Multi-agent Robotic System for Surveillance

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Abstract— Surveillance meaning to "watch over" is the act of monitoring the activities in an area mainly to recognize and monitor threats and to prevent any undesirable or criminal activity. Surveillance plays a very crucial role especially in fields like that of military, where security is of utmost priority. The traditional systems used for surveillance face a number of flaws and thus our project aims at providing a more efficient and reliable solution for the purpose of surveillance. This project is aimed at designing a simple yet elegant swarm robotic system that can perform the task of surveillance at a much higher degree of reliability and robustness than that which is provided by the current systems wherein either humans are used or then not very reliable systems such as CCTV cameras. *Swarm robotics* is the study of robotic systems consisting of a large group of relatively small and simple robots that interact and cooperate with each other in order to jointly solve tasks that are outside their own individual capabilities. Swarm robotic system will work in a distributed fashion so as to cover the entire intended area efficiently. The system would have decentralized communication and thus it would be very difficult to break down the system and thus providing very high reliability.

Index Terms— Moblie Surveillance, Multi-agent sytems, Intelligent task allocation, Emergent algorithms, Fault adaption,

1 Introduction

Surveillance deals with the monitoring of the activities in an area. The techniques used today, like the use of CCTV cameras face many problems, which we aim at providing a solution to. One of the main problems faced with the current techniques is that due to lack of mobility, they do not cover the entire area efficiently and also the reliability of the system is low. The field of view of a camera is limited and therefore a large number of cameras would have to be installed to cover a large area. In spite of this, it cannot be ensured that the desired area is covered with respect to all angles. We intend on using a homogenous Multi Agent system of Unmanned Aerial Vehicles (UAVs) which due to its dynamic nature has advantages over a static system of CCTV cameras. The UAVs can maneuver around at different heights thus making sure that the surveillance of the required quality and from all the desired angles is carried out.

Mobility of the agents will ensure that there are no blind spots during the surveillance. Contrary to a CCTV camera, the area being monitored by each agent could be changed dynamically and thus an overall comprehensive view of the area of interest can be obtained. Furthermore a mobile system will also ensure that if required, a particular area can be examined in further detail. This can be done by moving an agent closer to the particular area. This will assure a higher level of security.

Another major advantage that this system will provide is a much higher degree of reliability and robustness. Our project presents a distributed system that has a greater degree of resilience. The system uses distributed intelligence wherein there is no central controller and each agent makes its decision on basis of communication with the fellow agents. Thus unlike the traditional system, this set up cannot be easily pulled down. The decentralized nature of the execution of the system ensures that system continues to work in spite of some failures. This can overshadow the disadvantage of centralized systems wherein if the central system fails the entire system would fail to operate. The system is also incorporated with a fault adaption system for higher reliability. If for some reason any of the agents is unable to perform its allocated task, the work would get redistributed among the remaining agents. This can prove to be a great advantage over the traditional set up of cameras wherein a camera being damaged would mean loss of surveillance of the area that was being covered by, the now, damaged camera.

The self adaptive nature of this system also brings a huge advantage to it. The system can easily establish itself in complex environments. A task allocation algorithm will help to divide the tasks among the agents such that any given environment would be surveyed thoroughly. The intelligence embedded into the system will not only allow to easily adapt to any environment but also allow for computerized checking that all areas are under cover, which is more reliable than a human setting up the system.

The paper is arranged in the following manner. The general architecture is first discussed, which gives an overview of the working of the entire system. The decentralized nature of the system is discussed along with the communication and task allocation among the agents.

2 General Architecture

This section deals with the general layout of the system and the description of its behavior. The system that has been proposed for an efficient surveillance is that of a multi agent robotics system comprising quadcopters onto which cameras are mounted. Quadcopters are Unmanned Aerial Vehicles (UAVs) that are, here, used to establish a dynamic multi agent system for surveillance. The reason for choosing a dynamic system is to gain advantage over the presently used static system of CCTV cameras. This system will consist of a number of

agents, depending on the area to be surveyed, who will form a network to work together towards the goal of surveillance. The advantage of multi agent systems is that the agents are together able perform the tasks that are beyond the capabilities of a single agent. The network of multiple agents also ensures that the task is performed with high reliability and efficiency. The system that we propose consists autonomous agents that coordinate and cooperate their tasks in a fashion so as to work towards the final goal of overall surveillance.

