Multi Robotic Exploration with Communication Requirement to a Fixed Base Station

(Extended Abstract)

Piyoosh Mukhija
IIIT Hyderabad

Rahul Sawhney
IIIT Hyderabad

K Madhava Krishna
IIIT Hyderabad

ABSTRACT

We present an algorithm for multi robotic exploration of an unknown terrain where the robots are also required to serve the role of hops or nodes in a communication link maintained between a fixed base station and the last robot (end effector robot) in the chain. A baseline algorithm is presented as a tree traversal mechanism akin to a depth first strategy, further embellished by an adaptive rule that decides the number of children based on the local obstacle configuration at a node and avoidance of redundancy in traversal through a look-ahead method that decides the utility of spreading the tree from the current robotic hop node. This system finds immense utility in arenas such as planetary exploration, search and rescue scenarios and scenarios where the robots have limited on-board computing capabilities and need to continuously preserve the link with a fixed base station for receiving instructions or transfer of data.

Categories and Subject Descriptors

I.2.11 [**Artificial Intelligence**]: Distributed Artificial Intelligence—*Multiagent systems*; I.2.9 [**Artificial Intelligence**]: Robotics

General Terms

Algorithms

Keywords

AAMAS proceedings, LaTeX, text tagging, Multi Robotic Exploration, Fixed Base Station

1. INTRODUCTION

Various application entail the requirement for an ever-present communication link with the base station such as in planetary explorations, search and rescue scenarios and scenarios where robots have limited onboard processing and decision handling capabilities forcing to always be proximal to the base station to receive instructions.

While many approaches exist for dealing with various variants of multi robot exploration [1, 2],the only papers regarding exploration while maintaining a communication link with a fixed base station have been due to [3, 4].

The algorithm presented in [3, 4] suffered with traps and deadlocks as reported by the authors. Furthermore, the adherence with communication constraints was not proven for the duration when the robots navigate to the next computed set of locations. This paper presents an algorithm that solves the same problem but is different in multiple aspects. The novelty of this work lies in its method of interleaving exploration with the construction of a tree of cell-sites or nodes that maintains strict adherence to communication constraint even while navigating between different locations and provides a formal structure that is free from traps and deadlocks at the same time.

The paper describes a base line algorithm that propagates along fixed number of directions at every node and further improves its performance through methods that prune the propagation of a node or increase the number of propagations as the situation merits. Extensive simulations confirm the performance gain over and above the baseline methods due to pruning and adapting the number of directions to propagate. The simulations also show that the communication link is always intact between every robot and the base station.

2. METHODLOGY

The essence of the current algorithm is in the dynamic propagation of a tree of possible communication node sites with the base station as the root. Each robot is required to serve the role of either an *explorer* or a *communication link station (node)*. When acting as a node, a robot may not move. It serves to act as a repeater along the link chain (if it doesn't lie at the end of chain) and provide a communication link to explorers within its range. Thus, the comunication from the base station to a robot at a distance more than base station's range is maintained via hops through the nodes. At any instant, the distance between two nodes or between an explorer and its closest node is always within their communication range. The area within the communication range of a node is termed as a *cell* which is explored using frontier exploration method with all the available explorer robots. These cells are processed in a depth-first traversal fashion, described in detail in the following sub-sections.

2.1 Baseline Algorithm

The algorithm proceeds in a recursive fashion similar to depth-first traversal of a tree. After the exploration of the base cell C_0 (area under the direct range of base station), we

Cite as: Multi Robotic Exploration with Communication Requirement to a Fixed Base Station (Extended Abstract), Piyoosh Mukhija, Rahul Sawhney and Madhava Krishna, *Proc. of 9th Int. Conf. on Autonomous Agents and Multiagent Systems (AAMAS 2010)*, van der Hoek, Kaminka, Lespérance, Luck and Sen (eds.), May, 10–14, 2010, Toronto, Canada, pp. XXX-XXX.

