Coordination in Ambiguity: Coordinated Active Localization for Multiple Robots *

(Demo Paper)

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ABSTRACT

In environments which possess relatively few features that enable a robot to unambiguously determine its location, global localization algorithms can result in multiple hypotheses locations for a robot which makes active guidance for localization necessary. When extended to multi robotic scenarios where all robots possess more than one hypothesis of their position, there is the opportunity to do better by using robots apart from obstacles as 'hypotheses resolving agents'. The demo here showcases a unified framework accounting for the map structure as well as measurement amongst robots while guiding a set of robots to positions where they can localize to a unique state. Another aspect of framework demonstrates the idea of dispatching localized robots to locations where they can assist a maximum of the remaining unlocalized robots to overcome their ambiguity. The method presented has been tested in both simulation and real-time on robots and its efficacy verified.

Keywords

Active localization, Coordinated localization, multi-robot localization, multi-robot systems, probabilistic reasoning.

1. INTRODUCTION

It is possible for a global state estimation procedure to give several hypotheses of the robot state (position) in symmetric environments like corridors and office rooms. In these cases the ambiguity in position can be resolved by moving the robot to locations where the configuration of obstacles enables zeroing in onto a single hypothesis, a process called 'active localization'.

In this paper, we present a new approach to the problem of *actively localizing* a group of mobile robots, where the robots are capable of detecting each other and all robots possess more than one hypothesis of their position. The problem is tackled in two stages: in stage one, we propose a method that moves robots with multiple hypotheses to places such that a maximum number of robots can localize to a unique state. We consider frontier locations [2] as good places to move to since they are easy to compute and provide a sufficient set of places to visit for convergence to a unique hypothesis. The method presented choses a frontier for each robot to move to such that the probability of finding a unique hypothesis for the set is maximum. Intuitively the best frontiers are those at which the maximum number of unique measurements between robots (robot-robot detections) as well as from robots to the local map structure can be made. It is worth noting that multiple hypotheses arise because there are no unique measurements at those hypothesized locations that can differentiate that location from the other competing hypotheses. Hence the search for frontiers that provide as many unique measurements as possible. For a robot with multiple position hypotheses, a frontier corresponds to many locations in the map so the robot cannot hypothesize to reach any frontier location uniquely but only in a probabilistic sense. Hence a probabilistic framework is developed that finds the probability of reaching places where the number of unique measurements leading to unique hypotheses is maximum for the set of robots. Once shepherded to these positions some of the robots could attain a unique hypothesis. In the second stage localized robots are sent to positions where they help in localizing as many unlocalized robots as possible. In principle a localized robot can localize all others if it is able make a measurement on them. This framework also accounts for constraints such as the maximum distance that can be measured by the range sensors and the local map structure at frontier locations.

2. METHODOLOGY

The problem involves firstly the computation of probability of robots reaching or occupying frontiers (occupancy probability). Secondly the probability of obtaining at least one unique measurement for a set of robots is calculated. This probability depends on both the nature of the map structure and the placement of other robots. Unique measurements in case of robot-robot detection form range and bearing tuples $\langle d, \theta \rangle$ and in case of local map structure *'potential locations'* which provide discerning measurements to obstacles. Both the cases are considered. Also the modifications in the probability due to sensing range limits and other visibility constraints are incorporated. Thirdly, the net probability of a unique hypothesis is computed from union of unique measurement probabilities. The computational complexity can be reduced by clustering robots into what are called as base-pairs.

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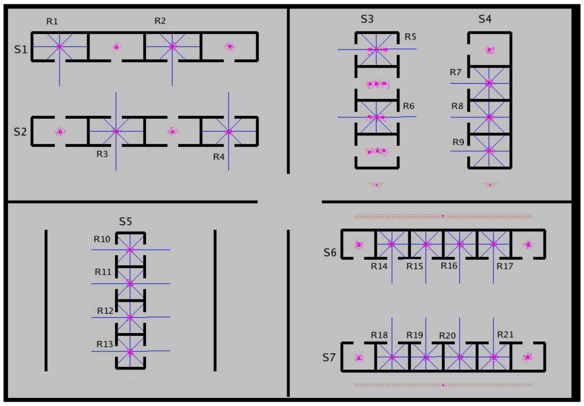

Figure 1: All robots with multiple states.

