David Winkler
12/10/02
EEL 5666 – Intelligent Machines Design Lab
Dr. A Antonio Arroyo
TAs: Uriel Rodriguez
Jason Plew
Final Report

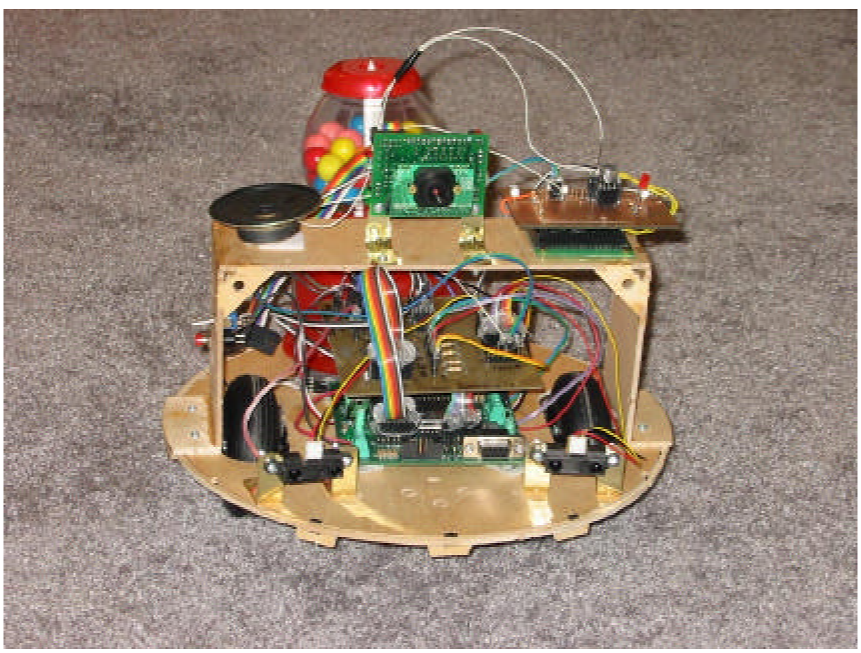


Table of Contents

Abstract

This document is the final report for Chester: the autonomous waiter bot. In this report, I intend to discuss my goals for Chester and what I achieved, including the robots behaviors and the sensors and electronics that were used. The ultimate goal for Chester was to use voice recognition to respond to a human request for service, find the human target, and serve him a drink and a snack. The project met all these objectives.

Executive Summary

This report describes the design and implementation of an autonomous mobile waiter robot named Chester. The robot is capable of responding to human voice command, finding the human, and then serving them a gumball. The robot is also capable of chasing around a red ball on command.

An Atmel AVR ATMega323 is used to control the behaviors of Chester. Chester sees his environment with four types of sensors including bump switches, IR detectors, a CMUcam, and a Voice Direct 364 Kit. These sensors are easily interfaced with the ATMega323 with plenty of room to spare.

The mobile platform for chester is made up of a 9 inch diameter circle supported by two 3" wheels and a rear castor. A bridge extends across the center of the platform and several devices are conveniently mounted on this bridge including the voice kit, speaker, microphone, and CMUcam. Actuation for the robot is achieved by two hacked Futaba S3003 servos that provide 42 oz-in of torque. Timer 1 output compare is in PWM mode to generate the necessary signals to drive the robot.

The bump sensors and IR detectors proved ample for the robot to perform obstacle avoidance. However, objects not directly in front of the robot and objects extremely close present problems for the IR. The bump switches compensate for this, but the robot could use more of them. The voice recognition kit is about 60% accurate if trained in the used environment and if the speaker is consistent in his/her speaking of the key words.

The CMUcam works well if used properly and can detect bright colored objects from distances up to 9 feet away. However, lighting plays a large factor in the success of this sensor. Florescent lighting seems to work best.

Overall the project was a success and the objective was achieved.

Introduction

I came up with my idea for Chester: the autonomous waiter bot while I was enjoying one of my favorite pastimes: being a couch potato. I thought to myself wouldn't it be great if I had a robot that was capable of responding to me and serving me drinks and snacks without any effort on my own part.

This report will outline my proposal for an autonomous waiter bot that will do exactly what I dreamed of: a robot capable of responding to a human request for service, finding the human, and providing a snack.

The brain of Chester is the Atmel AVR ATmega323 microcontroller. It is the duty of the ATmega323 to control the actuation of the robot, voice activation, obstacle avoidance, and the image processing features of the robot. Voice activation was realized with the Voice Direct 364 Kit, while image processing and human recognition was achieved with the CMUcam developed by researchers at Carnegie Mellon University.

