Development of a Swarming Algorithm for Mobile Robots

by

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LIST OF ABBREVIATIONS

ACO	Ant Colony Optimization
ADC	Analog to Digital Converter
API	Application Programming Interface
BT	Bluetooth
dBm	Decibel milliwatts
DC	Direct Current
GND	Ground
GPS	Global Positioning System
I/O	Input/Output
IR	Infrared
LED	Light Emitting Diode
NPN	Negative Positive Negative
PC	Personal Computer
PCB	Printed Circuit Board
PIC	Programmable Integrated Circuits
PSO	Particle Swarm Optimization
PWM	Pulse Width Modulation
RF	Radio Frequency
RFID	Radio Frequency Identification
RSSI	Receive Signal Strength Indicator
RX	Receive
SMT	Surface Mount Technology
TX	Transmit
UART	Universal Asynchronous Receiver- Transmitter
USB	Universal Serial Bus

VCC	Common Collector Voltage
V_{in}	Input Voltage
V_{out}	Output Voltage

LIST OF SYMBOLS

%	Percentage
−	Negative
+	Positive
β	Beta
V	Voltage (volt)
Ω	Resistance (ohm)
°	Degree

Pembangunan Algoritma Berkerumun untuk Robot Bergerak

ABSTRAK

Robot berkerumun pada dasarnya terdiri daripada sekumpulan robot ringkas yang berinteraksi dan bekerjasama antara satu sama lain untuk mencapai matlamat bersama. Ia diilhamkan daripada serangga sosial, yang boleh melaksanakan tugas-tugas yang di luar kemampuan individu. Dalam tugas pandu arah, sistem robot tunggal tidak sesuai digunakan disebabkan tugas pandu arah yang biasanya meliputi kawasan yang luas. Tambahan pula, sistem robot tunggal adalah lebih rumit dan memerlukan kos yang lebih tinggi untuk dibina disebabkan struktur robot yang lebih kompleks untuk membolehkan keupayaannya. Disebabkan itu, sekumpulan robot ringkas diperkenalkan. Kumpulan robot boleh melakukan tugasan bersama dengan lebih cekap berbanding dengan robot tunggal, sekaligus membangunkan satu sistem yang lebih mantap. Tesis ini membentangkan satu pendekatan algoritma berkerumun menggunakan robot bergerak. Algoritma berkerumun dilaksanakan dengan menambah keupayaan platform robot bergerak dengan autonomi dan pengesanan bau. Tugasan ini memberi tumpuan kepada pengesanan sumber bau kimia dalam persekitaran ujian dan pelaksanaan sistem ketua dan pengikut melalui komunikasi tanpa wayar. Projek ini telah dibangunkan secara berperingkat, bermula dengan pelaksanaan perkakasan di mana robot bergerak telah diberi keupayaan untuk mengesan halangan. Sensor TGS 2600 Figaro telah digunakan untuk membolehkan keupayaan mengesan bau. Bagi membolehkan robot bergerak berkomunikasi antara satu sama lain dan melaksanakan sistem ketua dan pengikut sebaik sahaja lokasi bau kimia ditemui, robot telah dipasang dengan modul X- Bee. Robot yang pertama sekali mengesan bau kimia akan menjadi ketua dan lain-lain secara automatik akan menjadi pengikut. Kekuatan Isyarat Petunjuk (RSSI) X- Bee digunakan sebagai parameter untuk menganggarkan jarak antara ketua dan robot pengikut. Algoritma ini telah dibina menggunakan persekitaran pembangunan Arduino. Dengan menggabungkan ketiga-tiga peringkat algoritma, algoritma berkerumun diuji. Di dalam kajian ini, penetapan sistem ketua- pengikut telah dicadangkan sebagai kaedah pencarian menggunakan robot berkerumun. Keputusan menunjukkan bahawa kaedah pencarian menggunakan sistem ketua- pengikut menghasilkan komunikasi berpusat antara semua robot bergerak. Komunikasi ini membawa kepada pertukaran data tanpa wayar yang lebih baik antara robot berbanding komunikasi agihan di mana setiap keputusan adalah berdasarkan kepada setiap ejen di dalam persekitaran ujian. RSSI yang digunakan di dalam kajian ini boleh dijadikan parameter untuk mengukur anggaran jarak di antara robot bergerak. Penggunaan RSSI adalah kaedah baru di dalam pengiraan jarak antara dua nod komunikasi tanpa wayar berbanding Bluetooth, sensor ultrasonik dan Sistem Kedudukan Global (GPS) yang telah digunakan secara meluas. Berdasarkan nilai RSSI, eksperimen sistem berkerumun ditunjukkan. Daripada keputusan eksperimen, penstabilan nilai RSSI semasa penghantaran data tanpa wayar boleh dikembangkan pada masa hadapan.

