Behavior Learning of Swarm Robot System using Bluetooth Network

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Abstract

With the development of techniques, robots are getting smaller, and the number of robots needed for application is greater and greater. How to coordinate large number of autonomous robots through local interactions has becoming an important research issue in robot community. Swarm Robot Systems (SRS) is a system that independent autonomous robots in the restricted environments infer their status from pre-assigned conditions and operate their jobs through the cooperation with each other. In the SRS, a robot contains sensor part to percept the situation around them, communication part to exchange information, and actuator part to do a work. Especially, in order to cooperate with other robots, communicating with other robots is one of the essential elements. Because Bluetooth has many advantages such as low power consumption, small size module package, and various standard protocols, it is rated as one of the efficient communicating technologies which can apply to small-sized robot system. In this paper, we will develop Bluetooth communicating system for autonomous robots. And we will discuss how to construct and what kind of procedure to develop the communicating system for group behavior of the SRS under intelligent space.

Key Words : Bluetooth Network, Behavior Learning, Swarm Robot System(SRS), Intelligence Space

1. Introduction

Recently the research against the system which is composed of the swarm robot extension of robot application field plentifully is realized. Specially, research regarding of swarm robot system that autonomous distribution which is a feature of the natural world living thing the interest is realized. The like this swarm robot system compares in center civil official elder brother system, the next some feature be hold. First the each robot recognizes the environment of circumference and or the behavior back of the object and the different robot, also accomplish the behavior of the-oneself independently and it will be able to cooperate in order to a position work well the different robot. Second autonomous distribution robot system has robustness and flexibility [2]. The some robot breakdown, don't gives an effect to normal operation of system and against a position work only it will be able to apply in multi branch work only behavior rule of the robot to change, with zoom. Third even though size of system is bigger, complexity of system is not increase because of judges and decisive in circumference situation of the-oneself of the robot of each one and complicated boat song of decisive [3].

In the Swarm Robot Systems (SRS), each independent individual robot understands its situation through the surroundings, and then operates its given jobs through cooperation with each other. For these cooperative works, the exchange of the information between the robots should be essential and communication module is an important element to construct a distributed autonomous robot[4-7].

Bluetooth[8-9] is a kind of short-distance wireless communication methods. It is developed for portable device and has several kinds of more advantageous things than other wireless communication methods - low power consumption, cheap price, and small package size etc. Moreover, Bluetooth provides various standard protocols. Because of these reasons, Bluetooth is regarded as the most suitable wireless technology for build up the small-sized SRS.

In this paper, we will introduce Bluetooth network for distributed autonomous robotic system. First of all, the Bluetooth network has the ability of independent operations.

We will design the system to organize a network scheme and to maintain the network scheme in the small sized communication module. In addition to these features, the network module should serve a kind of standard interface which commonly used by the most people. If the Bluetooth network is developed in this way, development convenience will be increased because of independent operation of each part in the robots and this Bluetooth network will be applicable to other embedded systems easily.

Except the previous hardware features, many considerable view points are remained - about network scheme, constructing sequence, and routing problem. We should deliberate on how to organize the network system, what kind of network form to be constructed, and what sequence to be used

On the other hand, an Intelligent Space (iSpace) proposed by

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Hideki Hashimoto is vary interesting concept in the SRS environments, which is able to support human in informative and physical ways. Most of intelligent system interacts with human in a passive space, but in iSpace, a space, which contains human and artificial systems, is an intelligent system itself. Human and artificial systems become clients of iSpace and simultaneously the artificial systems become agents of iSpace. Since the whole space is an intelligent system, iSpace, a spatial system, is able to monitor and to provide services to clients easily. Specific tasks, which cannot be achieved only by iSpace, are accomplished by utilizing its clients. For examples, iSpace utilizes computer monitors to provide information to the human, and robots are utilized to provide physical services to the human as physical agents. Robot as well as human is supported by iSpace if it is necessary. When a robot is lacking of sensors to navigate around in iSpace, the robot is treated as a client of iSpace and lacking information is provided to the robot by iSpace. The ultimate goal of iSpace is to accomplish an environment that comprehends human's intentions and satisfies them. It seems that such a system is hardly achieved, since a huge number of functions should be prepared and human-like intelligence is required. Even though such a complete system cannot be achieved immediately, it is convinced that a useful system can be achieved with current technology by proper system integration.