Integrated Systems

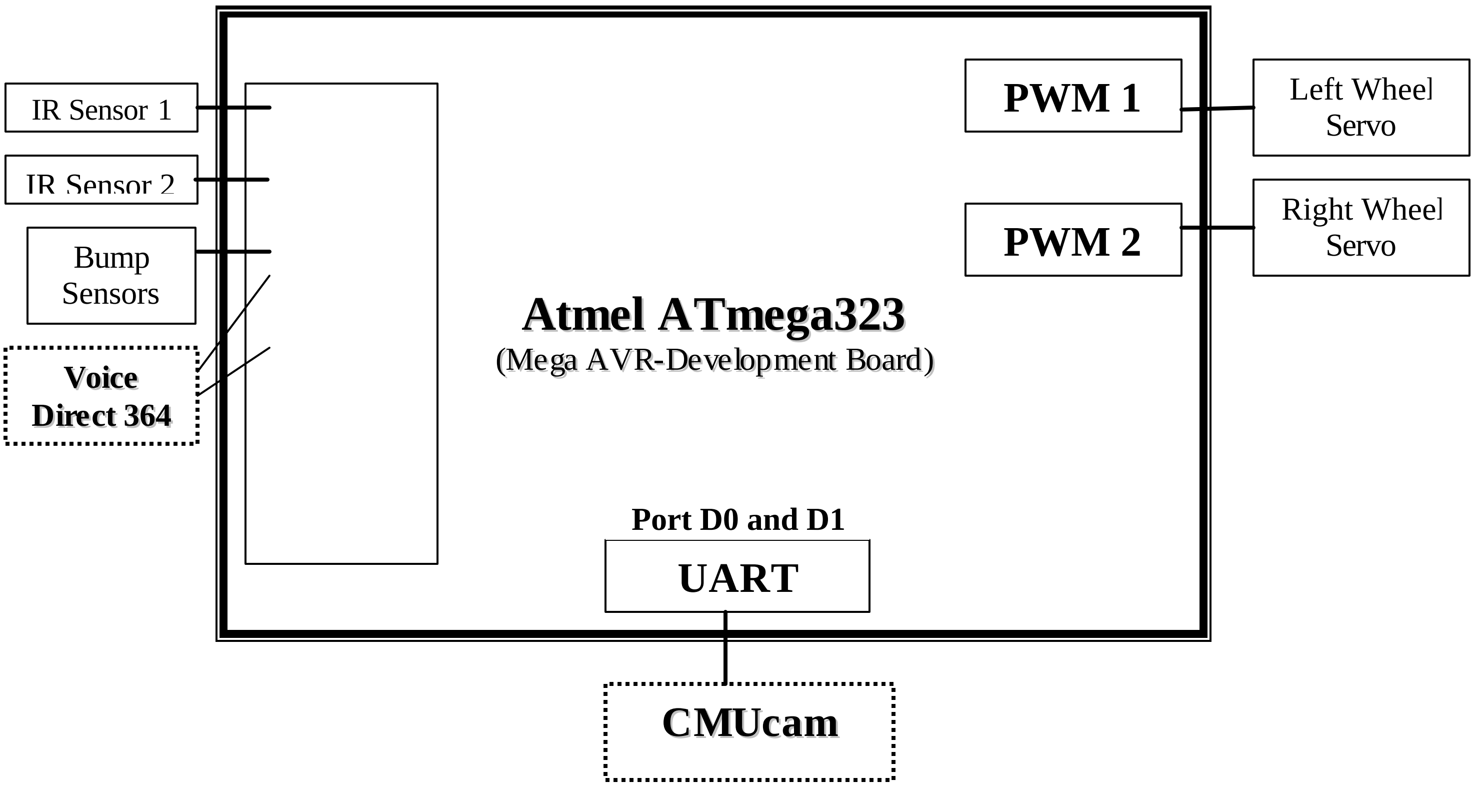


Figure 1. Integrated Systems of Chester

Chester is comprised of four main systems:

- Object avoidance system
- Voice recognition system
- Human recognition system
- Object dispensing sytem

Three of those systems are controlled by the onboard microcontroller. The microcontroller I used for control was the Atmel AVR ATmega323.

Following the KISS principle the object dispensing system was controlled by the microcontroller. The human is able to dispense the objects he/she desires and notify the robot via a voice command that they have taken what is desired from the robot.

The Object avoidance system is comprised of two Sharp GP2D12 IR detectors and bump switches. The Voice recognition system is built upon the Voice Direct 364 (www.voiceactivation.com). Some of the features of the Voice Direct 364 (courtesy of the www.sensoryinc.com) are

- Seaker-Dependent and Continuous Listening speech recognition technologies
- Minimal external components
- Recognizes up to 60 words or phrases in slave mode, or 15 in stand-alone mode (broken in to 1, 2 or 3 sets)
- Over 99% recognition accuracy with proper design
- Phrase recognition up to 2.5 seconds
- User-friendly speech prompting

The human recognizing system was achieved by using the CMUcam. The CMUcam is capable of detecting and tracking bright colors. The camera detects a human by tracking a brightly colored object placed next to the human requesting service from Chester.

