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Swarm Optimization For Fire Fighting Systems

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Abstract

Swarming is a mechanism where a group of animals or bees collectively accomplish a behaviour or tasks which are performed collectively which cannot be performed alone. A collective behaviour shown by a set of creatures traditionally, where enormous entities collectively form a single behaviour, which works on the principle individually taken from different members exhibiting swarm behaviour. Human fire fighters are at a risk of emerging close to fire, they are at a high risk from burns, inhaling smoke and other hazards affecting them during fire fighting. In this paper we are focussed on a swarm of robots collectively exhibiting fire in warehouses, firecrackers making industries, and others. The formation based on planning of robots for simple algorithm. These robots are capable of performing collective actions performed in coordination for navigation purposes to achieve the objective of fire fighting to assist the feedback given by the robotic sensors for providing extra backup. Additional backup is also provided for other robots in a swarm environment.

Introduction

There exists always a risk of fire in ware houses or departmental stores which is a nightmare. In a scenario where fire breaks out while no-one is around in the presence of combustible liquid or furnishings the flames are spread everywhere in less time. This fire results in huge loses, destruction of property, loss as well affect lives of people. By installing a fire fighting system, it reacts the moment fire strikes. The system in addition to using sound alarms but it needs to automatically counter the fire when it strikes as soon as possible.

Fire sprinkler system is the solution discovered so far and the best till present date which is automatic known as fire suppression sprinkler system. Their function is to control the water flow through the valves, when the glass bulb (heat resistant device) is operated the flow of water is controlled. Hence this fire sprinkleris exposed in a heating environment for sufficient amount of time increasing its value to a sufficient amount of time to a temperature above a specific value to the heat sensitive element.

Fire which is occurs as a result of gas leakage and inflammable liquids results in an explosion. This is very risky and dangerous to human beings to overcome this situation. Though the fire fighters are given rigorous training to survive in all the conditions, puts them at risk in actual real-life scenario to keep them alert from actual fire preventing from burns. They have to be in the front-line and face various lethal risks and burns as well. Inhaling various smoke resulting from fire breakouts as well as to counter other hazards. Varying the temperature levels and the amount of heat produced by the fire outbreak is above the capability of fire fighters to detect the reaction instantly.

As the technology is advancing resulting in an effective solution which employs robotic technology which is embedded in many algorithms. The fire-fighting robots, which help fire fighters, extinguish fire. Sensors are kept in external environment, internally also in the robots to get an action at the location where fire occurs by using the robot system at high temperature with minimal loss. Many algorithms which are based on swarm behaviour are implemented based on the requirements for its effective functioning. In this paper the system is entirely focused on controlling a swarm of robots which perform fire fighting. The proposed model here is basically focused on developing a swarm of robots by combining the robotic technology with swarm algorithms who assist in fire fighting in place of fire like industrial warehouses. Once the robots are capable of performing much cooperation and collaboratively localizing the navigation, they function in an efficient way and are independent. There is nil intervention in the working of such a system, to facilitate an independent system.

2. PROPOSED METHODOLOGY

Our proposed model consists of two design mechanisms, for the creation of swarm robots for use in fire fighting 1) the design of the model, its function, and the robot's communication architecture. 2) A swarm control method that is derived for the aim of swarm optimization.

The important assumptions made in the environment as well as our system to carry out various tests is given as:

1) The existence of fire outbreak after each level.
2) The swarm behaviour exhibited by the robots may move in all directions.
3) The swarm robot's movement distance is set to 0.4m following each command.
4) The industrial Warehouse that is being investigated has dimensions of 4*4. The industrial warehouse is divided into each block of 0.4m*0.4m and numbered with their corresponding grids as indicated in table 2.1 because of the above-discussed assumptions.
5) The number of swarm robots in the system is approximately fewer or equalising the count of occurrence of fire strikes.

