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Development of Leader and Follower Strategy for Swarm Robot Applications

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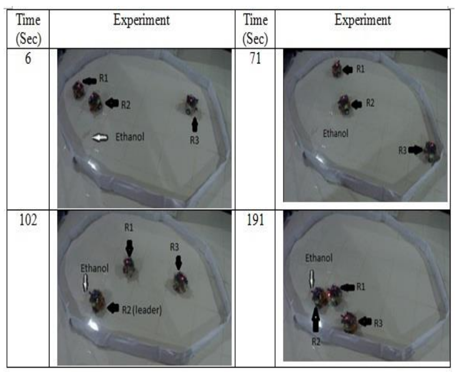
Graphical abstract



Abstract

Swarming robots basically consist of a group of several simple robots that interact and collaborate with each other to achieve shared goals. A single robot system is not suitable to be used as an agent for the navigation usually covers a wide range of area. 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. In order to interact, a wireless communication strategy is implemented to enable the group of mobile robots to perform their tasks. 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. 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 RSSI value of X-Bee module is used.

Keywords: Communication, leader-follower, RSSI, swarm, wireless, X-Bee

Abstrak

Robot berkerumun pada dasarnya terdiri daripada sekumpulan robot mudah yang berinteraksi dan berkerjasama antara satu sama lain untuk mencapai matlamat bersama. Sistem robot tunggal tidak sesuai digunakan sebagai agen mencari disebabkan proses mencari meliputi kawasan yang luas. Oleh sebab itu, sekumpulan robot mudah diperkenalkan. Robot berkumpulan dapat melaksanakan tugas mereka bersama dengan lebih berkesan berbanding satu robot; membolehkan sistem yang lebih teguh dibangunkan. Untuk berinteraksi, strategi komunikasi tanpa wayar dilaksanakan bagi membolehkan sekumpulan robot bergerak menjalankan tugas mereka. Projek ini membangunkan algortima berkerumun dengan menambah keupayaan robot bergerak secara autonomi dan pengesanan bau. Kerja ini memberi tumpuan terhadap pencarian tempat bau kimia di dalam persekitaran ujian dan pembentukan sistem ketua dan pengikut melalui komukasi tanpa wayar. Untuk membolehkan robot bergerak berkomunikasi antara satu sama lain dan melaksanakan sistem ketua dan pengikut sebaik sahaja sasaran dijumpai, nilai RSSI modul X-Bee telah digunakan.

Kata kunci: Komunikasi, ketua-pengikut, RSSI, kerumun, tanpa wayar, X-Bee

1.0 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. 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 [1]. 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.

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. The strategy employing a team of robots in order to achieve a specific goal has many advantages over the deployment of a single robot. First, a team of robots will create an intelligent system to fulfill some tasks. Second, a team of robots can avoid fault in case the robot is damaged or run out of battery. A swarm of robots too is needed in accomplishing tasks that are difficult for human beings. Reference [2] has identified eight primary researches within multirobot systems. The research axes are biological inspiration, communication, control approach, mapping and localization, object transport and manipulation, motion coordination, reconfigurable robotics, learning and task allocation.

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 localization. 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.

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. 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 [3]. 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 [4]. By using the Received Signal Strength Indicator (RSSI), an estimated distance between transmitter and receiver can be measured. The exchange of RSSI data between mobile robots involved wireless communication. In this paper, the leader and follower strategy via wireless communication is discussed further.

2.0 METHODOLOGY

Wireless communication between robots is very important in swarming robot research since the robots can be independent and work as a single agent. Therefore the methods used as wireless communication among robots have developed widely. Robots communicate either in explicit communication or implicit communication. Explicit communication is where the messages are broadcasted or directed. Infrared (IR) and Radio-frequency (RF) are two widely used technologies for explicit communication. Implicit communication includes the interaction of robots between its neighbours or environment. As explained in [2], in communicative swarming, the robots may exchange and use information of all other robots which allows for cooperative behaviours such as cooperative search, cooperative area coverage, and cooperative gradient following and formation control.

Since the previous research encountered problems while applying the ultrasound, infrared or Wifi as the wireless communication [4], the X-Bee module has been chosen as the new method to be investigated. The Received Signal Strength Indicator (RSSI) of X-Bee is used as the parameter to estimate the distance between two nodes of X-Bee. The research contributed in the swarming system development by applying the centralized control approach using the leader and the follower concept. The centralized communication is used because of its advantages in producing an optimal plan for the mobile robots group [5]. In order to assign the leader in the testing environment, the mobile robot which found the odour source first will become a leader to the other. The communication between the mobile robots is based on the implicit communication, where the data packets broadcasted by the leader are used by the follower to gather the information of the leader's location.