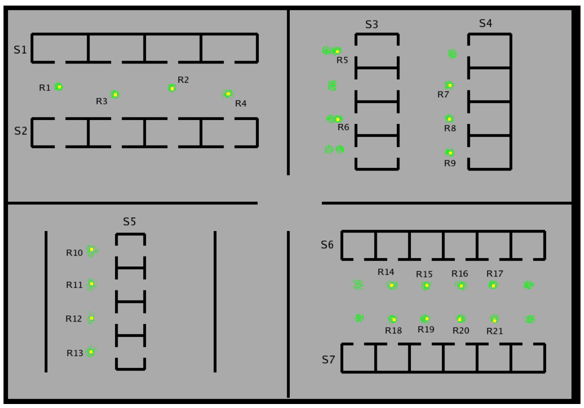

Figure 2: Stage1 localizes only R1, R2, R3 & R4.

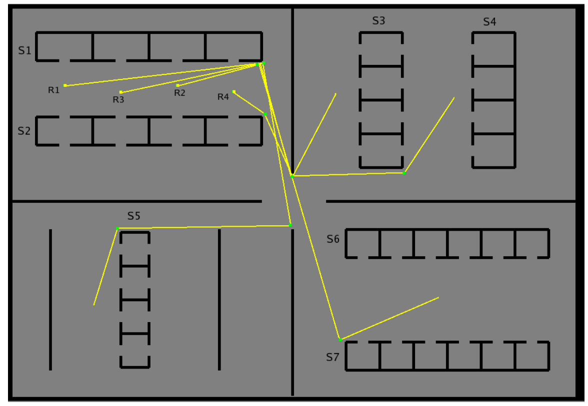

Figure 3: Paths from localized robots to clusters.

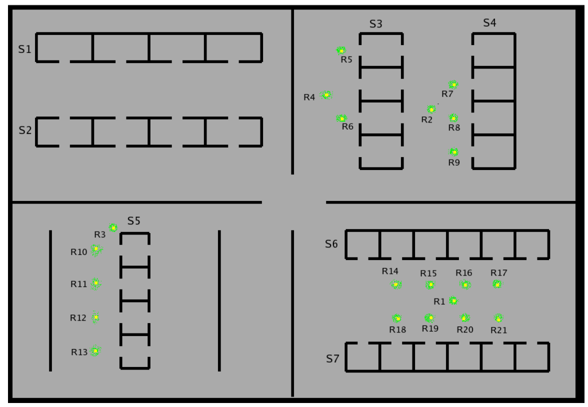

Figure 4: After the stage 2 of the algorithm.

3. DEMONSTRATION SCENARIO

The demonstration scenario has two parts: A simulation and an implementation on real robots.

Figure 1 shows a map with 21 robots arranged in 7 suites named S1, S2, . . . , S7. The robots are labeled R1, R2, . . . , R21 which are placed as shown and the blue lines show the initial scan of the sensors which create mutli-modal probability distributions for the positions of each of the 21 robots. The hypotheses positions are shown as pink clusters (with a mean). Figure 2 shows the posterior after the first stage of active localization where some robots (R1, R2, R3 and R4) are localized to unique hypothesis and the remaining robots still have multiple hypotheses. One should make a note that the robots in suite S5 also have the multiple hypotheses for their states with one set of hypothesis near suite S3. As mentioned in the previous section, clusters of hypotheses locations of unlocalized robots are formed and localized robots are assigned to these clusters. The computed paths from the localized robots to the clusters can be seen in yellow in Figure 3, intermediate points along the path are marked with green circles. The path planning is done using a visibility graph. Figure 4 shows the scenario in which all the robots are localized after the coordinated localization. The localized robots have reached their corresponding cluster centers to enable the coordinated localization.

For real-time implementation, the method is demonstrated on a pack of Amigobots equipped with 8 sonar transducers. External hardware in the form of IR transceiver circuit was interfaced to the serial buffer of the Amigobot's controller board to facilitate easy detection of one robot by other. The details cannot be explained due to brevity of space.

4. CONCLUSION

This demo has presented a novel method of navigating robots for rapid elimination of multiple position hypotheses among them. It presents a unified probabilistic framework that takes into account the role of measurements between robots as well as the measurements made on the local map structure in deciding the best locations to move to. This framework also incorporates the constraints due to sensing range limitations and the presence of obstacles that prevent robots from detecting each other by a unique measurement leading to a unique hypothesis. The method operates in two stages: active localization followed by coordinated localization and is called 'Coordinated-active localization'. Simulation results and real experiments confirm the efficacy of the method. This method finds utility in several multi-robotic scenarios, where robots have multiple hypotheses and require the assistance of other robots to resolve ambiguity as well as to improve the accuracy of their state estimates.

5. REFERENCES

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