In this paper, the features of Bluetooth are briefly demonstrated in the chapter 2. The Group Behavior of SRS under Hexagon-Based O-Learning Algorithm is described in the chapter 3. In the chapter 4, we show the experimental environment with Bluetooth host, Bluetooth client, furniture and home appliance, and robots. And the chapter 5 is conclusion.

The robots basically performed patrol guard to detect unexpected penetration, and to keep home safely from gas-leakage, electric leakage, and so on. They were out to patrol for a robbery while navigating in a living room and a private room. In this task, we used a target search algorithm based on dynamic programming to control the robots. Second, the robots communicate with Bluetooth host device to access and control a home appliance. The Bluetooth host offers a manual control to person by inquiring a client robot when one would like to check some place especially. In this exercise, we organize asynchronous connection less (ACL) between the host and the client robots and control the robot maneuver by Bluetooth host controller interface (HCI).

2. Bluetooth

Bluetooth was developed as low power consumption and low price solution to connect mobile phone with peripheral device by Ericsson in 1994. After it was proved the potential of wireless communication solution, Bluetooth SIG was organized and it was occupied one of the wireless communication technology.

2.1 The standard and technology

Bluetooth is designed for portable devices using the power of a battery, so it satisfies the conditions – low cost, low power, and compact size. This inexpensive communication standard allows various types of electronic equipment to communicate with each other through a wireless system without direct action from a user. These communication speeds from Bluetooth are real time and do not require humans to plug or pull the cables. Besides elimination of cables, Bluetooth eliminates the drawbacks of other wireless connections such as infrared and cable synchronizing. First, Bluetooth uses a radio frequency to communicate through the devices. Second, Bluetooth provides agreement on when and how many bits are sent at a time, and it makes sure the message sent is the same message received. Once the agreement is reached, the Bluetooth enabled products communicate at a frequency of 2.45 GHz.

When Bluetooth devices come within proximity of each other, they electronically and automatically communicate and establish if they have data to share or when one needs to control the other. Each Bluetooth enabled peripheral has a programmed address transmitter in it, which is within a range of addresses established for a certain device. The device sends out radio signals, and if another device within the same address range receives this signal, it will send a signal back to the original device and a personal area network (PAN) is formed. Bluetooth devices can only communicate with each other if they have the same profile and capabilities [10].

2.1 Features

This technology commonly supports various standard protocols. Basically most of Bluetooth modules serve HCI level interface and higher protocol stacks are implemented by software. Sometimes, the rest serve RFCOMM level interface – higher protocol than HCI – in the Bluetooth module. The following figures show compositions of Bluetooth Stack in the typical system using Bluetooth.

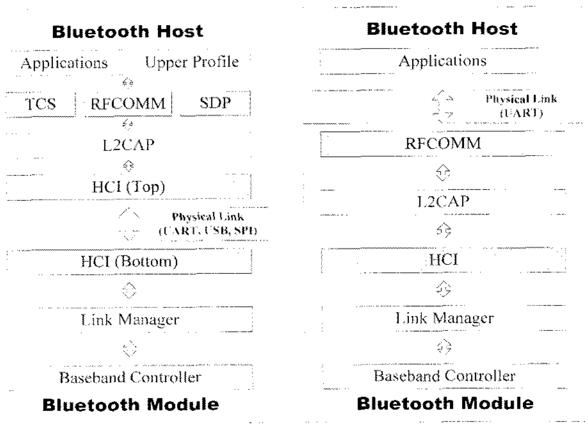

Fig. 1. Bluetooth Stack and Typical Bluetooth System

2.2 Bluetooth Network Module

Bluetooth network module is composed basically of a Bluetooth module and a network controller to organize a network system with the Bluetooth modules. We use the Bluetooth module which contains CSR Bluetooth chipset [8] - It support UART interface - and use ATmega128 [9] - Atmel's 8bit RISC microcontroller - as a network controller. The reason why we choose the CSR Bluetooth chipset is simple. This chipset supports UART interface and is the most commonly used. An ATmega128 contains about 128KB memory and supports 2 UART interfaces and is widely used in the world. The network controller communicates only HCI commands with the Bluetooth module. Interfacing with network controller and Bluetooth module, logic voltage difference problem may occur. However, it is easily solved by a level shifter device. If external UART use the same voltage of Bluetooth module, exchanging ATmega128 for ATmega128L can solve the interfacing voltage problem.