Mobile Platform

For the mobile platform, I ended up modifying the Talrik Pro platform because of my limited experience and to keep things as simple as possible. The platform is circular in shape and is 9” in diameter. It rolls along on two Du-Bro 3” diameter wheels powered by two hacked Futaba S3003 servos. Spanning across the center of the platform is a bridge on which is mounted the voice kit and the CMU cam. A small bump skirt surrounds the platform and provides a contact mechanism with four bump switches placed strategically around the periphery of platform. The gumball dispensing machine is placed on the rear of the platform and is secured with velcro. A small caster wheel is mounted on the rear of the platform. For power, I used 8 1700mAh NiMH batteries. The batteries were secured to the bottom of the platform with a velcro tie. Figures 2,3, and 4 show the layout of the platform.

Figure 2. Rear view of Chester

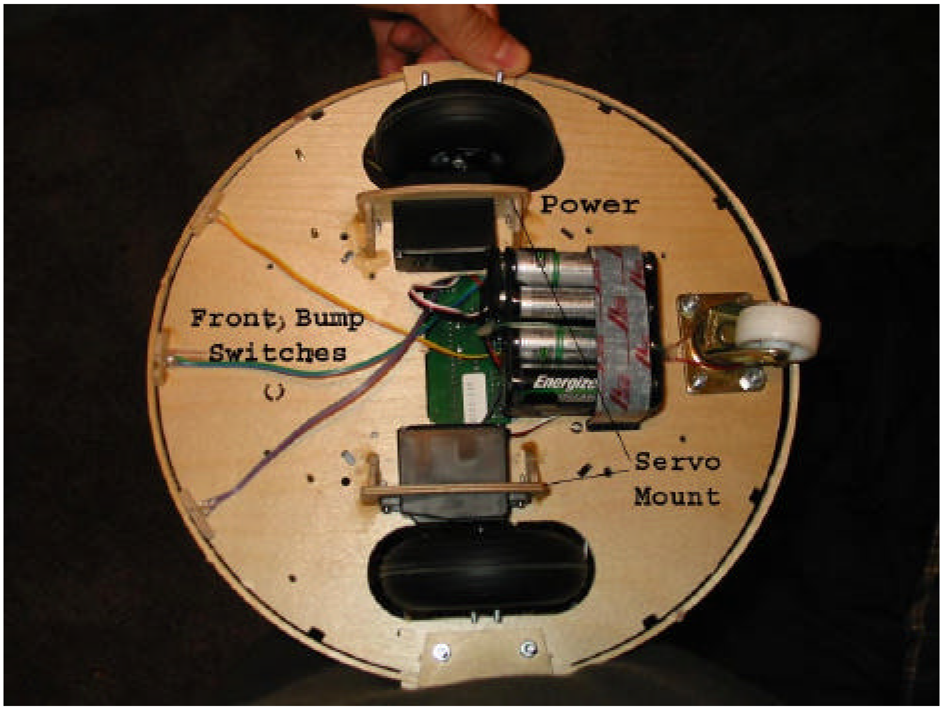


Figure 3. Bottom view of platform

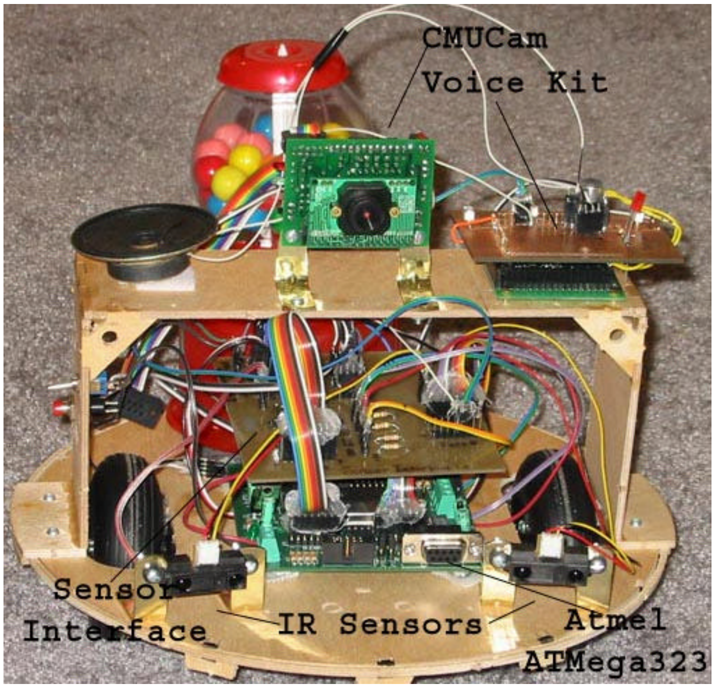


Figure 4. Front view

Actuation

For movement the robot rolls around on two 3" Du-Bro wheels that are powered by two hacked Futaba S3003 servos connected to the ATmega323's PWM channels. Timer/Counter 1 was used to generate the PWM. Only two noticeable speeds were generated by varying the PWM. castor wheel on the back provided support for the platform, but it kept the robot from moving in a straight line. Perhaps a ping-pong ball or something else would support the platform and not interfere with the direction trying to be imposed by the movement of the wheels. I also had a problem with the hacked servos. Initially they were calibrated to not move for a given PWM, but they eventually became misaligned and would move slightly when given the stop PWM. The servos unfortunately were glued to the platform and could not be removed. To compensate for this, I just disabled the PWM whenever the robot came to a stop.

