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Evolving Control Logic Through Modeling and Simulation

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Modeling and Simulation (M&S) has been typically used for training and experimentation. In this paper, we describe how we can use M&S for another purpose, that of providing a learning environment to evolve the logic for controlling and coordinating robotic team in achieving a given task. Our approach coupled a rule learning system based on Genetic Algorithm (GA) and Reinforcement Learning (RL) to a M&S system. We call this approach Simulation Based Rule Mining (SRM). Our idea is that rules learned from the M&S environment (simulated robots and simulated environment) can then be transferred onto real robots in real environment. In this way, we can automate the tedious task of programming the logic by hand. We depict the SRM approach in Figure 1 below.

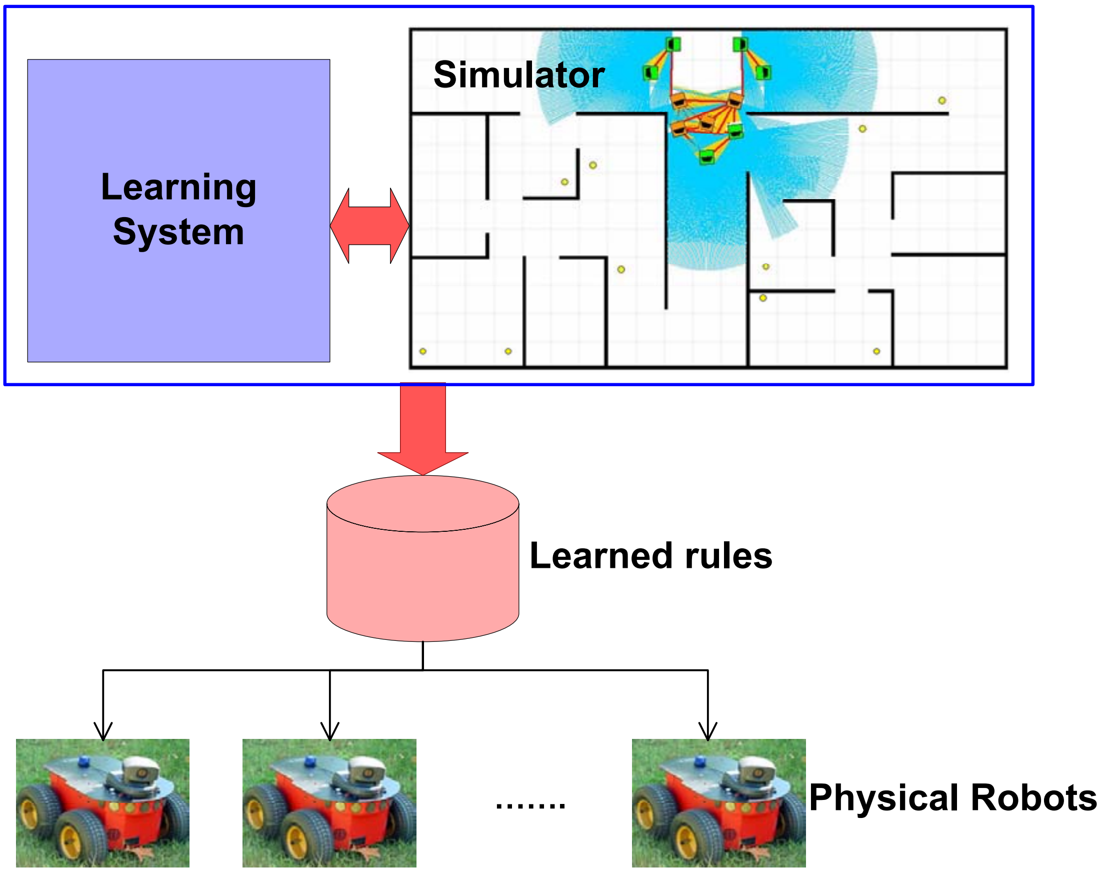

Figure 1: Outline of Simulation Based Rule Mining approach.

In the SRM approach, the control logic for a robotic platform is encoded in the form of IF-THEN rules. Such rules are easy for humans to understand. In addition, using rules as the knowledge representation makes it easy for us to incorporate a priori knowledge into the system to bootstrap the learning process. We use a learning approach of Reinforcement Learning (RL) and Genetic Algorithm (GA). RL was chosen because it is well-suited to solve sequential decision problems, one which the control logic programming problem belongs to. But classical RL algorithms require all possible state-action combinations (or rules in our case) and their utility values to be stored. This seriously limits the applicability of such algorithms to the control logic programming problem, since it has a large number of states. The GA is used to overcome this problem. The GA does a distributed search through the space of state-action combinations and retains only those combinations that give higher payoff at every iteration. The utility values of these combinations are then further refined by RL. In this way, the GA significantly reduces the number of state-action combinations that RL works on at any one time, without any loss of information (since we are generally not interested in low payoff state-action combinations). To reduce the learning time, a parallel GA was implemented to allow multiple evaluations to be performed concurrently instead of sequentially.

We have tested the SRM approach to evolve the logic for controlling a robotic team to carry out search and destroy mission in an urban room environment. In this test, each robot needs only be equipped with sensors for navigation and target detection. There is no need for the robot to know its own position or to have the means to communicate with other robots.

In this paper, we will describe the SRM approach and its effectiveness in learning the rules to control a robotic team for urban search and destroy mission. The effectiveness of the SRM approach is measured in terms of how well the learned rules generalize across different simulated urban room layout as well as how the learned rules from a simulation environment transfer across to a real environment.