The swarm behaviour exhibited by the robots in our proposed model operate according to the commands received from the server in return the swarm robots sent back the external environment data. The data required to sense the occurrence of fire or when a fire strike is sent back to the central server. It has the capacity to hold the algorithm, which works on entire situation awareness, and it automatically takes the routing decisions for the swarm robots according to changes exhibited by the surroundings. The model that has been proposed is displayed in Figure 2.1

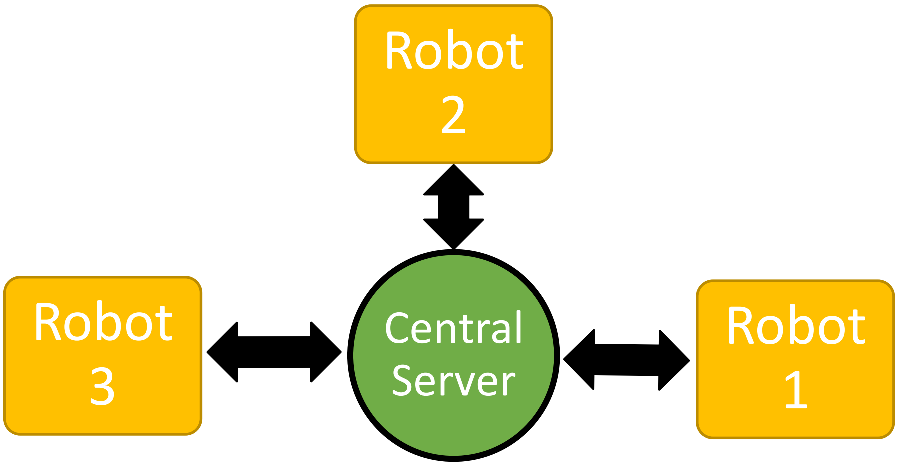

Figure 2.1 Proposed Swarm Systems

There are numerous advantages to the proposed system, the existing system in terms like scalability, addition of swarm robots in the system not necessarily requiring any changes, strong enough, as well for the system to function effectively while some of the swarm robots are not functioning. The capability of our proposed model to fight fire outbreak over a wide temperature range variation in the configuration. The capacity of the system to fight fire outbreak at different locations. The system provides good response in comparison with traditional methods. The ability to combat fire rather than the classification of earth approach. Swarm behaviour dependent algorithms have the capability to produce low cost, quick, and strong solution to tough problems. Without human intervention, they provide assistance to the fire fighters the feedback is given by sensors present in swarm robots for extra support.

3. The Robot's Design, Functionality, And Communication Interface

The flame sensor, which is kept in the front area of the robot, is used to detect a fire outbreak by the swarm robot. The ultrasonic sensors placed along all the directions in the robot are necessary to detect any obstacles; the swarm robots have obstacle detection function. The motor driver used here is L239D Motor Driver. The control system ensures that the robot makes a 90 degree turn as shown in the below figure 3.2. To make a perfect 90 degrees turn in either left or right direction. A loop control mechanism that is closed which uses a magnetometer as well as a Here, a servo motor is used. A tower pro SG90 Servo that rotates. a QMC5883L Magnetometer in, left or right direction accurately. The robot's structure is depicted in Figure 3.1.

