Change the Plan - How hard can that be?

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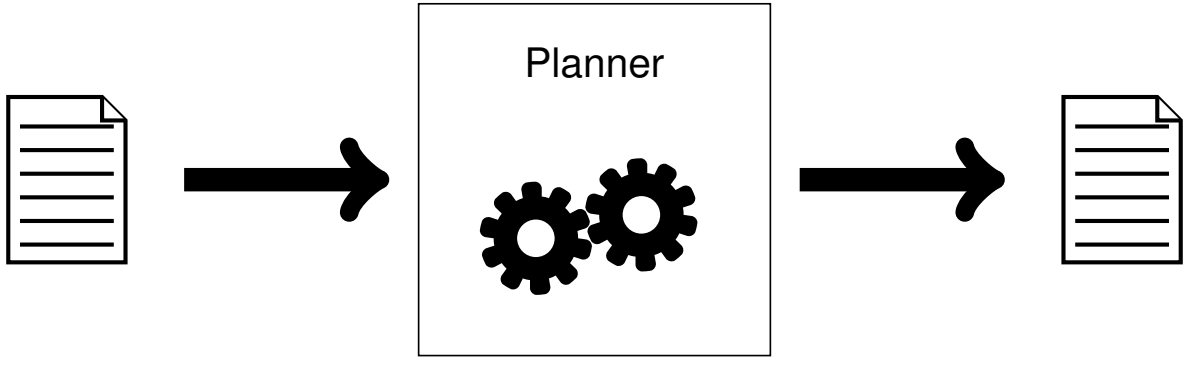
Changing Plans



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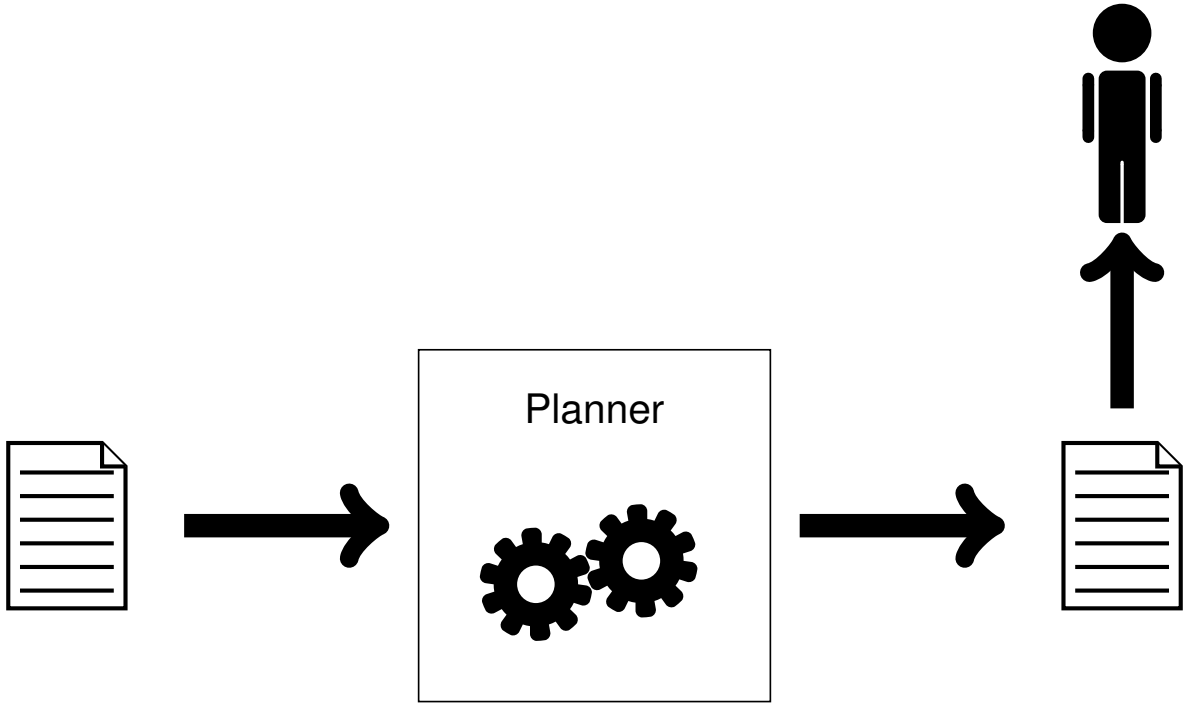

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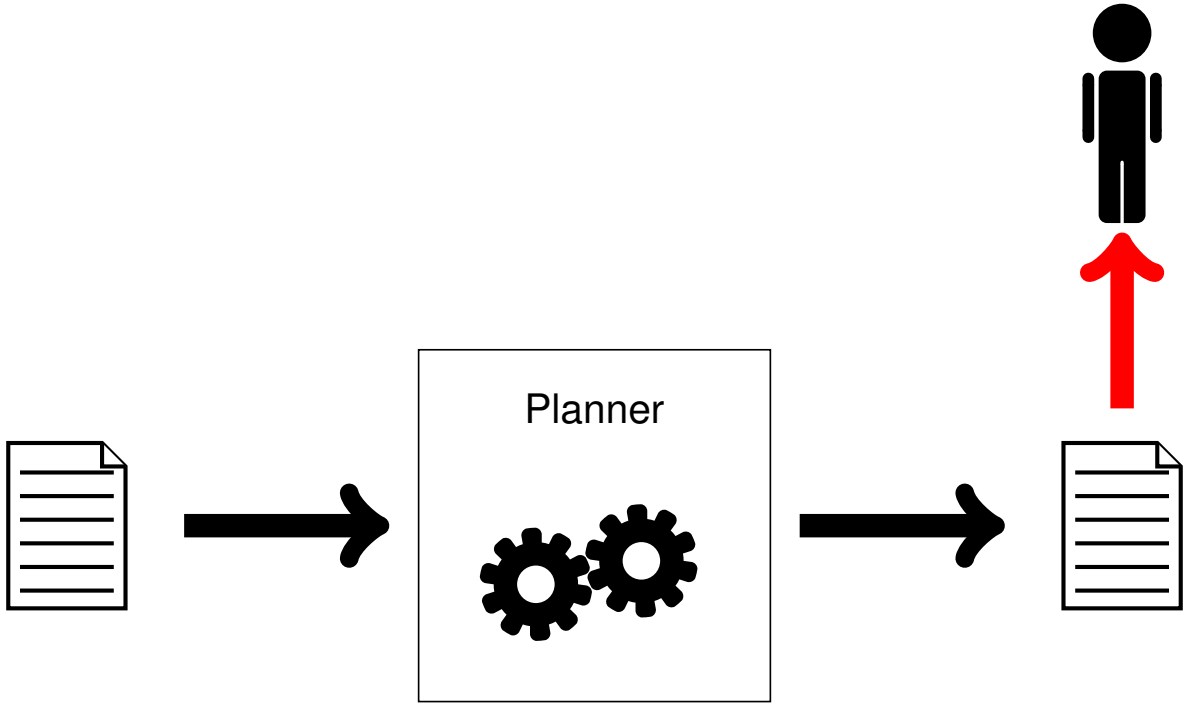