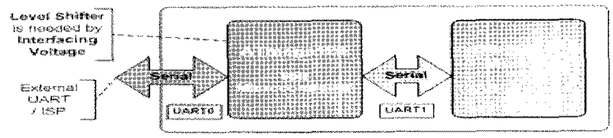

Fig. 2. Bluetooth Network Module Diagram

2.3 Adaptation to Robots

In our lab, we are developing SRS agent robots. In this SRS robot, Bluetooth network module takes an important role of communication part and uses UART as an interface with other parts. Our small mobile robot consists of four subparts and a main controller part. Fig. 3 shows each sub-parts, that is, (a) sensor part, (b) motor driving part, (c) main control part, (d) Bluetooth control part, (e) vision processing DSP module, (f) the appearance of robot. Each subpart has its own controller, PIC16f873A, to perform its unique function more efficiently. The main controller part, Atmega128, controls the other subparts to avoid process collision and to determine the actions at each state. Then, drive the motors to move the robot toward the next state under the applied algorithm.

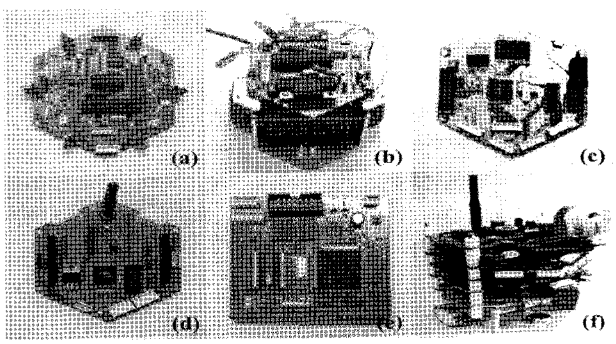

Fig. 3. (a) sensor part, (b) motor driving part, (c) main control part, (d) Bluetooth control part, (e) vision processing DSP module, (f) the appearance of robot

2.4 Development & Test

Bluetooth module which we use supports several kinds of interfaces such as UART, USB, and SPI. In order to test Bluetooth network system in the same environments that robot operates, we had better directly program to the robot. However, if only the operation of Bluetooth module is inspected, the result would be similar to that of direct programming. So we recommend the following procedures.

(1) The operation procedures of every Bluetooth module should be designed in order of time sequence.

(2) After that, to test the designed procedures is executed. In this stage, we recommend test with serial dongles, because HCI level command is standard and HCI level test program is offered [10].

(3) If thus much is correctly performed, network controller may be programmed. After the programming, test of each Bluetooth network module and entire Bluetooth network system should be examined. Passing the test, the Bluetooth network system would be operated well.

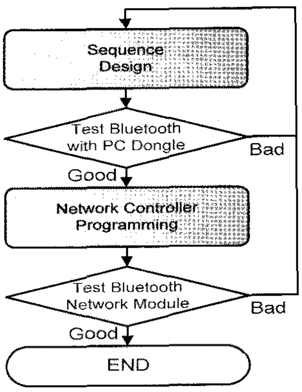

Fig. 4. Bluetooth development and Test

3. Behavior Learning of SRS under Hexagon-Based Q-Learning Algorithm

In this research, we focused on Q-learning as a reinforcement learning technique. It is because Q-learning is a simple way to solve Markovian action problems with incomplete information. Also wrap up it can map state-action pairs onto expected returns on the basis of the action-value function Q. In this paper, we propose the hexagon-based Q-learning so that the learning process can adapt to real world situations better.

