Swarm Robotics: Information Sharing By Multirobot System Using Distributed Control And Cooperative Manipulation

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ABSTRACT

Swarm robotics is a relatively new technology that is being explored for its potential use in a variety of different applications and environments. These include robot autonomy; decentralized control; large numbers of member robots; collective emergent behavior and local sensing and communication capabilities. Developing multi-agent systems with self interested agents with a large behavioral repertoire is a great challenge. In this paper, to explore the challenges, we have outlined a general platform considering the various design and protocol aspects that can be used to develop any specific application in the field of swarm robotics .The goal of multi-agent robots is to move as a cohesive team by sharing their distributed learning behaviors and navigating in autonomous reconnaissance missions. Finally some preliminary experimental results are presented of the developed collaborative navigation algorithm between robots to reach the target and achieve their goal sharing their knowledge.

Keywords – **Communication Protocol , Decentralized, Information Sharing, Localization, Swarm.**

1. Introduction

Swarm robotics is a new approach to the coordination of multirobot systems which consist of large numbers of mostly simple physical robots. It is supposed that a desired collective behavior emerges from the interactions between the robots and interactions of robots with the environment. Swarm robotics is a relatively new field that focuses on controlling large-scale homogeneous multirobot systems [1]. These systems are used to develop useful macro-level behaviors while being made of modules that are very simple in design and compact in size. These properties allow robot swarms to reach populations ranging from a dozen modules to hundreds of modules. The theme of simplicity and elegance resonates throughout swarm robotics research in both the designs of the robots as well as the algorithms that are devised for these systems. The algorithms are based on the idea that complex macro-level behaviors can emerge from simple local interactions between agents.

1.1 Definition

As with many technologies, there is no formal definition for swarm robotics that engenders universal agreement, however there are some characteristics that have been generally accepted. This approach emerged on the field of artificial swarm intelligence, as well as the biological studies of insects, ants and other fields in nature, where swarm behaviour occurs.

1.2 Inspiration to swarm robots

Ants are fascinating social insects. They are only capable of short-range interactions, yet communities of ants are able to solve complex problems efficiently and reliably [2]. Ants have therefore become a source of algorithmic ideas for distributed systems where a robot or a computer is the 'individual' and a swarm of robots or the network plays the role of the 'colony.' Ant robotics is a rapidly growing area in both artificial intelligence and robotics as shown in Fig. 1

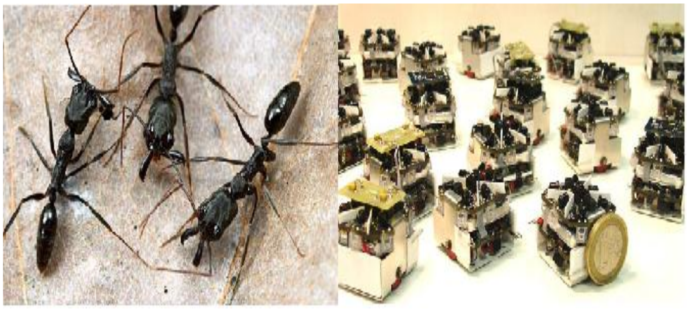


Fig. 1 Relation between Ants and Robots

1.3 Swarm Robot Versus Single Robot

1.3.1 A large range of task domain: The first improvement is an obvious one: robot swarms are able to cover more area than an individual robot.

1.3.2 Fault Tolerance: The swarm robotics algorithms do not require robots to depend on one another. If a single module fails, the rest of the swarm can continue performing its actions as if that module never existed.

1.3.3 Robustness: An individual robot system may become worthless if there is a failure in a critical component.

2. Concept

As the cost of robotic hardware has come down and availability has gone up, there has been growing interest in robotic systems which are composed of multiple simple robots rather than one highly-capable robot. This tradeoff reduces the design and hardware complexity of the robots and removes single point failures, but adds complexity in algorithm design. The challenge is to program a swarm of simple robots, with minimal communication and individual capability, to perform a useful task as a collective.

