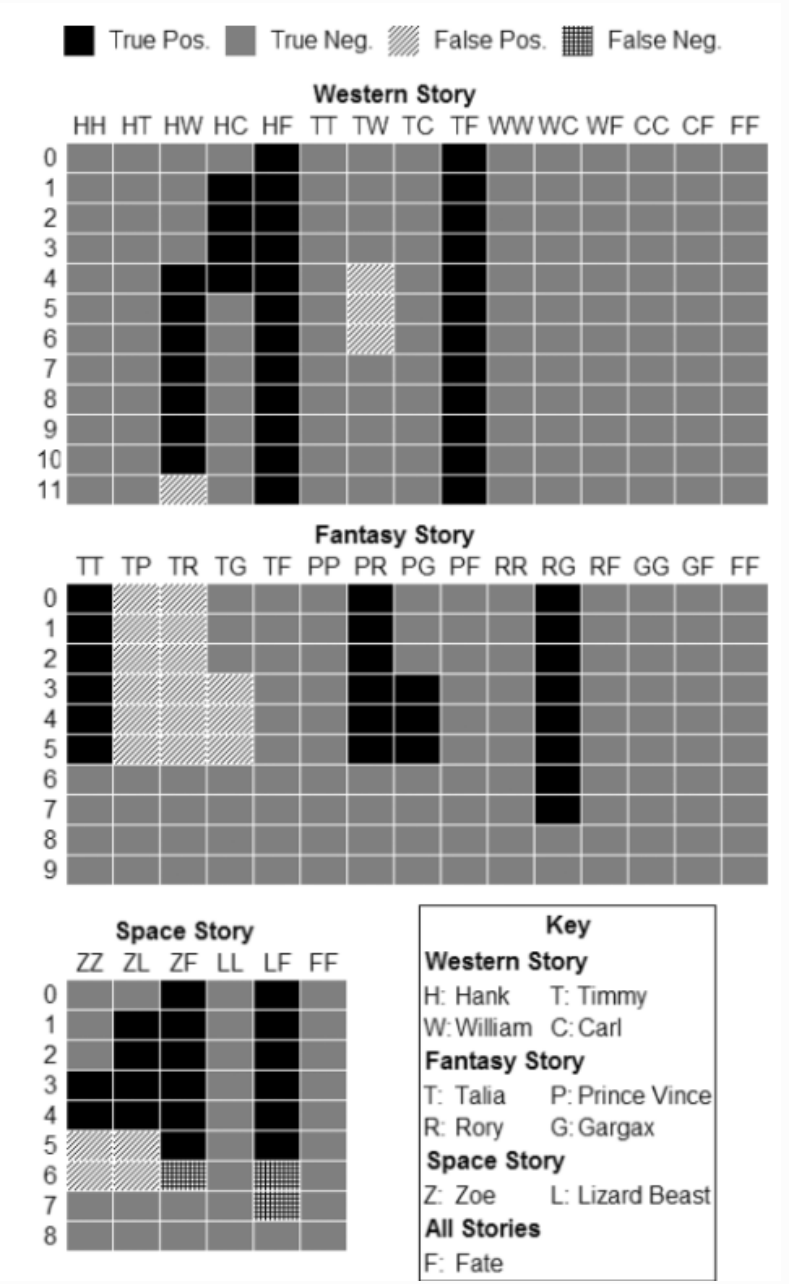
TABLE IV
CPOCL'S ACCURACY (ACC.), PRECISION (PRE.) AND RECALL (REC.) FOR BOTH TASKS

	Task 1			Task 2		
Story	Acc.	Pre.	Rec.	Acc.	Pre.	Rec.
Western	0.81	0.57	1.00	0.98	0.90	1.00
Fantasy	0.79	0.50	1.00	0.90	0.61	1.00
Space	0.86	0.67	1.00	0.87	0.82	0.86
Average	**0.82**	**0.58**	**1.00**	**0.92**	**0.77**	**0.95**



2nd Experiment

- How long are two characters in conflict?
- Compared answers of human subjects vs CPOCL
- True positives – both in agreement
- False Positives – human says no, CPOCL says yes



Dimension Validation

- Human subjects told to rank 4 stories (from western domain) based on balance, directness, stakes, and resolution
- Grey boxes indicate the calculated dimensional score, values indicate Kendall's distance

TABLE VII
TOP SIX AND BOTTOM ONE ORDERINGS FOR DIMENSIONS BASED ON τ_{avg} (PREDICTED ORDERINGS IN GRAY)

Balance		Directness		Stakes		Resolution	
Order	τ_{avg}	**Order**	τ_{avg}	**Order**	τ_{avg}	**Order**	τ_{avg}
C D A B	1.26667	B A C D	0.56667	B A C D	1.73333	D C B A	0.66667
C D B A	1.66667	B A D C	0.96667	B A D C	1.93333	D C A B	1.20000
D C A B	1.73333	A B C D	1.36667	A B C D	2.13333	C D B A	1.40000
C A D B	2.00000	B C A D	1.36667	B C A D	2.26667	D B C A	1.40000
D C B A	2.13333	A B D C	1.76667	A B D C	2.33333	C D A B	1.93333
C B D A	2.26667	B D A C	1.90000	B D A C	2.33333	D A C B	1.93333
(17 omitted)	(17 omitted)	(17 omitted)	(17 omitted)	(17 omitted)	(17 omitted)	(17 omitted)	(17 omitted)
B A D C	4.73333	D C A B	5.43333	D C A B	4.26667	A B C D	5.33333

Questions