Oscar; A Theatrical Prop Handling Robot

H.C. Lilly III, Dr. A. Antonio Arroyo
Machine Intelligence Laboratory
University of Florida

Abstract

Set pieces can be used to enhance the impact of any presentation. Trees, bushes, park benches and other similar props can add interest to a stage, and can set the mood for a production. Moving set pieces into place can become a problem, since props must be moved in a matter of seconds, and often in the dark. Limited manpower exacerbates the problem.

The robot presented in this paper, Oscar, moves props to specified locations on stage. It detects ambient light, and moves only in the dark. During non-performance times, it exhibits "standard" robot behavior (wandering, avoiding obstacles, etc.).

This paper describes the mechanical, electronic, and software subsystems that make up Oscar. This robot is rectangular in shape, with four wheels. It carries a large sensor circuit board that implements the entire sensing subsystem. It has bumpers, IR detectors, and ambient light detectors. The software architecture is modeled after a state machine. It uses a special process to scan the multiplexed analog sensors.

Introduction

Set pieces, which are items ("props") used to enhance the appearance of a stage, can add interest to, and set the mood for any presentation. Set pieces can by anything ranging from sections of a wall to park benches to trees and bushes. Dramatic productions use a wide variety of set pieces to suggest a location. A section of a brick wall with graffiti, a dimly illuminated street lamp, and a section of chain link fence could suggest an inner city alley. A row of trees or bushes might suggest a park, or could be used to create a calm mood for a lecture.

Moving set pieces into place can become a major problem. In a typical dramatic production, each new scene (or "set") requires a completely new set of props. These props must all be moved on or off stage in a matter of seconds, and often in the dark. If manpower is limited set changes become nearly impossible.

Oscar is my response to this problem. Oscar is designed to work as a "stage hand," moving props to the proper location on stage at the proper time.

Integrated System

Oscar is based on a four-wheel rectangular platform. Its wheels are on axles, and are driven by servo motors through gears. Oscar has an IR sensing system, a cadmium sulfide ambient light detector, and bump sensors. The sensory subsystem is integrated onto a single large (5" by 6.5") circuit board. Oscar's program reads the sensors, and controls the motors to move to a specified spot on stage.

Mechanical Subsystem

Oscar's platform is a 13" by 17" rectangle with 5" cutouts for the wheels. It is made of thin plywood. The platform appears as figure one. This platform has four recessed wheels. Figure one also shows the locations of the main 68HC11 EVBU board, the sensor circuit board, and the IR detectors.

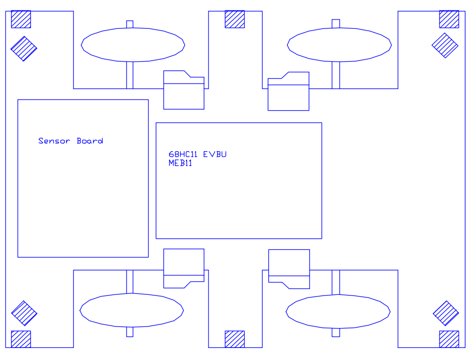

Figure 1: Platform Diagram

Oscar's wheels are mounted on 5/32" steel piano wire axles. The axles attach to the platform with 5/32" plastic brackets designed to hold the landing gear on a radio-controlled airplane. The wheels are 3.5" model airplane wheels, made by Du-Bro. The wheels have a bearing mechanism detailed as figure two. A 32 pitch, 81-tooth gear attaches to each wheel. The wheel/gear assembly rides on a 3/16" brass sleeve. A 3/16" collar holds the wheel and gear in place on the sleeve. Two 5/32" collars hold the brass sleeve in place on the axle. The axle/sleeve combination forms an inexpensive and effective bearing. It spins freely, even without lubrication.

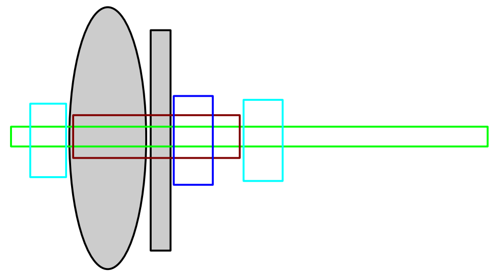

Figure 2: Wheel / Axle Assembly

Four modified servo motors drive Oscar's wheels. The mechanical stops and the electronics were removed from the servo, to create a gear head motor. Each servo drives a 32 pitch, 91-tooth gear. The motors are positioned on the platform such that the gears mesh with the gears on the wheels. Hot glue was not strong enough to hold the gears together, so I bolted the motors to the platform. Two bolts go through the body of each servo, in the space where the electronics were.

Electronics and Sensor Subsystem

A Motorola 68HC11 EVBU board controls Oscar. The EVBU board runs IC (Interactive C, an interpreted C language). A Novasoft Mekatronix Expansion Board (MEB11) completes the processor. The MEB11 contains 32K bytes of SRAM, two motor controllers, and a 40 kHz signal generator. The 68HC11 EVBU board and the MEB11 board together form Oscar's "brain".

A single large (5" by 6.5") circuit board holds the electronics for the sensors. The sensor board contains a cadmium sulfide ambient light detector, five sets of IR LED drivers, sixteen analog inputs (for IR detectors and cadmium sulfide cell), two sets of bump sensor inputs, two seven-segment LED displays, and an eight bit DIP switch input.

A 74HC138 (3:8 decoder) and a 74HC10 (3 input NAND) perform address decoding for the board. The board responds to address locations $6XXX. The 74HC138 breaks this space down into four read and four write address spaces. In the following discussion, the write addresses will be denoted by a "w" after the address, and the read addresses will be marked with an "r."

