An Investigation of Hybrid Maps for Mobile Robots

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Autonomous robots typically rely on internal representations of the environment, or *maps*, to plan and execute their tasks. Several types of maps have been proposed in the literature, and there is general consensus that different types have different advantages and limitations, and that each type is more suited to certain tasks and less to others. Because of these reasons, it is becoming common wisdom in the field of mobile robotics to use *hybrid maps* that integrate several representations, usually of different types. Hybrid maps provide scalability and multiple views, allowing for instance to combine robot-centered and human-centered representations. There is, however, little understanding of the general principles that can be used to combine different maps into a hybrid one, and to make it something more than the sum of its parts. There is no systematic analysis of the different ways in which different maps can be combined, and how they can be made to cooperate. This makes it difficult to evaluate and compare different systems, and precludes us from getting a clear understanding of how a hybrid map can be designed or improved.

The investigation presented in this thesis aims to contribute to fill this foundational gap, and to get a clearer understanding of the nature of hybrid maps. To help in this investigation, we develop two tools: The first one is a conceptual tool, an *analytical framework* in which the main ingredients of a hybrid map are described; the second one is an empirical tool, a *new hybrid map* that allows us to experimentally verify our claims and hypotheses.

While these tools are themselves important contributions of this thesis, our investigation has resulted in the following *additional outcomes*:

- A set of concepts that allow us to better understand the structure and operation of hybrid maps, and that help us to design them, compare them, identify their problems, and possibly improve them;
- The identification of the notion of synergy as the fundamental way in which component maps inside a hybrid map cooperate.

To assess the significance of these outcomes, we make and validate the following claims:

1. Our framework allows us to classify and describe existing maps in a uniform way. This claim is validated constructively by making a thorough classification of the hybrid maps reported in the literature.
2. Our framework also allows us to enhance an existing hybrid map by identifying spots for improvement. This claim is verified experimentally by modifying an existing map and evaluating its performance against the original one.
3. The notion of synergy plays an important role in hybrid maps. This claim is verified experimentally by testing the performance of a hybrid map with and without synergy.