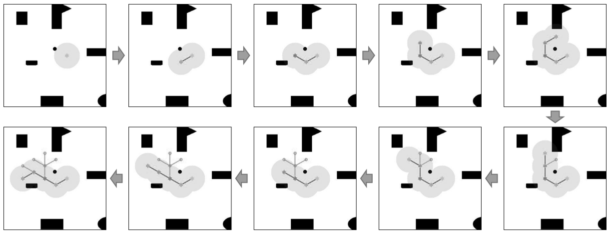

Figure 1: Initial Exploration sequence for 4 robots with a base station

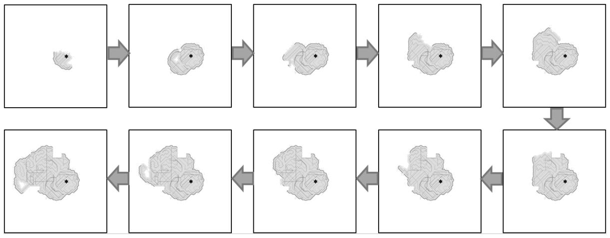

Figure 2: Area explored corresponding to stages in Figure 1

determine possible node locations (*hinge-points*) in all the directions at the cell boundary. The cells corresponding to each of these node locations form the children (C_1, C_2, ..., C_M) of the root node. Each of these children is then processed in a sequential order. For every child C_i, we identify a fixed number of possible child locations (C_{i1}, C_{i2}, ..., C_{iN}) close to the cell boundary and then process them in order. This recursion behaves exactly like depth-first traversal. As for each level, one of the explorers changes its role to a node, the maximum depth of the tree for K robots is $K-1$ when only one explorer is left. The role of a node in the chain changes back from node to explorer when the chain retracts after processing all the children of the corresponding cell. Figure 1 displays the progress of the node chain (shown as a dark line) for exploration of first 10 cells. In the given figure, there are 4 robots with a base station. A node (including base station) is marked by a star and the light-gray area denotes the area under communication range. The gray lines with circles show the history of node chain with past node locations as circular vertices thus representing the exploration tree. Stages 2 to 5 and 9 in the figure show only expansion of the node chain from the respective previous stages while stages 6 to 8 and 10 show a consecutive retraction and expansion for the chain. The snapshots of area being explored in the midst of each of these stages respectively are shown in Figure 2.

2.2 Chain Expansion

Once the candidate location for a child cell is identified, an explorer robot (R_j) neares to the location moves to it and changes its role to a node N_P, thus creating a cell C_x. Now, the remaining robots from the other areas in the chain can enter and explore the unexplored parts of the newly created cell. The procedure is just opposite to that shown for Chain Retraction in Figure 3.

2.3 Chain Retraction or Node Rollback

The procedure for retraction of the chain (consisting of nodes B,N_1,N_2,.., N_P, N_R in order starting from base) by one level, is shown in the Figure 3. First, all the explorer robots in the chain's last cell i.e. cell belonging to N_R move to the parent cell i.e. cell of N_P. Next, the node N_R changes its role to back to explorer R_j and joins the other explorer robots for the next steps.

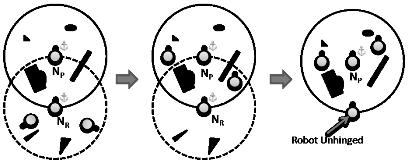

Figure 3: Retraction of node chain by one cell

2.4 Embellishments to the baseline algorithm

The exploration tree or the cell tree would have many children hinge-points in the middle of the explored area. Hence, by emulating the depth-first traversal along its children's directions, we prune the further depth-processing from a node without actually moving the robots. Emulation allows calculation of the utility metric using the history of explored area and in case of a positive utility, the node chain is expanded to target state directly. This results in a drastic performance gain compared to the baseline algorithm.

Before retraction, we also check for any unexplored areas just beyond cell boundary in case some space between any two children is left unexplored. This doesn't result in any performance gain, but maximizes the coverage for all kinds of obstacle scenarios by increasing the number of children adaptively according to obstacle configuration at cell boundary.

3. CONCLUSION

A novel method of interleaving multi robotic exploration with construction of a tree network that satisfies the constraint that all robots must maintain a communication to the base station is presented. The baseline method propagates the exploration tree in a fixed number of directions and is embellished by methods to either prune or increase its number of propagations. Future scope includes dovetailing this approach for effective implementation on a pack of robots as well as finding answers to theoretical issues such as finding the network architecture that gives the best possible exploration possible performance.

4. REFERENCES

[1] W. Burgard, M. Moors, C. Stachniss, and F. Schneider,"Coordinated Multi Robot Exploration", IEEE Transactions on Robotics, 21(3), 2005.

[2] J. Ko, B. Stewart, D. Fox, K. Konolige, and B. Limketkai, " A Practical, Decision-theoretic Approach to Multi-robot Mapping and Exploration", IROS 2003

[3] Martijn N. Rooker and Andreas Birk, "Multi Robot Exploration under the Constraints of Wireless Networking", in Control Engineering Practise Journal, 2007

[4] Martijn N. Rooker and Andreas Birk, "Communicative Exploration with Robot Packs", in Lecture Notes in AI, 2006