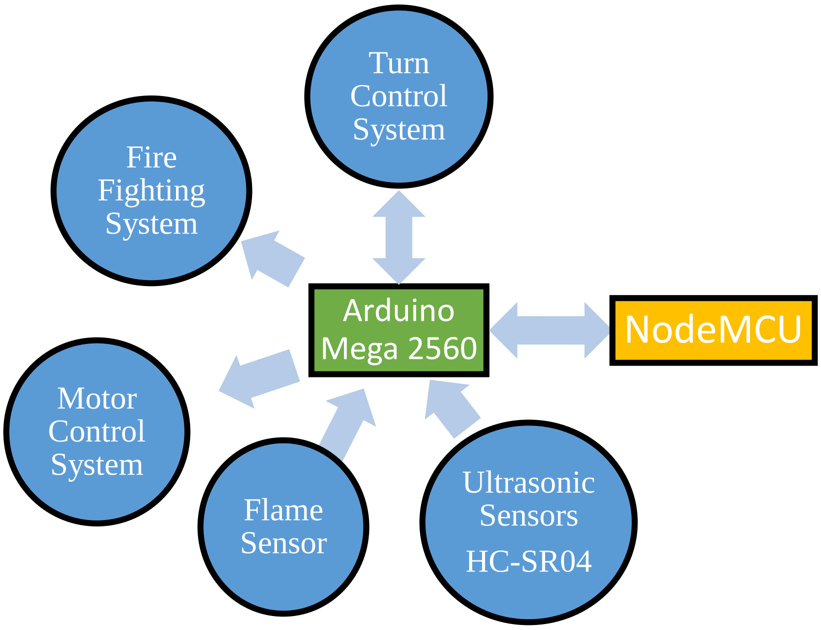

Figure 3.1 The Robot's Structure

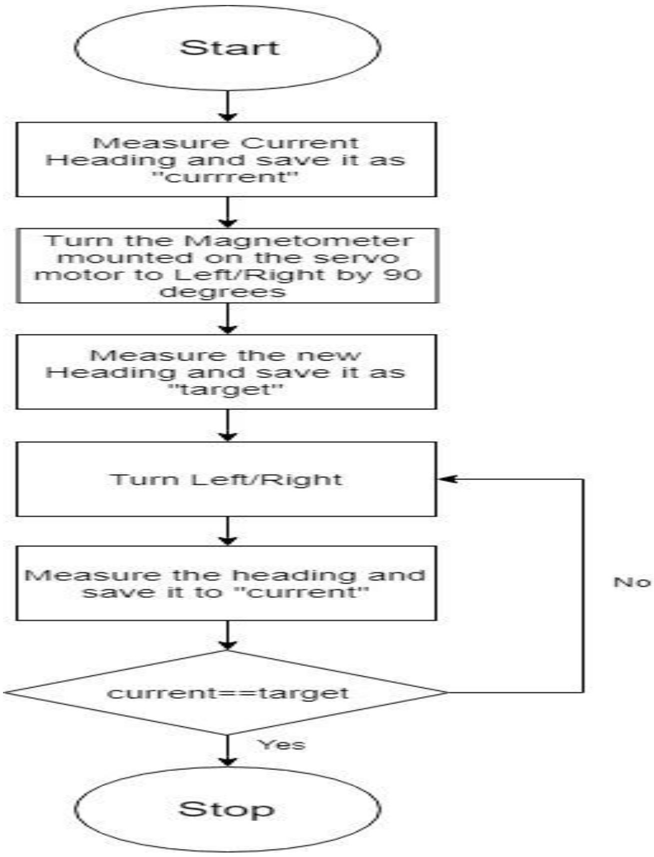

Figure 3.2: Turn control system flowchart

The Arduino IDE 1.8.1 was used to implement the Robot's capabilities. The following libraries were utilised to improve code reusability and readability, as stated in table 3.3.

Table 3.3: Components with Libraries table

Component	Library
HC-SR04 Ultrasonic Sensor	New Ping[12]
Tower Pro SG90	Servo [13]
Node MCU	Wifi Esp[14]
QMC5883L Magnetometer	QMC5883L [15]

The swarm behaviour exhibited by the Robot connects to a Wi-Fi network, and the Magnetometer will point in the right direction for the robot if the connection is successful. The Network assigns each Robot a unique IP Address. The IP addresses of the three robots are listed in table 3.4.

Table 3.4: IP Address of the swarm Robots while you are connected to a Wi-Fi hotspot.

Robot1 (Green Robot)	http://192.168.43.84
Robot2 (Yellow Robot)	http://192.168.43.42
Robot3 (Blue Robot)	http://192.168.43.206

The tabular representation of GET call, along with this the action performedby the swarm robot then accompanying action are shown in table 3.5.

Table 3.5 shows the Robot's actions for several GET calls.