Development of Swarming Algorithm for Mobile Robots

ABSTRACT

Swarming robots basically consist of a group of several simple robots that interact and collaborate with each other to achieve shared goals. It is inspired by social insects, which can perform tasks that are beyond the capability of an individual. In a navigation task, a single robot system is not suitable to be used as an agent for the navigation usually covers a wide range of area. Furthermore, a single robot system is more complicated and requires a higher cost to build since the mobile robots need to be more complex in order to enable their abilities. Therefore, a group of simple robots is introduced. A group of robots can perform their tasks together in a more efficient way compared to a single robot, hence develop a more robust system. This thesis presents an approach for swarming algorithm using autonomous mobile robots. This project implements the swarming algorithm by supplementing the ability of mobile robot platforms with autonomy and odour detection. The work focused on the localization of chemical odour source in the testing environment and the leader and follower swarm formation through wireless communication. The project was developed in stages, namely hardware implementation where the mobile robots were given the ability to detect obstacles. A TGS 2600 Figaro sensor was utilized to provide the ability to detect odour. To enable the mobile robots to communicate with each other and able to perform leader and follower designation once the target has been found, the robots were installed with X-Bee module. The robot which found the odour source first will be the leader and the other will automatically become a follower. The Received Signal Strength Indicator (RSSI) of X-Bee is used as the parameter to estimate the distance between the leader and the follower robots. The algorithm was developed using Arduino development environment. By combining these three algorithm stages, a simple swarming system is tested. In this research, the leader-follower designation has been proposed as the method of swarming searching behaviour. The results show that the searching method provides a centralized communication between all the mobile robots. This communication leads to a better wireless data exchange between mobile robots compared to the distributed communication approach which decision making is based on each agent in the testing environment. The RSSI used in this research shows the reliability as an estimation parameter between mobile robots. The use of RSSI is a new method of estimating the distance between two wireless communication nodes despite the widely use of Bluetooth, ultrasonic sensors and Global Positioning System (GPS). Based on the RSSI value, the swarming system experiment is demonstrated. From the results, future work on the stabilization of the RSSI value during the wireless data transmission can be further investigated.

CHAPTER 1

INTRODUCTION

1.1 Project Overview

Swarm robotics is an approach of the coordination of large numbers of robots that takes inspiration from the abilities of social insects such as ants, bees and termites. The interest in this field of research has started since early 1980's and grows continuously every year (Beni, 2005).

A single robot may be difficult to accomplish certain complex tasks alone. Therefore swarm robotics may provide an efficient solution to the problem that requires a lot of energy and cover large spaces. The system may be made more robust compared to the single robot system since it can avoid the system failure if one of the robot does not function. The applications of swarming robots have been implemented in military, hospitals, search and rescue and even for observation in a place that hardly reachable to human being.

Nowadays, instead of self-build robot, many robot platforms have been commercialized by researchers to expand and encourage research in robotics. E-Puck, Khepera, Alice and Jasmine are some of commercial robot platforms available. Usually these mobile robot platforms had been occupied by sensors and communication module and ready to use. Most of these robots are suitable to be used as agents for indoor or outdoor based on their characteristics and size.

One of the most important criteria in swarming robot is method of communication. The implementation of swarming renders the use of tethered approach unusable, hence is the only option considered. The process of choosing the suitable communication method is usually based on the criteria of the project.

This project entails the investigation and implementation of swarming robot application employing mobile robot communication and odour localization. The swarming application is based on the centralized communication between the leader robot and the follower robot. This is because the leader and follower strategy is more suitable for the optimal plan can be generated for the swarm robot team, compared to distributed communication which all the decisions are based on individual.

An Arduino based mobile robot and E-Puck have been used as the agents for the experiments. The work focuses on the development of algorithms to perform the swarming behaviour from single movement to searching and targeting. Hardware experiments were conducted in this project.

The development of an algorithm is divided into three stages. The first stage is the basic algorithm for the basic abilities of the mobile robot, such as obstacle avoidance algorithm. The second stage is an algorithm to develop wireless communication among agents. In this process, X-Bee module has been chosen as a wireless communication module. The third stage is the development of an algorithm for swarming robot behaviour which is achieved when all the agents able to communicate with each other to exchange data and find the leader.

1.2 Problem Statement

If part of the single robot system fails, the whole system might be seriously affected by it. However, in swarming system, if one robot breaks down the role of the robot can be replaced by the others. Therefore the system is not significantly affected by individual failure. This capability makes the swarm robotic system more robust compared to single robot system. Based on the statement, the swarming strategy is chosen to be investigated in this project.

