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Towards Advance Research in Swarm Robotics

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Abstract: ***Swarm robotics is a field of multi-robotics in which large number of robots arecoordinated in a distributed and decentralized way.Large number of simple robots can perform complex tasks in a more efficient way than a single robot, giving robustness and flexibility to the group.In this paper, an overview of swarm robotics is given, describing its characteristics, modeling&control ,different applications scope.This approach emerged in the field of artificial swarm intelligence as well as the biological study of insects, ants and other fields in thenature, where a swarm behavior occurs.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.***

Keywords: Swarm robotics; Cooperative control; Modeling; Simulation; Swarm intelligence, System of Systems (SoS)

1. 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 group of robots is not just a group. It has some special characteristics, which are found in swarms of insects, that is, decentralized control, lack of synchronization, simple and (quasi) identical members.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.

1.1 Swarm Intelligence

Swarm intelligence is a soft bionic of the nature swarms, i.e. it simulates the social structures and interactions of the swarm rather than the structure of an individual in traditional artificial intelligence. It is a new computational and behavioral metaphor for solving distributed problems, it is based on the principles underlying the behavior of natural systems consisting of many agents, such as ant colonies and bird flocks. The application of SI principles to multiple-robot systems leads to three main advantages: first, scalability of the control architecture, from a few to thousands of units; second, self organization, as units can be dynamically added, removed, or reallocated to different tasks without explicit reorganization; and third, increased system robustness, not only through unit redundancy but also through the design of simple units. One way to analyze and understand underlying common principles of swarm systems (both natural and artificial) is to capture their dynamics at more abstract levels. Modeling is a means for saving time, enabling generalization to different platforms, and estimating optimal system parameters. The swarm can complete the tasks that a complex individual can do while having high robustness and flexibility and low cost. It takes the full advantage of the swarm without the need of centralized control and global model, and provides a great solution for large-scale sophisticated problems.

1.2 Definition of Swarm Robotics

Swarm robotics is a new approach to the coordination of multi-robot systems which consist of large numbers of mostly simple physical robots. It is supposed that a desired collective behavior emerges from the interaction between the robots and the interaction of robots with the environment.The research of swarm robotics is to study the design of robots, their physical body and their controlling behaviors. A key-component is the communication between the members of the group that build a system of constant feedback. The swarm behavior involves constant change of individuals in cooperation with others, as well as the behavior of the whole group.

The potential applications of swarm robotics include the tasks that demand the miniaturization, like distributed sensing tasks in micro machinery or the human body. On the other hand, the swarm robotics can be suited to the tasks that demand the cheap designs, such as mining task or agricultural foraging task. The swarm robotics can be also involved in the 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.

1.3 Characteristics of Nature Swarm

Since the swarm robotics is mostly inspired from the nature swarms, it's a good reference for analyzing the characteristics of nature swarms. The research of swarm robotics started a century ago.The first hypothesis is quite personified and assumes that each individual has a unique ID for cooperation and communication. The information exchange in the swarm is regarded as a centralized network. The queens in ant and bee colonies are supposed to be responsible for transmitting and assigning the information to each agent.The biologists can now assert that there are no unique IDs or other globally storage information in the network. No single agent can access to all the information in the network and a pacemaker is therefore inexistent.

The biologists now believe that the social swarms are organized as a decentralized system distributed in the whole environment which can be described through a probabilistic model [27]. The agents in the swarm follow their own rules according to local information. The group behaviors emerge from these local rules which affect information exchange and topology structure in the swarm. The rules are also the key component to keep the whole structure to be flexible and robust even when the sophisticated behaviors are emerged.

1.4 Advantages of swarm roboticS

These characteristics are quite similar to that of nature swarm.

