SWARM ROBOTICS: DECENTRALIZED PATH FORMATION USING B.A.T.M.A.N. APPROACH

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ABSTRACT: This article presents a swarm robotic algorithm that enables to move an object in one target location to another location by following shortest possible route found. The algorithm is inspired by neighboring node existence identification concept used by *Better Approach To Mobile Ad-hoc Networking* (B.A.T.M.A.N.) protocol and foraging behavior of ants. The algorithm consists of two distinct set of robots. Nodes are path formation robots between food location and nest location. Worker robots move foods from food location to nest location by following the path formed by nodes. The algorithm is modelled on Net Logo agent-based modelling environment and measured the performance of the algorithm. Performance analysis shows that path completion by node robots, and food collected, and food returned by workers robots also improved its performance with large robot group sizes in worlds with and without obstacles. Additionally, it has been observed that increasing node switching probability (probability of leaving path formed from food location or nest location before joining both to form a single paths) is not desirable as it decreases the path forming capability of the node robots.

KEYWORDS: *Swarm Robotics; Path Formation; Multi-agent System; Agent-Based Modelling.*

1.0 INTRODUCTION

In the recent years there has been increase research interest on study of swarm robots, which forms coordination and collective behavior, following simple rules and orders with limited capabilities. In many robotic applications, certain tasks such as searching space and path formation may be too complex to be accomplished by a single robot having high capabilities. Since the cost of robotic hardware has come down and its availability increases, usage of several robots with limited capability may be easier and cheaper to achieve such kind of objectives.

Even though robot of swarm minimizes the hardware and design complexity, it increases the complexity in algorithm design. Because, to replace the single highly capable robot, it must take over all the challenges that single robot have to face to achieve the goal. Another challenge is that the global behavior is raised as a result of individual's local behavior and coordination between them is established in decentralized manner.

Therefore, swarm robotic algorithms did not instruct the robot to complete the whole task. Instead it gives instructions that can be followed by individual robots, based on its simple capability, interacting with neighbors and its environment to produce large and complex result. Due this kind of reasons and others, developing robot swarm has become research field of its own (Alunni et al., 2011)

The work in this paper is focused on developing an algorithm that can be used to search and move object in one target location (food) to another location (nest). For this algorithm the basic idea has been inspired from foraging behavior of ants however, instead of chemical pheromone concept, a set of robots that carry numerical values as virtual pheromone is used for path formation.

Communication between neighboring path forming robots is inspired from the neighboring node existence and identification concept used by **B.A.T.M.A.N.** protocol. B.A.T.M.A.N. stands for Better Approach To Mobile Ad-hoc Networking, it is a routine protocol that convey decentralized message which can be used to identify best next direction towards all other nodes in the network. The proposed algorithm is modeled on NetLogo and simulated to analyze the performance of the algorithm for swarm robotics.

2.0 RELATED WORKS

Better Approach To Mobile Adhoc Networking (B.A.T.M.A.N.)

According to Morot (2011), Barolli *et al*.,(2009) and Lang (2010), the acronym B.A.T.M.A.N stands for Better Approach To Mobile Adhoc Networking. Morot (2011) continues to argue that an ad hoc network is a network system that is decentralized which never relies on any pre-existing infrastructure for example a wired network or a router. Lang (2011) described that B.A.T.M.A.N is a multi-hop mesh network that is an ad hoc routing protocol. With its non-reliance on a pre-existing infrastructure for connectivity and communication, the B.A.T.M.A.N is able to provide connection in the event of a natural disaster like hurricanes and earthquakes, Internet censorship like in China and military conflicts that have in the past relied on wired and microwave connections (Morot, 2011).

Since there are no routers in the B.A.T.M.A.N protocol, each node acts as a router that forwards data that has been received from other nodes. This means that the transmission of the data is made to be dynamic since the determination of the node to transmit does not rely on network connectivity. This makes B.A.T.M.A.N protocol a better emergency response network system in times of calamities (Morot, 2011)

The B.A.T.M.A.N algorithm is such that there is selection of the best route to follow, one with the shortest distance between communicating nodes (Lang, 2010). Author continues to argue that every node receives and retains the only information on the best available and most appropriate hop option in reference to other nodes. This makes global knowledge on local topology changes to be irrelevant since there are no TIMEOUTS neither are there scheduled topology information when deciding which route to optimize (Lang, 2010).

Like swarm algorithms, B.A.T.M.A.N protocol decentralizes knowledge about the best end to end path (source to destination) between nodes (agents) in the network to all participating nodes. Individual nodes save information about the best next direction towards all other nodes so that data gets passed on from node to node so that dynamically create routes. B.A.T.M.A.N is not focusing to find the shortest path between two nodes in the network, instead it provides the most reliable and stable route that can send data per unit time (Buss et al., 2008).

3.0 METHODOLOGY

The algorithm consists of two distinct set of robot agents. They form decentralize path between two target locations (food and nest) at unknown distance and follow the formed path to move object (foods) from food location to nest location, optimizing the time taken to travel along the targets. The robots are assumed to have only local communication capabilities and they are not aware of global behavior that arises as a result of their actions.

