Scientific Journal of Impact Factor (SJIF): 3.134
e-ISSN (O): 2348-4470
p-ISSN (P): 2348-6406

International Journal of Advance Engineering and Research Development

Volume 3, Issue 1, January -2016

SWARM ROBOTICS: A NATURE INSPIRED MULTIROBOTICS SYSTEM

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Abstract *- Swarm robotics is a field of multi-robotics in which large number of robots are coordinated in a distributed and decentralized way. Swarm robotics is to study the design of large amount of relatively simple robots, their physical body and their controlling behaviors. The individuals in the swarm are normally simple, small and low cost so as to take the advantage of a large population. A key component of the system is the communication between the agents in the group which is normally local, and guarantees the system to be scalable and robust. A plain set of rules at individual level can produce a large set of complex behaviors at the swarm level.*

Keywords – *Swarm Robots, Stigmergy, De-centralized and Cooperative algorithms*

I. INTRODUCTION

Swarm robotics is the study of how to coordinate large groups of relatively simple robots through the use of local rules. It takes its inspiration from societies of insects that can perform tasks that are beyond the capabilities of the individuals. The individuals in swarm are not highly intelligent, yet they complete the complex tasks through cooperation and division of labor and show high intelligence as a whole swarm which is highly self-organized and self-adaptive. These individuals are not necessarily unwise, but are relatively simple compared to the global intelligence achieved through the system. A key component of the system is the communication between the agents in the group which is normally local, and guarantees the system to be scalable and robust. The swarm is distributed and de-centralized, and the system shows high efficiency, parallelism, scalability and robustness.

The potential applications of swarm robotics include the tasks that demand the miniaturization, like distributed sensing tasks in micro machinery, tasks that demand the cheap designs, such as mining task, tasks that require large space and time cost, and are dangerous to the human being or the robots themselves, such as post-disaster relief, target searching, military applications, etc. This paper summarizes the research performed during the last years in this field of multi-robotic systems. The aim is to give a glimpse of swarm robotics and its applications.

II. ADAPTIVE STRATEGIES

The collective behaviours of social insects, such as the honey-bee's dance, the wasp's nest-building, the construction of the termite mound, or the trail following of ants, were considered for a long time strange and mysterious aspects of biology Social insects are able to exchange information, and for instance, communicate the location of a food source, a favourable foraging zone or the presence of danger to their mates. This interaction between the individuals is based on the concept of locality, where there is no knowledge about the overall situation. The implicit communication through changes made in the environment is called stigmergy. Insects modify their behaviours because of the previous changes made by their mates in the environment. Organisation emerges from the interactions between the individuals and between individuals and the environment. These interactions are propagated throughout the colony and therefore the colony can solve tasks that could not be solved by a sole individual. These collective behaviours are defined as self-organising behaviours. Self-organisation relies on the combination of the following four basic rules: positive feedback, negative feedback, randomness, and multiple interactions.

- Bacteria colonies

Bacteria often function as multicellular aggregates known as bio films, exchanging the molecular signals for inter-cell communication.

- Fish schools

The fishes pay close attention to their neighbors when schooling with the help of eyes on the sides of heads and "schooling marks" on their shoulders. The fishes can benefit from fish schools in foraging and predator avoidance.

- Bird crowds

The birds gather into special formations during migration and locate the destinations with the aid of a variety of senses including sun compass, time calculation, magnetic fields, visual landmarks as well as olfactory cues.

The Characteristics of swarm robotics are described below

1. Parallel
2. Scalable
3. Stable
4. Economical
5. Energy efficient
6. Autonomous Decentralization
7. Local sensing and communications
8. Homogenous and flexible.

III. MODELLING SWARM ROBOTS

1. General model of swarm robotics

In the model, the robots in the swarm should have some basic functions, such as sensing, communicating, motioning, etc. The model is divided into three modules based on the functions which the module utilizes to accomplish certain behaviors: information exchange, basic and advanced behavior. The information exchange among three modules plays the most important role in the model. The Robots in the swarm exchange the information with each other and propagate the information to the whole swarm through autonomous behaviors resulting in the swarm-level cooperation. General model of swarm robotics is shown below. The robots communicate with each other. In some cases, the global positioning or central commands are introduced, but the swarm should still be able to complete the task if global communication is blocked.

2. Other Modelling methods for swarm robotics

Considering the characteristics of swarm robotics, the Modelling methods are divided into four types; sensor-based, microscopic, and macroscopic and swarm intelligence-based. The four methods are described in detail in this section.

