Communication aware coordination of multi-robot systems

PhD Position - Description of the Research

Context and Goal of the Research

Multi-robot systems have recently become a significant area of research with applications in search and rescue, environmental monitoring, industrial and warehouse robotics, and coordination of self-driving vehicles. Existing theoretical research in multi-robot systems is limited to a simplistic and unrealistic model for communication, and previous hardware research is often limited by their application-specific nature and by their high cost.

In this work, we propose to perform an experimental comparison of distributed and centralized multi-robotic control paradigms with an emphasis on exploring the effects of a non-ideal wireless communication channel. Furthermore, we propose to develop communication aware algorithms for coordination of robotic swarms as applied to self-driving convoys and warehouse robots.

Description of the Research

(1) Development of a Multi-Robot Experimentation Platform.
A single robot that is suitable for scaling to mass-production has already been developed (DotBot, shown in Fig.1). The functionality of this robot, both as an individual and as a member of a multi-robot system, is critical to the completion of the PhD. It will be used as the experimental platform for the remainder of the research in the thesis.

Fig. 1 DotBot robotic platform

(2) A Comparison of Distributed versus Centralized Localization in Multi-Robot Systems.
In addition to IMU dead-reckoning, we propose to use the Valve HTC Lighthouse for distributed robot localization as an indoor analog for GPS. The primary benefit of this technique is that a robot can localize itself in a global coordinate frame which enables completely distributed localization (e.g. in Fig 2). This comes with an intrinsic trade-off between the amount of traffic in the channel and the complexity of local control on each robot. We will investigate this trade-off in the specific instance of decentralized collision avoidance in a crowded warehouse.

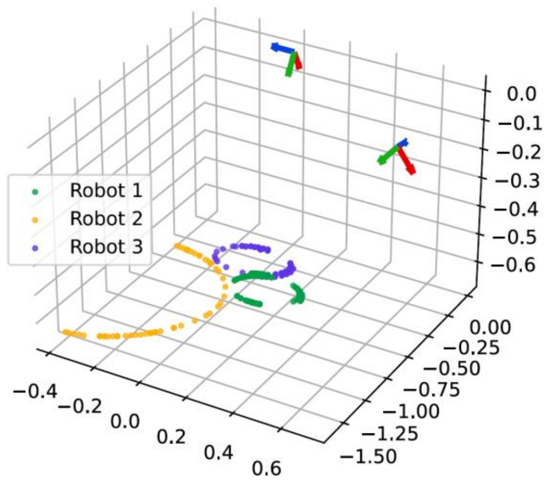

Fig. 2 Scene solving and localization of three robots driving in circles.

(3) Human-in-the-loop Swarm Command and Control.
Human command of robotic swarms (or individual agents within a robot swarm) is an active area of research in human-computer interaction. We intend to apply a similar approach – taking inspiration from real-time strategy (RTS) games in which a single user controls many individual agents. We intend to extend this approach to make it distributed in order to reduce the strain on the wireless communication infrastructure as the number of agents increases. Furthermore, we will explore algorithms in which a single human controlled element must navigate to avoid an existing, and possible moving, autonomous robot swarm.

(4) Distributed Multi-Agent Control
A natural extension of human command is complete swarm autonomy. Extensive theoretical work has been done on algorithms and techniques for distributed control under various swarm behaviors, such as flocking and convoying [1]. The first component of the research in this PhD is to perform a comparison of these existing techniques using our experimental swarm platform with realistic communication (a real channel with finite reliability and non-zero latency). The next component is to apply communication techniques explicitly designed for control-over-wireless in an attempt to mitigate problems with the distributed control algorithms that can be attributed to realistic communication problems such as fading, packet collisions, and unpredictable latency.

Skills and Expertise

We are looking for an aspiring researcher ready to make a significant contribution to the field of wireless ranging and localization.

- Experience developing new hardware systems.
- Experience with embedded systems with an emphasis on robotics
- Experience with control systems and some familiarity with wireless communications

References

[1] A. Prorok, M. A. Hsieh and V. Kumar, "The Impact of Diversity on Optimal Control Policies for Heterogeneous Robot Swarms," in IEEE Transactions on Robotics, vol. 33, no. 2, pp. 346-358, April 2017, doi: 10.1109/TRO.2016.2631593.