Minimizing Exploration Time Using Cluster Heads Tree in Multirobot Area Exploration

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ABSTRACT

Multirobot systems are required to perform quicker in various areas of robotics ranging from localization to mapping and exploration. Cluster formation and creating Cluster head is performed in order to reduce exploration time in Multirobot area exploration. In particular, it is not known how to choose the best candidates for the cluster head roles. Proposed method is creating Cluster Head from an already created Tree that goes for decreasing the investigation time and to limit the overall traverse distance of the robots by planning the cluster heads. Cluster Heads(CHs) are selected from set of nodes. Applications of Clustering includes habitat monitoring, area monitoring, water quality monitor, landslide detection, disaster detection. The simulations will be performed on Matlab.

Keywords: Exploration, Multi-Robot, Cluster Heads, Exploration Time, Random nodes.

I. Introduction

Multirobot Cluster Networks have been seen and explored in recent years[1]. These systems are made out of hundreds or a large number of sensor hubs which have a wide range of sorts of sensors. Clustering in multi Robot Systems is an exceptionally essential research region inside Robotics and Artificial Intelligence and are required to perform quicker in various territories in robotics[2]. Although they can be treated as a particular case of Multi Agent Systems, it appears to be fitting to comprehend the Multi Robot Systems from an arranged perspective, as issue comes in practical scenarios. A multi robot system can be highly beneficial for core robotics task. Mobile robots used for coverage and exploration for tasks such as in mines, intrusion detection, sensor deployment, search-and-rescue operations, for medical purpose, natural calamities and harvesting. When using a group of robots, the overall performance can be much faster and more reli-able. Minimizing the exploration time is the one of the major concern when robots explore an area. Exploration is done by forming a tree from randomly distributed nodes in an area. To further reduce the exploration time, concept of clustering and cluster heads is introduced. Just bunch heads are included in the arrangement period of tree structure, i.e. all bunch heads are dealt with as a vertex of a tree structure in the wireless sensor network[3]. In this proposed work the network which was already in tree form is made into clusters and then cluster heads are selected on the condition if adjacent nodes are more than 3 that node is made cluster head. Later just bunch heads are incorporated into the arrangement period of the tree structure, i.e. all cluster heads are treated as a vertex of a tree structure in the wireless sensor network. Section II includes the previous work on clustering of nodes , creating Cluster Heads and minimizing one of the parameters like energy, distance or time. Section III deals with the methodology along with assumptions taken while section IV discusses the Experimental details followed by section V with results obtained and lastly Discussion and Conclusion and Future scope in section VI and VII respectively.