Odour detection and localization has been the main focus of this research. In a single robot system, a problem arises when the robot needs to cover up a large space of area to detect and locate the odour source in the environment. A single robot may need a more complicated design to be able to function everything on its own. This will lead to a higher cost in building a single robot. Furthermore, the time spent for a single robot to cover a large space of navigation area will be longer. In order to save the time spent and to make the work easier, a group of simple robots is used for odour detection. Despite its low costs because of its simplicity in design, a group of robots also can cover a much wider area thus improving the time spent for searching activity.

From the previous research, the odour detection using a group of mobile robots is not widely studied yet. Localization of odour source is the biggest issue as without the accurate positioning, the mobile robot would wander away from the targeted source and failed to complete the tasks given (Marjovi, Nunes, Sousa, Faria, & Marques, 2010).

The use of GPS, infrared, ultrasound and WiFi has been developed, but each of them shows the weaknesses at certain times. Therefore, the use of Zigbee is investigated in this research. The Zigbee is chosen because of its cheaper costs and less power consuming (Noh, Lee, & Ye, 2008). By using the Received Signal Strength Indicator (RSSI), an estimated distance between transmitter and receiver can be measured.

1.3 Project Objectives

There are several targeted objectives to achieve once this project completed. These objectives are:

i. To investigate the effectiveness of using a group of robots to complete certain tasks.
ii. To perform an odour localization strategy using three mobile robots by supplementing the centralized communication between robots.
iii. To investigate the use of Received Signal Strength Indicator (RSSI) of Zigbee communication in estimating the distance between mobile robots.
iv. To perform the swarming robot behaviour experiment after all the abilities of mobile robots are achieved.

1.4 Project Scope

The scope of this project covered on the localization of odour source in the testing field using two types of mobile robots, E-Puck and Arduino which has been enhanced with the abilities to sense odour source, avoid obstacles and communicate wirelessly using X-Bee. The mobile robots used centralized communication and searched by using the leader and follower strategy. From the previous research, the RSSI is compatible to be used for the swarm mobile robot for its simplicity and wider communication distance (Noh, Lee & Ye, 2008; Jeong & Lee, 2011). Therefore, RSSI of X-Bee is proposed as the new method of estimating the distance between mobile robots. The swarming algorithm is developed to test a simple swarming system of mobile robots in testing field.

1.5 Thesis Outline

This thesis is divided into five chapters. Each chapter will discuss a specific area of the development of swarming algorithms for mobile robots.

Chapter 1 consists of an introduction of the concept of swarming behaviour and its application in swarm robotics. The objectives, scope of the project and problem statements were discussed in this chapter.

Chapter 2 discuss about the literature review of swarming robots. All the research is compiled and studied. Similar project by previous researchers are discussed to find the best method and solution for this project.

Chapter 3 explains the methodologies and experiments conducted in testing E-Puck and Arduino mobile robot for swarming system development. Every step of the process to develop and enhance these mobile robots is discussed in this chapter. This chapter covers both the software and hardware testing before the swarming system is implemented.

Chapter 4 covers the development of algorithms and results and discussions from the experiments. The entire algorithm used for the experiment is presented here, as well as the flowchart of each sub-algorithm and the whole swarming algorithm. All the results are discussed and evaluated to determine whether the objectives of the project were achieved.

Chapter 5 summarizes the project and the results obtained from the experiment. Recommendations are listed to inspire the other researchers to improve the work in the future.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The research of swarm robots has started since 1980's, and grows rapidly when the world started to discover its advantages, as they can fulfill certain tasks that are quite complicated for a single robot to accomplish. The application of multi robots can be seen in many applications, such as factory automation, dangerous environments, office, hospitals, surgery, agriculture, military and so on.

Swarm robots were inspired by biological studies of self-organized behaviour in social insects (Garnier, Gautrais, & Theraulaz, 2007). Natural examples of swarms also include schools of fish, flocks of birds and herds of sheep.

Swarm robotics acts like a massive parallel computational system and thus carry out tasks beyond the possibility of the other types of robotic systems, either complex single robots or centralized group of robots (Beni, 1989). In other words, the swarming behaviour makes the tasks which are impossible to be completed by one single robot to be easier and required much less time.

There are a few characteristics of swarm robotics listed by researchers, which are robust to environmental disturbances or member faults, flexible which can coordinate actions to achieve something and scalable (Sahin, Girgin, Bayindir, & Turgut, 2008).

In addition to the characteristics above, the swarm robotic system must also be able to detect the other agent communicates among each other and having physical