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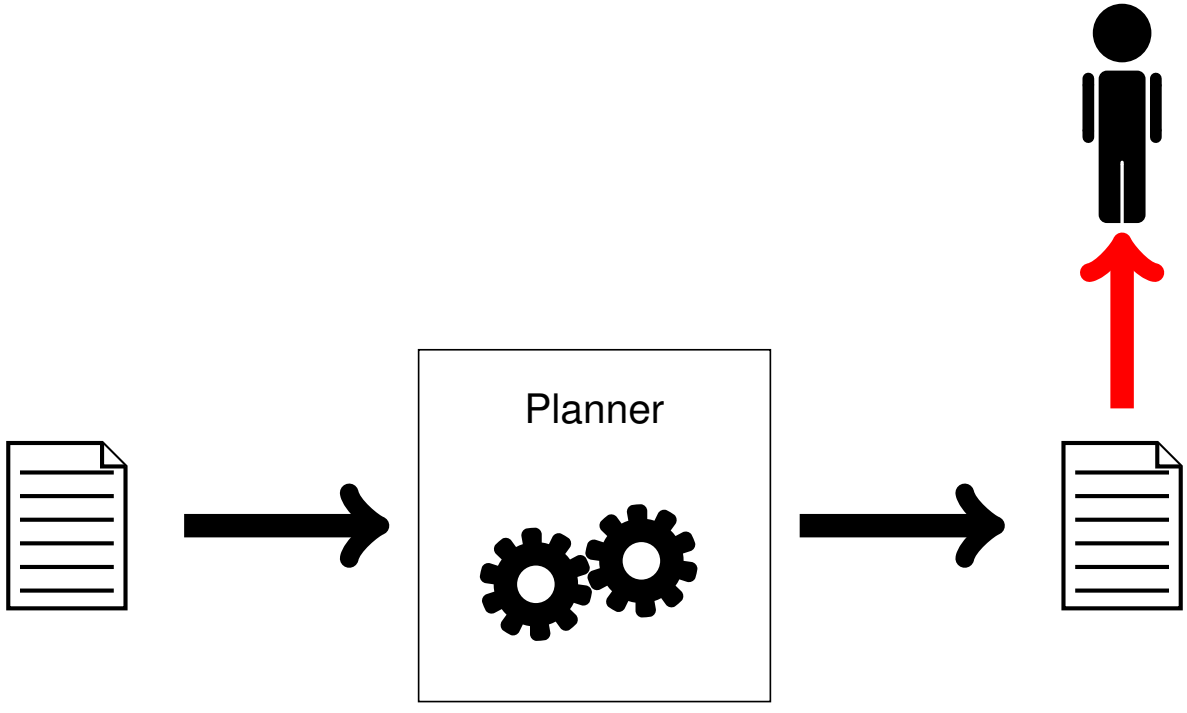

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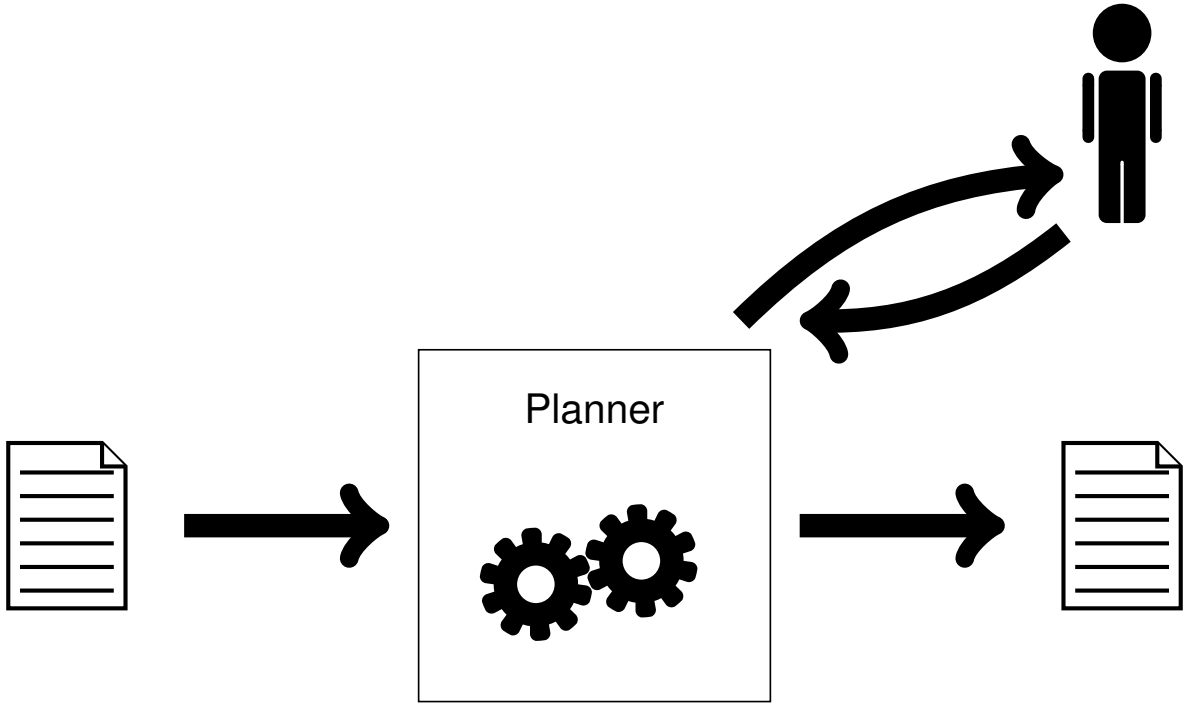