Each quadcopter is an independent autonomous agent of the system. It is equipped with all the sensors and hardware required for a smooth flight. It would also have a controller mounted onto it that makes the agent autonomous. The IMU sensor helps in navigation and for a stable flight. They are also equipped with a camera for the purpose of surveillance. Details about the hardware and sensors are given in detail in the following section.

The map of the area to be surveyed is known or could be drawn by initial mapping operation of the area. Once the map is known the area is divided according to the number of agents and the task allocation algorithm is used to allocate an area to each agent. The areas that are allocated are such that the areas of no two agents are overlapping. While allocating tasks, the height that the agents can position themselves at is also considered. A suitable height could be chosen such that a large area is covered by a single agent and at the same time it also provides a good quality. The height of the agents is changed periodically so that the area can be monitored with great detail. As one of the agent changes its height, the area it covers will also change and thus the tasks have to reallocated. If any particular area needs further examination, one of the agents can fly down therefore enabling a better scrutiny of the area but it would also cause that particular agent to cover a smaller area. Thus the remaining agents would have to readjust their own tasks in such a way that the entire area is still under proper scrutiny.

Once the tasks have been allocated, each agent will have to make sure that it performs the task efficiently and completely. Thus the controller of each agent has to work to ensure this. It has to process the signals from its sensors and perform the job that is assigned to it.

3 Task Allocation And Execution

The task of surveying is distributed among the agents in such a way that all the agents together can complete the entire task. The following algorithm can be followed for distributing the tasks:-

1. A map of the area to be surveyed is evaluated. From the map, the area covered by the buildings is deducted and the exact area for which the surveillance is to be carried out is found out.
2. Depending upon the size of the area, the number of agents are chosen. The area that can be covered by each agent can be evaluated by the height at which it is expected to work. A camera is mounted at the base of each quadcopter thus the area covered by each is in the form of a cone. Dividing the total area by the area of each agent, the number of agents required can be known.
3. For assigning tasks a factor is evaluated for each agent. The factor would be dependent on the quality and the cost of the agent.

$$F=Q/C \qquad \ldots(1)$$

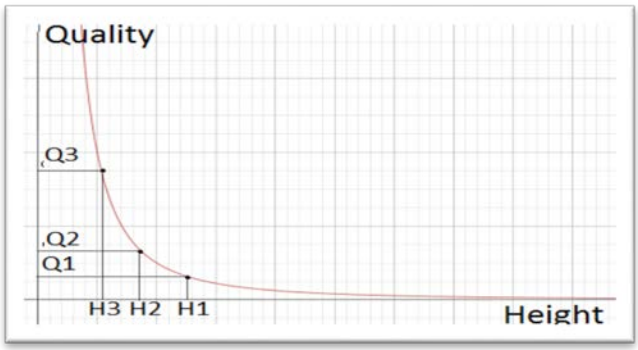
Where Q is quality that can be delivered and C is the cost that would be incurred. Quality is the degree to which the details of an area is being provided. Higher the degree, better the quality. Quality of surveillance changes with the height at which the agent is working. Cost would mean the distance of the agent from the desired point for which the decision has to be taken. An area is allotted to an agent with the highest factor.

4. Each area is further divided into grids for better analysis. Each grid is assigned a quality bar to monitor the quality of surveillance being delivered to it. The height would be divided into a number of levels and a quality factor is evaluated for each level. The quality of surveillance being provided to a grid depends on the height from which surveillance is done. Lower the height, better the quality, which is reflected in the quality bar. The quality varies with height as follows:

$$\text{Quality}(Q) \propto 1/(H^2)$$

$$Q=k/H^2 \qquad \ldots(2)$$

The variation of quality with height is shown below



The area being covered by each agent varies in direct

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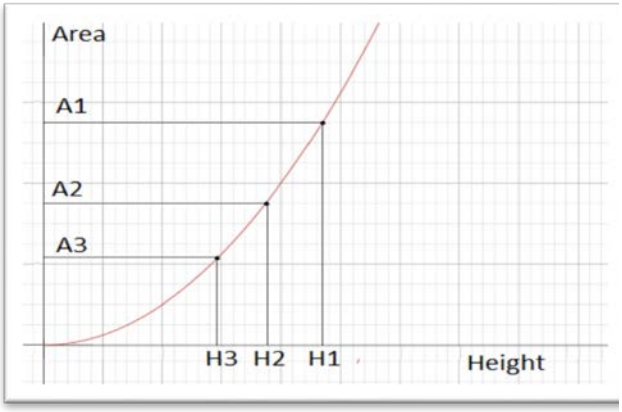
proportion with the square of the height.

$$A \propto H^2$$

The variation is depicted in the following graph.



