A. Title

Final report of Development of Control and Coordination of a Multi-robot System

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B. Restatement of the problem researched, creative work, or professional enhancement opportunity

Although the advances in autonomous navigation of mobile robots and all their current applications (planet exploration, delivery of meals in hospitals, etc.) has been amazing, it is recognized the need[3] of multi-robot systems[1,2] to increase the range of future applications for robots, like exploration in hazardous environments, execution of a task beyond the limits of single robots, ability to complete a task more rapidly and robustly, performance of a complex task by multiple specialized robots, highly distributed sensing (sensor nets) with mobile sensors[3].

One of the main applications of mobile robots is terrain coverage: visiting each location in a known terrain to perform a task. Terrain coverage is crucial for tasks ranging from mundane lawn mowing, cleaning or harvesting to search-and-rescue missions, intrusion detection or mine clearing. It is frequently desirable to minimize the time by which coverage is completed[5].

A Multi-robot system presents capabilities and performance beyond typical single robot applications. Hence, the design of multi-robot system is highly desired. However, the design of multi-robot system is more complex than the design of single robot systems. Small differences between a theoretical robot model and single real robot are intensified in multi-robot systems due to the large number of robots, interactions between robots, and the effects of asynchronous and distributed control, sensing, and actuation[4]. One of the challenges of implementation of these systems is the development of the hardware/software setup needed for study of motion control and coordination. The main focus of this research study was the development of the hardware/software setup of a set of three robots suitable for the study of control and coordination of multi-robots systems.

C. Brief review of the professional enhancement opportunity, creative work, or research procedure

In this research a hardware/software setup of three robots for the study of Control and Coordination of Multi-robot systems was built. First, a set of three small robots was selected and equipped with XBee modules to provide them with wireless communication capabilities. The Pololu 3pi robots were selected because of its size, price and technical support available for their configuration and programming. Due to space constraints in the Robotics Lab, size was a fundamental concern. The Pololu 3pi robot has a diameter of only 3.7 inches what makes possible control several of them inside relative small areas. The PI has been using Pololu 3pi robots in the undergraduate ELEG 3133 Microprocessor System Design and the experience about the robots' quality has been excellent. They are very well built. All these factors led the PI to select 3pi robots for this research.