II. Previous Work

Flooding Algorithm in Multirobot Exploration[4] goes for lessening of exploration time and to limit the general separation navigated by coordination of robots partaking in investigation. It allowed a number of homogeneous robots to explore an environment modeled as finite and undi-rected tree. Multirobot Path Finding with wireless Communications[5] included several advantages like capacity enhancement and coverage expansion are larger than its disadvantage of multihop delay. Each robot equipped with sensors detects walls and paths and also saves the learned map on its memory and move towards desired path. Approximating Optimal Multicast Trees in Wireless Multihop Networks[6]: Using the concept of cluster formation and computing minimal cost multicast trees in multi-hop wire-less mesh networks. Focus is mainly on multi-hop wireless networks in static multihop wireless networks, also known as mesh networks. A Steiner tree no longer offers the lowest consumption of bandwidth in this paper. So, a re-formulation of the problem in terms of lessening the number of transmissions is done. It is also discussed that new problem is also NP-complete and propose heuristics to approximate such trees. A Cluster-Tree based Data Dissemination Routing Protocol [3] Cluster based routing tree based routing and routing combing the above two are discussed. The division of random nodes into grids and creating tree from the cluster heads selected randomly from each grid.
Immobile sensor nodes are deployed in the gigantic area and a network is created from it, known as the Wireless Sensor Network (WSN). Energy productivity and network lifetime is the prime worry of the WSNs. [7] Minimum-energy broadcast problem in multi-hop wireless networks is formulated, with the goal that all communicate demands created by different source hubs occur on the single and same broadcast tree. Using a similar broadcast tree, the aggregate power which is expended for broadcasting from a given source hub is at most double the aggregate power devoted for broadcasting from some other source hub. Then a polynomial-time approximation algorithm is develop to solve this problem. For the building of a single, broad-cast tree. [8] extended the tree multicast concept to wireless, mobile, multihop networks for applications ranging from ad hoc networking to disaster recovery and battlefield. The main challenge of rapidly changing environment is corrected through: (a) soft state; (b) assigning various roles to hubs based on their portability (2-level mobility model); (c) proposed an adaptive scheme that joined the shared tree and per-source tree benefits, and finally (d) powerfully relocating the shared tree Rendezvous Point (RP). Spanning tree is used for autonomous deploying wireless nodes and sinksDeploying character in this method[9] is multi-robot system. Here robots will be acting as dispenser for nodes in wireless. Utilizing spreading over tree as a calculation including investigation helps robot to perform full scope arrangement of hubs. For breaking down the calculation utilizing multirobot a simulation test bed is created with a parameterized situation with deterrent. The result showed performance of sensing coverage in different environments. In sending hubs with traversing tree calculation three parameters were worried by robots that committed for conveying nodes. [10] Distance being the main parameter between the hubs. Since the technique of conveying with spreading over tree is by and large sort of network based sending so the separation among the hubs is ascertained as square of the separation, its mean a similar separation shape hubs in matrix organization from four corner. The second parameter was secured regions utilizing sinks and robots ought to incorporate hubs inside these regions. Lastly as the field was comprising of obstruction and the area is obscure for robots so another errand for robots is making way by staying away from deterrent. So the calculation ought to be proficient for conveying hubs in this environment and keep the most extreme scope be sending hubs in ideal position outside the obstacles. An MR-DFS algorithm[11] for investigating an obscure diagram with hazy edges by multiple robots was proposed. Chaohui Gong[12], in 2012 displayed a calculation for deterministically mapping an undirected graph-like world with various synchronized operators. The use of this calculation is the aggregate mapping of an indoor situation with numerous mobile robots while averaging an embedded topological decomposition of the environment. This algorithm depends on a gathering of specialists that all leave from a same starting vertex in the chart and spread out to explore the graph. A concentrated tree of chart theories is kept up to consider circle conclusion, which is deterministically verified when specialists watch each other at a common vertex. To accomplish proficient mapping, presentation of dynamic investigation technique is done in which operators powerfully ask for meet errands from other accessible specialists to approve graph hypotheses. During mapping, incremental expansion and pruning is done so that the tree according to the measurements is obtained. [13] LRV is based on a robot which can carry network nodes as payload. As the robot moves, it stores hubs into nature in light of certain neighborhood criteria. These hubs, once put in the earth, discharge route bearings for the robot as it passes by. Nodes recommend directions least recently visited by the robot, hence the name LRV. Zheng et al. [14] builds upon the work in [15] by a variation on the MSTC algorithm called Multi-Robot Forest Coverage (MFC). Jin Hong Jung[16] showed wireless multihop communications to the collaborative path- problem using cooperative path finding algorithm (CPA) and verified its performance by real implementation on Zig-Bee based micro-robots as well as on MATLAB Simulations.

III. Methodology

The proposed method of Flooding Approach for Multirobot Area Exploration can be easily explained from a flow chart is described below(Fig1). This multirobot Exploration approach aims at reducing the time of exploration and minimize the overall traverse distance of the robots by coordinating movement of the robots performing the exploration. Comparison of this technique is to be done with other approaches. Simulations will be performed on Matlab.

The proposed convention accept that all hubs non heterogeneous in nature and conveyed haphazardly in the network region of 1Km square. Cluster Network environment includes some basic assumptions such as:

- Every node has ability to convey the message from one node to another node as well as to mobile sink.
- All randomly distributed nodes and cluster heads are immobile in nature.
- Exploration Time of the original tree created by random nodes[4] is calculated ,it is then compared with the method proposed ie creating cluster heads and then again forming a tree using these cluster heads and calculate Exploration Time with lesser number of nodes.
Finally comparing the results of the proposed method with the original tree formation. Figure 2 shows how nodes are deployed in an area connected to each other and so forming a tree. Network after formation of cluster heads—Cluster formation phase is initiated by checking the outgoing edges for each node, formation phase where cluster heads are formed after the formation of the grid or cell. Cluster head (CH) and cluster nodes (CNs) are two different categories:

1) Cluster Head: Also called as head node and has connectivity with more than 3 nodes in the network.

2) Cluster Nodes: Nodes that are remaining other than the head nodes in cluster.

Figure 3 shows the network after selection of cluster heads from the deployed nodes.

Generating Random Points - 50 Nodes are distributed randomly in 1 Km2 area. The position of nodes will vary on every run. Figure 4 shows the created simulation environment in Matlab deploying 50 random nodes.

