Work in Progress - Capstone Experience - Visual Navigation of an RC Vehicle using Wireless Video Feedback to a PC

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Abstract – An innovative Capstone design project was completed at Western New England College by a single student during an 11-week period. The primary pedagogical objective of the project was to provide extensive opportunity for a student to engage in self-directed learning. To this end, a project was chosen that involved image processing, control theory, circuit design, PC interfacing, and software design. A radio controlled vehicle was designed to track predetermined objects using wireless video feedback. The student had no prior knowledge of four of the five engineering principles involved in the system. The system required the control of speed and direction of a radio controlled (RC) vehicle using monocular video images that were wirelessly transmitted to a PC and captured with a video capture card. The camera and video transmitter were mounted on the top of the car. The images were processed on the PC using Visual Basic and vector control was sent to a student-fabricated interface to a handheld RC controller that controlled the speed and direction of the car. A graphical user interface (GUI) was designed to aid in development. It allowed for simplified access to color balance calibration, steering and speed calibration, and image initialization. A summary of the development process, the design, the results, and the pedagogical insights of the Capstone design project are presented in this paper.

Index Terms – Remote control vehicle, image processing, and object tracking.

INTRODUCTION
Capstone design projects should involve significant design requiring students to utilize much of the knowledge attained in their previous three to three and a half years of engineering education. Projects may also require students to engage in independent research to enable them to solve problems outside of their existing knowledge base. The project described in this paper required a student to use both existing knowledge and to learn and apply new engineering skills. Designing and building a complex system with aspects outside of one’s knowledge base prepares students for their career quite well because it teaches them how to engage in lifelong learning.

The project objective was to build a vehicle that utilized video feedback to control the trajectory of a radio-controlled (RC) vehicle that would follow a known object at a fixed distance. The project required knowledge of circuit design, PC interfacing, software design, image processing, and control theory. This pedagogy behind the project was to enable a student to engage in the practice of lifelong learning by building a system that contains numerous engineering principles that are not in the student’s background. In this case, the student was studying computer engineering and had no prior knowledge of control theory, PC interfacing, image processing, or graphical user interface (GUI) design. The student was able to learn the basic principles of all four subjects and successfully implement a system using this new knowledge. The project was successfully designed, built, and tested during an eleven-week timeframe.

This paper will summarize the system that was built, and provide brief details of feasibility and outcomes of the project. Finally, pedagogical insights will be briefly discussed.

SYSTEM DESIGN OVERVIEW
An overview of purchased and designed hardware and software components is presented.

I. System Overview

The system was designed to control a remote vehicle using only video frames sent to the desktop computer from a camera mounted on top of the vehicle. Figure 1 shows the RC vehicle with the camera mounted on its roof. The system consisted of several components, including the remote vehicle, a wireless camera system, a desktop PC, and circuits to interface the computer to the RC vehicle controller. All communication between the components utilized wireless transmitters and
receivers. A block diagram of the system illustrating the components is shown in Figure 2.

The boxes that are not shaded indicate those components that were purchased. The boxes shaded in blue are hardware components designed and built, and the box shaded in green, was software that was written for the vehicle. The yellow box indicates a component that was purchased, but was modified to fit the project’s application.

The control loop worked as follows: A video frame is sent via a wireless transceiver from the car to the PC. The frame is captured and processed by the vehicle control program. The image processing algorithm is a color segmentation and size of mass and center of mass algorithm. The size of mass algorithm is used to determine the distance from the target using monocular vision. The center of mass algorithm is used to determine the proper direction of the target. A speed sensitive steering control algorithm is employed to track the object at a predetermined distance. The speed and steering commands are sent to the handheld transmitter via the parallel port and a student-designed D/A circuit. The analog signals were replaced by the analog signals that are normally determined by the joy stick potentiometers of the handheld transmitter. The analog signals are interpreted by the transmitter and converted to appropriate RF-control signals to the vehicle. On the vehicle, the control signals cause the speed and steering servos to turn. The steering servo and mechanism was unaltered. The speed control servo, however, was connected to a potentiometer and student-designed speed control circuit. The speed control was designed to allow for a more sensitive level of control of slower speeds. If the speed control were unaltered, the vehicle would have been much more difficult to control. As each frame is captured, new speed and steering commands are calculated and sent to the vehicle.

The student also developed several GUIs to aid in the testing. Specifically, speed calibration, steering calibration, and image calibration was designed. The image calibration allowed for adjustments due to lighting conditions and the average color of the object to be tracked.

II. Testing and Results

Figure 3 shows an example of an original image and a color segmented image when the vehicle was tracking an orange traffic cone.

The system was tested with the traffic cone and was able to locate and track the object 100% of the time in 70 trials with starting distances of 10 and 20 feet and a tracking distance of 6 feet. Further details are omitted for brevity.

PEDAGOGICAL INSIGHTS

Students who are going to engage in self directed learning during their capstone project must be presented with the opportunity to learn new concepts, principles, or topics. If students engage in self-directed learning, they will be better prepared to engage in lifelong learning throughout their careers.

When Litzinger et. al. studied the effects of capstone projects on students’ readiness for self-directed learning, they suggested that assignments and projects requiring self-directed learning must be integrated into the curriculum if students are to make improvements in this important skill [1]. Candy states that by the time that students graduate they should “have had (the) experience of setting goals, researching topics, and generally learning on their own.”[2] The intentions of this wip-paper are to demonstrate that the self-directed learning process is actively being pursued at Western New England College and to convey project ideas to the academic community at large.

REFERENCES