The CMUcam also has a servo port capable of using a servo to track a color. This could add another level of actuation to the robot. However, this would add complexity to the object tracking code so this feature was not used.

Sensors

There are four different types of sensors used in Chester.

1.) Infrared (IR) detectors

2.) Voice Recognition

3.) Bump Switches

4.) Image Processing Camera – CMUcam

IR Sensors

Chester uses two Sharp GP2D12 IR detectors mounted on the top of the platform for obstacle avoidance. The GP2D12 sensors measure distances of 4" to 30" and return an analog voltage. The analog voltage from Chester's IR sensors are sent to PortB0 and PortB1, which are channels 0 and 1 of the Atmel ATMega323 A/D converter. The analog voltage is then converted into a number between 0 and 255 and various decisions can be made based on the converted values.

The IR detectors are placed at 15 degree angle inward and are placed on opposite sides of the platform. For two IR sensors, this arrangement works well as Chester has been able to avoid obstacles with the current obstacle avoidance routine that I have written. The only problem I've had with this configuration is in the case when objects are not directly in front of Chester, yet they are still in the path of the robot. In the current configuration of the IR sensors it will not be possible for this situation to be detected. However, with the addition of a couple of bump sensors this problem can be eliminated. The following diagram shows the placement of the IR detectors:

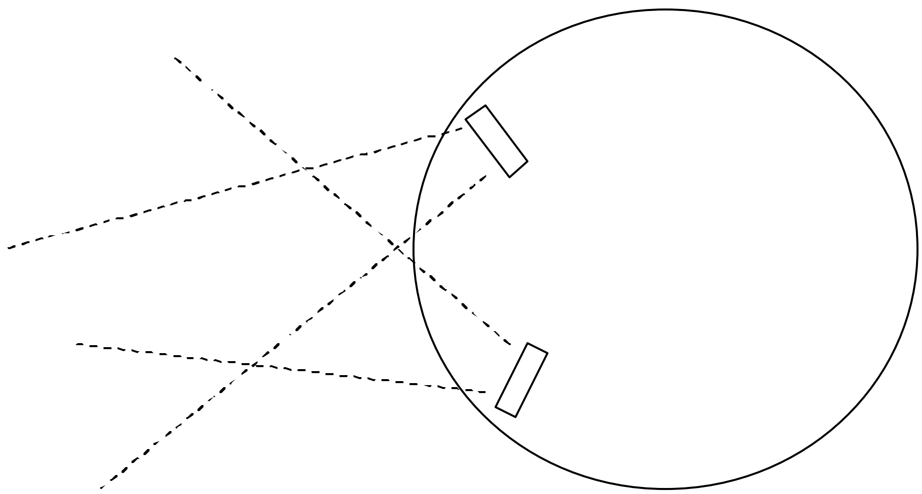


Figure 1. IR Placement

There may be a more optimal placement of the IR sensors. I've been experimenting with different configurations to see if it improves my obstacle avoidance algorithm.

Bump Sensors

Four bump switches are placed on the perimeter of Chester's platform. These provide another means of obstacle avoidance given that the IR sensors fail. The following is the placement of the bump sensors on the platform.

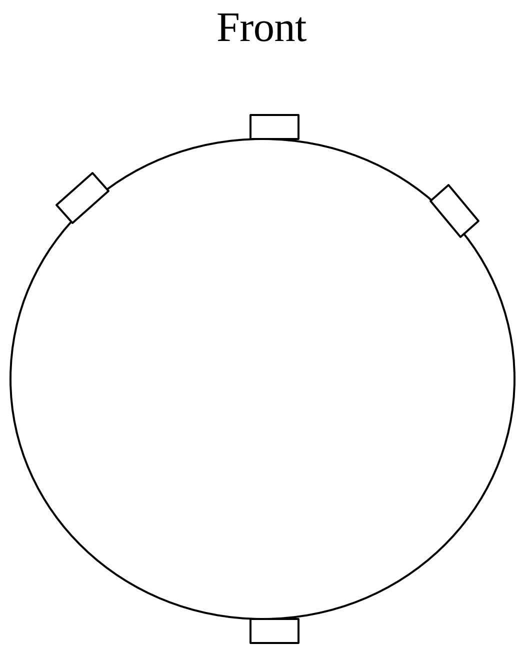


Figure 2. Bump Switch placement on mobile platform.

