A Framework for Interactive Hybrid Planning

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Motivation

Automated AI planning systems are neither applicable nor accepted for many real-world domains.

- human users want to be *responsible* for key decisions 
- any automated system can hardly take into account *all relevant aspects* related to a particular application domain 

Objective

Provide a generic approach for interactive planning:

- applicable to a large set of *applications*
- supporting different *interaction modalities*
- allowing for flexible and adapted *dialog* between the human user and the automated system
- preserving the soundness of the *plan generation procedure* and the consistency of the *results*

Mixed-initiative paradigm

This paradigm establishes a *flexible dialog* between the human user and the planning system.

- Humans: experience, intuition, high-level view on the application domain, knowledge that is not encoded
- AI planning systems: systematic exploration of the underlying search space with all its details

Mixed-initiative planning

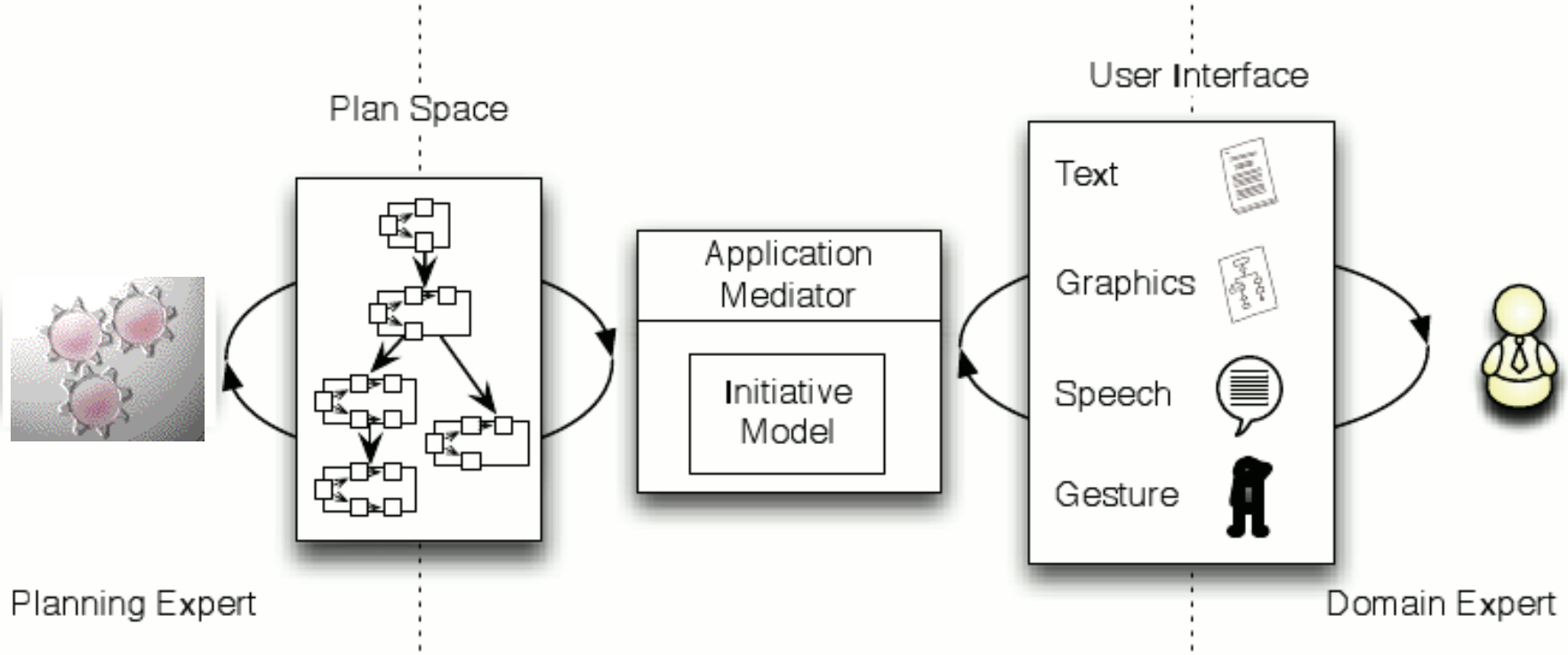
This is a *mediated process* between a domain-independent semi-automated plan generation and an interactive domain-specific application.

