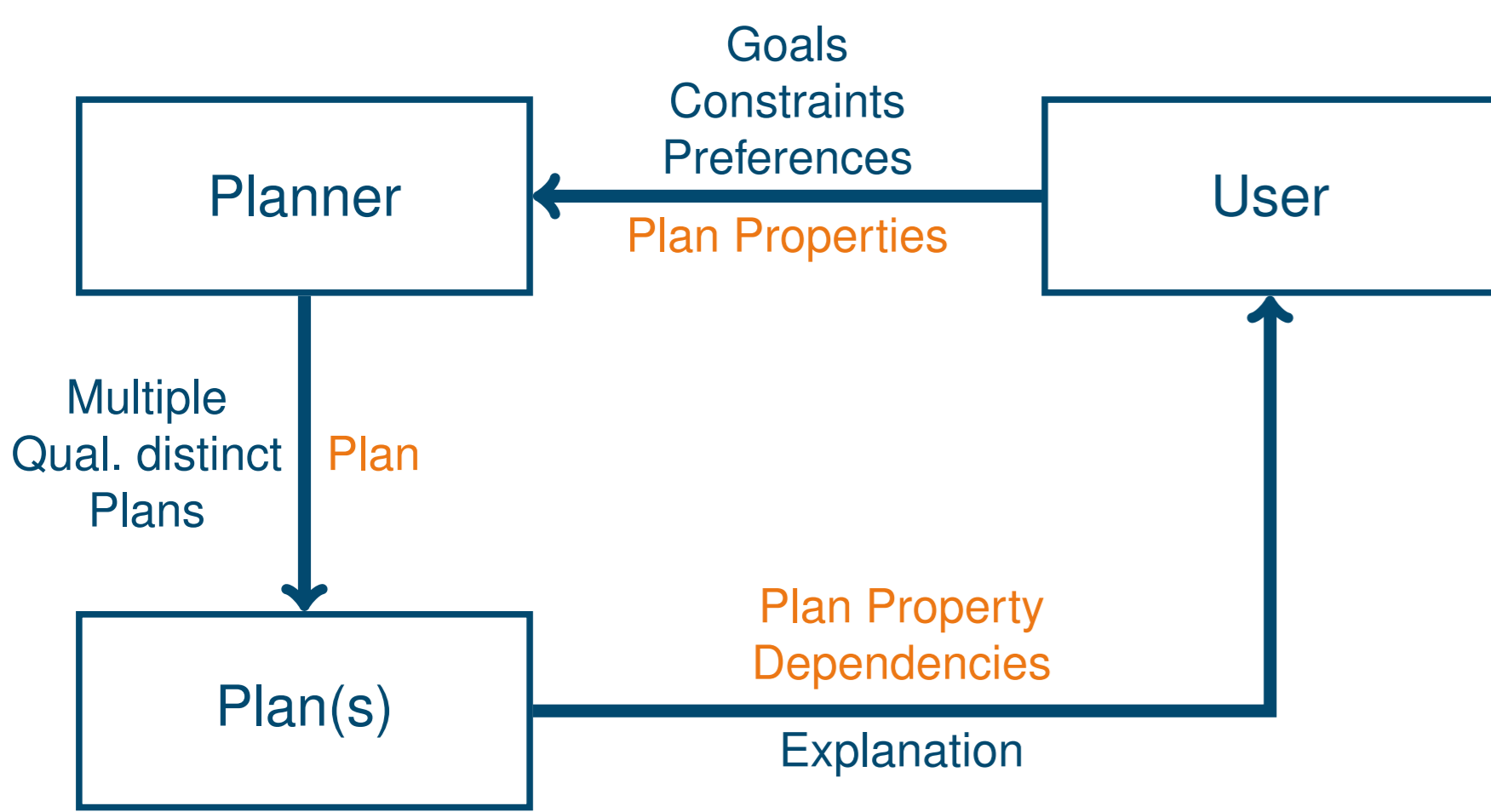


# Iterative Planning with Plan-Space Explanations: A Tool and User Study

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## Planning as an Iterative Process [3]



## Platform - Iterative Planning Interface

1) graphical representation of the planning task for layer person

2) hard goals and the additionally satisfied soft goals of the selected plan

3) questions and answers for the current plan

4) interface for selecting the hard goals for the next iteration

## Platform - Key Features

The Web-based platform supports/provides:

**Iterative Planning** with plan properties representing goals and preferences

**Changing Preferences** reflected by enforcing plan properties across planning iterations

**Explanations:** ask contrastive questions about the iteratively refined plans

**New Issues:** adding new plan properties to hone in on new issues that become apparent during the iterative planning process

**Layer Person:** simplified version with fixed set of plan properties, enriched visualization of the planning task

**User Study:** for developers and test persons

## Platform - Questions and Answers

### solvable hard goals

**Question:** selection of not satisfied soft goals  $P_Q$

**Answer:** plan properties you have to give up, when enforcing  $P_Q$

Why not ... ?