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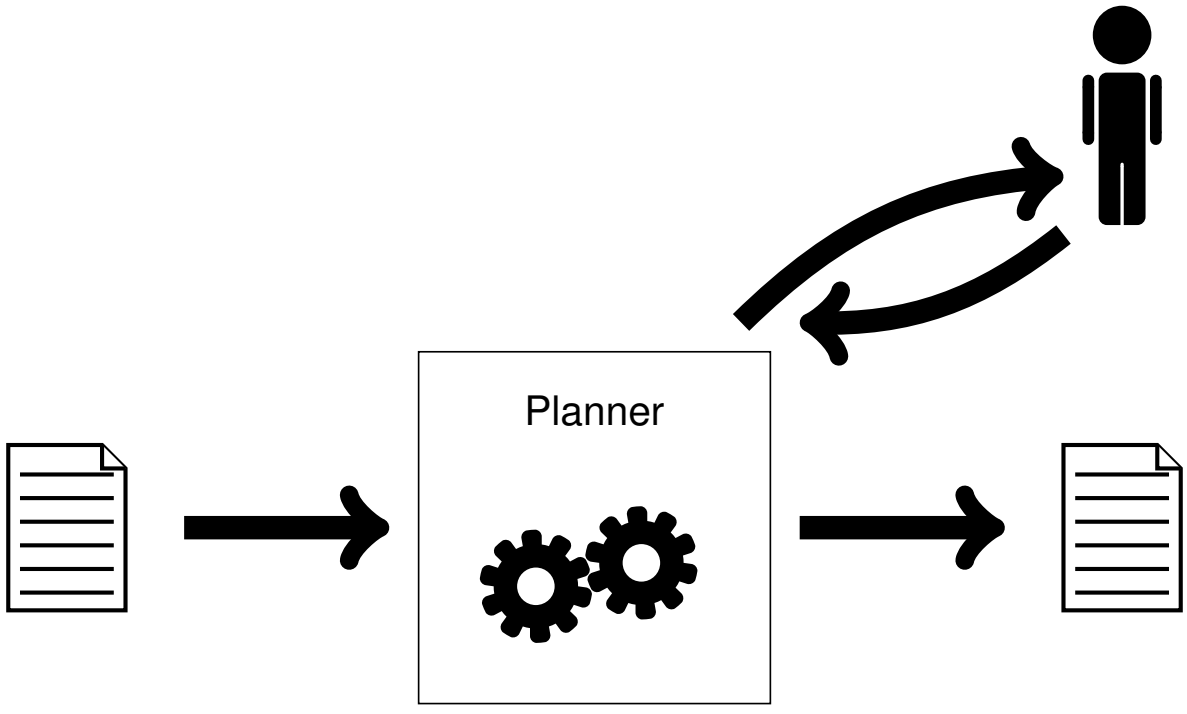

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$\Rightarrow$ We have to allow for changes to plans

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Changing plans is important for user-centred planning applications,
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We want to understand its theoretical foundations

- Discuss what changing plans means in an HTN context
- Provide formal descriptions of several change operations
- Investigate their computational complexity

Hierarchical Task Network (HTN) Planning

$$\mathcal{P} = (P, C, c_I, M, L, s_I)$$

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primitive compound

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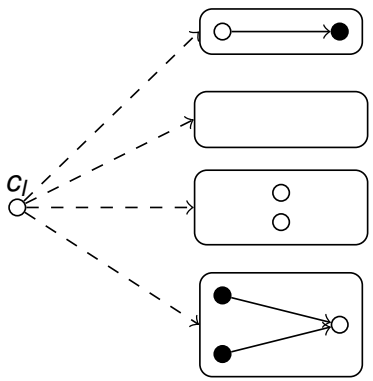

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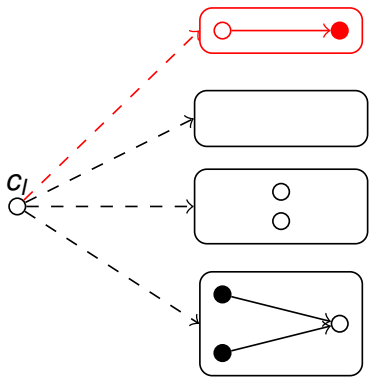

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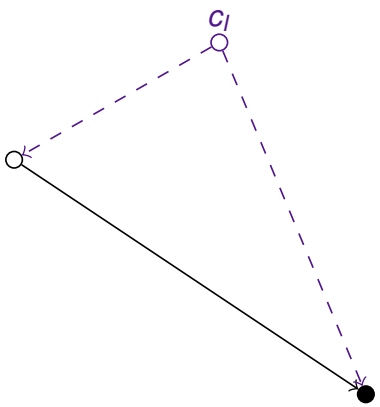