3.0 RESULTS AND DISCUSSIONS

3.1 Communication Using X-Bee Module

In wireless communication algorithm, the RSSI of X-Bee is the most important parameter being measured in order to estimate the distance between two Arduino mobile robots. In this experiment, an X-Bee has been chosen as the wireless communication module between Arduino mobile robots. The main objective of wireless communication is to locate the current position of the leader robot in the testing environment. The localization of the leader robot's position is done by a follower robot. The RSSI indicator is a parameter in –dBm unit used to measure the signal strength between two nodes of X-Bee. In order to validate the possibility to use the RSSI, an experiment was conducted to get the RSSI profile before the data being used as a parameter to search for the leader in the testing environment. This profile is very important since it can affect the mobile robot's searching behaviour.

There are two experimental conditions that have been tested, which is:

i. Unblocked condition
ii. Blocked condition (room to room)

Theoretically, the RSSI value will decrease once the distance between two X-Bees are increased. This characteristic will let the mobile robots to search for their leader by estimating the distance based on the RSSI value. The first experiment was an unblocked condition where the Arduino mobile robots were placed side by side without any blocking materials between them. The RSSI readings between two mobile robots were taken for 10 times starting from 12.5cm which is from X-Bee to X-Bee at the top of the robots. The distance then is added every 5cm to find if there were any differences in the RSSI reading. The Table 1 below shows the average data of RSSI over distance from X-Bee to X-Bee between two Arduino mobile robots.

Table 1 Average RSSI value over distance for unblocked condition between two Arduino mobile robots

Distance (cm)	RSSI (dBm) (Unblocked)
12.5	-28.0
17.5	-28.7
22.5	-31.0
27.5	-31.0
32.5	-31.0
37.5	-34.6
42.5	-35.9
52.5	-35.6
62.5	-37.0
72.5	-38.0
82.5	-39.2
92.5	-42.9
102.5	-43.0

The data are plotted to get a clearer RSSI characteristic for the unblocked condition.

Figure 1 shows the RSSI value of unblocked condition. From the plot, the RSSI value is lower as the distance between these two mobile robots getting longer. Therefore, the RSSI is reliable to be used to track the leader robot since the readings are constantly decreasing over distance and only fluctuate sometimes due to interference in the laboratory especially the electronics and wireless components.

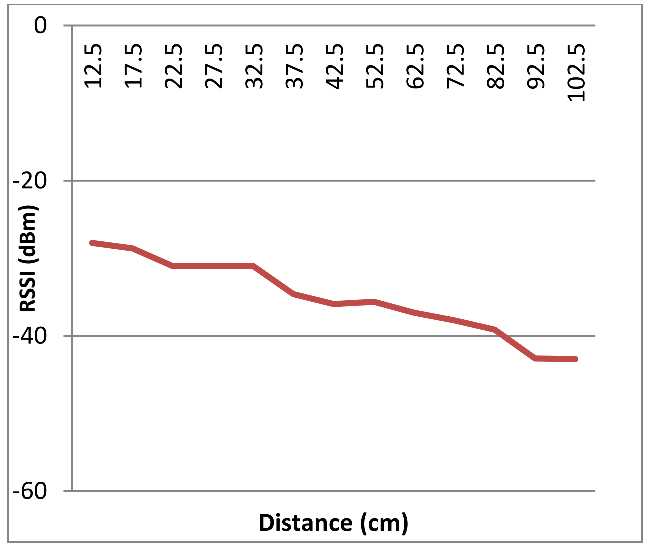


Figure 1 Plot of average RSSI value over distance (cm) between two Arduino mobile robots in unblocked and blocked condition

The experiment is repeated in room to room condition to analyse if there is any difference in RSSI profile compared to results from Figure 1 above. Arduino mobile robots are placed side by side in two different rooms and separated by a door which acts as separator in the experiment. The distance started at 18cm which is the distance from X-Bee to X-Bee of the mobile robots plus 5.5cm thick separator. The distance then is added every 5cm to see if there is any difference in RSSI readings. For each distance, the RSSI value between these two mobile robots is taken for 10 times. Table 2 below shows the average RSSI value in room to room condition between two Arduino mobile robots in blocked condition. The data are plotted to get a clearer RSSI characteristic for the blocked conditions in two separate rooms.

Figure 2 shows the average RSSI value between two Arduino mobile robots when separated in two different rooms. The result shows that the RSSI value is lower when the distance is longer. Compared to Figure 1, the RSSI value of Arduino mobile robots separated in different rooms is lower than the RSSI value without blocking materials. This shows that the RSSI readings are affected when two X-Bees is communicated within the obstacles or walls between them.

Since the characteristic of RSSI often leads to a noisy and unreliable data, the exact distance measurement is probably hard to obtain. Therefore, to solve the problem, the data from RSSI can be measured as relatively close or relatively far from the modules [8]. This has resulted in the measurement of RSSI between two X-Bee modules using –dB range as mentioned in section 3.0.

