

A Behavior-Based Control System for Mobile Manipulation

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The field of industrial robotics can be defined as the study, design and use of robot systems for manufacturing. Although the problem of designing a controller for industrial robots has been the subject of intensive study, a number of assumptions are usually made which may seriously limit the applicability of these robots. First, the robotic manipulator is usually considered to be positioned at one place, which means that it can only work in its limited working envelope fixed to this position. Second, it is usually assumed that the environment of the manipulator (workcell) is carefully engineered to suit the task and the configuration of the manipulator. The workcell is usually controlled in a way that makes it fully predictable. Finally, the control program of the manipulator is often designed assuming that the task will not change, and it is difficult to reprogram it to fit other tasks and/or other environments.

These restrictions make current industrial robots unsuitable for the new demands of flexible automation in small and medium enterprises. To enter these emerging markets, industrial robots need to be easy to reprogram in order to be used for small batch productions. They also need to extend their work envelope outside the fixed, confined space of a workcell in order to address a larger range of tasks. Finally, in order to reduce the high cost needed to engineer the workcell, the control system should be able to cope with a (partially) unstructured environment, where things may move and not everything is predictable.

In this thesis, we develop techniques that extend the applicability of current robotic manipulators, by addressing the above limitations. We propose an approach to sensor-based manipulation that has the following distinctive features.

- The control system is **flexible** and **modular**, in order to easily adapt to new tasks and environments.
- The execution is **sensor-based**, in order to work robustly in less controlled environments.
- Our approach applies to the more general problem of combined **mobility** and **manipulation**, in order to extend the work space of the manipulator.

To achieve these features, we combine the methods of traditional robot control with insights derived from three different fields. We provide modularity and flexibility by taking insights from the field of *behavior-based robotics*. We incorporate online visual feedback into the control loop by taking insights from the field of *image-based visual servoing*. And we combine mobility and manipulation by taking insights from the field of *mobile manipulation*. To demonstrate the effectiveness of our approach, we develop a complete mobile manipulation system, and we validate its performance in a number of experiments involving the collection of objects from a large floor, whose position is not known *a priori*, and which may be moving.