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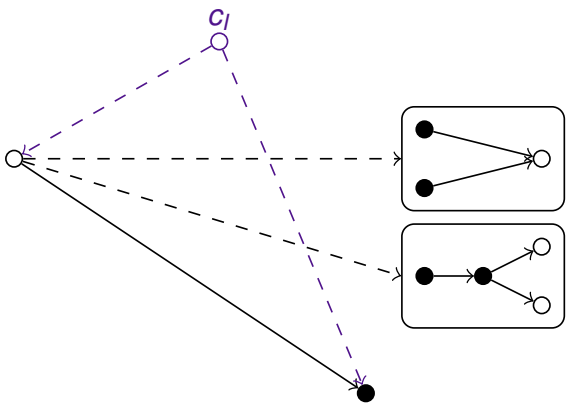

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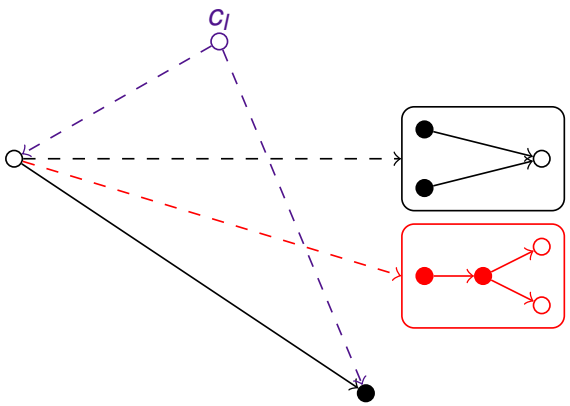

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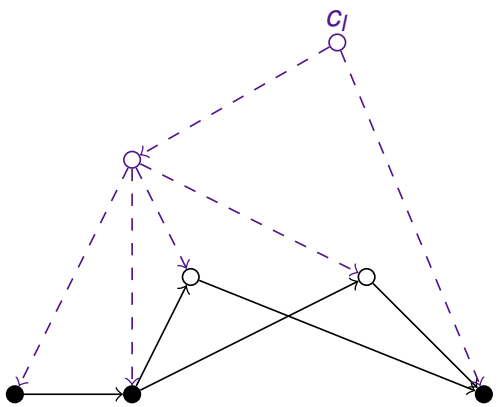

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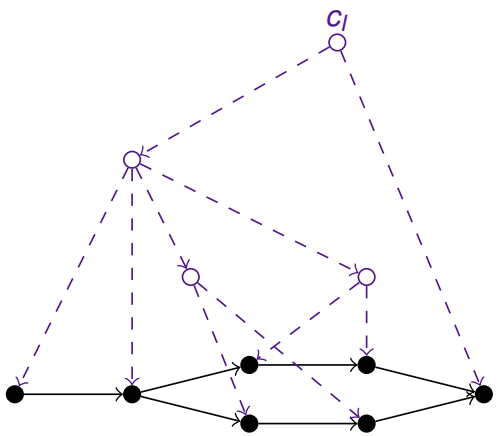

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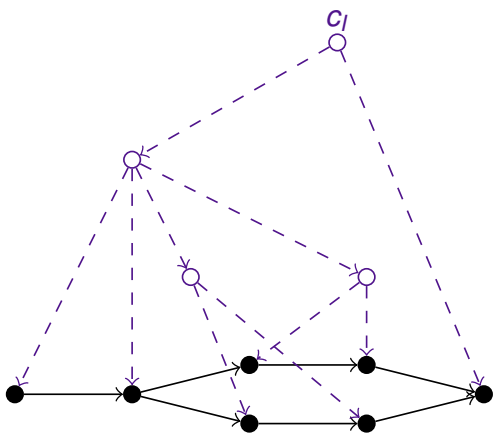

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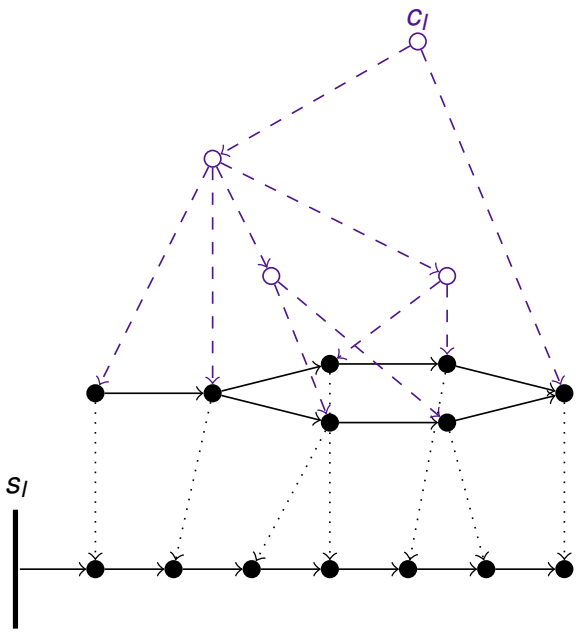

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- only contain primitive tasks
- have a linearization, executable from the initial state

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Results

We've investigated a wide range of change requests

- 5 request objectives
- 3 request restrictions

	add	delete	exchange	order	avoid effect
no changes	**NP**	**NP**	**NP**	**NP**	**NP**
k changes	**NEXPTIME**	**NEXPTIME**	**NEXPTIME**	**NEXPTIME**	**NEXPTIME**
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- Most proofs are structurally similar
- We will only show one from each group

Add Task – no changes

Definition (ADD-NO-CHANGE)

Given a planning problem $\mathcal{P}$, a solution $tn \in Sol(\mathcal{P})$, and task t.
ADD-NO-CHANGE is to decide whether the task network tn', which is tn with an additional task t and some ordering constraints added, is still a solution.