3.1 Q-Learning Algorithm

Q-learning is a well-known algorithm for reinforcement learning. It leads an agent to acquire optimal control strategies from delayed rewards, even when it has no prior knowledge of the effects of its actions on the environment. Q-learning algorithm is presented in Table 1, where s is a possible state, a is a possible action, r indicates an immediate reward value, and γ is the discount factor. The formula to update the table entry value is:

$$\hat{Q}(s,a) \leftarrow r + \gamma \max_{a'} \hat{Q}(s',a'). \quad (1)$$

Table 1. Q-Learning Algorithm

For each s,a initialize the table entry $\hat{Q}(s,a)$ zero
Observe the current state s
Do forever
• Select the action a and execute it
• Receive the immediate reward r
• Observe the new state s'
• Select the action
• Update the table entry for $\hat{Q}(s,a)$
• $s \leftarrow s'$

Figure 5 explains Q-learning algorithm more clearly more clearly. Each grid square presents the possible states. 'R' stands for a robot or an agent. The values upon the arrows are relevant $\hat{Q}$ values with the state transition. For example, the value $\hat{Q}(s_1, a_{right}) = 72$, a_{right} refers to the action that moves 'R' to its right.

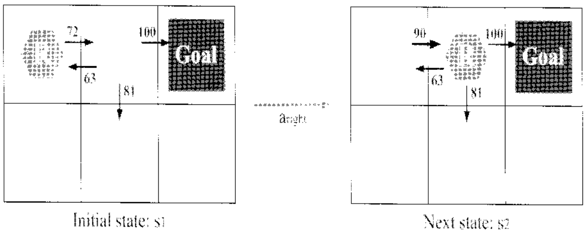

Fig. 5. An illustrative example of Q-learning.

$\hat{Q}(s_1, a_{right}) = 72$, a_{right} refers to the action that moves 'R' to its right.

If the robot takes the action to the right, the value will be updated for this entry where $r = 0$, $\gamma = 0.9$ are predetermined values. The formula is as follows.

$$\begin{aligned} \hat{Q}(s_1, a_{right}) &\leftarrow r + \gamma \max_{a_2} \hat{Q}(s_2, a_2) \\ &\leftarrow 0 + 0.9 \max_{a_2} \{63, 81, 100\} \\ &\leftarrow 90. \end{aligned} \quad (2)$$

3.2 Hexagon-Based Q-Learning Algorithm

The unique type Q-learning for our robot system is adapted to enhance the area-based action making (ABAM) process. The adaptation can be performed with a simple and easy modification, namely, hexagon-based Q-learning.

Figure 6 illustrates example of hexagon-based Q-learning. Compared with normal square-based state space, the only thing that was changed is the shape of state space. The reason why we changed the shape of the space from a square to a hexagon was that the hexagon is a polygon which can be expanded infinitely by its combination. According to this adaptation, the robot can take an action in 6-direction and have 6-table entry $\hat{Q}$ value. In Fig. 4, the robot is in the initial state. Now, if the robot decides that +60 degree guarantee the widest space after calculating of its 6-areas of surrounding, the action of the robot would be $a_{+60°}$. After the action is taken, if *Area6'* is the widest area, the value of $\hat{Q}(s_1, a_{+60°})$ will be updated by the formula (1) and (2) as

$$\begin{aligned} \hat{Q}(s_1, a_{right}) &\leftarrow r + \gamma \max_{a_2} \hat{Q}(s_2, a'_\theta) \\ &\leftarrow 0 + 0.9 \max_{a_2} \{Area1', \cdots, Area6'\} \\ &\leftarrow \gamma Area6'. \end{aligned} \quad (3)$$

where s is a possible state, a is a possible action, r indicates an immediate reward value, here is predetermined 0, and γ is the discount factor [11]-[14].

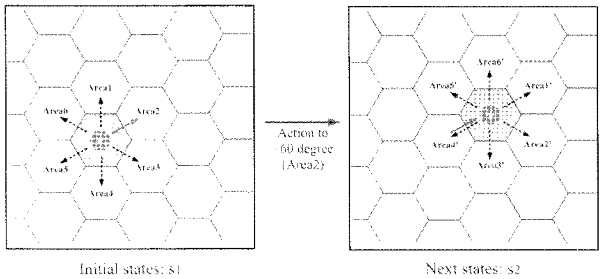

Fig. 6. An illustrative example of hexagon-based Q-learning.

