UNIVERSITI TEKNOLOGI MARA

GRID-BASED SIMULTANEOUS LOCALIZATION AND MAPPING USING RAO-BLACKWELLIZED PARTICLE FILTER WITH NEURAL NETWORK FOR MINI ROBOTS

NORHIDAYAH BINTI MOHAMAD YATIM

Thesis submitted in fulfillment
of the requirements for the degree of
Doctor of Philosophy
(Electrical Engineering)

Faculty of Electrical Engineering

July 2018

ABSTRACT

Mini robots can be used in many applications such as in domestic, industrial or humanitarian fields. Typically, mini robot platforms are equipped with sparse and noisy sensors on board such as array of infrared sensors. In robotics, the ability to map the surrounding area and determine self-location is essential for a robot to be truly autonomous. This research aims to develop such capability known as Simultaneous Localization and Mapping (SLAM) algorithm for mini robots with array of infrared (IR) sensors. Existing methods had implemented either feature-based or occupancy grid map (OG) as map representation. In SLAM with feature-based map, prior knowledge of the environment is required to associate sensor measurements with the right features. OG map representation does not need for landmark identification but described occupancy of an area. In this research, to enable mini robots to operate in various environment, OG map with SLAM or grid-based SLAM algorithm was developed. Previous works in this domain had to assume for all walls in the environment are either parallel or perpendicular to each other. Another assumption is to implement grid-based SLAM algorithm with rather accurate odometry data. These limitations are not suitable for mini robots to operate in various structure of environment. Furthermore, mini robots often have significant odometry error due to wheels' slipping. In this research, neural network (NN) was used to interpret adjacent sensor measurements. Thus, adjacent sensors can be interpreted into grid cells occupancy better, compared to a single sensor interpretation. The neural network integrated algorithm is named as RBPF-NN, where Rao-blackwellized particle filter (RBPF) was integrated with NN in grid-based SLAM algorithm. One of the issues in RBPF algorithm, is to reduce number of particles to reduce overall computation cost. To address this, a better proposal distribution is needed when sampling the next generation of particles. In this research, three models of RBPF-NN algorithms were developed using three different proposal distributions; 1) motion model, 2) Gaussian approximation, and 3) two-step sampling. The RBPF-NN algorithm were tested using mini robot platform named Khepera III in Webots robot simulator. For validation, three grid-based SLAM with the same proposal distribution methods but without NN, were developed. The existing models are coined as RBPF-XNN to reflect the absent of NN integration. The performance of RBPF-NN and RBPF-XNN algorithms were compared. From the performance analysis of robot's state estimate and map estimate accuracy, it is identified that the RBPF-NN algorithm with motion model proposal distribution has the highest map accuracy and lowest robot's state error at 85% and 9.42cm respectively. As for the existing algorithm, RBPF-XNN with Gaussian approximation gives the best result at 69% map accuracy and 12.7 cm robot's state error. Thus, the RBPF-NN algorithm improves the map accuracy by 26% and state estimate error is reduced by 25.8% compared to the existing algorithm. The good performance of RBPF-NN with motion model is because of neural network improves the accuracy grid cells' occupancy. Thus, this improves the importance weight computation in RBPF-NN Model 1 which make use of cells occupancy value. Consequently, resulting a better accuracy of map and robot's state estimate. This finding concluded that a robust grid-based SLAM algorithm for mini robot platform using array of IR sensors can be obtained by using RBPF algorithm with motion model proposal distribution and neural network integration.

ACKNOWLEDGEMENT

In the name of Allah Most Gracious, Most Merciful. I wish to thank The Almighty for giving me the opportunity to embark on this PhD journey. My gratitude and thanks go to my supervisor Prof. Ir. Dr. Norlida binti Buniyamin for her patience, motivation, encouragement and endless support. Her guidance has helped me in research and writing of this thesis. Besides my supervisor, I would like to thank my co-supervisor Dr. Juliana binti Johari for her valuable comments and encouragement in completing this thesis.

My sincere appreciation also goes to the committee of my examiners, Ir. Dr. Nina Korlina Madzhi, Assoc. Prof. Dr. Hamzah Ahmad, and Prof. Dr. Mauridhi Hery who had provided me with their insightful comments that inspired me to widen my research field.

This thesis is dedicated for my family who have been with me throughout this challenging and valuable journey. My husband, Khairil Safwan bin Sirajuddin, and my children; Nur Insyirah and Muhammad Isyraq who have been my pillar of strength. Their love, support and encouragement means the world to me. My parents; Cikgu Mohamad Yatim bin Husin and Cikgu Site Fatimah binti Mohamad, that have always believed in me. My parents-in-law Dato' Sirajuddin bin Saleh and Datin Khairiah binti Majid for their never-ending support. All my siblings and sibling in-laws; Norazlina, Norfadzliah, Suliana, Norlizah, and everybody, my helper; Ecih Kasnali, I can't thank them all enough. Their help, understanding and encouragement has made this journey less tough for me.

I am also deeply grateful for my dear friends at the CSES laboratory of FKE, UiTM who have accompanied and supported me throughout my study, Nabilah, Kasumawati, Nazliah, Zarina, Usamah, Hasniliati, Azlina, Rosnah, and Syamimi. My dear friend, Zarina binti Mohd Noh who has been with me through thick and thin. I am forever grateful for our friendship.

This is indeed a valuable journey for me. May Allah blessed this outcome. May Allah grants us all His forgiveness. May Allah strengthen this ummah. All praised to Allah The Almighty, Most Merciful. May Allah accept this as my 'ibadah. May He grants us His Redha.

Alhamdulillah. All praise to Allah.

TABLE OF CONTENTS