5. For every quality level a certain time frame would be allotted and after that has been exceeded it has to be made sure that the grid is given a better quality of surveillance. For example, if the quality bar is divided into 3 levels, then the bar can stay at level 1(lowest quality being delivered) only for some time. After that the quality has to improve. For this, the agent providing service to this grid must lower its height to provide better service. As one of the agents lowers its height, the grids that it now covers, decreases. Thus another agent would have to take care of the grids that are now not being covered by this particular agent.

6. This can be done by an intelligent coordination between the neighboring agents using emergent algorithms for coordinated approach. The concept will be further explained in the following section. Through inter-communication with the neighboring agents each agent adjusts its position accordingly so that the output of the system is as desired. In this case, when one agent lowers its height, the neighboring ones will rise, so that all the grids are still being covered. This can be illustrated through an example. Let us consider a particular area that is covered by three agents.

7. Thus each agent covers one—third the total area. All three agents are now at the same height and therefore delivering a quality, say 'Q'. Now, if the agent in the middle is expected to provide a quality twice as better, it will have to decrease its height. The change in height is calculated as:

Present height : $H = \frac{1}{\sqrt{Q}}$ …(3)

New height: $Hnew = \frac{1}{\sqrt{2Q}}$ …(4)

Change in height is:- $(H - Hnew)/H$ …(5)

The above calculation gives a **change of 29.3%** in the height to increase the quality by a factor of 2.

For the new height, the area covered changes by 50%.

Thus this agent would now cover only one-sixth of the total area. The one-sixth portion that is not being covered by this agent now has to be covered by the other two. For this they will have to increase their heights so as to now cover an area of 5A/12, where 'A' is the total area. Thus the change in height that is required is

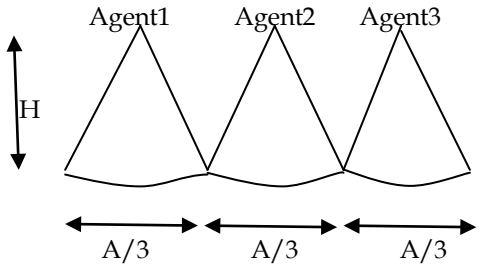
Present height = $\sqrt{A/3}$ …(6)

New height = $\sqrt{5A/12}$ …(7)

Therefore, change in height is

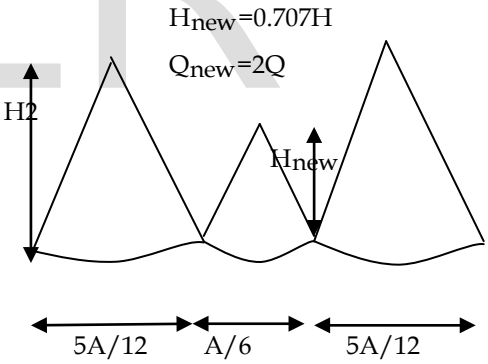
$$(\sqrt{5A/12} - \sqrt{A/3}) \,/\, (\sqrt{A/3}) \quad \ldots(8)$$

From the above calculation it can be evaluated that the neighboring agents will have to increase their height by **13.2%.** The above example is also illustrated in the diagram below.



Previous state

(For quality being delivered by Agent2 is Q.)



Next state

(For quality being delivered by Agent2 is 2Q.)

8. Thus we can see that by continuously varying the heights from which the surveillance is done, a very secure surveillance system can be set up. All points in the area are covered at all times and at the same time a very high degree of quality of surveillance is obtained. The system will ensure a robust and reliable surveillance.

9. The system also allows for fault adaption. If for some reason any of the agents is unable to perform its tasks, it would soon be understood by the system and the

tasks would get reallocated among the remaining agents.

