University of Pennsylvania
Department of Electrical and Systems Engineering

ESE SENIOR DESIGN PROJECT - ADVISOR PROJECT SUBMISSION FORM

1. Project Title:

Embedded Camera Systems for Enhanced Operation of a Mobile Legged Robot

2. **Proposer's Name:** Dr. Galen Clark Haynes, Postdoctoral Fellow, ESE
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Co-advisors: Prof. Daniel E. Koditschek, Chair, ESE
Berkay Deniz Ilhan, Ph.D. Student, ESE

Are you willing and able to serve as advisor for this project? Yes

3. Brief Project Description:

The goal of this project is the integration of small, cheap imaging sensors — commonly found in cell phones and laptop computers — as primary sources of feedback and control for a legged robot. Because they are so minimal, both in total size and in power consumption, a multitude of low-quality and inexpensive sensors can be hosted on a mobile robot, as compared to the traditional strategy of a single high-quality, expensive imager. The first goal of this Senior Design Project is to research, develop, and integrate imager electronics into a mobile robot. Upon successful completion, further project possibilities include the design of teleoperator interfaces for the system and/or the use of image processing techniques to control the legged robot.

Teleoperator Interfaces: With a multitude of imagers integrated into a mobile robot, high resolution panoramic views of the robot's surroundings are possible, and can provide a teleoperator with visual cues useful for navigation in complex environments, such as a legged robot climbing through piles of rubble or debris. Creating an immersive view that presents salient imager information to an operator, while minimizing network bandwidth, is a key goal.

Image Processing: Through embedded technologies such as FPGAs and GPUs, high-throughput image processing can be achieved by small scale electronic systems. Research into effective image processing techniques given poor quality imagers should yield useful methods that can be used to perform feedback control for a mobile robot.

4. **Project Design Objectives:**

1. Research the possibilities of embedded imagers, obtain evaluation materials from manufacturers, and integrate a prototype system onto a legged robot, EduBot, for the purpose of teleoperation via a single imager.
2. Upon selection of imager components, design the embedded circuitry to interface the imagers as a set of simple USB cameras, fabricate, and integrate the eventual electronic system into either EduBot or the larger, more powerful X-RHex legged robot.
3. Research immersive teleoperator interfaces and design and build a system to interface the array of cameras via a network connection to the robot. Using techniques from multi-view geometry, investigate methods of presenting scene geometry that can be useful to a robot operator.
4. (Replacement of or follow-up to #3) Make use of image processing techniques, such as feature point extraction, optical flow, and visual odometry, to provide sensor feedback to the legged platform, leveraging an existing on-board GPU computer to ease the computational burden.

5. Project Prerequisites:

What specific knowledge (e.g. courses or topics) and skills (e.g. programming languages or software packages) will this project require? Please rank order the knowledge and skills you have identified, with the most important at the top of the list.

The advisors of this project have experience with mobile robots, embedded control systems, and computer vision techniques, and can advise a team of 3 to 4 highly-motivated ESE Senior Design students while leveraging extensive lab infrastructure, including software and robotic systems. Collectively as a team, the students should have experience with:

1. Design of digital electronic circuits to interface hardware components
2. Low-level C programming for embedded systems
3. High-level programming experience in C/C++, Matlab, or Python

Additional experience with the following is extremely useful, but not necessary:

4. Experience with graphical user interface toolkits and OpenGL
5. Knowledge of imaging systems, including camera geometry and image processing techniques.
6. Experience with control of mobile robotic systems