- Package 4 is delivered to the packing station
- The same truck is used for package 0 and 2
- The road between the cafe and the packing station is not used with the red Truck
- Package 4 is delivered to the post office
- Package 0 is delivered before package 1

Question

Why not ...

Package 4 is delivered to the post office

Answer

... because then you have to live without:

- You have to give up at least one of ...
- Package 1 is delivered to the green house
- You have to give up at least one of ...
- Package 2 is delivered to the blue house and
- The same truck is used for package 2 and 3

### unsolvable hard goals

**Answer:** smallest subsets of hard goals causing unsolvability

Question

Why is the selection of hard goals unsolvable?

Answer

... because you can not satisfy all properties in:

- Package 2 is delivered to the blue house
- The same truck is used for package 0 and 2

## Framework [1, 2]

### Oversubscription Planning (OSP) Task

- $V$ : variables
- $A$ : actions
- $c: A \mapsto \mathbb{R}_0^+$ : cost
- $I$ : initial state
- $G^{\text{hard}}$ : hard goals
- $G^{\text{soft}}$ : soft goals
- $b \in \mathbb{R}_0^+$ : cost bound

Plan:  $\pi = \langle a_1, \dots, a_n \rangle$  applicable in  $I$  and  $\sum_{i=1}^n c(a_i) \leq b$

### Plan Property

- Propositional formula  $p$  over atoms  $g \in G^{\text{soft}}$
- In general: function  $p: \Pi \mapsto \{\text{true}, \text{false}\}$
- Language: LTLf over facts and actions

### $\Pi$ -Entailment

OSP task  $\tau = (V, A, c, I, G^{\text{hard}}, G^{\text{soft}}, b)$ ,  $\Pi$  its set of plans  $\pi$ .

- $\mathcal{M}_\Pi(p) := \{\pi \mid \pi \in \Pi, \pi \models p\}$
- $p$   $\Pi$ -entails  $q$ , written  $\Pi \models p \Rightarrow q$ : if  $\mathcal{M}_\Pi(p) \subseteq \mathcal{M}_\Pi(q)$

