# Model-Free Execution Monitoring in Behavior-Based Mobile Robotics

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## Abstract

In the near future, autonomous mobile robots are expected to assist us by performing service tasks in many different areas, including transportation, cleaning, mining, or harvesting. In order to manage these tasks in a changing and partially unpredictable environment, without the help of humans, the robot must have the ability to plan its actions and to execute them robustly and in a safe way. Since the real world is dynamic and not fully predictable, the robot must also have the ability to detect when the execution does not proceed as planned, and to correctly identify the causes of the failure. An *execution monitoring system* is a system that allows the robot to detect and classify these failures.

Most current approaches to execution monitoring in robotics are based on the idea of predicting the outcomes of the robot's actions by using some sort of model, and comparing the predicted outcomes with the observed ones. In contrary, this thesis explores the use of *model-free approaches* to execution monitoring, that is, approaches that do not use predictive models. These approaches solely observe the actual execution of the robot, and detect certain patterns that indicate a problem. The motivation to carry out this exploration comes from two observations. First, there is very little work done on this topic, especially within the field of artificial intelligence and autonomous robotics. Second, model-free approaches have some complementary advantages and disadvantages compared to the model-based ones.

In this thesis, we show that pattern recognition techniques can be applied to realize model-free execution monitoring by classifying observed behavioral patterns into normal or faulty behaviors. We investigate the use of several such techniques, and verify their utility in a number of experiments involving the navigation of a mobile robot in indoor environments. Statistical measures are used to compare the results given from several realistic simulations. Our approach has also been successfully tested on a real robot navigating in an office environment. Interesting, this test has shown that we can train a model-free execution monitor in simulation, and then use it in a real robot.