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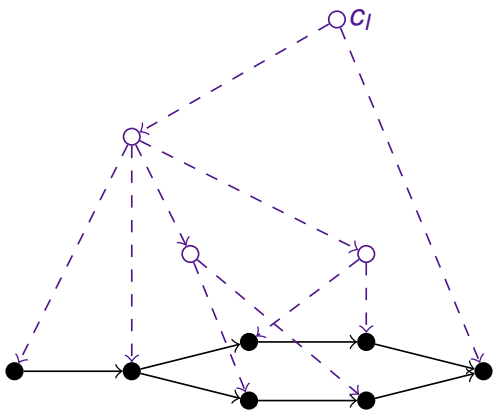

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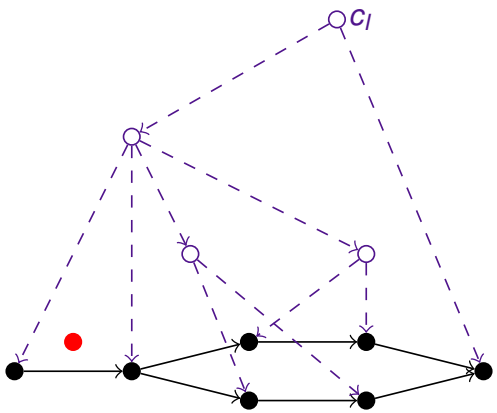

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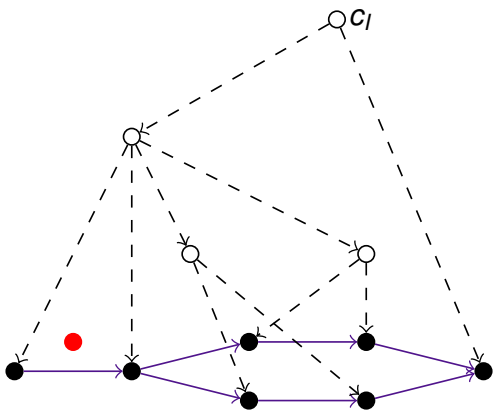

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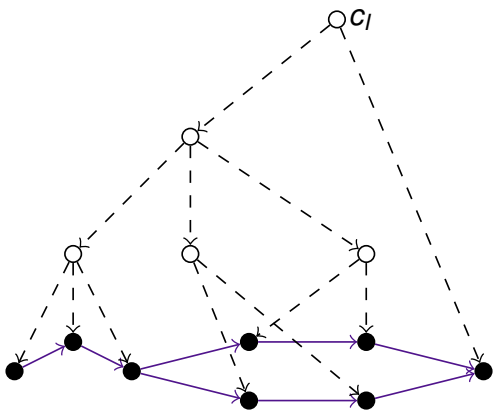

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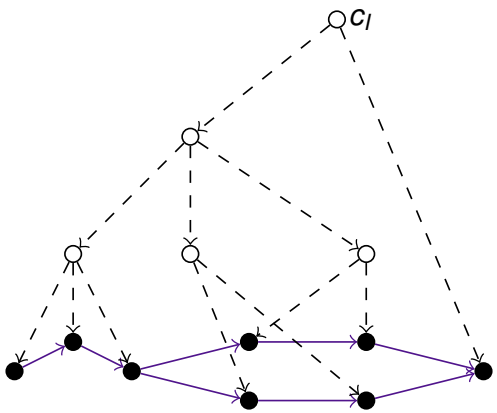

- Decomposition becomes invalid
- We (potentially) have to find a new linearisation

Plan Verification

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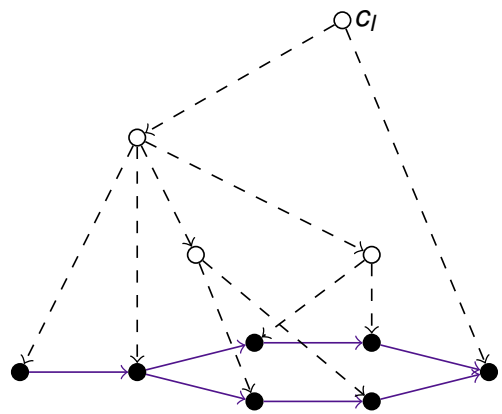

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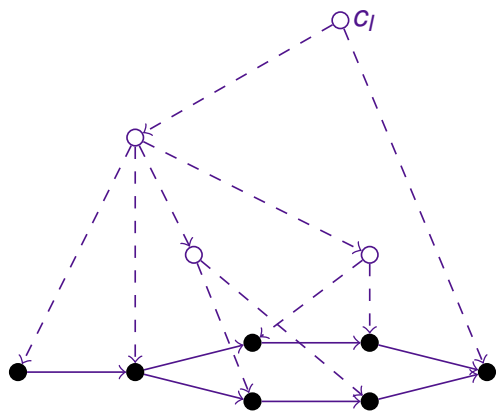

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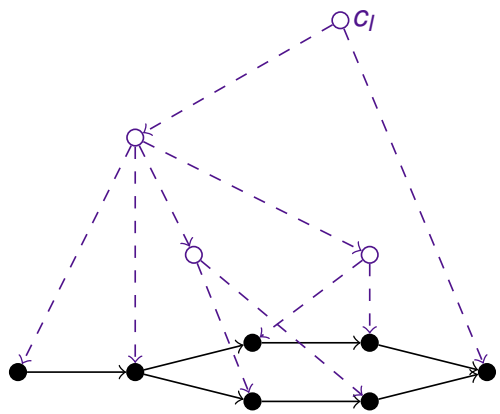

