

PhD Position: Robust HTN Planning Under Uncertainty

University: Univ. Grenoble Alpes (France)

Laboratory: Laboratoire d'informatique de Grenoble (LIG)

Team: Marvin

Supervisor: Damien Pellier (Damien.Pellier@imag.fr)

Recruitment Starting: September 1, 2026

Context of the Thesis

Automated planning is currently a central field of artificial intelligence, enabling the design of autonomous systems capable of reasoning over complex objectives and generating coherent sequences of actions to achieve them. Among existing approaches, Hierarchical Task Network (HTN) planning holds an important place due to its ability to exploit expert knowledge in the form of a hierarchical decomposition of tasks. This approach is widely used in fields such as robotics, space systems, logistics, industrial workflows, and multi-agent systems.

However, classical HTN models generally rely on strongly deterministic assumptions. Actions are assumed to have durations known in advance, resources are considered fully available, and their consumption is perfectly defined. These simplifying assumptions severely limit the applicability of the models in real-world environments, where uncertainty is omnipresent and where systems must evolve within dynamic and partially observable contexts.

In many concrete applications, domain parameters do indeed exhibit significant uncertainties. The actual duration of an action can vary depending on the execution context, available resources can fluctuate over time, certain capabilities can become temporarily unavailable, and information available at the time of planning can be incomplete. For example, in robotics, the time required for a movement strongly depends on the environment and the state of the system. In industrial systems, human or material resources can be mobilized or become unavailable unpredictably. In embedded systems, available energy or memory capacities evolve dynamically.

Classical approaches to planning under uncertainty often rely on probabilistic models. However, these approaches generally require knowledge of precise probability distributions, which is rarely available in complex real-world environments. In practice, it is often more realistic to have only bounds or intervals describing the possible values of parameters. An action duration can thus be expressed as an interval, for example $[5, 10]$, energy consumption as bounds, for example $[2, 7]$, or resource availability as partially unknown. These approaches are closely linked to work in interval analysis [3] and robust optimization [6].

Objectives of the Thesis

In this context, this thesis proposes to study a new robust HTN planning framework based on an interval representation of uncertainties. The main objective is to develop a planning model capable of simultaneously managing multiple forms of uncertainty, including temporal uncertainties regarding action durations, quantitative uncertainties concerning consumed or available resources, and boolean uncertainties relating to the availability of certain capabilities. The core idea consists of replacing the deterministic values of classical HTN models with intervals or partially known states, in order to produce plans capable of remaining valid despite possible domain variations. This approach aims to provide a more robust and realistic alternative to complete probabilistic models,

building upon the foundations of HTN planning [1], hierarchical formalisms [2], constraint reasoning techniques [4], and temporal uncertainty management approaches [5].

The central scientific problem of this thesis can be formulated as follows: how can we generate robust hierarchical plans when action durations, available resources, and certain execution conditions are partially unknown or imprecise? This problem raises several major scientific challenges. The first consists of defining a formal model to integrate resources and durations in interval form within an HTN framework. The second concerns the propagation of these uncertainties within hierarchical decompositions, which can affect the entirety of the generated plan. Finally, a last major challenge lies in mastering the combinatorial complexity induced by the simultaneous consideration of multiple sources of uncertainty, while guaranteeing the feasibility and robustness of the produced plans.

Expected Results

This thesis aims to produce several complementary scientific contributions, both theoretical and algorithmic.

- **First Phase:** It will propose an extension of HTN formalisms to explicitly represent variable action durations, imprecise resource consumption, quantitative resources, and potentially unavailable boolean resources. This extension will also integrate explicit robustness constraints to guarantee plan validity under uncertainty.
- **Second Phase:** The thesis will focus on the formal definition of the notions of robustness and validity within an interval-based HTN framework. Several concepts could be studied, notably worst-case validity, validity over a set of possible scenarios, and forms of flexibility allowing for dynamic adaptation of plans during execution. These notions will build upon work in robust optimization [6] and constraint satisfaction [4].
- **Third Axis:** This will focus on developing planning algorithms adapted to this new framework. Interval constraint propagation mechanisms will be designed to reduce the search space and quickly detect inconsistencies. Specific heuristics for robustness will also be studied to improve the efficiency of plan generation. Particular attention will be paid to the interactions between hierarchy, temporal constraints, and resource management, which constitute one of the main scientific bottlenecks of the subject.
- **Validation:** Finally, an experimental validation will be carried out using existing hierarchical planning benchmarks [2], as well as application scenarios inspired by autonomous robotics, logistics, and industrial systems.

The expected contributions include the definition of a new HTN formalism under interval uncertainty, a characterization of the associated notions of robustness, the development of efficient algorithmic methods for generating robust plans, and the realization of an experimental prototype to evaluate the performance of the proposed model.

Profile Sought and Desired Skills

- Holder of (or future holder by Autumn 2026) a Master 2 degree in Computer Science or an Engineering degree, with a specialization in Artificial Intelligence or Operations Research.
- Good knowledge of automated planning, constraint programming, or optimization.
- Strong software development skills (Rust/C++) for the creation of the prototype.
- Proficiency in scientific English (written and spoken).

Thesis Conditions and Funding

- **Funding:** CHAIR MIAI Secure Hubot for a duration of 36 months.
- **Location:** Laboratoire d'Informatique de Grenoble (LIG), Marvin Team, Université Grenoble Alpes.

Application Procedures

Interested candidates must send an application package including a CV, a cover letter, Master's transcripts (M1/M2), and contact details for at least one academic reference to Damien Pellier (Damien.Pellier@imag.fr).

Applications will be reviewed on a rolling basis. After an initial contact, the candidate will be asked to complete a small software development task to validate their understanding of the topic using the library <http://pddl4j.imag.fr/>.

- **Application Deadline:** July 1, 2026.

References

- [1] Ghallab, M., Nau, D., Traverso, P. (2016). *Automated Planning and Acting*. Cambridge University Press.
- [2] Bercher, P., Alford, R., Höller, D. (2019). *Hierarchical Task Network Planning: A Survey*. IJCAI.
- [3] Jaulin, L., Kieffer, M., Didrit, O., Walter, E. (2018). *Applied Interval Analysis*. Springer.
- [4] Rossi, F., Van Beek, P., Walsh, T. (2019). *Handbook of Constraint Programming*. Elsevier.
- [5] Morris, P., Muscettola, N., Vidal, T. (2001). *Dynamic Control of Plans with Temporal Uncertainty*. IJCAI.
- [6] Bertsimas, D., den Hertog, D. (2022). *Robust and Data-Driven Optimization*. Princeton University Press.