## Platform - Input

**Domain/Problem:** PDDL files

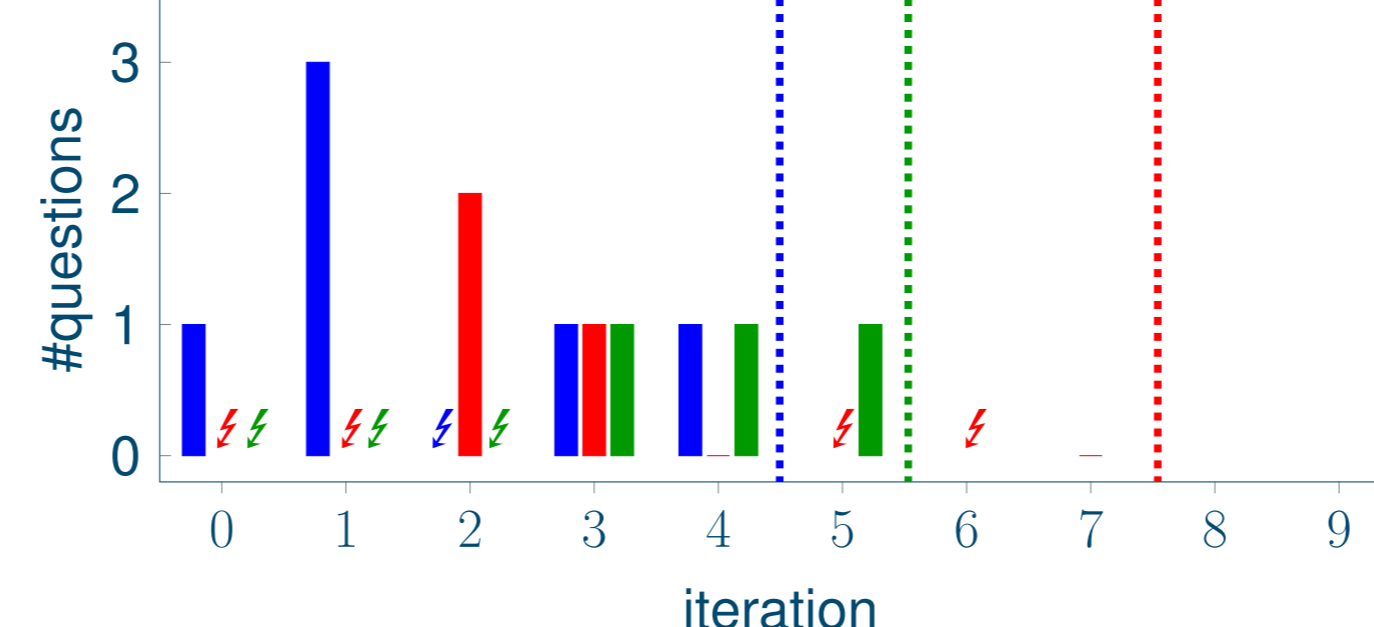
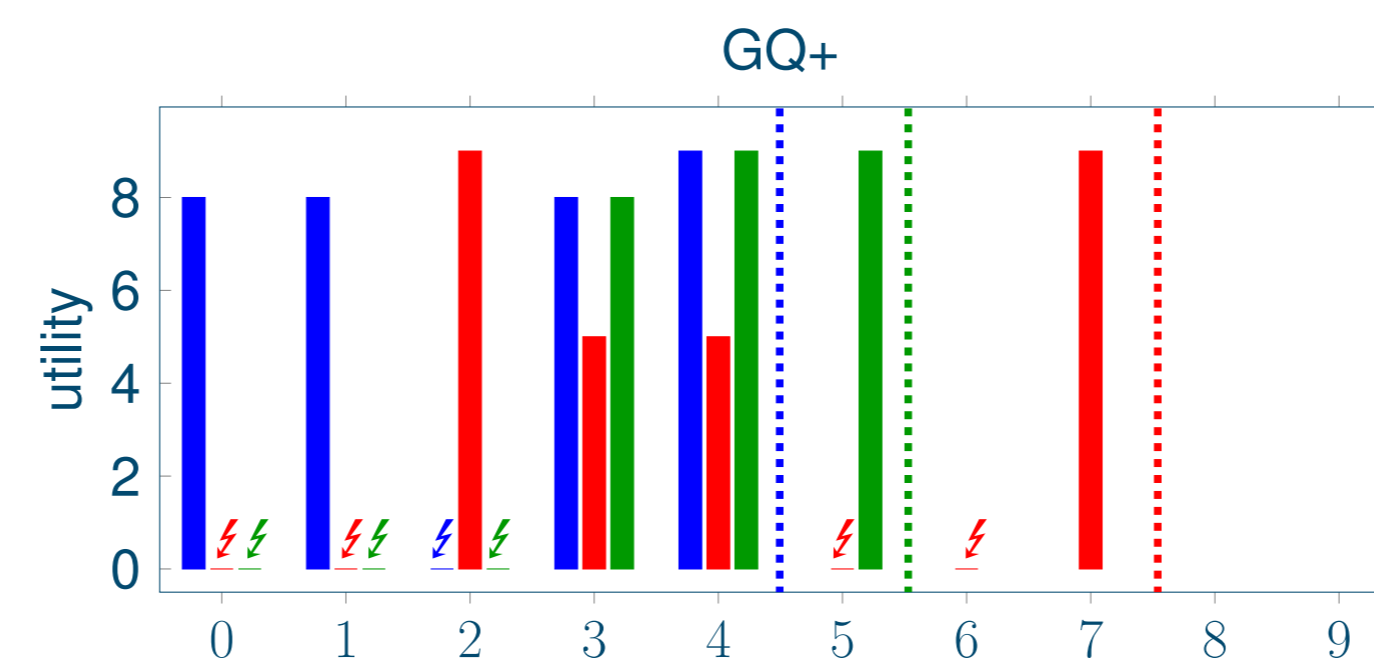
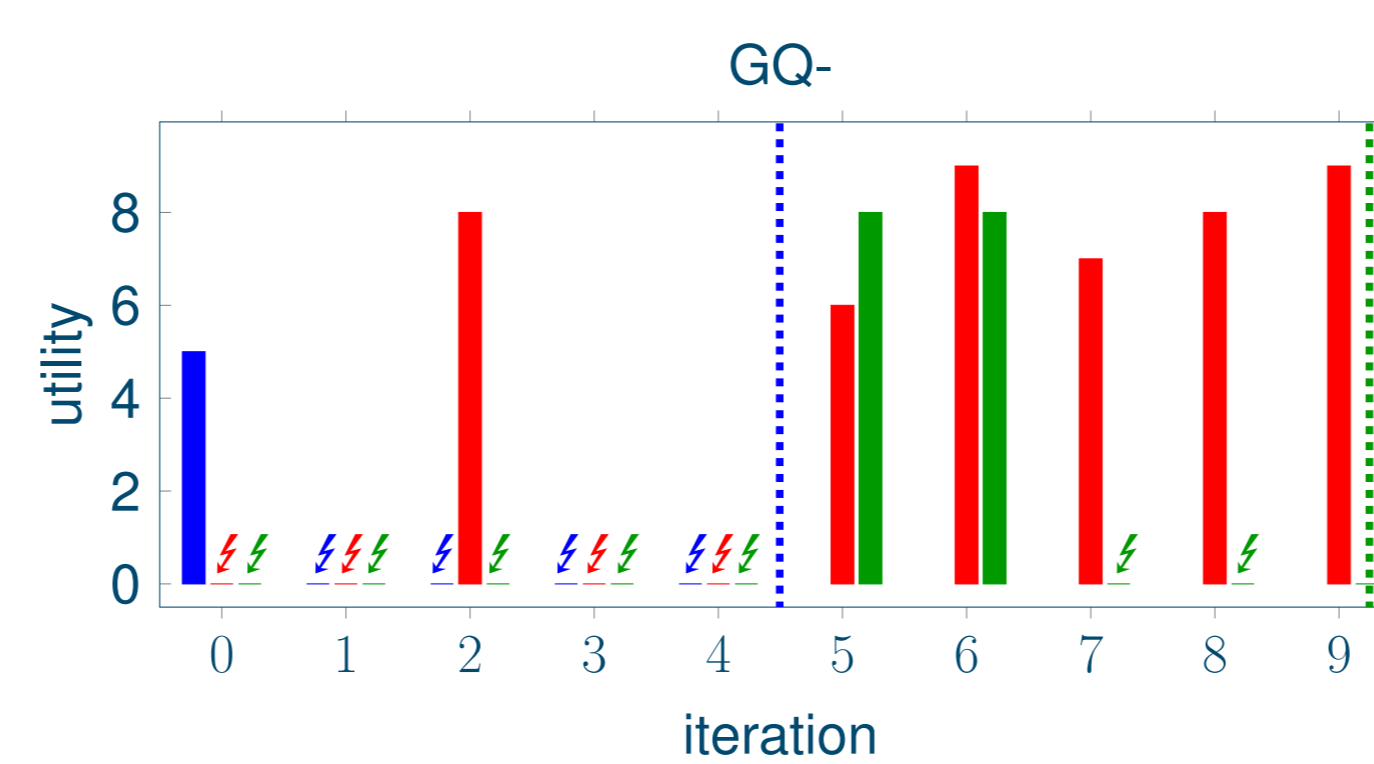
**Plan Properties:**