In this paper the proposed system considers collaborative interaction between robot team mates. When robots have individual goals, they are aware of their teammates, and their actions do help advance the goals of others. Each team member has his/her own goal of performing task, but by working together with others with complementary expertise, each can help other members to better achieve their individual goals. Of course, most of these collaborations are also cooperative, and it is possible to turn a collaborative team into a cooperative team by simply viewing the team goals from a higher perspective.

3. System design

Robots need to exchange certain information such as location and status in order to make global decision. In this case, maintaining continuous connectivity of a swarm is critical for the successful collaboration among robots within a swarm. The key challenge of coordination is how to ensure swarm connectivity without the prior knowledge about robot mobility pattern, i.e., robots can move freely based on its own intelligence and tasks. Compared to centralized approaches where a central control robot coordinate the movement of other robots, distributed approaches exhibits several advantages such as better scalability, efficiency, and fault tolerance. Based on collected information from neighbors through periodical message exchange, a robot can determine how to guide its own movement to achieve certain goals while maintaining effective connectivity[3].

3.1 Design Goals

1. Provide a modular hardware and software architecture. Individual modules should be easily modifiable and replaceable.
2. Provide a high performance microcontroller in a common and well supported architecture. Open source compilers and debugging tools should be available.
3. Provide a reconfigurable hardware component. Again, this component should be well supported with software tools and documentation.
4. Provide wireless communication. An inexpensive, off the shelf module is ideal.

3.2 Design requirement

Designing a robot's behavior is a challenging task that Researchers have been working for a long time. The behavior based approach to robot control has been the basis for many implemented robotics systems [4].

A simple task such as moving an object from one point to another implies the intervention of a set of abilities that a robot must be provided with in order to successfully achieve its goals. Some of these are: ability to perceive its environment, ability to make decisions when planning the task, ability to navigate through the environment and to avoid obstacles during the navigation, ability to execute the planned actions, and ability to recover from failure, among others. Clearly, the complexity of each individual's ability, and therefore the overall robot's behavior design, is related to the complexity of the environment where the robot carries out the task.

3.3 Design approaches

Based on the previous requirements mentioned various general approaches are considered. They are as follows:

3.3.1 Localization

In order for the robot to be truly autonomous, the robot has to know where it is via robot localization. The robot has to know where it is in order to execute its task. In order to localize, the robot has to obtain some reference point and which allows the robot to determine its relatively location from which the robot can gauge its environment and surrounding.

3.3.2 Mobility

Path finding is an important issue and one of the most fundamental problems in mobile robotics. It is to find almost reasonable collision-free path for a mobile robot to move from a start location to a destination in an environment with obstacles [5].

3.3.3 Wireless Communication

A wireless system replaces the need for a physical serial connection by establishing a layered connection between robots. One of the most crucial parts of robot is the need for a robust and reliable communication link between the robots. The communication is asynchronous so it will take huge power during transmission and monitoring. There are several solutions available to enable communication between the robots which the group will compare the advantages and disadvantages of each solutions.

4. Protocol design aspects

From the protocol design aspect, a set of protocols should be developed the following topics:

4.1 Distributed coordination of robot swarms

The problem of maintaining continuous connectivity is handled by incorporating network information such as topology, energy level, and link condition with robot status such as moving, working, or idle. In general, successful coordination protocols include, but not limited to the following [6]:

4.1.1 Movement based swarm coordination

It is desirable to have a distributed algorithm such that each robot determines its moving speed and direction to avoid link breaking.

4.1.2 Swarm partitioning recovery

A swarm partitioning recovery algorithm should be devised to first quickly detect the occurrence of the swarm partition. Then, based on the recorded historical connectivity knowledge, each robot decides its movement to recover the connectivity with previous neighbors.

4.1.3 Energy efficient swarm coordination

Since each robot only has limited battery power, it is important to minimize energy consumption. While coordination algorithms try to minimize necessary movements, power adjustment technique can be used to minimize the required energy to maintain effective connectivity.

4.1.4 Swarm deployment

Robots may move from one location to another location to perform certain tasks. How to maximize an area with a given number of robots is an interesting issue. A successful deployment algorithm has to be able to adapt to various environmental constraints such as obstacles and walls.