→ Deploy the planning engine *concurrently* to the application

Requirements of mixed-initiative planning

- Encapsulating plan generation
- No direct connection between the human user and the planning system
- An easy access to plan elements, plan deficiencies, and plan refinements (explicit representation)
- Maintaining the control over the planning process → initiative
- Integrating the human user in the plan-generation loop

Architecture of mixed-initiative planning



A formal framework for refinement-based planning

Our mixed-initiative approach is based on a *hybrid-planning* framework: Hierarchical Task-Network (HTN) Planning + Partial-Order Causal-Link (POCL) Planning

- Abstract and primitive tasks with preconditions and effects
- POCL-like plans and task networks (TE,<,VC,CL)
- Completely declarative domain model
- Causal interactions are preserved and refined during expansion

Search in plan space independent of implementation

A formal framework for refinement-based planning

Modification modules
- generate explicit plan refinements: *plan modifications*
- Example: insert a new task in the partial plan

Detection modules
- announce explicit deficiencies: *flaws*
- Example: a complex task is part of the partial plan
- trigger adequate modifications: α-function

Strategies

They compare the available *refinement options* and *plans* qualitatively and quantitatively and can choose opportunistically among them.

Combination of:

- Modification selection → *refinements for the current plan*
- Plan selection → *plan-space navigation*

Flexible strategies: Preferences not depending on modification type or flaw type but on *metrics* (e.g. ratio of published flaws to plan steps for the plan selection)

Domain expert = flexible strategy

Most challenging problem in mixed-initiative planning

Synchronizing the construction of the refinement space and the application focus in an adequate manner i.e. synchronizing

- the system fringe of the planning horizon 

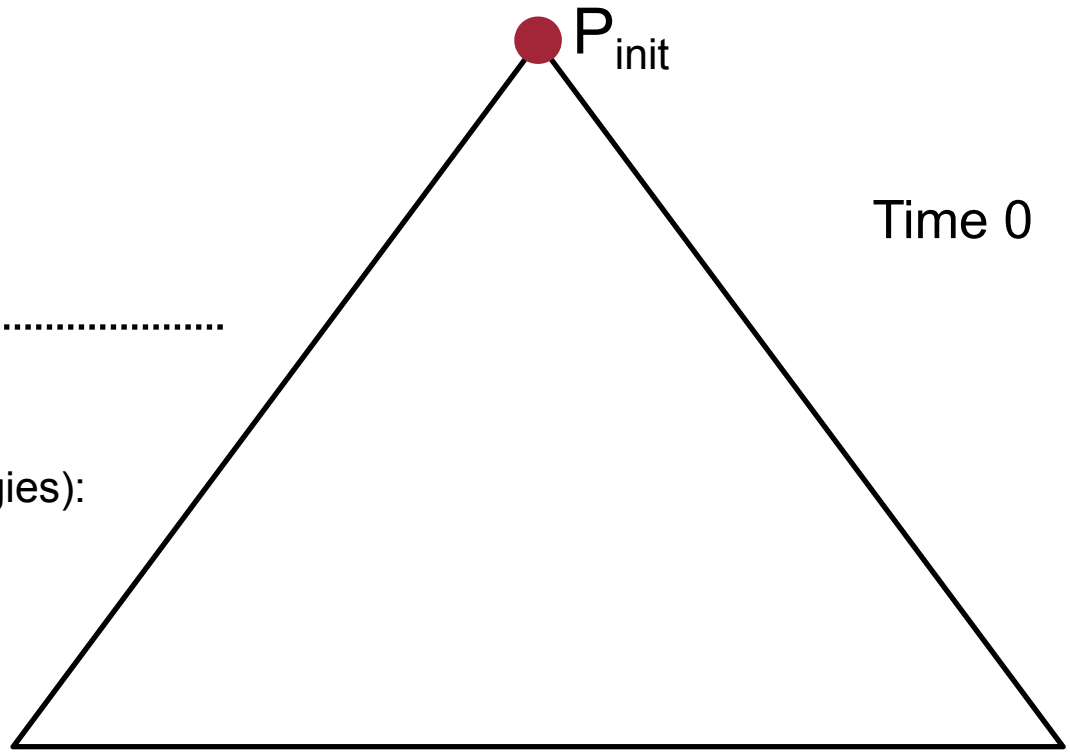
  and

- the application fringe 

Search space exploration

Application fringe:

System fringe (3 strategies):