4 EMERGENT ALGORITHMS AND ITS USE FOR THE CONTROL OF AGENTS ITATIONS

Emergent Algorithms:

Emergent algorithms take inspiration from the biological systems in which local interactions among a large number of simple components can produce a complex global behavior. Thus emergent algorithms can often be used in environments such as that of swarm robotics, wherein the agents interact locally with their neighbors and as a result can solve complex global problems efficiently. Emergent algorithms employ a decentralised approach which has significant advantages over conventional centralized software and hardware systems since the algorithmic complexity is achieved through simple components, each implementing simple rules, with well-defined interfaces and easily testable functionality.

In a system based on emergent algorithms, the performance of a system is the result of an autonomous decision made by each part, based on its own interpretation of the data or information. One of the major characteristics of Emergent Algorithms is the Decentralized Control and it is therefore also referred to as a distributed system. In this type of a system, there is no central controller. Instead, large numbers of simple units interact with each other to achieve complex, large-scale tasks. For instance, similar to the biological systems like that of a bee or an ant where the members communicate with each other to make an intelligent decision, swarm robotics too is based on information from its parts, while no central information processor is present or needed.

In the proposed system, the agents interact with their neighbors and accordingly navigate around. Thus we can see that in spite of the absence of a central controller, the agents, via intricate coordination, are able to execute the desired tasks. The agents use emergent algorithms in the following way:
Each agent communicates with its neighbors to know their positions and accordingly decides its own position. If an agent senses that its neighbor has decreased its height, it would decide to increase its own. In the system there is no central processor and each agent works in co-ordination with others to carry out the tasks.

The decision making process of each agent is influenced by two factors:- one, the quality bar of the grids that it is maintaining and second, the position of its neighbors. It will continuously monitor and work towards providing the quality of surveillance required by each grid, which is at most priority and then also check the position of its neighbors before making a decision about what its new position would be.

5 ARCHITECTURE OF EACH AGENT

Each agent is a quadcopter that is equipped with all the necessary hardware required for flying and for executing the given task.

Hardware:

1. Processor- STM32f4 DISCOVERY - A development board from ST Microelectronics with an ARM CORTEX M4 Processor.
2. IMU Sensor-MPU-9150 - The MPU-9150 is the world's first 9-axis Motion Tracking device designed for the low power, low cost, and high performance requirements of consumer electronics equipment. The MPU-9150 is a System in Package (SiP) that combines two chips: the MPU-6050, which contains a 3-axis gyroscope, 3-axis accelerometer, and an onboard Digital Motion Processor™ (DMP™) capable of processing complex Motion Fusion algorithms; and the AK8975, a 3-axis digital compass. The part's integrated 6-axis Motion Fusion algorithms access all internal sensors to gather a full set of sensor data

3. Camera-for surveillance.
4. Zigbee – for inter-communication between the agents. ZigBee is a wireless technology developed as an open global standard to address the unique needs of low-cost, low-power wireless M2M networks. The ZigBee standard operates on the IEEE 802.15.4 physical radio specification and operates in unlicensed bands including 2.4 GHz, 900 MHz and 868 MHz.
5. Ultrasonic sensor- for collision detection and avoidance and to calculate the height of the quad from

ground.

Software :

Panda pilot-it is an open source software for quadcopters.

Each agent has incorporated into it the algorithms for flying with stability, intelligent decision making, collision detection and avoidance. For collision detection stereo vision is used.

6 CONCLUSION

An intelligent system is developed that can, to a great extent, overcome the limitations of the traditional methods of surveillance. Not only does it introduce a new way of reliable and cost effective surveillance but also embeds a certain amount of intelligence into the system which helps the agents coordinate and perform the task in a highly reliable way.

The major advantages that are obtained by application of this system is the self-adaptive nature along with its robustness. The system does not have any centralized coordinator and therefore it is very difficult to bring down the system. The system is also instilled with a high degree of fault detection and adaptation. The intelligent agents can easily detect if one of their co-partners has been destroyed and can reallocate the tasks among themselves so that the entire area can still be surveyed. This serves to be a huge advantage over the present systems used for surveillance. This system also can be very easily installed anywhere. It is also cost effective and thus could provide to be good competitor for the current systems.

Swarm robotics can thus be very helpful in solving complicated tasks with great ease as the rules for implementation of each agent is easy and the entire system is set up by the interconnected working of individual agents. Thus a number of agents together perform the task that is beyond the capabilities of an individual agent.

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