To save analog ports, I used a voltage divider network and sent its output to Port B2 or channel 2 of the a/d converter. Table 1 summarizes the different digital values for the bump sensors and what they mean.

To make obstacle avoidance more robust, adding a left and right bump sensor may be necessary.

Voice Recognition

For voice recognition, I used the Voice Direct 364 (VD364) kit from Sensory Inc. The kit has two main modes, slave mode and stand-alone mode. Slave mode allows the microcontroller.to have complete control over the entire operation of the voice kit. However, slave mode require that the voice kit use the Serial Peripheral Interface (SPI) via a UART. This is problematic b/c the CMU cam will use the UART. In addition, the complexity of programming for the voice kit is exponentially greater than stand-alone mode.

Because of its simplicity, I've decided to use stand-alone mode for Chester. In stand-alone mode, there are three different options:

- Speaker-Dependent
- Single Word Continuous Listening
- Multi Word Continuous Listening

Chester will use single word continuous listening. In this mode, the voice kit listens for a single gateway word which will activate listening for any of 15 words which you can train. When a word is recognized, it activates an output pin for one second. This output will be a digital I/O on the Atmel chip and will be sampled by software to detect the presence of a command.

The circuitry for the voice circuit is very simple as can be found in the voice direct kit manual. Using Protel, I have prototyped this circuit and mated it with the VD364 kit. The following figure shows the final product.

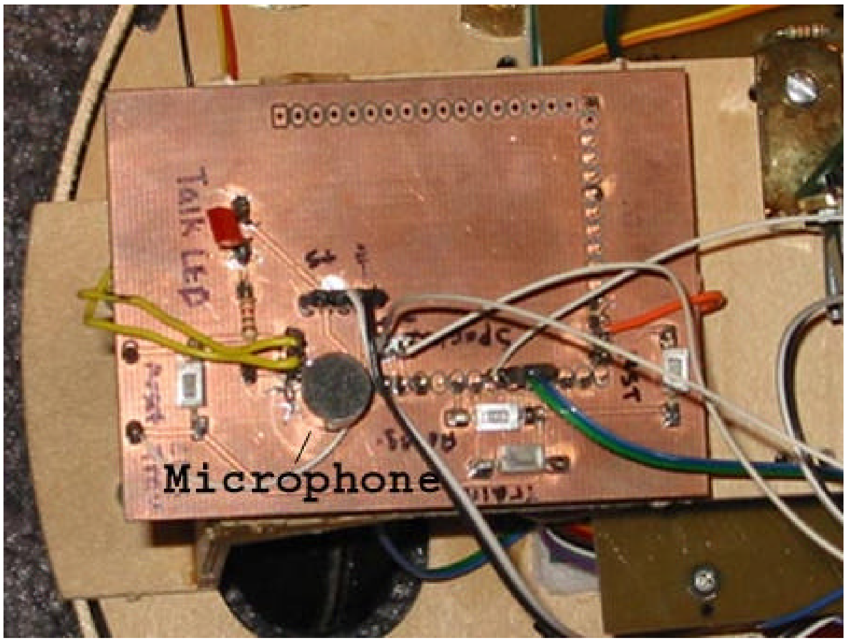


Figure 6. Voice Circuit

One thing to note about the VD364, is the choice of word for the recognition set. The performance of the kit depends highly upon what is chosen for a command set. The manual recommends choosing words that sound dissimilar and that vary in syllables. Also, intonation of the voice when training the kit is very important. I've had situation where I trained a the kit in a monotone voice, but when I go to give it a command, I get excited and change the intonation of my voice. The kit then has a hard time recognizing the word as part of its command set.

CMU Cam

Chester uses the CMUcam to find the human giving it the command. Using the CMU Cam's color tracking abilities, Chester will find the human which is giving it the command. The CMUcam communicates with the Atmel microprocessor via the USART. Using Codevision C compiler this is made easy. To send a command, you simply use the printf() function. For example, to send put the camera into poll mode you would just write the C code "printf("PM 1\r");" It is important, however to delay between commands to give the camera ample time to return from a command. One thing to note about Codevision is that the evaluation version is free, but if you want write larger programs you'll need the full version. Since the printf() command uses stdio.h, I ran into this problem very late into the semester. Luckily, I was able to share a license with my workplace. I probably would recommend sticking with GCC and AVR Studio unless you are willing to pay $150 for a Codevision license.

Camera settings that were altered were polling mode and raw data mode.