Search space exploration

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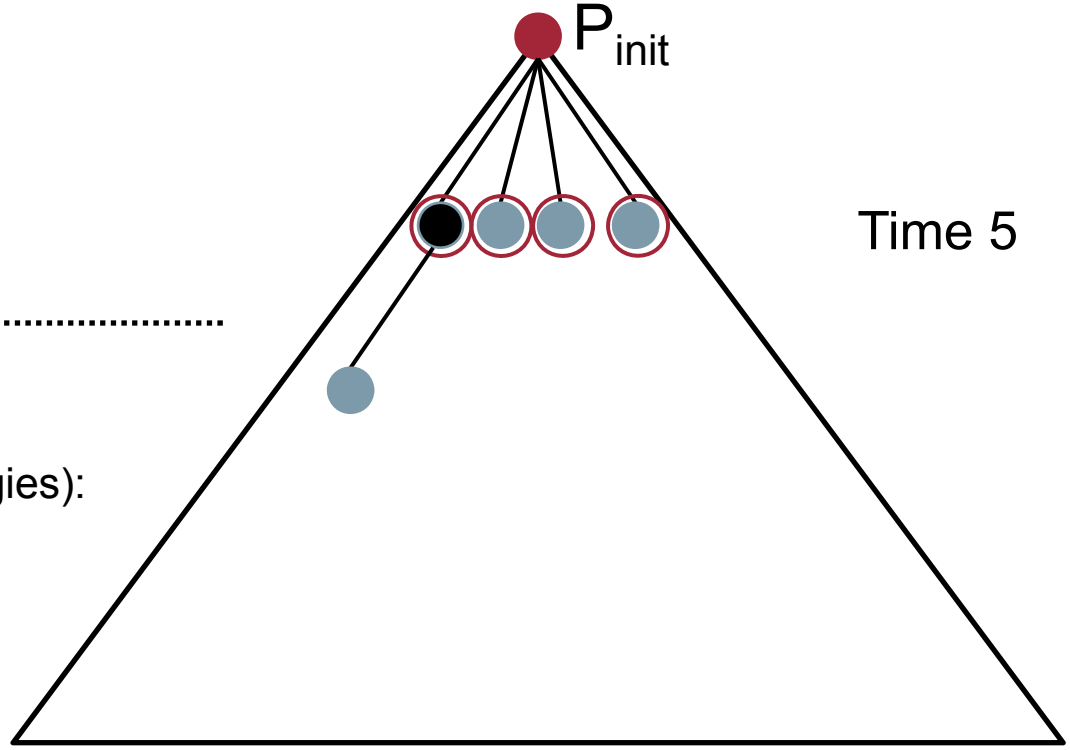

Search space exploration

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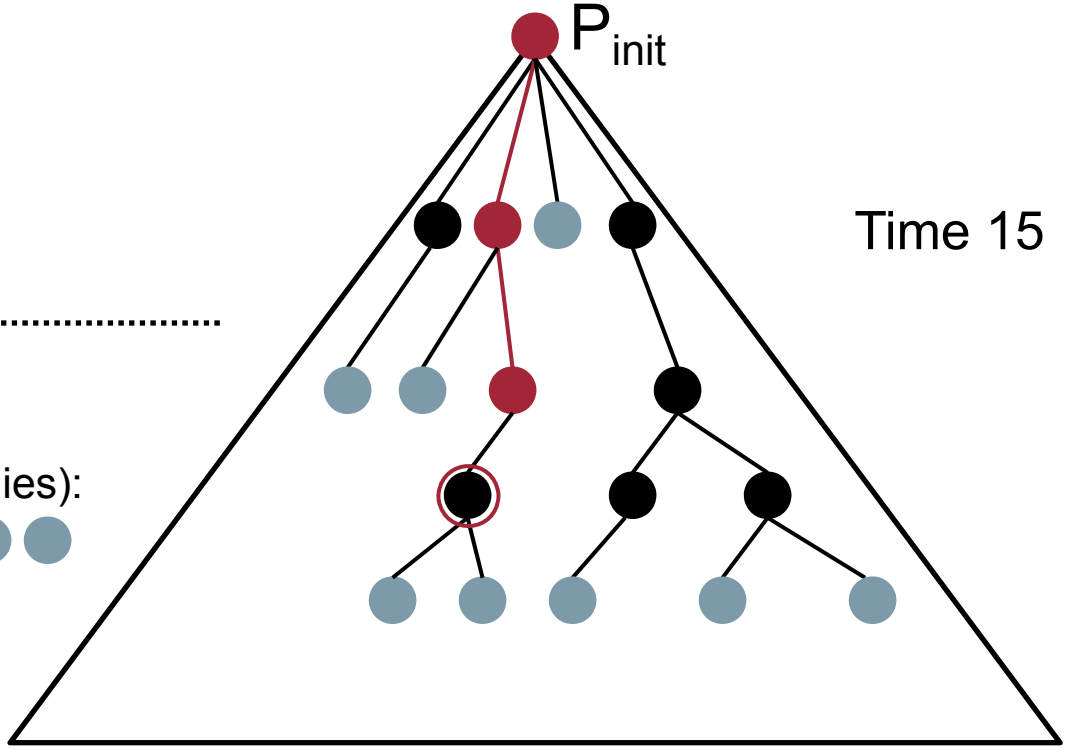
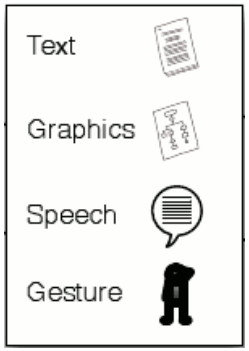


