Mapping the impact of faults in a multi-robot team

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Abstract

Hardware failure can have significant impact on the performance of a multi-robot team. The work presented here provides a preliminary assessment of this impact based on experiments conducted with physical robots. Two types of hardware failure are considered: motor failure and laser sensor failure. These can be *permanent* (where the robot does not recover during the mission) or *temporary* (where the robot does recover). Results show that permanent motor failure and laser sensor faults decrease the success rate of task completion to varying extents and laser sensor faults also cause significant errors of measuring distance travelled by the robot in faults. While these results are not unexpected, the contribution of this work is in laying out a structured baseline that will be used in the near future for comparison of recovery strategies.

Approach

- In order to investigate the impact of hardware failure in a multi-robot team (based on the MRTeAm framework [3, 2]), we induce different types of failures in a "faulty" robot at a randomly generated time point.
- This work investigates two types of hardware failure (motor and laser sensor) in three failure modes:
  - ▷ both motors encounter permanent complete motor failure (CMF);
  - ▷ both motors encounter temporary failure (TMF); or
  - ▷ laser sensor encounters permanent partial laser-sensor failure (PLF).

  No failure (NF) is included for comparison.
- To evaluate the impact of each failure type, we consider metrics that measure the performance of both individual robots and the team as a whole.
- Here we focus on the **distance travelled** by the robots executing allocated tasks; and **success rate** of task completion by each robot.

Experiments

- Our experiment consists of 3 TurtleBot3 Burger robot platforms (Figure 1).
- The operating arena is a $3.2m \times 3.2m$ office-like setting with a central corridor which connects each "room".
- Experimental missions have 8 tasks allocated to 3 robots using the *Sequential Single Item (SSI)* [1] auction mechanism.
- Our "faulty" robot employs a modified controller which will induce failure after a randomly generated time, chosen from a Gaussian distribution, and last for a random amount of time.
- 320 physical trials were conducted in total:

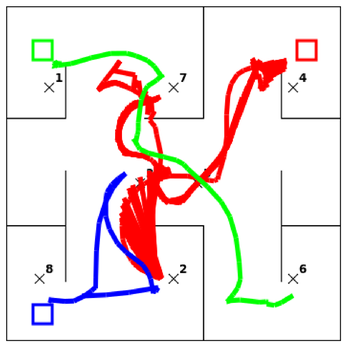
$$\textit{SSI auction mechanism} \times \langle SR|MR\rangle \times \langle IT|CT\rangle \times 2\ \textit{starting formations} \times 2\ \textit{scenarios} \times \{CMF|TMF|PLF|NF\} \times \{5\ \textit{physical trials}\}$$

Results

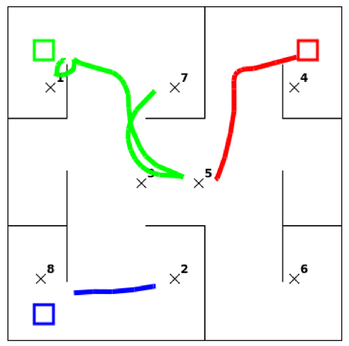
- Figure 4 shows the total distance travelled by the team as a whole, indicating clearly that when there is a partial laser sensor failure, the faulty robot has trouble localising and travels much further than it needs to, contributing to an outsize distance for that experimental condition.
- This is highlighted by the red path shown in Figure 2 and by the tallest (dark) bar in Figure 5.
- Figures 2 and 3 illustrate trajectories travelled by sample robots impacted by partial laser sensor failure (PLF) and complete motor failure (CMF), respectively, in one mission configuration (scenario 1, distributed start, MR-CT-SA).
- Figure 6 shows the success rate, which is measured as the percentage of assigned tasks that were completed.
- When failure is temporary and there are no failures, then all assigned tasks are completed.
- Complete motor failure has a more detrimental effect than partial laser failure.

Figures

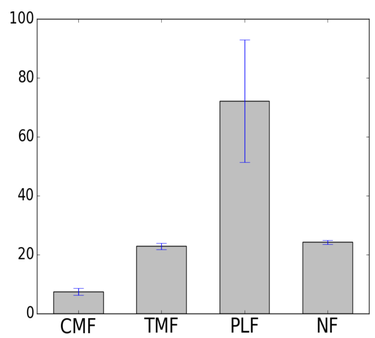
(1) Robot arena



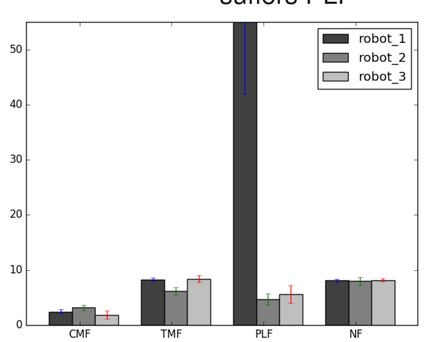
(2) Trajectories when robot suffers PLF



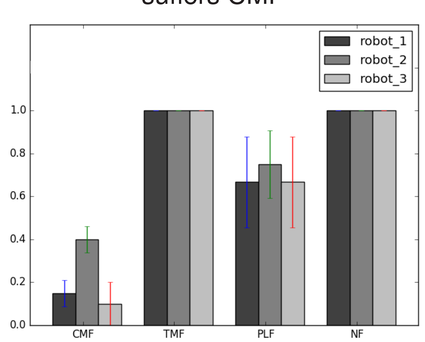
(3) Trajectories when robot suffers CMF



(4) Total distance travelled



(5) Distance per robot



(6) Success rate per robot

Summary

- We have shown preliminary results of baseline experiments designed to illustrate the impact of various types of hardware failures on the performance metrics achieved by a multi-robot team.
- A range of scenarios and mission configurations have been produced, though space constraints here allow showing only a sample for one such configuration.
- A more comprehensive report with complete results is under preparation.
- Next steps involve development of response strategies when failures occur, followed by experimental evaluation of our strategy.

References

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[3] Eric Schneider, Elizabeth I Sklar, Simon Parsons, and A Tuna Özgelen. Auction-based task allocation for multi-robot teams in dynamic environments. In *Towards Autonomous Robotic Systems: 16th Annual Conference (TAROS)*. Springer, 2015.