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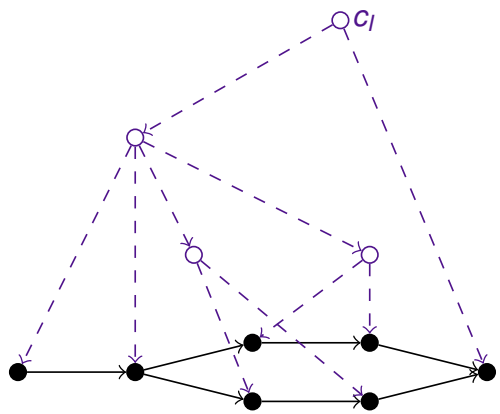

Theorem

VERIFYTN *is* **NP***-complete*

Add Task – no changes

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Proof:

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Proof: Membership:

- Add the new task t and guess some additional ordering constraints
- Check the resulting task network using the **NP** algorithm for VERIFYTN

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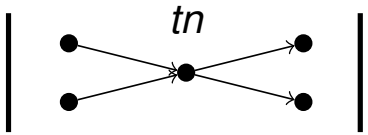

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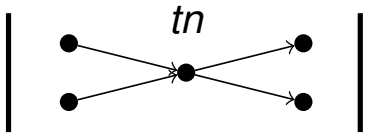

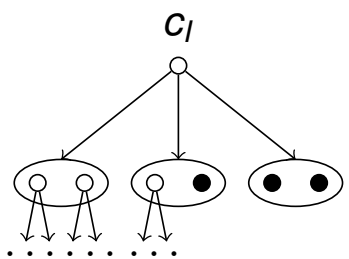

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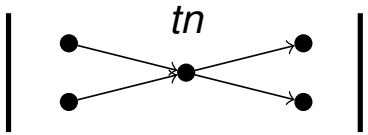

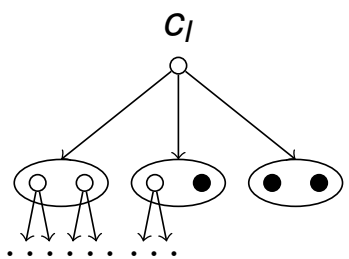

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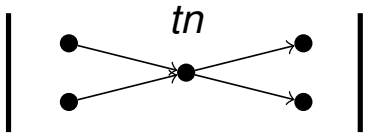

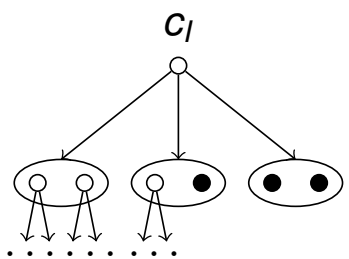

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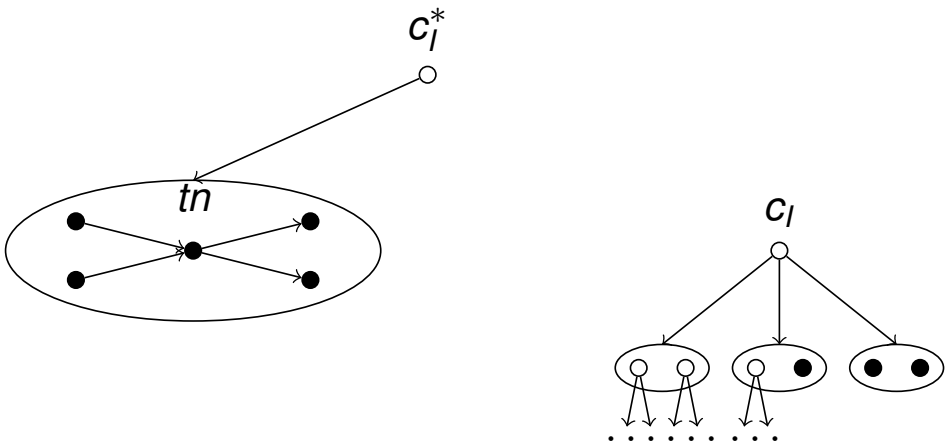

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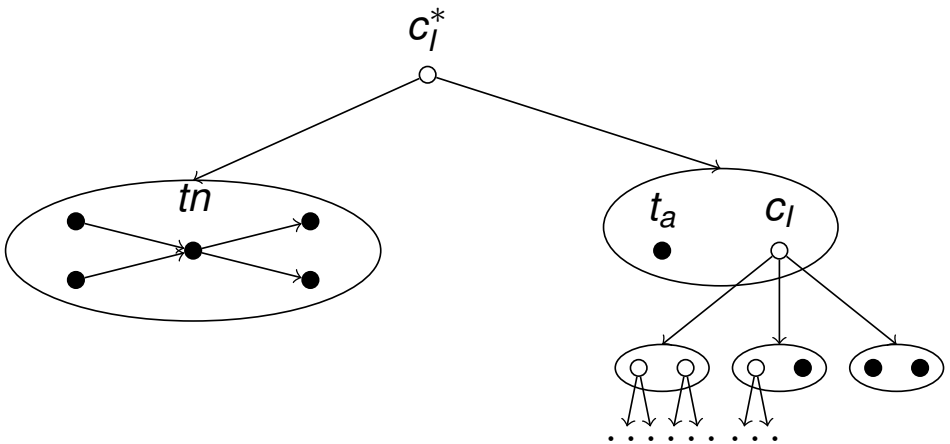

- Can we add t_a to tn?

□

Add Ordering – k changes

Definition (ORDERING-K-CHANGE)

Given a planning problem $\mathcal{P}$, a solution $tn \in Sol(\mathcal{P})$, and two tasks t_1, t_2 from tn. ORDERING-K-CHANGE is to decide whether another solution tn' can be obtained from tn by at most k of the following operations

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such that $t_1 < t_2$ holds in tn' and neither t_1 nor t_2 are deleted.