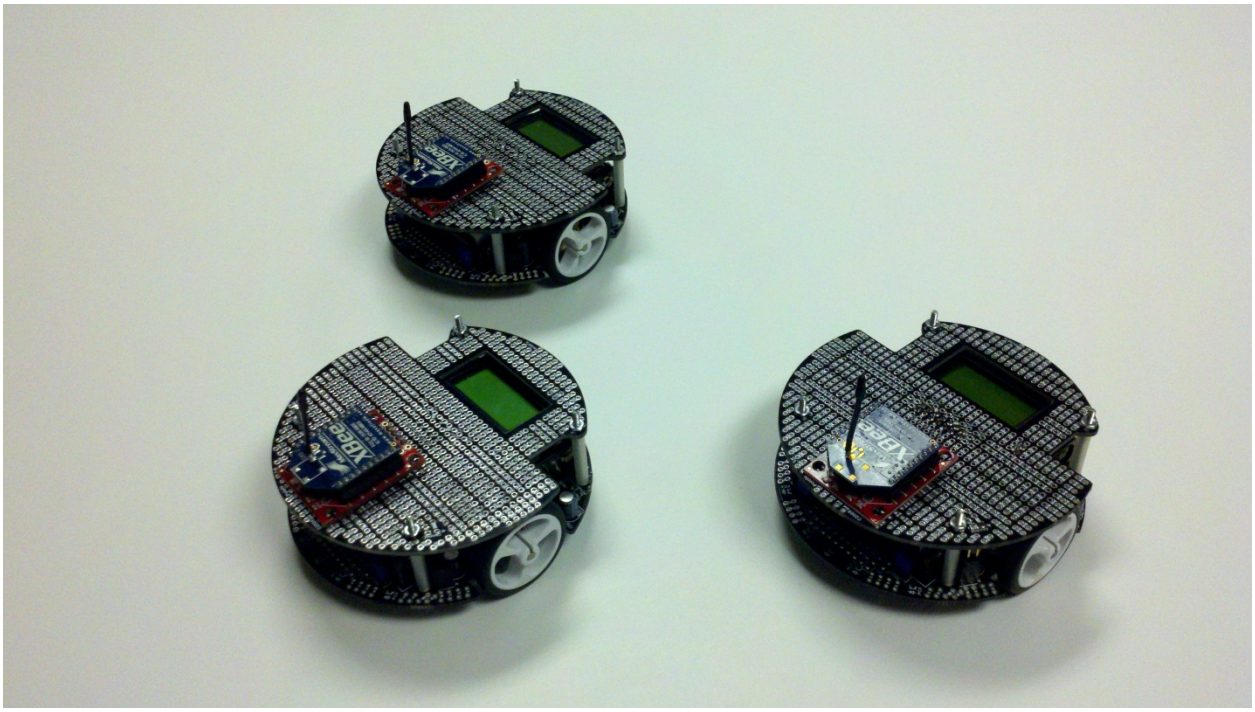

Figure 1 Set of Three Small Robots with Wireless Communication Capabilities

Second, a Global Vision System was implemented based on the open source for the Small Size League Vision (SSL-Vision) system software. The function of the Global Vision system is to detect the robot to be controlled inside of a given defined area. The control and coordination algorithms should keep the robot inside this area. Figure 2 shows the Global Vision system implemented based on the SSL-Vision software.

