UNIVERSITI TEKNOLOGI MARA

DEVELOPMENT OF SELF-LEARNING ALGORITHM FOR AUTONOMOUS SYSTEM UTILIZING REINFORCEMENT LEARNING AND UNSUPERVISED WEIGHTLESS NEURAL NETWORK

YUSMAN BIN YUSOF

Thesis submitted in fulfillment
of the requirements for the degree of
Doctor of Philosophy

Faculty of Electrical Engineering

December 2019

ABSTRACT

One of the key issues of developing an autonomous system is that it requires pre-defined knowledge by an expert. This knowledge is then converted into computer program or by utilizing exhaustively trained and tested Artificial Intelligence (AI) algorithm. With these methods of development, prior to deployment the system must be prepared to handle all unanticipated circumstances that will occur during deployment. The testing and training of such system prior to deployment must be thorough. As an alternative, having a self-learning algorithm embedded in an autonomous system allows the system to instinctively acquire new knowledge and learn from experience. In this thesis the research of a self-learning algorithm will be presented, outlined and discussed in detailed manner. The development of the algorithm starts by reviewing the characteristic of an autonomous systems. From the reviews, it is evident that autonomous system is set to handle finite number of encountered states using finite sequences of actions. In order to learn the optimized states-action policy the self-learning algorithm is developed using hybrid AI algorithm by combining unsupervised weightless neural network, which employs AUTOWiSARD and reinforcement learning algorithm, which employs Q-learning. The AUTOWiSARD learns to classify states without supervision, while Q-learning will determine what best action to be taken for a state from reinforcement learning. By integrating both algorithms, a system will be able to acquire knowledge, learn, record and recall experience thus enables an autonomous system to self-learn. In the algorithm development a step-by-step example of the algorithm implementation is presented and then successfully implemented in Lego Mindstorm obstacle avoiding mobile robot as a proof of concept implementation of the hybrid AI algorithm. In order to further test the algorithm robustness, it is then implemented in mobile robot obstacle avoidance simulation in complex environment. In the simulation the robot is equipped with thirteen distance sensing sensors. From the simulation result, by using these sensors information the AUTOWiSARD algorithm can successfully differentiate and classify states without supervision, while the Q-learning algorithm is able to produce and optimized states-actions policy. These proves that without prior knowledge, the hybrid AI algorithm can self-learn. In the future the research on improving the algorithm learning will be studied and the implementation in other types of autonomous system other mobile robot obstacle avoidance will be considered.

ACKNOWLEDGEMENT

Firstly, I wish to thank Allah S.W.T for giving me the opportunity to embark on my PhD and for completing this long and challenging journey successfully. My gratitude and thanks go to my supervisor Assoc. Prof. Dr. Hj. Mohd. Asri Bin Hj Mansor.

This thesis is dedicated to my very dear father and mother for the vision and determination to educate me, and to my beloved wife and son for the inspiration. This accomplishment is dedicated to all of you.

Finally, special thanks to my colleagues and friends for the moral support throughout the duration of my research study.

Alhamdulillah.

TABLE OF CONTENTS

CHAPTER ONE
INTRODUCTION

1.1 Research Background

In general, Artificial Intelligence (AI) refers to a set of computational technologies that makes machines smart like human. Since the inaugural inception of the formal introduction of the term AI in 1956 [1], countless number of researches and developments of systems has been acknowledged as AI algorithm and AI based systems. These AI algorithm and systems were developed to solve multitude problems in various subject domains ranging from transportation, home/service robot, healthcare, education and others[1].

As predicted by Moore in 1965, the number of transistors incorporated in a chip will approximately double every 24 month [2]. This has led to the tremendous improvement in computer technology which provides computing power that drives the development in intelligent devices; thus, paving the way to the development of autonomous systems in which AI is implemented.

1.1.1 Autonomous System

According to Xu et al [3], autonomous systems such as include robotics, autonomous vehicles and intelligent software agents in networks are a type of intelligent systems that can handle autonomous sensing, modelling, decision-making, and control in uncertain, dynamic environments.

In relation to the development of autonomous vehicle, the ability of an autonomous system enabled with intelligent navigation plays an important role such as self-driving car. In 2005, Stanford's robotic car "Stanley" won the "DARPA Grand Challenge," whereby the car follows a desert trail and became the first robot to finish the 210km. challenge. Later in 2007 DARPA Urban challenge which requires an autonomous vehicle to drive 97km through mock urban environment, the robot "Boss" won the first place [4] while the Stanford's "Junior" [5] shown in Figure 1.1 finishes second. These vehicles are considered the pioneer in the autonomous self-driving which