4.1.5 Data fusion and collaborative object recognition

Due to the limited knowledge at each robot, it is critical for robots to share the information with each other and reach the same conclusion. Then, data are analyzed to decide their relative importance for sharing.

4.2 Quality of service(QoS) support in wireless networks

4.2.1 Network reconfiguration

To design an automatic network configuration protocol such that the end device address of a robot swarm is dynamically changed according to the associated coordinator robot.

4.2.2 Load balancing

The QoS experienced by wireless end users is constrained by the number of gateway routers and available channels. Therefore, it is desirable to balance the load of network traffics going through gateway routers.

5. Algorithm

The algorithms are based on the idea that complex macro-level behaviors can emerge from simple local interactions between agents. A variety of algorithms have been implemented to be run on swarms of robots. Some provide basic functionality, such as dispersion, while others demonstrate seemingly complex teamwork, such as chain formation[7]. Although the algorithms all produce different emergent behavior, they all have many features in common.

5.1 Features

5.1.1 Simple and elegant

The robot controller that dictates the behavior of the individual robots is very simple. The behaviors of the individual robots can usually be represented as a state machine with few states and edges.

5.1.2 Scalable

Swarm robotics algorithms are designed so that they work for any number of robots. Also, they are expected to scale well as new robots are added.

5.1.3 Decentralized

The robots in a swarm are autonomous and do not follow any exterior commands. Although a member of a swarm can be directly and predictably influenced by the behavior of another, the choice is under its own accord. Being decentralized is often coupled with being scalable.

5.1.4 Usage of local interactions

Local interactions are used over broadcasting messages in the majority of these algorithms. Even broadcasts are implemented as message-hopping protocols.

5.2 Proposed Algorithm

In the following subsections we give an overview of a selected number of swarm robotics algorithms. For each algorithm we discuss how well they conformed to the ideals of swarm robotics.

5.2.1 Dispersion in Environment

One of the first algorithms deployed on a swarm robot is uniform dispersion. This algorithm is broken into two algorithms: one that disperses robots uniformly and one that explores boundaries as shown in fig.2. In this phase, each robot figures out if it is a wall node, a object node or an robot as obstacle. After this phase is done, the algorithm is switched back to the dispersion component.

Fig.2 Dispersion in environment

5.2.2 Distributed Localization and Mapping

A very common robot task is to explore a building, generate a map for human use and perhaps find items of interest. They devise a clever algorithm that moves the Swarm through an environment and generates a map with the constraint that the swarm must stay close together so that no communication links are lost. Therefore, the only way to map a large area is to move through it as a group. The robot must know where it is and its orientation to be able to map current sensor readings to a map. While these robots are moving about the environment, they will be generating maps individually. Since all robots are using the same frame of reference in the global environment, all maps are identical in scale and orientation.

5.2.3 Task Distribution

The next phase of algorithm for interaction in systems of distributed intelligence occurs when robots have individual goals, they are aware of their teammates, and their actions do help advance the goals of others. This part of the domain space is typically called collaborative, and is characterized by entities helping each other to achieve their individual, yet compatible, goals [8].

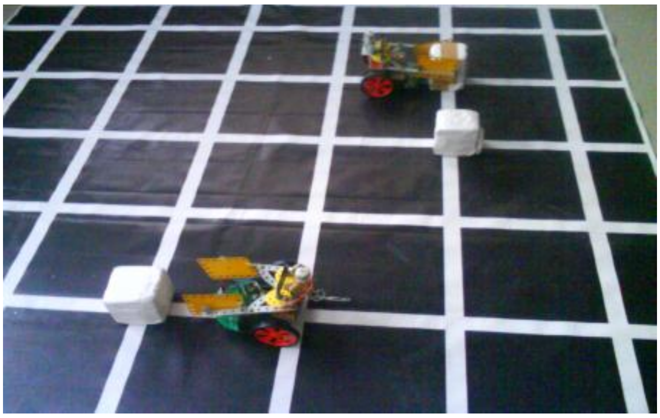
5.2.4 Information Sharing

A multi-robot example of a collaborative team is a group of robots that each must reach specified goal positions that are unique to each member. If robots are unable to reach their goal positions independently, due to sensor limitations, they could work together with other robots by sharing sensory capabilities to help all team members reach their individual goal locations. This type of collaboration is sometimes called coalition formation, and has been illustrated in multi-robot systems

6. Implementation

Experimental results showed that the robot system with our path finding ,object sensing and grid solving along with communicating algorithm can effectively collect information about the arena they explore and objects of their interest as depicted in Fig.3.They simultaneously perform pick and place operation in complex ground environment and avoid collision with the obstacles.

