FUZZY LOGIC AND REINFORCEMENT LEARNING BASED APPROACHES FOR MOBILE ROBOT NAVIGATION IN UNKNOWN ENVIRONMENT

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ABSTRACT
Fuzzy logic controller promises an efficient solution for the mobile robot navigation. However, it is difficult to maintain the correctness, consistency and completeness of the fuzzy rule-base constructed and tuned by a human operator. Reinforcement learning method is a type of machine learning. This approach is often used in the field of robotics. It aims of learning the fuzzy rules automatically and to generate a control law for a mobile robot in unknown environment when we assume that the only obtained information is a scalar signal which is a reward or punishment. The process of learning consists to improve the choice of actions to maximize rewards. It is an intelligent navigation method for an autonomous mobile robot. In this paper, the Q-learning algorithm of reinforcement learning and fuzzy controllers are used for the mobile robot navigation. In order to improve the mobile robot performances, an optimization of fuzzy controllers will be discussed for the robot navigation; based on prior knowledge introduced by a fuzzy inference system so that the initial behavior is acceptable. Simulation results show the obtained behaviors using the three approaches and the effectiveness of the optimization method presenting significant improvements of the robot behaviors and the speed of learning. The results are compared and discussed.

Keywords: *mobile robot, fuzzy controller, goal seeking, obstacle avoidance, Q-learning, fuzzy Q-learning, optimization.*

1. INTRODUCTION

The existence of robots in various types (walkers, manipulators, mobiles...) became very significant in the industrial sector and especially in the service sector. Due to the growing interest of the service robots, they can achieve their missions in environments contains several obstacles. One of the standing challenging aspects in mobile robotics is the ability to navigate autonomously. It is a difficult task, which requiring a complete modelling of the environment and intelligent controllers [1]. Navigation is a vital issue in the research of autonomous mobile robot. It may be considered as a task of determining a collision-free path that enables the robot to travel through an obstacle course, starting from an initial position and ending to a goal position in a space where there are one or more obstacles, by respecting the constraints kinematics of the robot and without human intervention. The process of finding such path is also known as path planning which could be classified into two categories: global path planning and local path planning [2]. Global path planning methods are usually conducted off-line in a completely known environment. May attempts at solving this problem have been tried [1][2], where an exact environment model has been used for planning the path.

Although these approaches have an exact solution, their time complexity grows with the geometry complexity and grows exponentially with the number of degrees of freedom in the vehicle's motion. This fact has led to the emergence of numerous heuristic or approximating approaches, which rely on either calculating the potential Fields [3] or performing a search through a state space model [4]. As a pre-specified environment is required for these methods to plan the path, they fail when the environment is not fully known.

On the other hand, the local path planning techniques, also known as the obstacle avoidance methods, are more efficient in autonomous mobile robot navigation in unknown or partially known environment [5][6]. These methods use the on-line sensory information to tackle the uncertainty. A control strategy with a learning capacity can be carried out by using the reinforcement learning and fuzzy logic approaches; which the robot receives only a scalar signal likes a feedback. This reinforcement makes it possible the navigator to adjust its strategy in order to improve their performances [7][8]. It is considered as an automatic modification of the robot behavior in its environment of navigation [6]. The reinforcement learning is a method of optimal control, when the agent starts from an ineffective solution which gradually improves according to the experience gained to solve a sequential decision problem [9]. The basic idea in reinforcement learning is that an agent is placed in an environment and can observe the results of its own actions. The agent goal is to maximize the received rewards.

To use reinforcement learning, several approaches are possible. The first consists in manually discrediting the problem for obtaining states and actions spaces; which could be used directly by algorithms using Q tables [9]. It is however necessary to pay attention to the choice of discretizations, so that they allow a correct learning by providing states and actions which contain a coherent rewards. The second method consists in working at continuous spaces of states and actions by using approximations of functions. Indeed, to use the reinforcement learning, it is necessary to estimate correctly the quality function. This estimate can be done directly by a continuous function approximation like the neural networks or fuzzy inference systems [10][11][12]. The use of these approximations permits to work directly in continuous spaces and to limit the effects of parasites which could appear with bad discretization choices [9].

In this paper reinforcement learning and fuzzy logic approaches are used for mobile robot navigation in unknown environment. These controllers are used for various tasks of a mobile robot (goal seeking, wall-following, and obstacle avoidance). The obtained navigators are able to perform successful navigation tasks in changed environments.

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