Adding a New Dimension to Automation:

Integrating Swarm Intelligence & Robotics

Introduction

The significance of automation in this period of Fourth Industrial Revolution can't be overlooked in any way. But typical automation has some shortcomings. For examples, robots in rescue operations can only do what its code tells it to do, they cannot make decisions or change their behaviour without the input of a human operator. Swarm robotics have been studied in the context of producing different collective behaviors to solve tasks such as: aggregation, pattern formation, self-assembly and morphogenesis, object clustering, assembling and construction, collective search and exploration, coordinated motion, collective transportation, self-deployment, foraging and others. Before jumping off to our main idea, here are brief discussions about some of the key terms.

An Overview on Swarm Robotics

What is Robotics?

According to Robot Institute of America, "A robot is a reprogrammable, multifunctional manipulator designed to move material, parts, tools, or specialized devices through various programmed motions for the performance of a variety of task." Robotics is an interdisciplinary sector of engineering, electronics, computer science, artificial intelligence, mechatronics and nanotechnology that is dedicated to the design, construction and use of mechanical robots. Since the earliest robot "UNIMATE" from "Universal Automation" was invented by George C. Devol in the 1950s, the robotics field has developed a lot. Swarm robotics is the newest addition to this research field. The application of the principles of swarm intelligence to robots is called swarm robotics.

Swarm Intelligence

Swarm intelligence (SI) refers to collective intelligence. SI is a branch of computational intelligence that discusses the collective behavior emerging within self-organizing societies of agents. The concept is employed in work on artificial intelligence. The expression was introduced by Gerardo Beni and Jing Wang in 1989, in the context of cellular robotic systems.SI was inspired by the observation of the collective behavior in societies in nature such as the movement of birds and fish. The collective behavior of such ecosystems, and their artificial counterpart of SI, is not encoded within the set of rules that determines the movement of each isolated agent, but it emerges through the interaction of multiple agents

Principles of Swarm Intelligence

1. **Awareness** Each member must be aware of its surroundings and abilities.

2. **Autonomy** Each member must operate as an autonomous master (not as a slave) this is essential to self-coordinate allocation of labor.

3. **Solidarity** Each member must cooperate in solidarity: when a task is completed, each member should autonomously look for a new task (leveraging its current position.)

4. **Expandability** The system must permit expansion where members are dynamically aggregated.

5. **Resiliency** The system must be self-healing: when members are removed, the remaining members should undertake the unfinished tasks.

Swarm Robotics

According to Dorigo and Sahin, "Swarm robotics is the study of how a large number of relatively simple physically embodied agents can be designed such that a desired collective behavior emerges from the local interactions among agents and between the agents and the environment". Beni describes this kind of robots' coordination as "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."

Mapping & Locating with Swarm Robots: How it works

Method

The robots are put in an unmapped bounded area where an accident (e.g.- fire explosion, building collapsing, earthquake) occurred. The goal is to find the victim. The victim is located somewhere in the area. The swarm robots use a depth first search to find that victim while mapping the area. They will identify surrounding obstacles and update the coordinates to a local server. Once a bot finds the victim, the search is over. His location will be updated and a signal will be sent to the other bots. Then the remaining bots will use a pathfinding algorithm to traverse their way towards their respective starting positions waiting to be respawned, because they no longer need search for the target object.

Key Characteristics of the Robots

Among different types of robots we will use AUTONOMUS robots for our project. The robots in the swarm have some basic functions, such as sensing, communicating, motioning, and satisfy the following properties:

1. **Autonomy**—as the robots are autonomous robots they are independent and can interact with each other and the environment.

2. **Large number**—they are in large number so they can cooperate with each other.

3. **Scalability and robustness**—a new unit can be easily added to the system so the system is easily scalable. More number of units improve the performance of the system. The system is quite robust to the losing of some units, as there still exists some units left to perform. However, in this instance, the system will not perform up to its maximum capabilities.

4. **Decentralized coordination**—the robots communicate with each other and with environment to take the final decision.

5. **Flexibility**—it requires the swarm robotic system to have the ability to generate modularized solutions to different tasks.

Objective

We will use our swarm robots for cooperative mapping and locating and thus rescuing a victim. From the mapping's point of view, the group of swarm robots can be interpreted as a distributed mobile mapping system. There are several applications where mapping solutions can be applied, such as, aiding first responders in rescue operations, hostage situation, or supporting military activities. In civilian applications, these systems can be used for building inspections, mining activities, or for other mapping demands. Locating solution can be applied in search and rescue operations in disaster scenarios, exploration for natural resources, environmental monitoring, air traffic control and surveillance.

Benefits of Swarm Robotics in Mapping & Locating

Main benefits of our project include-

- Multiple robots will examine the target area from multiple points of view and locate the victim more efficiently. Hence the result will be more accurate and the process will be less time consuming compared to that of a single robot.
- The systems are robust. Robustness is defined as fault tolerance and fail-safety and it is achieved by massive redundancy and the avoidance of single-point-of-failures. The swarm is homogeneous and hence each robot can be substituted by any other.

- The control of the swarm is decentralized. Every robot interacts only with direct neighbors and it also stores only locally obtained data (i.e., local information). Failure of a single robot within the group does not always result in mission failure.
- These swarm robots are more flexible. Due to homogeneity there is no specialization in terms of hardware. The swarm is able to adapt to a wide range of tasks because often specialization in terms of hardware is not necessary. The robots overcome limits in their capabilities by cooperation.
- Another advantage is scalability. The control algorithms of the robots scale to any size of the swarm. It can maintain its function while increasing its size without the need to redefine the way its parts interact.

Conclusion

Tasks like mapping and locating are challenging for a single robot. Errors in sensors, measurements, correspondence problem, hazardous environment often lead to wrong result or mission failure. The swarm will be of great help in these cases as we mentioned before that error in one robot will not result in the failure of the entire mission. Last but not least, swarm robotics is relatively a new research field. Understanding and implementing it properly will add a new dimension to mapping and locating and thus upgrade rescue operations.