Fig.3 Experimental Results



6.1 Description

In this system, we have described a design and implementation of an information sharing system performed by autonomous robots.

6.1.1 Working Arena

For prototype we have made a fictitious arena of a grid of size 8*8.Each block on the node positions can be ordered to be kept at any of the 64 positions. The robots will move on white line over black surface.

6.1.2 Zigbee modules

Each of the robot has a ZigBee transceiver which helps each robot to communicate with each other [9].

6.1.3 Gripping mechanism

We have used two servo motors to develop each picking mechanism. The mechanism functions by sequential control of the motors.

6.1.4 Object

To demonstrate the objects we are using 10*10*10cm square black Boxes.

6.2 Steps of Algorithm

6.2.1 Dispersion

Initially robots will be placed on any random node of the grid. In this phase the robot travels to the extreme of the grid in each direction.

6.2.2 Localization and Mapping

Localization in an unknown world is difficult for an individual robot. In this multi-robot approach the global frame of reference is maintained as the swarm moves onward. The map in our prototype constitutes the structure of the grid along with its dimension like length, breadth and area. Localizing deals with the position of each robot with respect to common frame of reference on grid.

6.2.3 Task Distribution

While closely associated to the cooperative domain we make a distinction here to focus on the ability of entities to work together to help others better achieve their individual goal. The task is to divide the region of exploration along with the distribution of the task of searching a particular type of object.

6.2.4 Information Sharing

The robots must work to coordinate their actions to minimize the amount of interference between themselves and other objects. In these systems, entities are aware of each other and share their respective goal of searching a particular type of object in given environment, thus by working together and sharing the information with each other can help the other members better achieve their individual goals.

7. Application

In this section we will discuss some potential applications for swarm robotics.

7.1 Military

In Military areas researchers are working with the objective of provide each soldier with an insect-size robot for intelligence purpose. Each insect-like robot is its own being that obtains, processes, and shares data with other units in the swarm [10].

7.2 Disaster Relief

Robot swarms could be deployed during disaster relief operations. Swarm of autonomous robots to navigate and search in situations which are dangerous and time-consuming for humans thus enhancing operational safety and saving lives.

7.3 Agriculture

Robot Swarm can be used in the field of agriculture to perform the task of monitoring , harvesting and cultivation of crops.

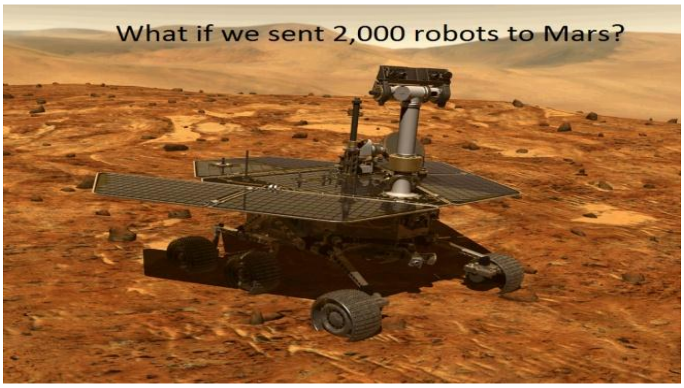
7.4 Pick and Place

7.4.1 Library: As we know that the books in the libraries are placed according to different subjects. The Robot can get the required book by mapping each section of library into grid. By communicating with each others, they can distribute the task and work accordingly [11].

7.4.2 Shopping Mall: Swarm robots can work as a guide to new customer to escort them to the shops.

7.5 Research Work(Mars Exploration)

Various space research organizations are planning to send out a multi robot system such that a desired collective behavior emerges from the interactions between the robots



and interactions of robots with the environment. With flavors of Mechanical Challenges and Swarm Intelligence, Space craft has to overcome the harsh terrain of Mars and successfully land the autonomous family of swarm bots on the planet to retrieve small rock samples back to the space ship in a specified order so that the collection can be organized as shown in Fig. 4 .The purpose of collecting rock is to discover if life ever existed on mars. If it did, the life cycle of mars may be used to learn important information for us here on earth [12].