GET Call	Action	Example
/F	Move Forward	http://192.168.43.42/F
/B	Move Forward	http://192.168.43.42/B
/L	Move Forward	http://192.168.43.42/L
/R	Move Forward	http://192.168.43.42/R
/M	Turn on Fire Extinguisher	http://192.168.43.42/M
/I	Ultra sensor Data	http://192.168.43.42/I

/	Flame Sensor Data	http://192.168.43.42/

4 SWARM CONTROL ALGORITHM

In our proposed model, a swarm control algorithm for fire fighters is used for glow-worm swarm optimization algorithm and the implementation has been carried out. The difference between the swarm control algorithm and glow worm swarm optimization is given by

- The Lucifer in is marked as an indicator to detect any obstacles the robots keep moving away from it.
- The fire locations which are marked as beacons are present in the external environment.

The commodities are obviously arranged in a regular sequence in the industrial warehouse, but their arrangement can be visibly hardcoded. The robots have previously been deployed in an environment or industrial warehouse with agents at specific locations in the warehouse in any way. During the initial configuration of the system, a programme is used to set the position and arrangement of the robots. When a fire breaks out, the site or places where the outbreak occurs are sent to a programme that can estimate which swarm robot is closest to the fire.

The shortest distance path for the swarm robot to reach the fire outbreak in the shortest time feasible is processed by a hybrid ASTAR and DSTAR planner once the robot has been assigned to a specific fire outbreak. The swarm robot then follows the path that has been set. The ultrasonic sensors are updated with external environmental parameters for any presence of barriers each phase the swarm robot shifts parallel along the grids. If an impediment is detected during the occurrence of a path that is intended for the swarm robot, the map is updated.

When a swarm robot performs a move, the current move is paused and restarted in the next step if an obstacle is identified on the path; otherwise, it follows the same course. Another option to solve this problem is to have the current move paused and resumed in the next step. If the robot that is generating the obstacle does not move, the current robot is given a new path. When the swarm robot progresses towards fire, it aligns itself the direction of the fire out breakthen begins the fire fighting operation. To prevent servo malfunction, each pump has a time limit of three seconds. The robot returns to its old location once the fire has been quenched. The robot's direction of travel

The current level will be completed after all of the swarm robots have returned to their starting place. Every time the swarm system receives data on the fire position, the next level will begin. The Lucifer in value of highest concentration is supplied to the point where the obstacles are discovered; this value is given before in parallel repetitions uncertainly the obstructions are detected in future levels; otherwise, the Lucifer in value decays, for implementation of the system, MATLAB was used. To present the status of the external environment in a central server, many MATLAB graphical functions were employed. Figure 4.1 depicts the flow chart of the implemented method.

The industrial warehouse that we looked at has a grid that is fixed in place. Warehouses already have products arranged in specific positions and can be blacked out. The map of the warehouse containing items is shown in Figure 4.2. Variables can be modified in different directions to vary the warehouse map.