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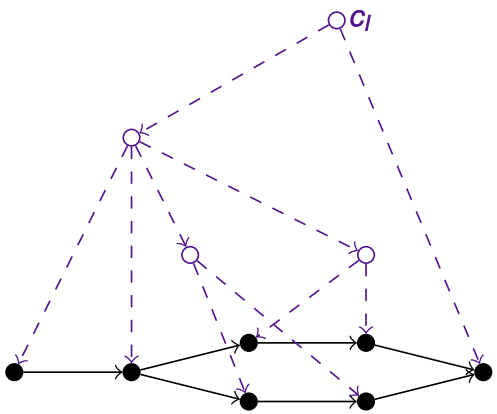

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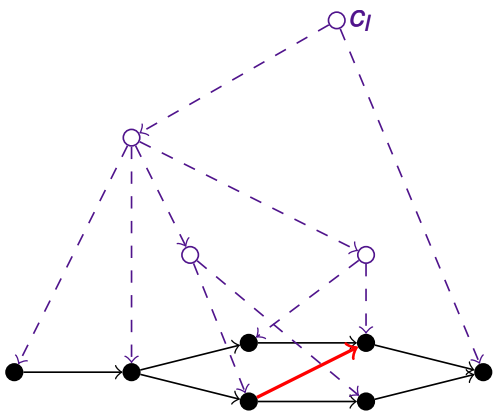

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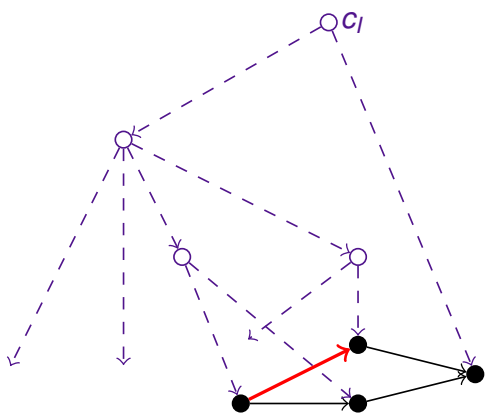

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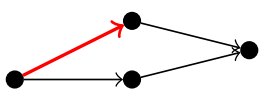

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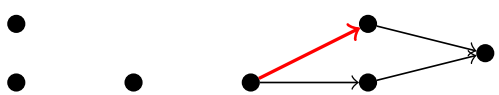

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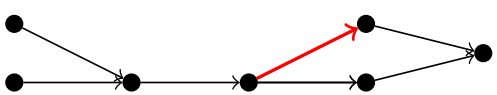

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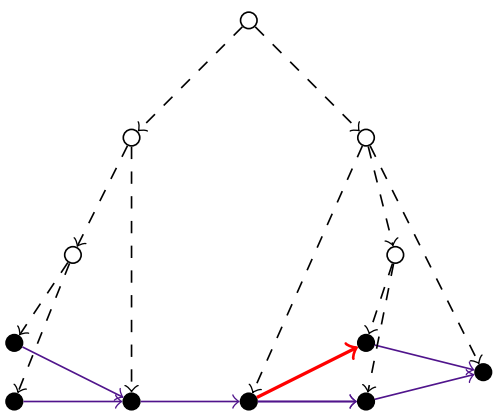

- Remove tasks
- Old decomposition becomes invalid
- Add new tasks
- Add new ordering constraints
- Find new decomposition

Add Ordering – k changes

Theorem

ORDERING-K-CHANGE *is* **NEXPTIME***-complete.*

Proof:

Add Ordering – k changes

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Proof: Membership:

- Guess a number $l \leq k$
- Apply l allowed operations to the task network tn
- Check the resulting task network using the **NP** algorithm for VERIFYTN

Add Ordering – k changes

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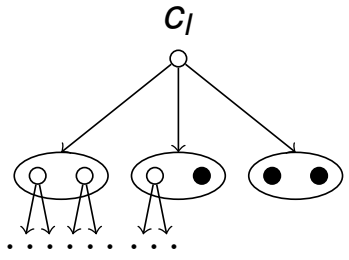
Proof: Hardness: Reduction from SOLUTION in acyclic HTNs.



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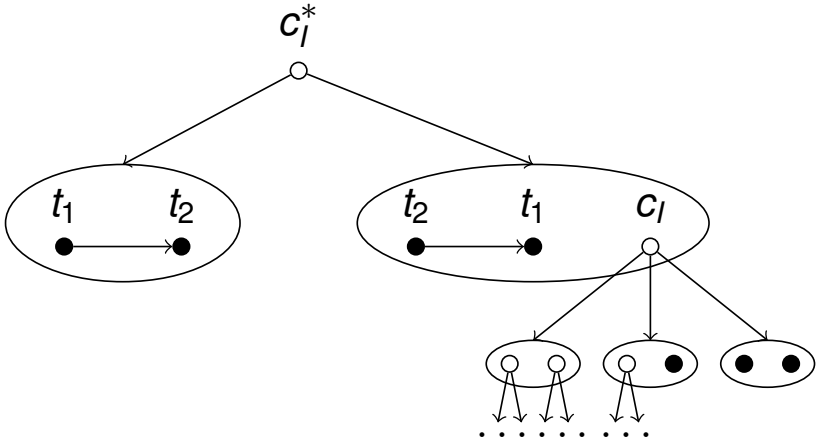