- definition: domain dependent templates or LTL formula
- features: utility, global hard goal, natural language representation

The road between 12 and 3 is used with Truck

plan property template

## User Study - Evaluation



Plan utility and #questions per iteration. The different colors correspond to the different test persons. Dashed lines indicate max number of used iterations.  $\text{!}$  indicates that the selected hard goals were unsolvable in this iteration.

## User Study

### User Preferences

- extrinsic motivation for non domain experts
- **utility:** integer value for each plan property

### Setup

- test persons are split in two groups of size 3 each: Group GQ+ was allowed to ask questions, group GQ- was not.
- NoMystery instance with 5 packages and 11 plan properties
- test persons goal: maximize the overall utility
- maximum number of iterations was fixed to 10

## References

- 1. Rebecca Eifler, Michael Cashmore, Jörg Hoffmann, Daniele Magazzeni, and Marcel Steinmetz. A new approach to plan-space explanation: Analyzing plan-property dependencies in oversubscription planning. In *AAAI*, 2020.
- 2. Rebecca Eifler, Marcel Steinmetz, Alvaro Torralba, and Jörg Hoffmann. Plan-space explanation via plan-property dependencies: Faster algorithms & more powerful properties. In *IJCAI*, pages 4091–4097, 2020.
- 3. David Smith. Planning as an iterative process. In *AAAI*, pages 2180–2185, 2012.

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