Temporal Hierarchical Task Network Planning with Nested Multi-Vehicle Routing Problems

- A Challenge to be Resolved

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An Example Scenario

Fig. 1 depicts a complex rescue mission after a disaster (e.g. earthquake) involving multiple rescue teams of different capabilities.
Marked in blue is a disaster-struck area; different locations within the area that require rescue operations are marked in orange, while the different objects (e.g. buildings, clusters of victims, etc.) within a location are marked with stars, the sizes of which also indicate the complexity (or rather the duration) of the rescue tasks to be performed. Team members can be human first responders, unmanned aerial or ground vehicles. The number of each type of team member varies in each team.

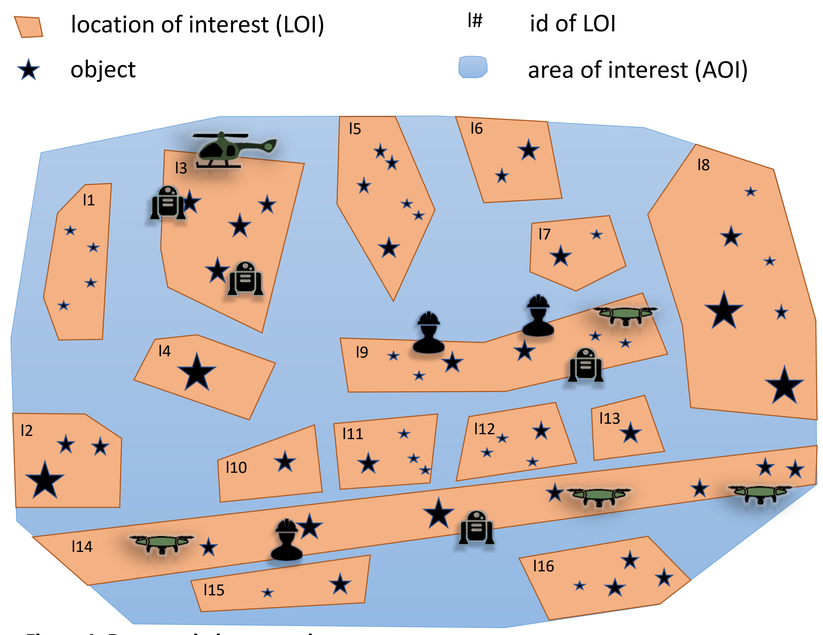
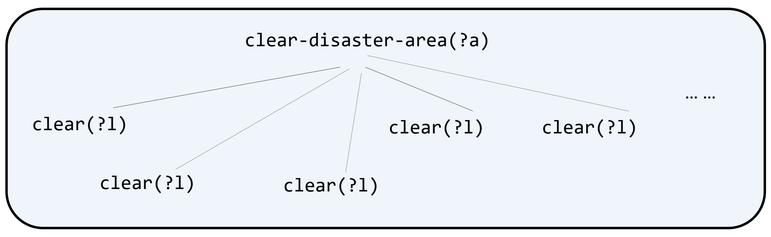
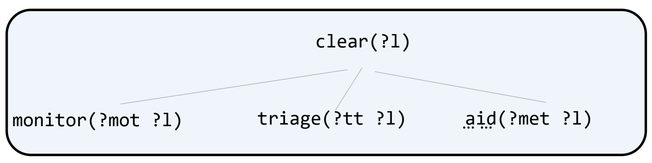


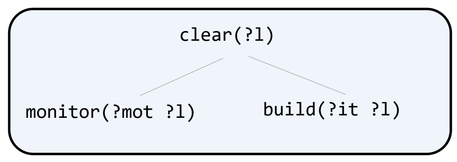
Figure 1: Rescue mission scenario

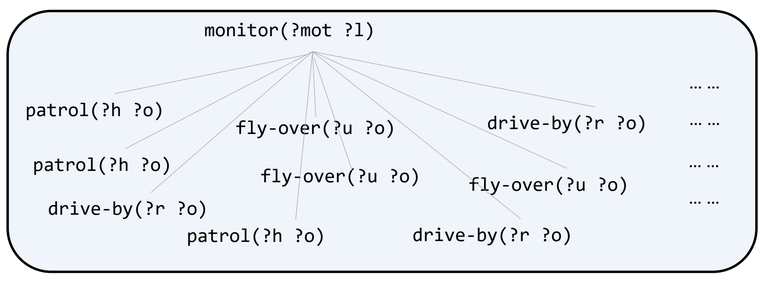
The benefits of using Temporal HTN Planning

- Known "recipe" by including experts' knowledge
- Natural simplication of problems by considering a limited search space
- Consideration of temporal constraints
- But… with nested Multiple-Vehicle Routing Problems (MVRPs), applicability of current techniques developed in Temporal HTN Planning is insufficient.









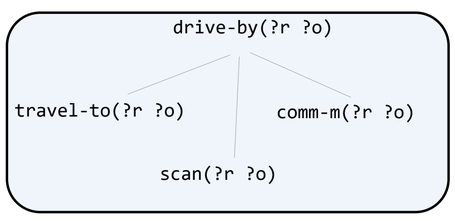


Figure 2: Decomposition of some abstract tasks

Challenge 1: Recursive Task Decomposition

Motivation:
The decompositions of the compound tasks, for instance clear-disaster-area(?a) and monitor(?mot ?l) terminate only if the subtasks altogether achieve the goals imposed by the compound tasks. For clear-disaster-area(?a), the decomposition terminates once all locations ?l within the area ?a are cleared, while for monitor(?mot ?l), the decomposition terminates after all objects ?o within the location are attended to by either the human first responder patrol(?h ?o), a robot drive-by(?r ?o) or an UAV fly-over(?u ?o).

Difficulties:
If the exact number of locations ?l is unknown at planning time (e.g. in a framework where planning and acting interleave), or if the knowledge on the number of locations changes due to updates of information, therefore requiring plan repair, a recursive decomposition is not straightforward.

Challenge 2: Complex Utility Function

Motivation:
Utility functions such as number of lives saved, cost of structural damages, cost of time, etc. are relevant metrics to measure the optimality of a plan.

Difficulties:
Utility function can often only be defined intuitively by the domain expert at a higher abstraction level, i.e. aid(?met ?l) for the lives saved and build(?it ?l) for the cost of structural damages. However, the exact evaluation of the utility functions can only take place at the level of the primitive tasks.

Determining heuristics capable of optimizing different utility functions can also be a challenging issue.

The challenge is even more amplified if multiple objectives are to be considered.

Challenge 3: Task Allocation to Multiple Agents

Motivation:
The allocation of subtasks to actors: This is relevant for example in the decomposition of monitor(?mot ?l), where the subtasks can be allocated to humans patrol(?h ?o), robots drive-by(?r ?o) and UAVs fly-over(?u ?o).

Difficulties:
The optimality of the allocation depends on the utility function.

The implementation can be challenging with respect to the formalism or modelling language, as well as the heuristics.

Conclusion and Future Work

Challenges to be resolved for more applicable Temporal HTN Planning:

1. Recursive decomposition
2. Complex utility function
3. Task allocation to multiple agents

Modelling Language

- Theoretical formalism
- Unified syntax for modelling such class of problems

Planning System

- Planning efficiency
- Quality of plans found (according to various problem-specific utilities)

Flexible Planning Framework

- Offline planning
- Planning and acting
- Plan and plan repair

Other applications are: maintenance of a big infrastructure, managing large-scale construction work, complex logistic problems