Two 74HC574's (Octal D flip-flop) at addresses $6000w (write) and $6400w control the IR LED's. The circuit diagram for the LED driver appears as figure three. The outputs of the 74HC574's are modulated by the 40 kHz signal from the MEB11. These outputs each drive the base of a 2N2222 (NPN) transistor. The transistors are used as digitally controlled switches. The 2N2222 was chosen for its ability to handle the 40 kHz modulation frequency, and for its low (essentially zero) voltage drop. The transistors are grouped into sets of three. Each transistor in a set uses a different scaling resistor to cause a different current through the LED's. The three transistors generate eight possible current magnitudes (LED intensities). Two IR LED's connect to each set of transistors through a small 10 ohm resistor. The small resistor compensates for differences in the LED's, preventing an LED with a smaller on voltage from drawing all of the current.

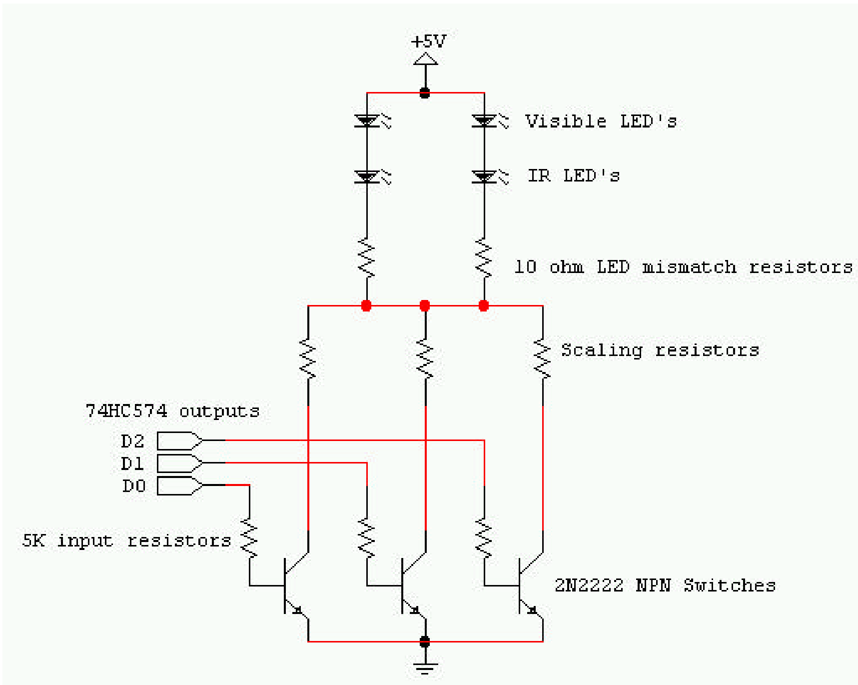

Figure 3: Eight Level LED Driver

Another 74HC574 at address $6C00w controls two 14051's (8:1 analog multiplexer). The lower three bits (bits 2-0) of the 74HC574 drive the three selecting lines of a multiplexer. Bits 6-4 drive the selecting lines of the other multiplexer. The two unused bits (3 and 7) drive two green indication LED's. The two multiplexed analog inputs attach to the microprocessor's analog ports A0 and A1.

A fourth 74HC574 at address $6800w drives two 7447's (BCD to 7-segment converters). The 7447's control two seven-segment LED displays.

A 74HC574 configured as an input port at address $6000r reads the state of the bumper switches. The inputs to the 74HC574 connect directly to the normally open switches in the bumpers, and to a 5k-ohm pull-up resistor.

One last 74HC574 at address $6400r reads a set of DIP switches. The inputs to this chip come from the DIP switch module and a 10k ohm pull-up resistor.

The cadmium sulfide sensor on this board is a light controlled resistor. Normal ambient light conditions cause this sensor to have a resistance of just under 2k ohms. In total darkness (simulated by covering the sensor), the resistance goes up to around 80k ohms. In normal shadow conditions, the sensor has a resistance in the range of 4k ohms to 10k ohms.

Oscar's IR detectors are a mixture of SHARP 40 kHz IR sensor modules, and Radio Shack 38 kHz IR detector modules (Radio Shack catalog number 276-137A). These sensors get power through the sensor board, and return their analog readings to the 8:1 multiplexers.

Software Subsystem

The core of Oscar's software is a state machine with different "modes" for different behaviors. The robot starts in a calibration mode, in which it moves forward until it bumps into something, and sets its IR thresholds appropriately. It then moves into a normal mode in which it wanders around avoiding objects. When the lights go out, it transitions to the stage mode in which it searches for the IR beacon indicating its commanded position on stage, finds it, and then moves to that location.

A lower layer of Oscar's software handles the analog sensor readings. The scan procedure implements this layer. The analog multiplexers necessitate this layer. In order to read one of the analog sensors, the software must first turn on the appropriate IR LED pair (if any), select the appropriate analog input (by writing to the selection switches at $6C00w), then finally read the values at A0 and A1.

The robot implements the stage behavior by turning off all the IR LED's, and wandering around until the IR sensors detect the light from the beacon. During this phase, object detection is done with the bump sensors.

Conclusion

Oscar is able to function as a stage hand using IR sensors, ambient light sensors, and bump sensors. For real-world applications, the robot would need a few more safety mechanisms. The bump sensors would prevent the robot from running over people, but would not keep it from running into people. Better position information would also enhance Oscar's performance.

The next step on this robot will be to work on positioning. There are several possible systems that could improve this, such as IR detectors optimized for finding an IR beacon, line following hardware, or radio/sonar position beacons.