The camera uses polling mode which sets the camera to send only one data packet back after each command rather than a constant stream of data. Raw data mode is used to put the returned data packets into raw data rather than printable ASCII characters. Raw data mode is nice because it allows the data to be easily processed. The two main commands that will be used are the Track Window (TW) and Track Color (TC) commands. TW used with no arguments is used to adjust the camera to the color found at the center of the tracking window. The data obtained from the TW command is sent to subsequent calls to

TC with no arguments. The TC command returns a data packet which is then used to make decisions as to how to position the robot. The following is the structure of a packet returned from TC.

Type M packet
M mx my x1 y1 x2 y2 pixels confidence\r

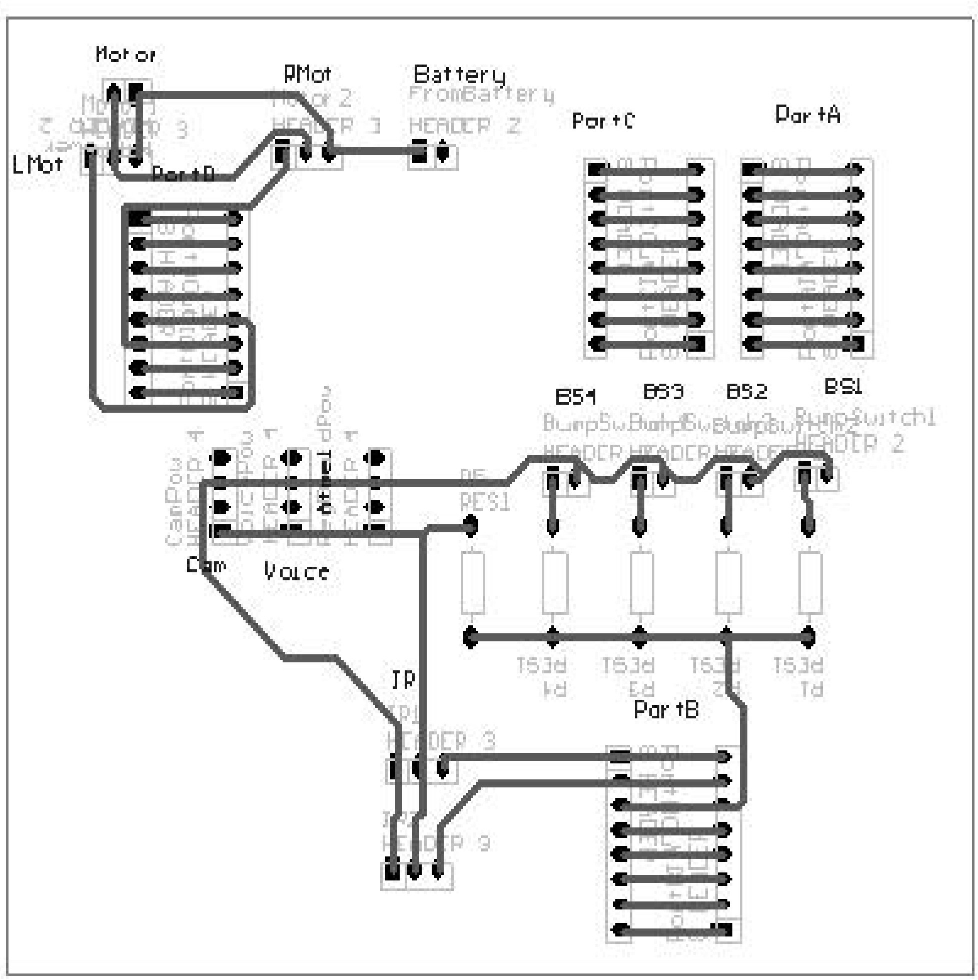
The M indicates that the camera is returning a middle mass TC packet. Mx is the middle mass x coordinate of the tracked region and My is the middle mass y coordinate. The next four bytes give the coordinates of the tracked rectangle. Pixels is the # of pixels in the tracked region capped at 255. Confidence indicates how well the camera has a lock on the desired color. A confidence > 50 indicates a good lock, while a confidence < 10 indicates a poor lock.

Chester uses an interrupt service routine to periodically check the confidence level for color tracking data and is able to determine if the colored object is nearby. For proximity measurements, # of pixes will be used to determine if the object is close or far away to Chester. Mx will be used to align the robot with the object and will keep the robot from veering of to one side.