After the movement from the initial state to the next state, immediate reward becomes the difference between the sum of total area after action is taken and the sum of total area before action is taken. Thus, the reward is where $Area_i \in s$, and $Area_j \in s'$ respectively. The hexagon- based Q-learning algorithm is presented in Table II.

$$r = \sum_{j=1}^{6} Area_j - \sum_{i=1}^{6} Area_i \quad (4)$$

Table 2. Hexagon-based Q-learning algorithm

For each s,a initialize the table entry $\hat{Q}(s,a_\theta)$ zero
Calculate 6-areas at the current state s
Do until the take is completed
• Select the action a_θ to the widest area and execute it
• Receive the immediate reward r
• Observe the new state s'
If $\hat{Q}(s', a'_\theta)$ is greater or equal than $\hat{Q}(s,a_\theta)$
• Update the table entry for $\hat{Q}(s,a_\theta)$
• $s \leftarrow s'$
Else, if $\hat{Q}(s', a'_\theta)$ is far less than $\hat{Q}(s,a_\theta)$
• Move back to the previous state
• $s \leftarrow s$

4. Experiment Results

In this paper, our experiments performed by using two control methods: ABAM and enhanced ABAM by hexagon-based Q-learning. The target was a stationary robot with the same shape as other robots and the color was green. It was a located at a hidden place behind one obstacle such like a desk. Three robots, whose mission is to find the target, would recognize it by its color and shape. They would decide whether they finished the task by detecting the target after each action was taken. First, ABAM is applied to the robots. They could sense their environment with 6-infrared sensors and calculate 6-areas. When the calculation was done, each robot tried to move toward the direction where the widest area would be guaranteed. Once the robots started to move, each robot spread out into the environment. In this paper, we used the hexagon-based Q-learning to ABAM as a modified control method. This method allowed the robots to reduce the probability of wrong judgment and to compensate wrong judgment with reinforcement learning. It also learned the experimental environment, state by state, and canceled the state transition if the action caused critical reduction of $\hat{Q}$ value. By using the hexagon-based Q-learning adaptation to ABAM, we could obtain more refined outcomes as more than two robots completed the task during ten trials and task completion time was faster. The search with hexagon-based Q-learning is presented in Fig. 7.

Fig. 7. Three robots are searching the object using hexagon-based Q- learning.

5. Conclusion and Future Works

In this paper, we develop the Bluetooth network system for the SRS. In this system, we use Bluetooth modules, because of its advantages – low power consumption, cheap price, small size, and various standard protocols. To guarantee the applicability and flexibility of the hardware module, we design Bluetooth network module with a microcontroller and additional circuits. Also To build simple and light weight structure, we select tree-shaped network scheme and define a simple construction algorithm. Nevertheless, this Bluetooth module has several problems. After understanding about this module's features, we could use the Bluetooth network system.

This Bluetooth System has numerous rooms for performance improvements in the circuit, network formation algorithm, and routings. We should try to increase the performance in various ways – hardware improvement and other network structure formation algorithm.

For hardware improvements, there are several possibilities. We can replace the Bluetooth module with another module which has more high speed transmission rate. Also circuital modification is needed for convenience of usage. If the higher profile stack and application program interface (API) are contained in the network controller, it is certain that easier and more flexible than that of the old system.

In the network scheme, we should compare a tree formation algorithm with the other network formation algorithm. We should examine what kind of algorithm is really suitable for the Bluetooth network system.

Also, In this paper, we presented the area-based action making (ABAM) process and hexagon-based Q-learning. Three small mobile robots were used to search for the object hidden in the unknown space. The experimental results from the application of the two different control methods in the same situations were presented.

For the future research, first, we need to clarify the problem of accessing the object. In other words, if multiple robots are to carry out a task such as object transporting or block stacking, they need to recognize the object first and then proceed to approach it. Second, our robot systems desire to be improved so that the main part and the subparts could adhere more strongly. In addition, stronger complex algorithms, such as Bayesian learning or TD (λ) method, need to be adapted. Third, a self-organizing Bluetooth communication network should be built so that robots can communicate with one another robustly even if one or more robots are lost. Finally, the total system unification using RoboSim simulator needs to be refined to obtain better results and offer the strong platform of mobile robot research.

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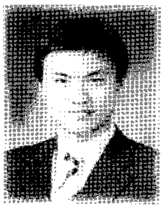

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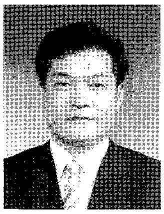

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