1.4.1 Comparing with a single robot

To complete a sophisticated task, a single robot must be designed with complicated structure and control modules resulting in high cost of design, construction and maintenance when a small broken part of the robot may affect the whole system and it's difficult to predict what will happen.It takes the advantage of reusability of the simple agents and the low cost of construction and maintenance. The swarm robotics also takes the advantage of high parallelism and is especially suitable for large scale tasks.The swarm robotics is inspired from the social animals.It's hard to simulate the human interactions using machines or computers while the mechanisms in animal groups are easier to apply. This gives the swarm robotics a bright future in dealing with complex and large scale problems.The advantages of swarm robotics are described below.

i) Parallel.

The population size of swarm robotics is usually quite large. Hence swarm can perform the tasks involving multiple targets distributed in a vast range in the environment, and the search of the swarm would save time significantly.

ii)Economical

The cost of swarm robotics is significantly low in designing, manufacturing and daily maintaining. The whole system is cheaper than a complex single robot.

iii) Energy efficient

Since the individuals in the swarm are much smaller and simpler than a giant robot, the energy cost is far beyond the cost of a single robot compared with the battery size. This means that the life time of the swarm is enlarged.the swarm robotics can be applied to sophisticated problems involving large amount of time, space or targets, and a certain danger may exist in the environment.

2. Modeling Swarms of Robots

The development of robots capable of acting in a swarm could be very costly. Tobuild and test tens, hundreds, or even thousands, of robots consumes scarce resources. Itis important to conduct as much development as possible without actually buildingdevices. Modeling can help determine design parameters in a number of areas.The physical characteristics of a potential vehicle can be modeled. The cost inweight, volume and power resources for each subsystem can be used in conjunction withthe payoff that each subsystem gives. This may help determine an optimum configurationfor an individual robot. Behavior or tactics may be modeled to help determine howindividuals should act in order to produce a desired group outcome. Complex modelsmay take into account both physical characteristics and behavior of individuals in orderto produce an overall system design.

i) General Model of Swarm Robotics

Swarm robotics model is a key component of cooperative algorithm that controls the behaviors and interactions of all individuals. 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 in Fig. 1. 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.

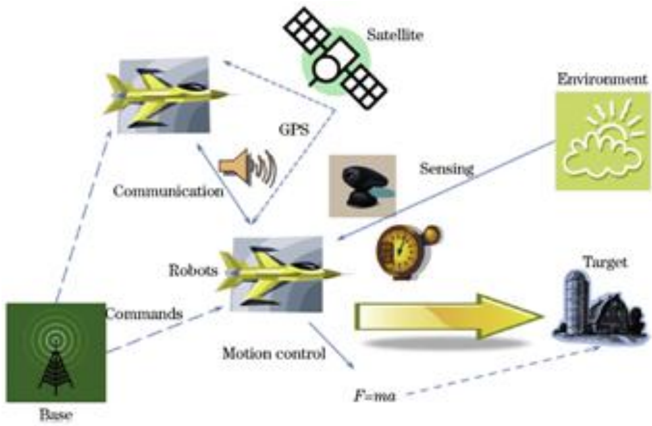

Figure 1: General model of swarm robotics

3. Simulation as a Modeling Tool

Simulation is the only tool currently available that allows researchers to model thecomplex systems faced in the design of robots to operate in swarms. A characteristic ofautonomous operation is the complexity associated with robot sensing, knowledge, andbehavior systems. Analytic models cannot be used to provide insight to basic questions inthis regard. The cheaply available power of current computing technologies allowssimulation to provide insight into many such problems. The computer simulation is developed to visually test the structures and algorithms on computer. Although the final aim of the research is real robots, it is often very useful to perform simulation prior to the investigation of real robots. Simulations are easier to setup, less expensive, normally faster and more convenient to use than physical swarms.