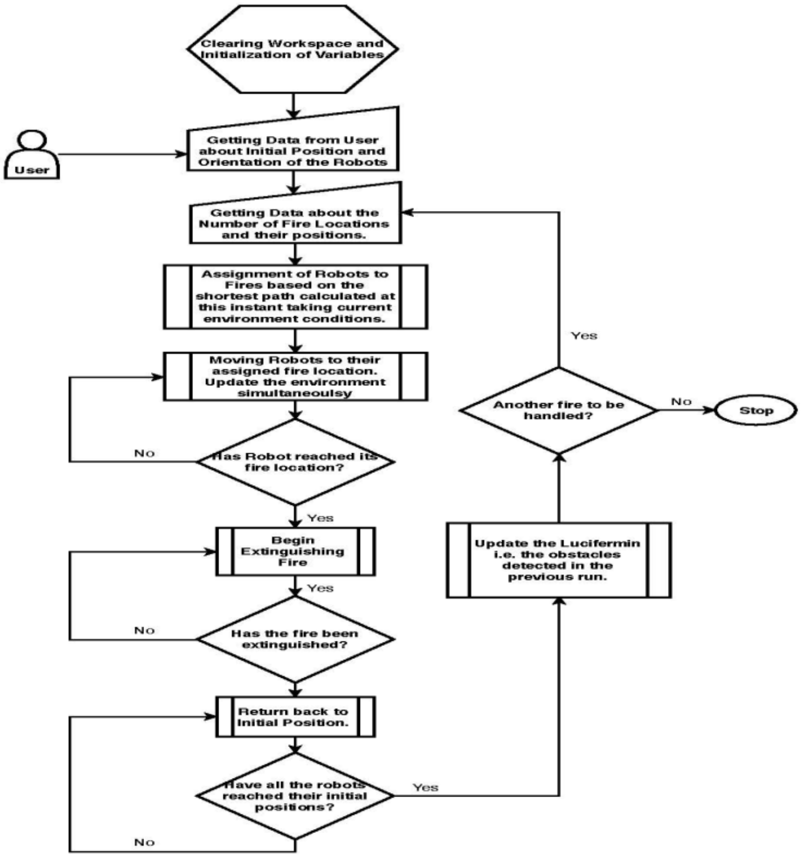

Figure 4.1 Representation of swarm control behaviour

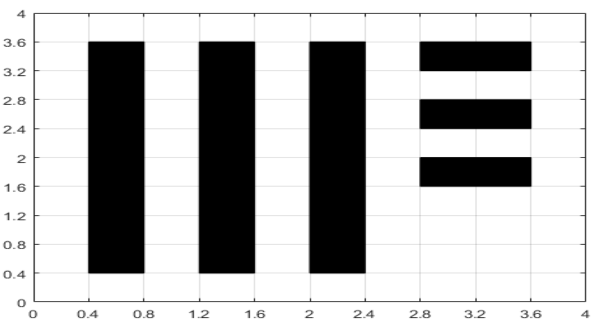

Figure 4.2 Sample Indoor Warehouse is depicted on a map.

5 RESULTS AND DISCUSSION

Based on the three case studies, the system built can handle up to three fire locations.

5.1.1 Case 1 – Three Fire Locations

Map status after execution of commands

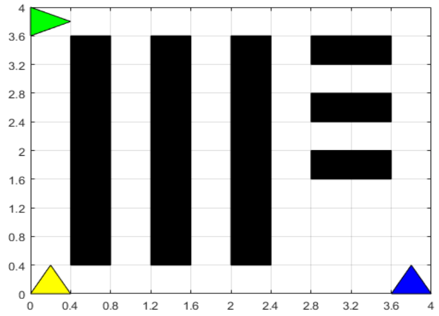

Figure 5.1 after the Robot Positions are given create a map.

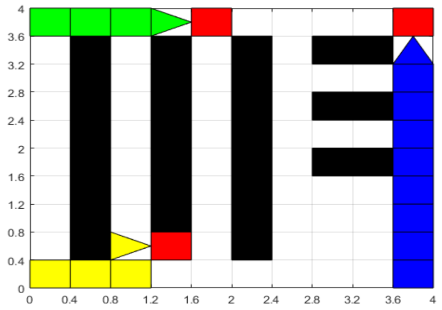

Figure 5.2 Map drawn for the Arrival of the robots at separate fire locations,

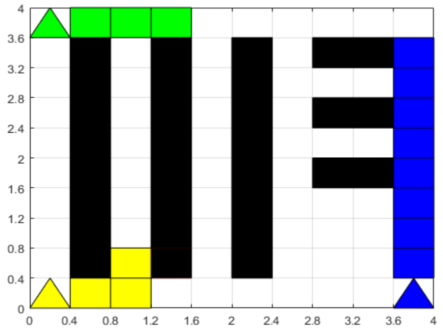

Figure 5.3 Robots' route to their initial positions once the fire has been extinguished