The algorithm consists of two parts. First part of the algorithm is intended to form a path between target locations (food and nest) by using the path formation robots called nodes and the second part of algorithm is used to perform foraging behavior using robots named as workers. Although each behavior is followed by different set robots, both must work together to achieve optimized foraging as goal.

Inspiration from B.A.T.M.A.N protocol

The proposed algorithm path formation is inspired from originator message (OGM) generation and best next hop identification concept of the B.A.T.M.A.N protocol. OGM of the proposed algorithm consists of food value and nest value that guides to reach food location and nest location respectively. Node robots that joined path update its OGM based on the OGM received from the neighbors in its communication range and broadcast it's OGM. When the path between food and nest location is completed, each node robot contributing to the completed path between targets carries OGM with food Value and nest value greater than zero. **Table 1** describes the inspiration from B.A.T.M.A.N protocol to the proposed algorithm.

Table 1. Inspiration from B.A.T.M.A.N. protocol for proposed algorithm

B.A.T.M.A.N. Protocol	Proposed Algorithm
Each node broadcast its originator message (OGM) to all its neighbouring nodes. OGM contain originator address, time to live and sequence number	Path formation nodes broadcast originator messages (OGM) which contain food value and nest value to all other nodes and workers in communication range
Neighbouring node retransmit OGM received from its originator	Does not retransmit OGM other than OGM it self
Based on OGM received, configure routine table to identify best next hop towards the OGM received	Update food value and nest value of the OGM by incrementing 1 to the minimum food value and nest value received from neighbour
Message delivered from one location to another by following routine table information	Workers robots use food value and nest value of node robots to travel between target locations

Proposed Algorithm

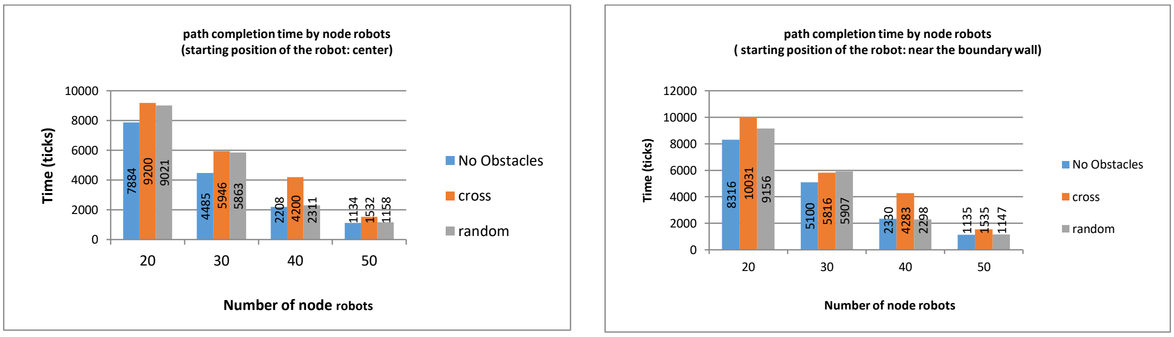
There are two types of robot, namely *Node* and *Worker* robots. Initially *node* robots carry zero as its food value and Nest value. *Node* robots start food location and nest location search with random movement and avoid obstacles by turning either right or left with wiggle angle. The first node robot that finds food location in its vision range stops and become stationary node and carries food value 1.

Similarly, the first *node* robot that finds nest location also follows the same rules and update nest value equal to 1. Other nodes that find food location or nest location stop and join food path or nest path if its neighbor stationary nodes are away from distance greater than node radius and less than Vision range.

4.0 RESULT

Analysis on path completion time

The effort for path completion by group of 20, 30, 40 and 50 node robots are displayed in **Figure 1**. Simulation run in fixed length of 4.9m x 4.9m world without obstacles and with the presence of obstacles. Number of worker robots are 35 in all the world configurations. The result shows that time taken to form the path between food location and nest location decrease with increasing the number of node robots. Path completion with cross type obstacles become more difficult compared to other world configurations.



(a) **(b)**

Figure 1: The plots show average time consumed by various set of node robots to complete path between food Location and nest location at different world configurations with fixed starting position at center of world (a) and near the boundary wall (b)

5.0 CONCLUSION

Swarm robotic algorithms can be formulated for various types of applications. In this dissertation a swarm robotic algorithm that can be used to move an object in one target location to another target location is presented. The algorithm is formulated based on ant foraging behavior. The algorithm consists of two distinct set of robots. The path formation robots are called nodes. Node robots act as locations in the path and transmit two virtual pheromone values called food value and nest value. These values are called originator messages and are inspired by the neighboring nodes existence identification concept used by B.A.T.M.A.N protocol. The second set of robots named as worker use this transmitted originator message to identify most appropriate route suitable to move object from one target to another. In the proposed algorithms robots should avoid obstacles and colliding with other robots. The algorithm is modeled and simulated using NetLogo software.

6.0 DECLARATION

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