Some interaction aspects

The mixed-initiative paradigm emphasizes a *dynamic notion* of initiative: the role of the experts is subject to change during the plan-generation phase.

The architecture supports different display modalities and interaction modalities.



The representation mechanism of the framework realizes a complete encapsulation of the *interface's display metaphor* and *interaction metaphor*.

An interactive planning assistant

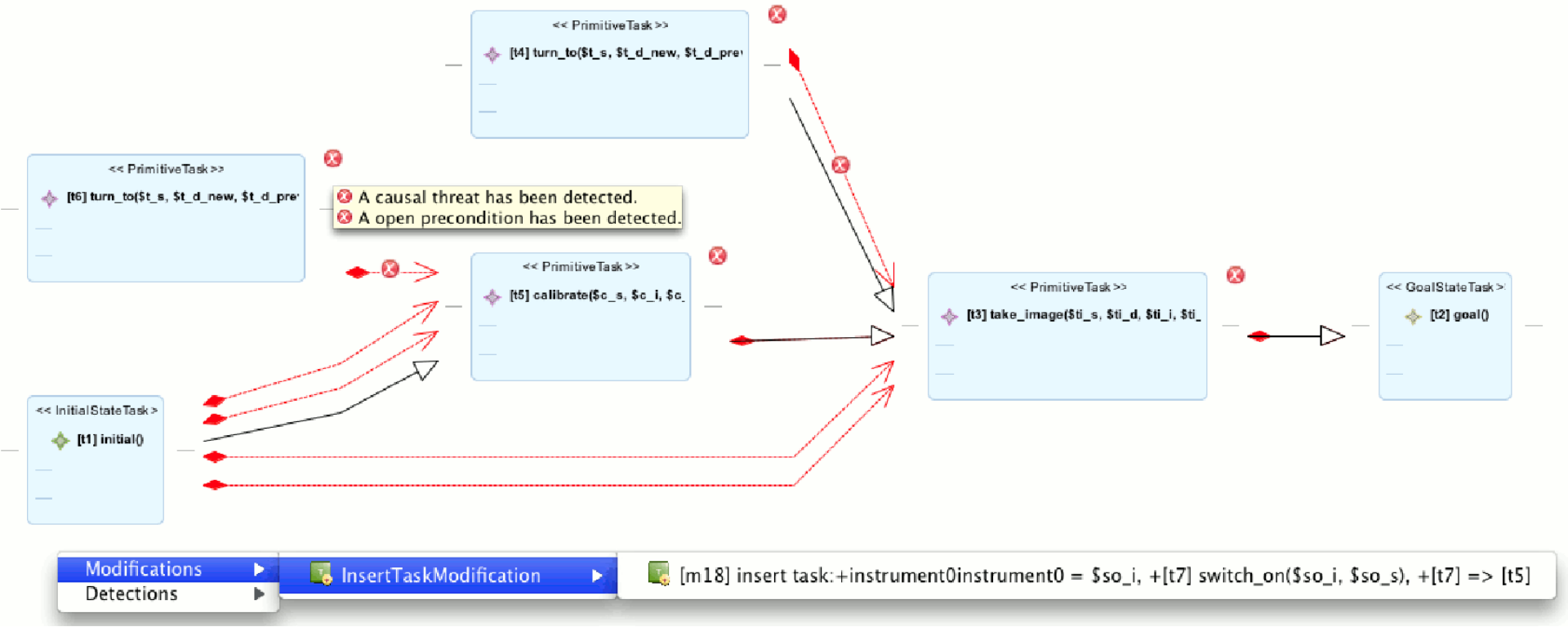
Implementation of our approach for explaining hybrid planning to students and for debugging models and problem definitions