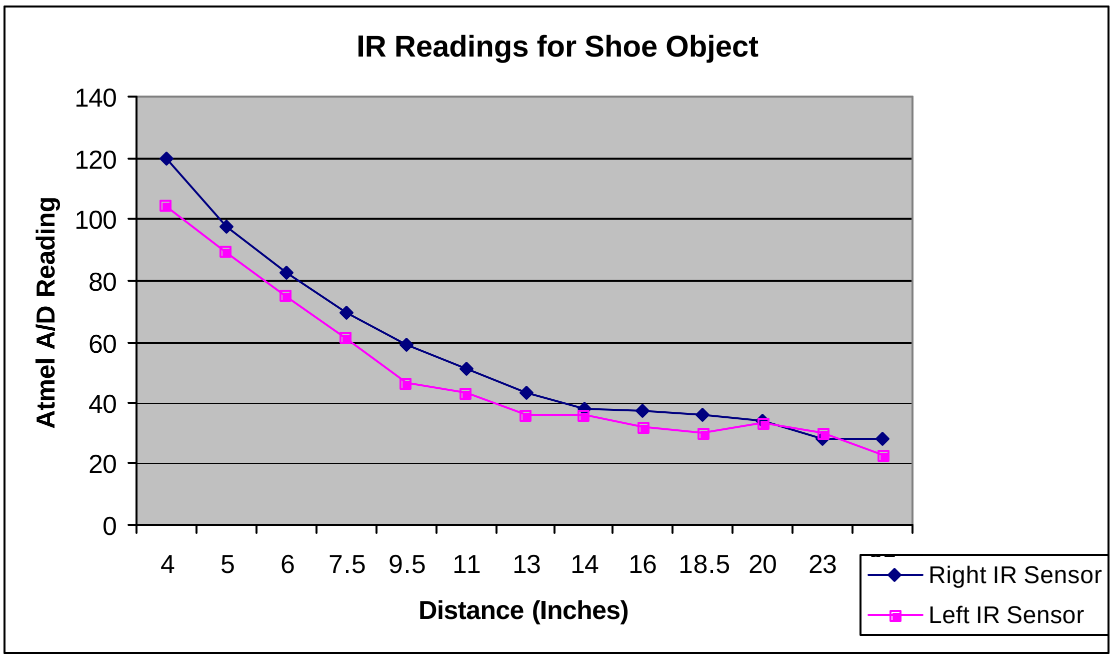
For more information, see the CMUcam user manual (http://www-2.cs.cmu.edu/~cmucam/Downloads/CMUcamManual.pdf). It describes the entire serial command set and what all the extrapolated data means.