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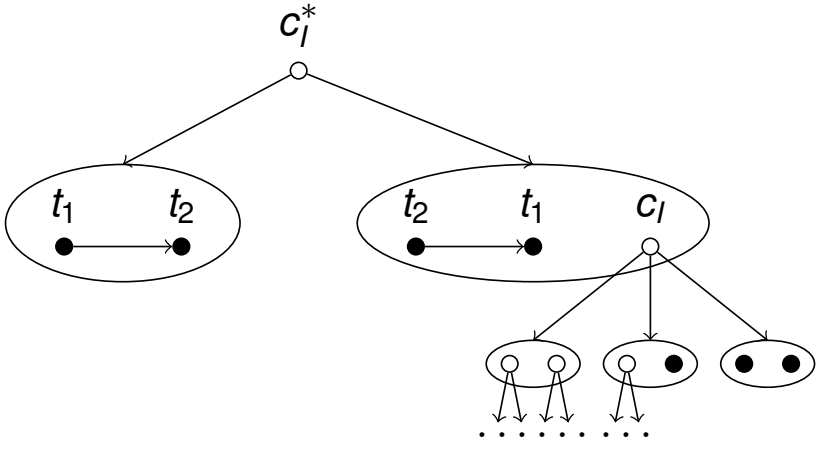

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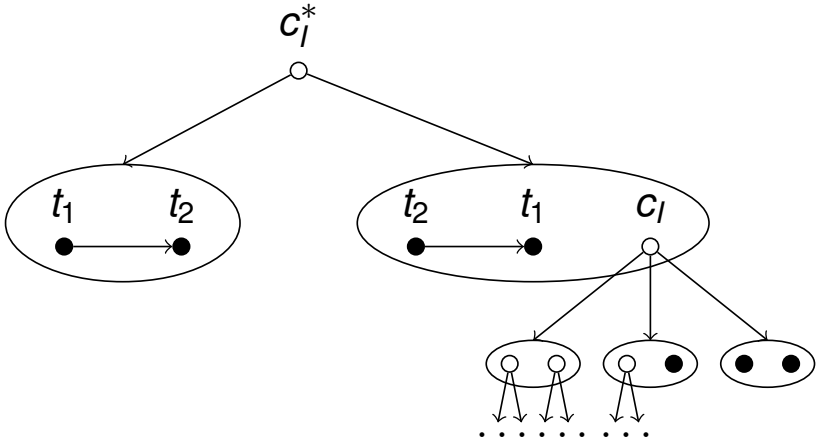

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- Choose $k = m^{|C|} + (m^{|C|})^2$

□

Add Ordering – any changes

Definition (ORDERING-ANY-CHANGE)

Given a planning problem $\mathcal{P}$, a solution $tn \in Sol(\mathcal{P})$, and two tasks t_1, t_2. Is there any solution to $\mathcal{P}$ containing t_1 and t_2 and the ordering constraint $t_1 < t_2$?

Add Ordering – any changes

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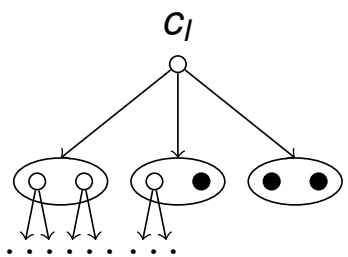
- The solution *tn* does not really help

Add Ordering – any changes

Theorem

ORDERING-ANY-SOLUTION *is undecidable.*

Proof:



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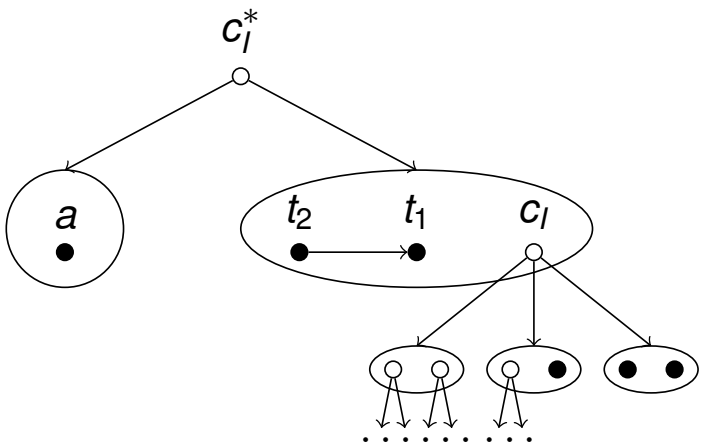

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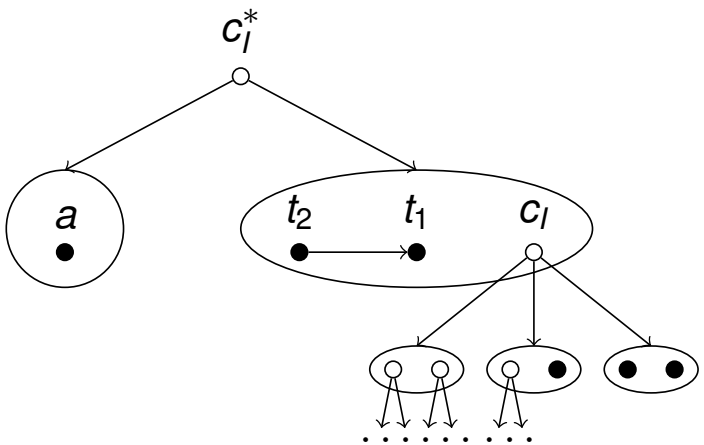

- The task network containing only a is a solution
- Ask whether a solution containing $t_1 < t_2$ exists

□

Conclusion

- Adding ordering constraints or actions to HTN Plans is
  - **NP**-*complete* if we can't alter the plan otherwise
  - **NEXPTIME**-*complete* if we can perform up to k changing operations
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Further results can be combined to obtain the following classification

	add	delete	exchange	order	avoid effect
no changes	**NP**	**NP**	**NP**	**NP**	**NP**
k changes	**NEXPTIME**	**NEXPTIME**	**NEXPTIME**	**NEXPTIME**	**NEXPTIME**
any changes	*un-dec*	*un-dec*	*un-dec*	*un-dec*	*un-dec*

Provided the first theoretical investigation of MIP requests to change plan