4. Control

There has been a strong focus on new System of Systems (SoS) concepts and strategies. The concept of SoS arises from the need to more effectively implement and analyze large, complex, independent, heterogeneous systems working cooperatively. The need for mathematical modeling among a group of heterogeneous systems in order to realize a common objective is essential to design a System of Systems. The concept of SoS arises from the need to more effectively implement and analyze large, complex, independent, heterogeneous systems working cooperatively. The SoS paradigm presents a new school of thought in Systems Engineering. The driving force behind the desire to view these systems as a System of Systems is to achieve higher capabilities and performance than would be possible with a traditional stand-alone system. The SoS concept presents a high-level viewpoint and allows understanding of the interactions between each of the independent systems. Each system in a System of Systems should be modeled to be controlled. There are generally two methods of modeling, physical modeling and mathematical modeling. In the classical modeling each system is modeled regardless of its cooperativeness with other systems. . The problem even gets worse in case of designing an optimal of adaptive controllers, which tend to be highly sensitive to the environmental influences on the system, such as noise. Simulation is to be carried out to demonstrate the use of robotics in a net-centric System of Systems to profit mankind

5. Applications

Regarding the domain of applications, the swarm robotic systems can be applied in various scenarios

i) Foraging
This scenario has many different applications and demands several fundamental skills from a group of robots, such as collective exploration, shortest path finding and efficient task allocation. It also includes the transport sub-task, which covers the important issue of collective transport].Some examples of applications of foraging scenario are toxic waste clean-up, search and rescue (SAR) and collection of terrain samples.

ii)) Dangerous tasks
Individuals that create a swarm-robotic system are dispensable making the system suitable for domains that contain dangerous tasks. For instance, demining can be cheaply accomplished by a swarm of robots.

iii) Exploration and mapping
Advancements in the design that lead to further miniaturization and lower cost of robotic units open many new possible scenarios. The inspection of all kinds of engineered structures can be carried out using swarms of robots, where process is usually time consuming and cost intensive. Robots in a swarm have limited sensing capabilities, but collective perception of the swarm can be used to create global knowledge (e.g. construct a map of the area). In the trophall axis-inspired strategy was used to successfully perform collective perception. It was used in different types of trilaterationas a localization method and combine it with the information exchange between robots to create a distributed framework for new applications. Some applications still appear to be distant future, such as use of robot swarms for Space exploration or use of nan robots moving through human veins and arteries for medical purposes (e.g. to fight certain types of cancer). They can also be used in military to form an autonomous army of their own. Recently, the U.S. Naval forces have tested a swarm of autonomous boats that [3] can steer and take offensive action by itself

6. Conclusion

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.

References

[1] Garner S, Gantries J, Theraulaz G. The biological principles of swarm intelligence. Swarm Intell 2007;1(1):3e31.
[2] Wang M, Zhu YL, HE XX. A survey of swarm intelligence.Comput Eng 2005;31(22):194e6 [in Chinese].
[3] Acer EU, Cholet H, Zhang YG, Shrewish M. Path planning for robotic demining: robust sensor-based coverage of unstructured environments and probabilistic methods. Int J Robot Res 2003;22(7e8):441e66..
[4] Xue SD, Zeng JC. Swarm robotics: a survey. Pattern RecognitArtif Intell 2008;21(2):177e85 [in Chinese].
[5] Spears WM, Spears DF, Heil R, Kerr W, Hettiarachchi S. An overview ofphysicomimetics. In: Swarm robotics, lecture notes in computer science, vol. 3342. Springer; 2005. p. 84e97
[6] Balch T. Communication, diversity and learning: cornerstones of swarm behavior. In: Swarm robotics, lecture notes in computer science, vol. 3342. Springer; 2005. p. 21e30.
[7] Hawick KA, James HA, Story JE, Shepherd RG. An architecture for swarm robots. Wales: DHCP-121. University of Wales; 2002
[8] Dorigo M, Tuci E, Groß R, Trianni V, Labella TH, Nouyan S, et al. Theswarm-bots project. In: Swarm robotics. Lecture notes in computer science, vol. 3342. Springer; 2005.p. 31e44.