Table 2 Average RSSI value over distance for blocked (room to room) condition between two Arduino mobile robots

Distance (cm)	RSSI (dBm)
18	-38.4
28	-39.0
38	-41.3
48	-45.5
58	-48.0
68	-48.7
78	-51.8
88	-52.7
98	-55.1
108	-56.1

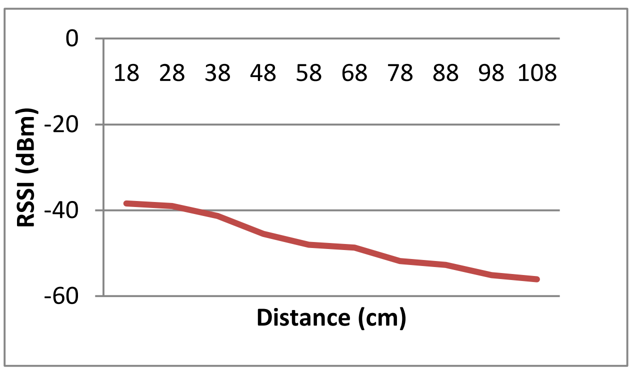


Figure 2 Plot of average RSSI value over distance (cm) between two Arduino mobile robots in room to room position

3.2 Development of Algorithm

From the results of the RSSI characteristics, an algorithm of follower robot searching for the leader robot and an algorithm of the swarming system demonstration were developed. In swarming experiment, the RSSI indicator is used to locate the location of the robot leader in the environment. When the leader has already detected an ethanol in the testing environment, the leader will stop at the odour source location and an API data frames are broadcasted to the follower to inform the presence of chemical odour in the testing environment as well as the RSSI of the current location of the leader.

First, the follower robot will stay at its initial condition and then it will continue checking if any values have been sent into the serial communication. Once an API data frames containing RSSI of X-Bee is sent into the serial communication, the follower robot will start moving forward with obstacle avoidance to track the position of the leader robot. At the same time, the follower will read the RSSI value sent by the leader continuously.

Based on RSSI value of unblocked condition in Figure 1, when the RSSI value is already between -28dBm and -43dBm, the follower will stop searching since the leader's RSSI is at the minimum range of RSSI, which is about 12.5cm to 102.5cm distance from the leader. This means that the leader is already nearby the follower.

The swarming experiment is conducted using three mobile robots. All the mobile robots are searching for the odour source at the same time. The mobile robot which found the odour source first will become a leader automatically and transmit its RSSI to the other members. When the other mobile robots received the signal, they automatically become followers and started searching for the location of the leader. The experiment is shown in the Figure 3 below.

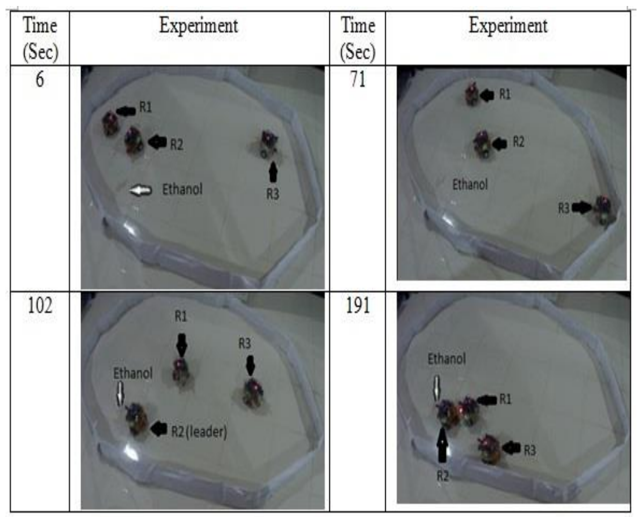


Figure 3 Experiment of swarming exploration

Figure 3 shows the movements of three mobile robots labeled R1, R2 and R3 in the testing environment with obstacle avoidance and odour localization ability. The experiment begins with the search for an odour source by these three Arduino mobile robots. At 67 seconds, R2 found the odour source and automatically set itself as the leader. It then transmits the RSSI signal to the other mobile robots, which are R1 and R3. Once R1 and R3 in the testing environment received the RSSI signal, they automatically assigned themselves as the followers and started to move to locate the leader by updating the RSSI transmitted by the leader. The swarming system ended at 91 seconds, when both followers (R1 and R3) found their leader (R2).

4.0 CONCLUSION

The research has come out with the method that is less investigated by previous researchers, which is the use of RSSI in tracking the mobile robots. The wireless communication algorithm allows the mobile robots to have a centralized communication where the leader robot and the follower robot communicate wirelessly through X-Bee to find the location of odour source. The implementation of the swarming strategy for the mobile robot then utilises all of the functionalities provided for the robot. The swarming algorithm used two main programming functions, which is the leader function and the follower function.

Based on the results, the leader- follower formation is effective in searching and localizes the odour source and their leader in the testing environment. The advantage of using the RSSI is that the X-Bee can communicate up to 30m, while IR signal and Bluetooth signal can go up to 10m only [7]. Furthermore, the Bluetooth communication is easily broken above 15cm, whereas the X-Bee can still communicate effectively up to 2m [7]. This shows that the use of RSSI is more effective than the Bluetooth in covering the large space of area.

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