Fig. 5 Single robot landed on Mars

8. Conclusion

In this paper, we have outlined aspects of the field of swarm distributed intelligence, focusing on the types of interactions that can occur in such systems. To explore the challenges, we have outlined a general platform considering the various design and protocol aspects that can be used to develop any specific application in the field of swarm robotics. The challenge as system designers is to create and make use of the appropriate system that best address the specific constraints and challenges of the application at hand.

9. Future work

We believe this time of inventing "neat robot tricks" for robot swarms is over. It is time for researchers to take swarm robotics to the next level and develop robust frameworks for developers to take full advantage of previous work. At this point, most emergent behavior must be hard-coded into an algorithm similar to the ones presented in this paper. A framework would allow developers to skip this step and go straight to writing applications in terms of macro-behaviors.

The results of the research are excellent and the advantages of swarm robots over traditional individual robots are clear. It is peculiar that this research has not been picked up more as a tool in practical applications. More research should be done to discover which real world scenarios swarm robots are actually effective in. In conclusion, we believe that swarm robotics is leaving its infancy and new research should focus more on applications of previous work.

References

[1] (2011) Swarm Robotics [Online] Available: http://en.wikipedia.org/wiki/Swarm_robotics

[2] (2011) Ants Colony [Online] Available: http://www.swarm-bots.org

[3] Patrick Benavidez, Kranthimanoj Nagothu, Anjan Kumar Ray," *Multi-Domain Robotic Swarm Communication System",* University of Texas at San Antonio, USA, 978-1-4244-2173-2/08/$25.00 ©2008 IEEE.

[4] Lynne E. Parker, Distributed Intelligence: Overview of the Field and its Application in Multi-Robot Systems, *JOURNAL OF PHYSICAL AGENTS, VOL. 2, NO. 1, MARCH 2008, 18-68-1-PB*

[5] Anhui CAI, Toshio FUKUDA, Fumihito ARAI, Koji YAMADA, Shiro MATSUMURA*,"Path Planning and Environment Understanding Based on Distributed Sensing in Distributed Autonomous Robotic System"*, 0- 7803- 3219- 9/96/$5.00 *0* 1996 IEEE.

[6] Ming Li, Kejie Lu, HuaZhu, B. Prabhakaran,*" Robot Swarm Communication Networks:Architectures, Protocols, and Applications",* Communication and Networking in china,2008,978-1-4244-2374-3.

[7] Mohiuddin Ahmed, Md. Raisuddin Khan, Md. Masum Billah, A Novel Navigation Algorithm for Collaborative Multi Robots, *European Journal of Scientific Research*,ISSN 1450-216X Vol.41 No.3 (2010), pp.472-481.

[8] Nicholas R. Hoff III, Amelia Sagoff, Robert J. Wood, Radhika Nagpal, "*Two Foraging Algorithms for Robot Swarms Using Only Local Communication"*, ROBIO 2010,978-1-4244-9319-7.

[9] Baoding Zhang, Shulan Gao, *"The Study of Zigbee Technology's Application in Swarm Robotics System",* 978-1-4577-0536-6/11/$26.00 ©2011 IEEE

[10] Fiona Higgins, Allan Tomlinson and Keith M. Martin,*" Survey on Security Challenges for Swarm Robotics",* Autonomic and Autonomous Systems, 2009. ICAS '09. 10.1109/ICAS.2009.62.

[11] Feng, K.; Hoberock, L.L.*; "An optimal scheduling of pick place operations of a rorobot-vision-tracking system by using back-propagation and Hamming networks",* Robotics and Automation, 1992,10.1109/ROBOT.1992.220085

[12]Jason M. Fox and Michael McCurdy, *", Activity Planning for the Phoenix Mars Lander Mission,"* in Aerospace Conference, *2007 IEEE*, 10.1109/AERO.2007.352951.