5.1.2 Case 2 – Two Fire Locations

Status of Map

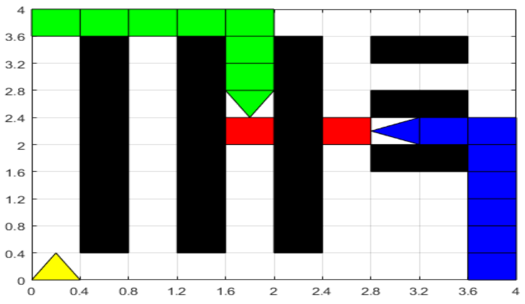

Figure 5.4 Map drawn for arrival of robots at respective fire outbreak

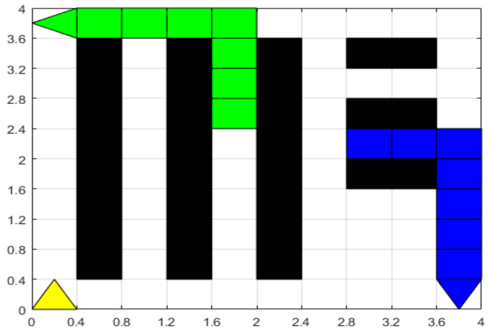

Figure 5.5: Robots' route to their beginning location once the fire outbreaks

5.1.3 Case 3 – One Fire Location

Status of Map

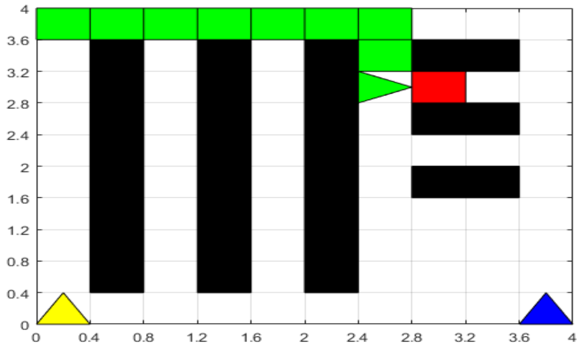

Figure 5.6 Map drawn for arrival of robots at respective fire outbreak

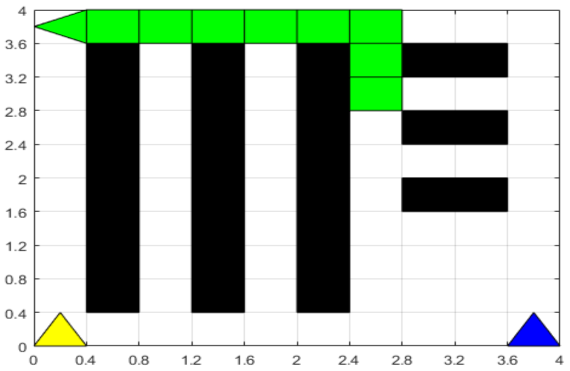

Figure 5.7: Robots' route to their beginning location once the fire outbreaks

We noted the subsequent reaction time for getting to the fire site indicated in table 5.8, considering simulation timings, considered as real response time, as well as elements such as the robot's battery, network latency, the time it takes for the robot to turn/move one unit, and so on.

Table 5.8: Swarm System Response Time for Various Circumstances

Case	Response Time in seconds
Three Fire Locations	14.284549
Two Fire Locations	12.284793
One Fire Location	11.234535

The Swarm control method [12-14] uses a swarm of robots to address numerous fire spots. It tells the nearby swarm robot to go to the nearest fire strike. It is worth noting that the System's Response Time is fully variable, since it depends on a variety of parameters including the swarm robots in the system, the size of the indoor environment and the distance of the grid location.

6 CONCLUSION& FUTURE WORK

The attributes of swarm intelligent systems such as strength, flexible in nature, as well as scalable have been accepted for the creation of these systems. By displaying its capability to resume completing the task, irrespective the loss of a particular entity, which allow a flexible technique to reach various tasks constructed on the active external situation by proving it experimentally along with new swarm robots, is effortless and allows the swarm nature to enhance the capacity irrespective of the extra configuration without human intervention.