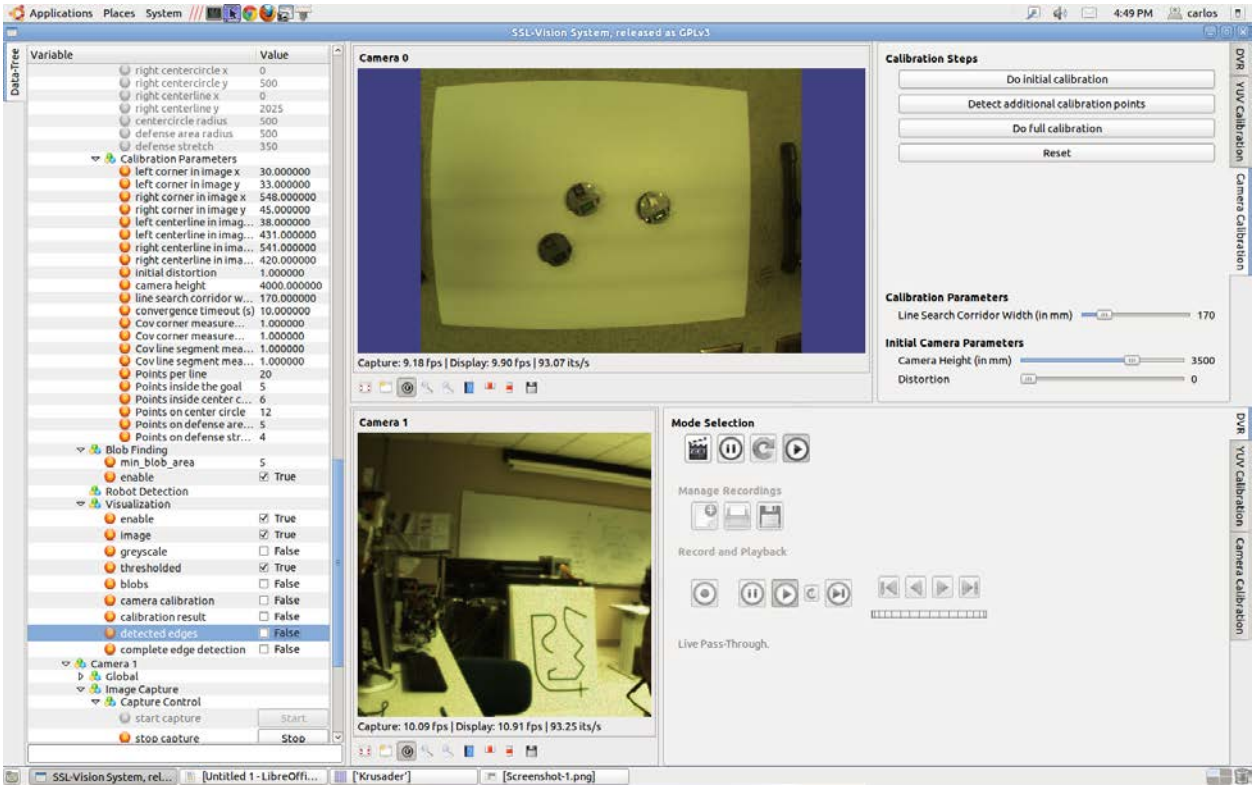

Figure 2 Global Vision System based on the SSL-Vision Software

The Global Vision was used to detect the robots using some camera calibration procedures. Figure 3 shows the two AVT Guppy FireWire cameras purchased for the Global Vision system. Figure 4 shows the detected edges of the working area. Figure 5 shows the results of the camera calibration. Figure 6 shows a zoom of the robots detected using a segmentation algorithm. Figure 7 shows the Global vision system implemented in the Robotics

Lab. It is comprised, basically, of two AVT Guppy FireWire Cameras, and a PC running Ubuntu 11.04 “Natty”.