➢ Sensor-based Modelling

In the sensor-based Modelling method, the sensors and actuators of the robots are modelled as the main components of the system along with the objects in the environment. Then the interactions of the robots are modelled as realistically and simply as possible. This Modelling method is mostly used, and the oldest method is used for robotic experiment.

➢ Microscopic Modelling

In the microscopic Modelling, the robots and interactions are modelled as a finite state machine. The behaviors of each robot are defined as several states, and the transfer conditions are based on the input from communication and sensing.

➢ Macroscopic Modelling

Macroscopic Modelling is a Modelling method opposite to the microscopic Modelling. In the macroscopic Modelling, the system behavior is defined as difference equation, and a system state represents the average number of robots in this state at the time step.

➢ Modelling from swarm intelligence algorithms

Cooperative schemes from swarm intelligence algorithms have been introduced into the swarm robotics in many researches. Since the robots use the same or similar schemes with these algorithms, the models and other methods used to analyze these algorithms, which are quite mature than that in swarm robotics, can be used directly for robot research.

The most commonly used algorithm from swarm intelligence is the particle swarm optimization (PSO) which mimics the flocking process of the birds. The particles fly in the field and search for the best. It can be found obviously that many commons remain between PSO and swarm robotics. A mapping between particle and robot can be presented easily

Besides PSO, the researchers also introduce other swarm intelligence algorithms into swarm robotics. Many successful swarm models were inspired from the ant colonies. These inspired approaches provide an effective heuristics for searching in dynamic environment and routing.

IV COOPERATION BETWEEN ROBOTS

Cooperation belongs to the advanced behavior in the swarm robotics model. In swarm robotics, cooperation occurs at two levels: individual level and swarm level. The former is must for robot's activities and coordinates the inputs from environment with the response, learning and adapting behaviors. The latter is an aggregation of former cooperation, resulting in the typical collective tasks such as gather, disperse or formation. Several sub-problems have been proposed for cooperation between robots which are described in detail in this section.

➢ Architecture of swarm

The architecture of the swarm is a framework for robotic activities and interactions and determines the topology for information exchange among robots. The swarm performance in cooperation depends largely on the architecture. The architecture of the swarm should be selected carefully according to the scale, relations and cooperation of the robots.

- Locating

Each robot in the swarm has to maintain a local coordinating system and should be able to distinguish, identify and locate the nearby robots. Thus, a method for rapidly locating other robots using on-board sensors is very important for swarm robotics
The absolute positioning technologies from single robots have been applied in some researches and the combination of sensors with special filters has been adopted. The sensors can sense different waves, including ultrasonic, visible light, infrared ray or sound

- Physical connections

Physical connections are used in the situations that single robot can overcome, such as over passing large gaps or cooperative transportation. In these tasks, the robots should communicate and dock before they continue to execute their tasks.

- Self-organization and self-assembly

Self-organization is a dynamic scheme for building a global structure through only local interactions of the basic units. The basic units or robots do not share a global control or have an external commander. The swarm level structure emerges from the individual level. The commonly used Cooperative algorithms are:

1. Particle Swarm Optimization
2. Ant System
3. Ant Colony System
4. Bees Algorithm
5. Bacterial Foraging Optimization Algorithm

Several potential applications of swarm robotics which are very suitable are described below.

1. Tasks which cover large area
2. Tasks dangerous to robot
3. Tasks which require scaling population
4. Tasks which require redundancy
5. Post-disaster relief operations
6. Target searching
7. Military applications

V FUTURE SCOPE

Swarms of robots acting together to carry out jobs could provide new opportunities for humans to harness the power of machines. The ability to control robot swarms could prove hugely beneficial in a range of contexts, from military to medical. The robots can also group themselves together into a single cluster after being scattered across a room, and organize themselves by order of priority.

On a larger scale, they could play a part in military, or search and rescue operations, acting together in areas where it would be too dangerous or impractical for humans to go. In industry too, robot swarms could be put to use, improving manufacturing processes and workplace safety. The bionic aero vehicles inspired from swarm intelligence technology will become applicable in a few years. It can be foreseen that machine bees or cockroaches with reconnaissance equipment and bombs will possibly show up in future war.

VI CONCLUSION

Swarm robotics is a relatively new researching area inspired from swarm intelligence and robotics. Besides the cooperative algorithms to provide control for the swarm, the manufacturing is a fundamental need for developing the swarm robotics systems. With the help of advance in Micro Electro Mechanical technology in the aspects of mechanical transmission, sensors, actuators and electronic components, the size and cost of robots have been significantly reduced. The progresses of hardware technology and cooperative schemes in both biology and swarm intelligence in future will boost the development of swarm robotics systems.

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