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Precision Locomotion on Constrained Low-Cost Robot Hardware

Rational

The prevalence of low-cost robot hardware is increasing, with focal points in cost-effective methods for mass-producing robots for STEM education and productivity advancements. This independent study plans to conduct research in precision locomotion in constrained low-cost robot hardware, seeking to optimize the localization system for the Petoi Bittle robot using a monocular camera. We seek to push the constraints of tiny-robots by mapping visual odmoetry localization algorithms, able to run on the Raspberry Pi 3 Model B.

This project entails a literature review, analyzing existing approaches to locomotion algorithms, designing our own constrained low-cost robot localization system, coding the system from scratch, and finalizing it into a research paper targeted for the iROS 2024 conference. Previous research focuses on global terrain mapping, but we seek local methods. Local mapping will allow for increased capabilities of tiny robots for precise locomotion on detailed or highly-dense environments, something lacking in current research.

Proposal

This project expands on the computer vision for tiny robots project, *Visual Motion Estimation*, at Professor Brian Plancher's Accessible and Accelerated Robotics Lab (A^{2}R Lab) at Barnard College. The aim of the research is to explore the constraints of precision locomotion on low-cost robot hardware using computer vision algorithms, specifically for the Petoi-Bittle quadruped. This involved generating an 8-10 page robotics research paper as well as coding up the kernels for our own optimization algorithm from scratch in C++.

The ultimate goal of the project is to generate a Bittle-locomotion system using real-time local terrain mapping of computer vision to navigate detailed-terrain with a high-degree of accuracy. Prior to generating workable code for the Petoi Bittle, this requires first conducting a literature review, exploring Simultaneous Locailization and Mapping (SLAM)/ Visual-Inertial Odometry (VIO)/ Terrain Mapping for Locomotion. Analyzing the generation of pre-existing algorithms allows us to identify necessary kernels (image segmentation, two frame depth perception, etc.) applicable to our constrained system for precision mapping. Based on the 10-15 kernels per algorithm identified, our research focuses on designing a system in C++ that orients these kernels for our own algorithm. With several iterations, we seek to identify methods for precise localization for cost-contrainted robots, something that was previously declared for cost-constrained tiny robots to not be capable of. Using computer vision techniques on low-cost robots will give insight on how to leverage pre-existing hardware to increase accessibility and applications of tiny-robots.

With the ultimate goals are to 1. Investigate solutions for low-cost space constrained hardware for computer vision on tiny-robots to explore capabilities of high-cose vs low-cost robots, 2. Label and explore the necessary kernels for tasks in precision control between different systems. These guide us to the questions: what existing algorithms are used for high-cost robots? What would we need to add or take away for the Bittle system? What core new technical constirbutes are we enabling with our approach to local terrain mapping? These shed insight and will provide solutions for hardware that were declared as “incapable” of these tasks previously. Potential applications could be in walking across a bridge, going through a highly dense terrain, or generating a low-cost backup system for a larger robot.

The A^2R Lab meets weekly (1hr/week for 15 weeks), requires weekly progress reports, and involves 2 other students on this CV tiny-robots team. Team-dependent meetings will be twice weekly (2h/meeting) with the physical Bittle robot (4hr/week). Other work includes team/lab-level progress documentation, individual work reading papers, coding kernels, and running tests, exceeding 9-hours of work per week. These will culminate in a collective report and code, that will result in a robotics research paper that is 8-10 pages long, the standard length of a robotics research paper. Given 10-15 kernels for our algorithm, the code will well exceed 500 lines of code, totaling 20-25 pages of writing. The code will be accessed in a Git repository belonging to the A^2R Lab.

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