Figure 3 AVT Guppy FireWire Cameras

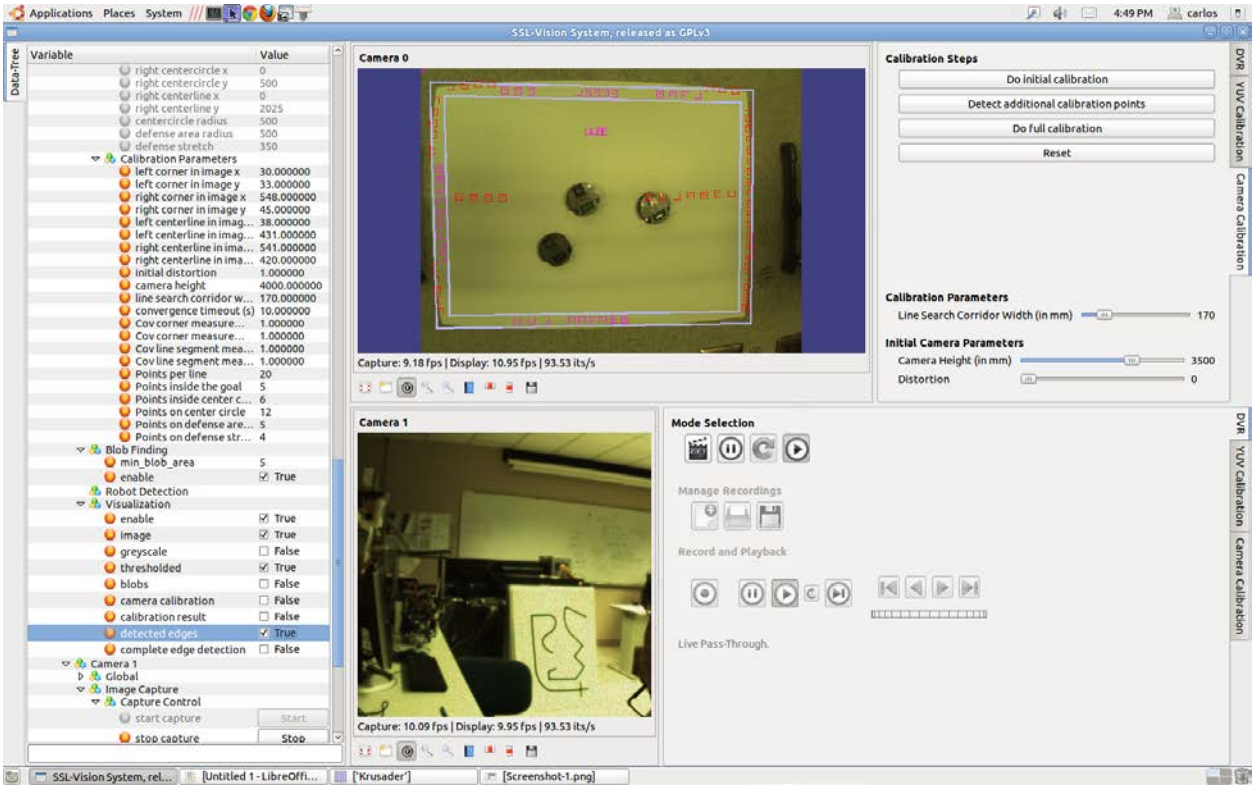

Figure 4 The Global Vision System detects the Edges of the working Area

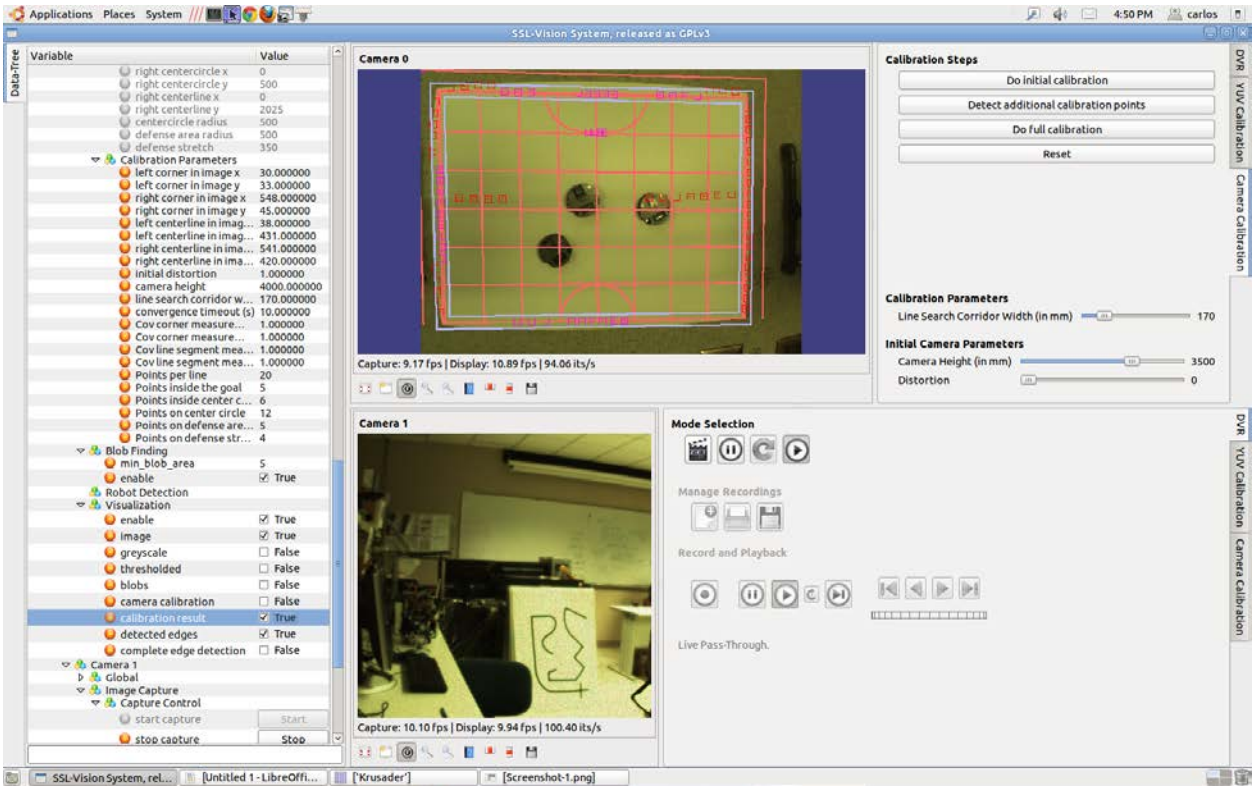

Figure 5 Camera Calibration Results

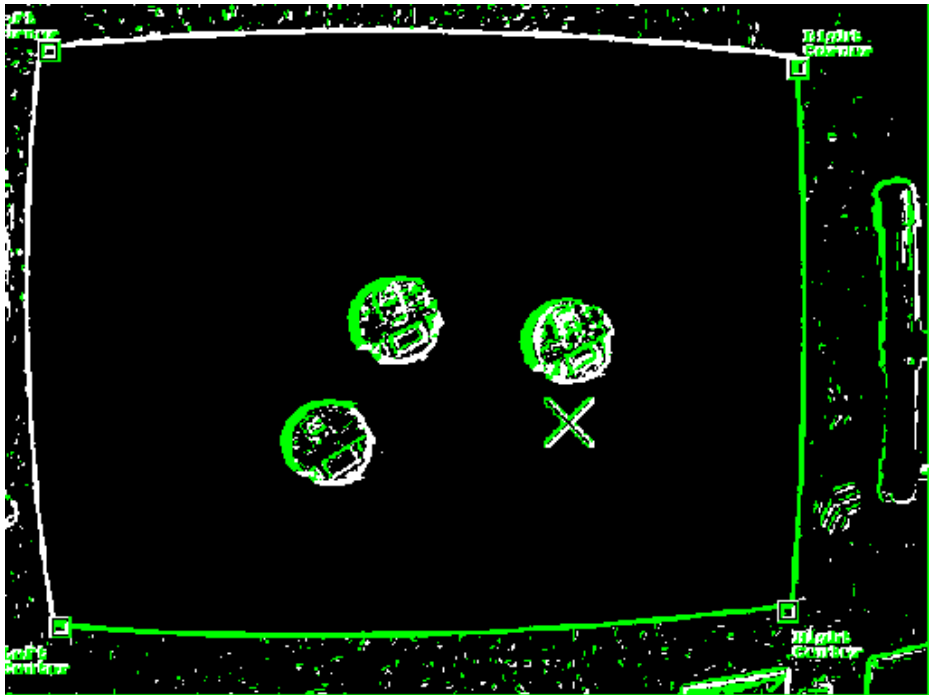

Figure 6 Zoom of the Detected Robots

Figure 7 The Global Vision System Consisting of Camera and a Linux Computer running the SSL-Vision Software

Through the use a C program implemented in the Pololu 3pi robots, some open-loop motion control experiments were implemented.

D. Summary of findings, outcomes, or experiences

The Fire4Linux libraries needed to be removed to test the cameras. AVT libraries and viewer/configuration tools were installed. The SSL-Vision software does not provide the camera configuration options needed to take full advantage of the high speed (60 frames per seconds) of the AVT Guppy cameras). Maximum

rate obtained with the current configuration options was around 10 frames per second. The slave program provided by Pololu for the 3pi robots was modified in order to be used for the open-loop motion control and coordination experiments. The motion control consisted of time controlled trajectories.

E. Conclusions and recommendations

In conclusion, a Global Vision system based on the SSL vision software was successfully implemented. Several open-loop motion control experiments were implemented. Future work will consist in the implementation of closed-loop motion control and coordination. The number of robots will be increased to five. Modification of the SSL-Vision software are planned to take full advantage of the high-speed of the AVT Guppy cameras.

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