Planning expert: hybrid-planning development platform PANDA

Graphical planning editor that shows a detailed representation of single plans

Interaction via the tool metaphor through *mouse gestures*

An interactive planning assistant



Conclusion

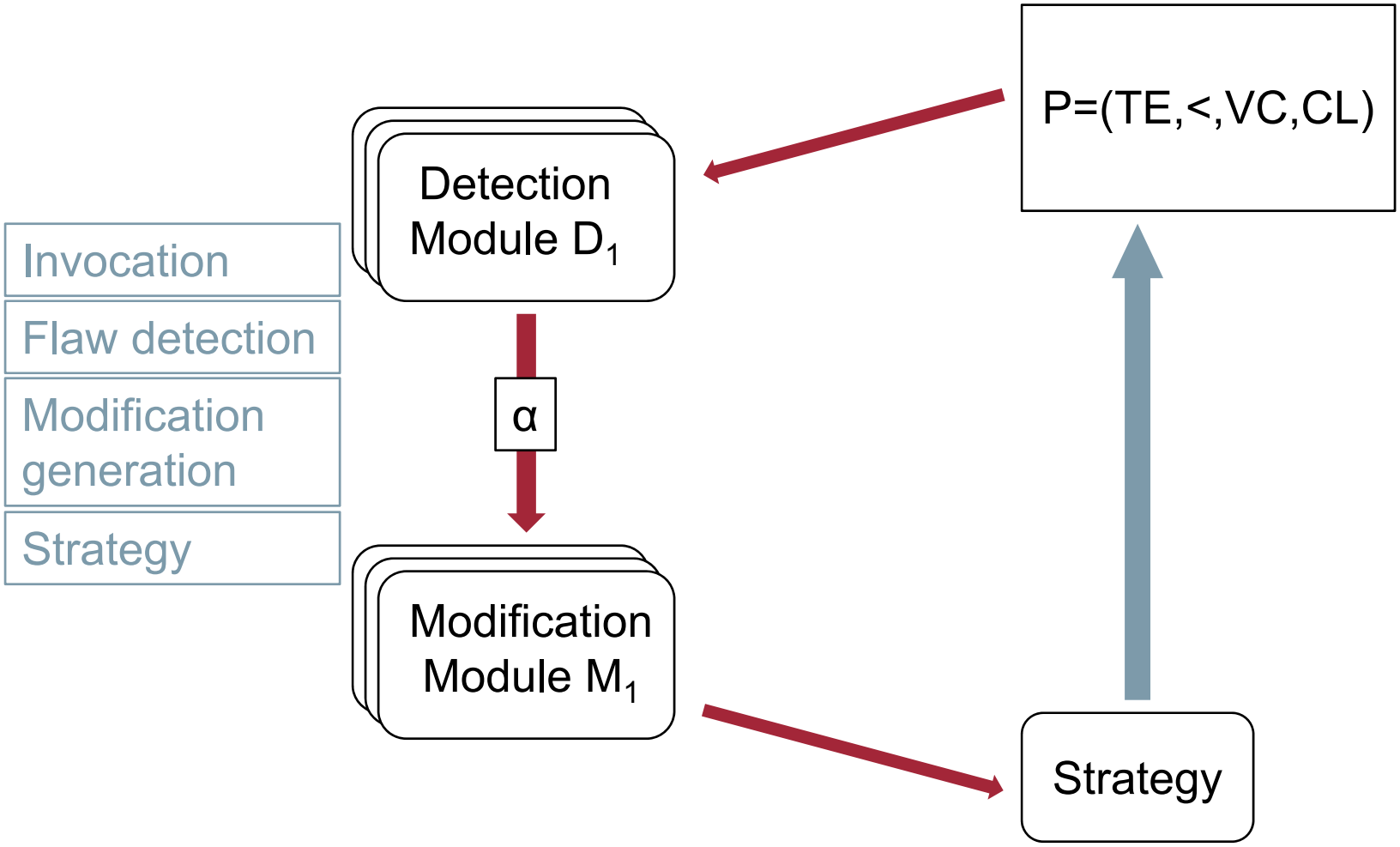
Contributions:

- a model for *mixed-initiative planning* based on a hybrid-planning framework
- a prototype for editing plans with a *GUI* and *mouse*-based interactions
- another prototype with a *text*-based user interface and interactions via a *console*
- implementations of this approach useful for *supporting the design of and debugging complex application domains*

Future work:

- investigating suitable interaction modalities and the representations of modifications with respect to usability aspects
- research on dynamic initiative

A generic planning procedure



Hybrid planning

Combination of:

- Hierarchical Task-Network (HTN) Planning
  - Predefined plans implement abstract actions
  - Utilizing procedural procedural knowledge → expressivity
- Partial-Order Causal-Link (POCL) Planning
  - Synthesizing partially ordered plans by causal reasoning
  - Handling underspecified procedures → flexibility

This provides a powerful mechanism to address real-world planning problems.