Three robots are designed with the essential features which assist or help to extinguish fires when a fire strikes. The necessary algorithm to implement swarm behavioural design and communication in amongst the robots is inbuilt into them beside with these methods required for fire detection and fire extinguishing. Simulating the proposed system in different situations to thoroughly recognize the performance of the system which is accomplished along with this the necessary adjustments need to permit them adjust themselves to the external environments. Which results in successfully implementing the swarm systems for fire fighting using the modified GSO and they are acceptable for great performance to be accomplished in comparison along the primitive firefighting mechanisms.

The future work of our current system is extended as; this system is used in fighting fire outbreaks in forests by embedding the information obtained by Earth Observation Satellites that give live data regarding Forest Fires. This system could also be combined with crowd control systems such as Active Denial System to assure no harm for the population.

7. References

1. Asha Gowda Karegowda, Mithilesh Prasad, “A Survey of Applications of Glowworm Swarm Optimization Algorithm”, International Journal of Computer

Applications(0975 – 8887) International Conference on Computing and information Technology (IC2IT-2013)

2. Ibrahim Aljarah, Simone A. Ludwig,”A New Clustering Approach based on Glowworm Swarm Optimization”, IEEE Congress on Evolutionary Computation, June 2013, pp. 2642-2649
3. K. N. Krishnanand, Debasish Ghose,” Multimodal Function Optimization using a Glowworm Metaphor with Applications to Collective Robotics”, Proceedings of the 2nd Indian International Conference on Artificial ,December 20-22, 2005, pp. 328-346.
4. Amrit Saggu, Pallavi Yadav, Monika Roopak, “Applications of Swarm Intelligence”, International Journal of Computer Science and Mobile Computing, Vol. 2, Issue. 5, May 2013, pg.353 – 359.
5. Belkacem Khaldi, Foudil Cherif,” An Overview of Swarm Robotics: Swarm Intelligence Applied to Multi-robotics”, International Journal of Computer Applications (0975 – 8887) Volume 126 – No.2, September 2015.
6. Hui Keng L. 2012. Error Detection in Swarm Robotics:A Focus on Adaptivity to Dynamic Environments. PhD Thesis. University of York, Department of Computer Science
7. Beni G., Wang J. 1989. Swarm Intelligence in Cellular Robotic. In Systems Proceedings of NATO Advanced Workshop on Robots and Biological Systems. 102(1989)
8. O’Grady R., Christensen A., Dorigo M. 2009. SWARMORPH: multi-robot morphogenesis using directional self-assembly. IEEE Transactions on Robotics, 25(3), 738–743.
9. Stirling T., Floreano D. 2010. Energy efficient swarm deployment for search in unknown environments. In Lecture notes in computer science. Proceedings of the 7th international conference on swarm intelligence. 562– 563.
10. Pini G. 2014. Task partitioning in swarms of robots an adaptive method for strategy selection. URL http://iridia.ulb.ac.be/supp/IridiaSupp2011- 003/index.html.
11. Ying T., Zhong-yang Z. 2013. Research Advance in Swarm Robotics. Science Direct. Defence Technology9(2013).doi=http://dx.doi.org/10.1016/j.dt.2013.03.001.
12. Turgut A. E., Çelikkanat H., Gökçe F., Sahin E. 2008. Self-organized flocking in mobile robot swarms. Swarm Intelligence. 2:2–4. 97–120.Cybernetics. Tenerife, Spain. December 14-16, 2007.
13. Bighnaraj N., Sarita M., Subhra S., Swadhin K.B. 2012. Cooperative Swarm based Evolutionary Approach to find optimal cluster centroids in Cluster Analysis, IJCSI International Journal of Computer Science Issues. 9(2012).
14. Eliseo F. 2009. A Control Architecture for a Heterogeneous Swarm of Robots, Rapport d’avancement de recherché (PhD), Universite Libre De Bruxelles; Computers and Decision Engineering, IRIDIA