Creating a Tree from joining Random Points—A Finite Tree is created by joining these random points according to the given conditions: Here if distance between source to other nodes less than or equal to 0.2 units, then it joins the two nodes. The nodes with distances greater than 0.2 are discarded. Figure 5 shows a finite Tree covering the target area for exploration.

Calculate Exploration Time for Single Robot.
Plot Edges Vs Exploration Time Graph(Single Robot)-As Edges vary exploration time is twice the number of edges as a single robot would move till the leaf node and then returns back to root node. This is done by using Flooding algorithm[4]. Exploration Time for single robot is twice the number of edges present. Exploration Time(Single Robot)=2*m, where m is the number of edges. Figure 6 shows variation of Exploration Time with number of edges.

Plot Edges Vs Exploration Time Graph(MultiRobot)-The exploration time is reduced as the area which was earlier traversed by a single robot is now done with multirobots using total exploration time as D+m, where D is the Diameter of the tree and m is the number of edges. The Diameter D also gives the number the robots required to complete the exploration. Figure 7 gives a relation between Exploration times as number of edges are increased. This can be seen from the figure by using multi robot system the exploration time has reduced considerably.

Cluster Heads (CHs) Selection - Cluster heads are selected from the given set of nodes by applying the criteria that when number of edges corresponding a particular node is more than 3, then that node or vertex is made as cluster head. Figure 8 shows selection of cluster heads from the deployed 50 nodes in the network.

Tree formation from CHs-Same Technique as adopted earlier is used.

Algorithm 1: Cluster Head Formation

1. Initialization Phase:
2. Set the Input as 50 Random distributed nodes.
3. Set the Output in Tree formed as Cluster Heads.
4. Traverse Tree using Single robot and Multirobot.
5. Calculate Exploration Time for both.

4. Implementation Phase:
7. while Edges greater than 3 do
8. for each node do
9.   if Edges Less than or equal to 3 then
10.      Treat that node as normal node
11.   else
12.      Make the node as Cluster Head.
13.   end
14. end
15. Final Phase:
16. Observe the new set of Cluster Heads.
17. Create Tree from the newly created Cluster Heads.
19. Calculate Exploration Time for both.

IV. Results And Discussion

Fig. 7. Exploration Time Vs Edges plot for Multirobot Robot.

Fig. 8. CHs Position.
Figure 9 and 10 shows various cases of selecting cluster heads from 50 random nodes. Cases on left show the complete tree generated from 50 random nodes, while on right shows cluster heads selected out of the deployed nodes. These cluster heads again form a tree using the same flooding algorithm as done earlier for single robot as well as for multirobot.

Exploration Time is calculated in terms of distance i.e. the number of edges, with each edge corresponding to about 200 metres or 0.2 Kms. Table 1 shows that Exploration time is reduced when we switched to multirobot, as the number of robots increased performing the exploration. This Exploration Time is further reduced to an extent by creating cluster heads, again forming a tree from it and then calculating Exploration time.

### Table 1. Exploration Time for Single and Multirobot Exploration

<table>
<thead>
<tr>
<th>Exploration Time - Single Robot (Edges)</th>
<th>Exploration Time Multi Robot (Edges)</th>
<th>Cluster Heads - Edges more than 3</th>
<th>Exploration Time - Single Robot (Edges)</th>
<th>Exploration Time Multi Robot (Edges)</th>
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### Table 2. Reduction in Exploration Time - Percentage

<table>
<thead>
<tr>
<th>Reduction in Exploration Time (E.T)</th>
<th>Reduction in E.T Single Robot - Percentage</th>
<th>Reduction in E.T Multi Robot - Percentage</th>
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Table 2 shows the percentage by which exploration time is reduced using cluster approach.

Single Robot: Exploration Time = 2 * Number of Edges(m).
Multi Robot: Exploration Time = D + m, where D = Diameter
Diameter is the Longest distance between the Root Node to the Leaf Node
Dividing the area in Clusters and Creating CHs, Exploration Time is reduced considerably.

V. Conclusion and Future Scope

Single robot led way to Multi robot exploration. Flood-ing Approach method involves exploration by using random Nodes and single and multi robots. The proposed method of using Multihop with cluster heads is a time-efficient
method with relatively less Exploration Time, this superiority increases the network lifetime. AMultihopClustering is a coalition of two ideas, these are cluster formation concept and tree formation concept of the area to be explored, so this exploration method is much more reliable and redundant than any other cluster based or tree based method. By analysing the results it is observed that exploration time is optimised. We can extend the concept of creating cluster heads in immobile nodes i.e. not taking the nodes as static, in that scenario every time, robot has to update its cluster heads map, as that would change on each run.

References