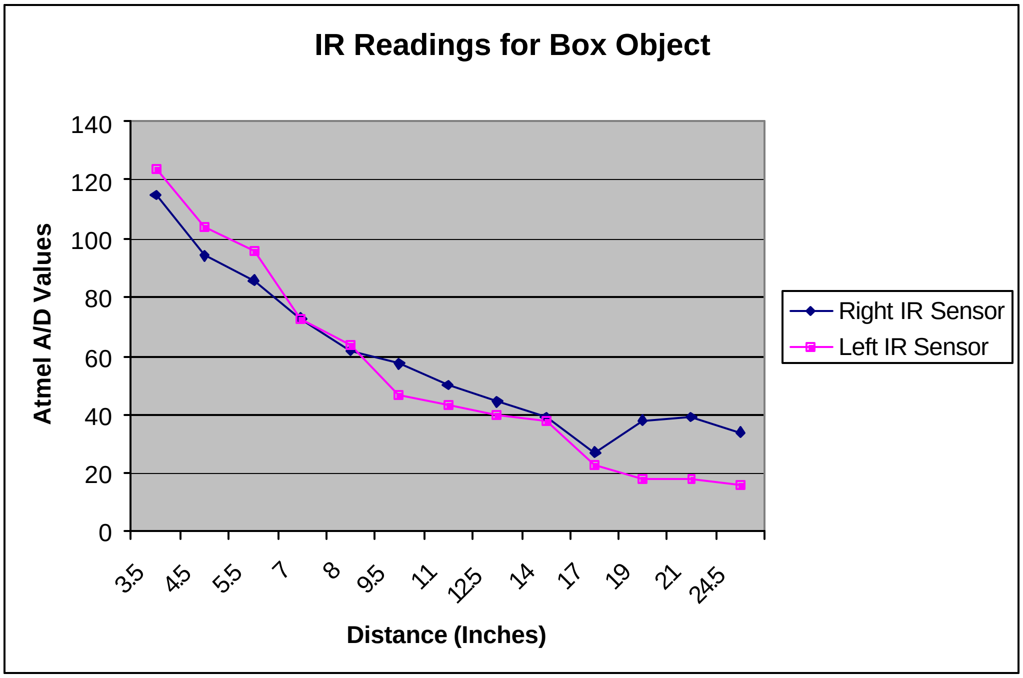
Experimental Layout and Results

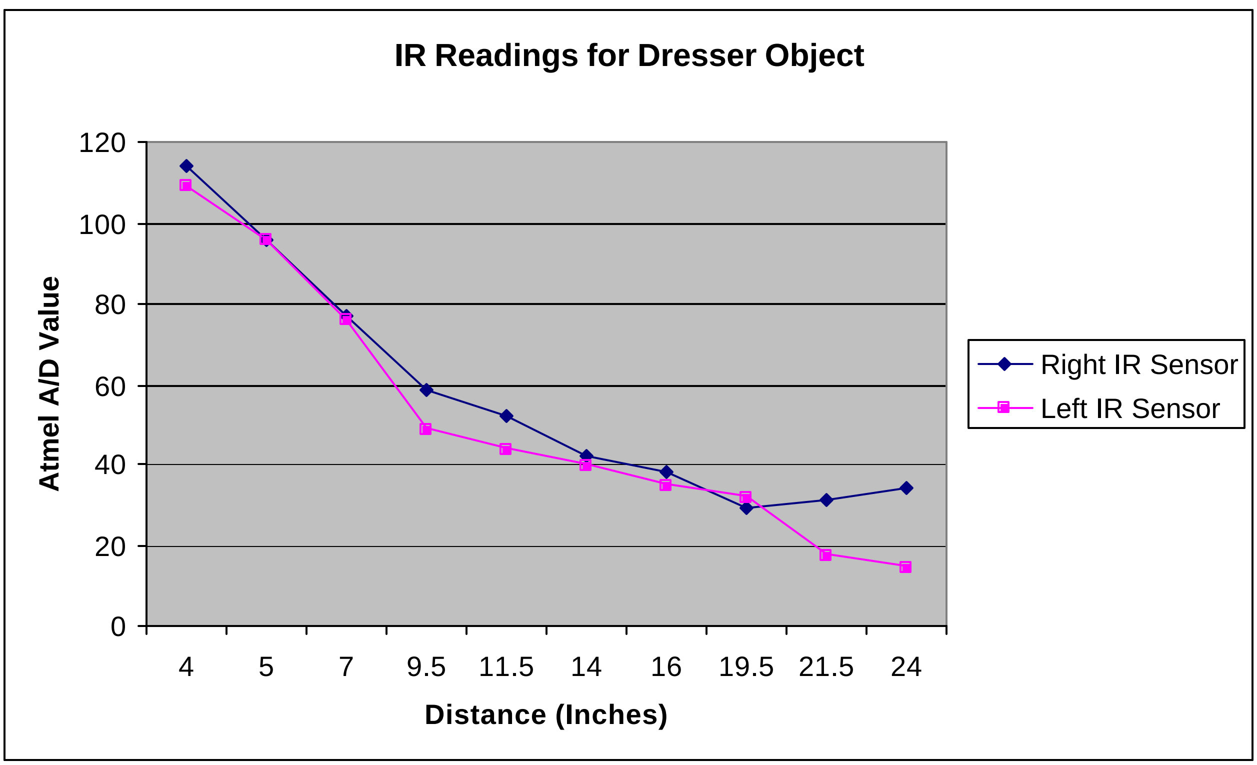
The following PCB is what I used to connect the sensors to my microprocessor board:



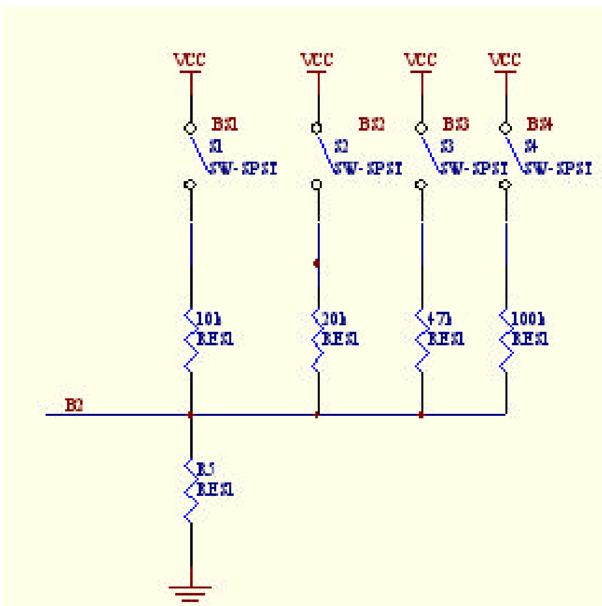
First, I will discuss the tests I did on the IR sensors. To test the IR sensors I wrote a program which would get data from the IR sensors and print them to the computer screen through the UART. I placed several different objects in front of Chester and read off the values of the IR sensors for different distances. I obtained the following results.




IR Readings for Box Object
Atmel A/D Values
140
120
100
80
60
40
20
0
3.5
4.5
5.5
7
8
9.5
11
12.5
14
17
19
21
24.5
Distance (Inches)
Right IR Sensor
Left IR Sensor


IR Readings for Dresser Object
Atmel A/D Value
120
100
80
60
40
20
0
4
5
7
9.5
11.5
14
16
19.5
21.5
24
Distance (Inches)
Right IR Sensor
Left IR Sensor

The program used to test the IR sensors was also used to test the bump sensors. The code for this program is provided in the appendices. The following voltage divider circuit was used to distinguish between the different bump sensors.



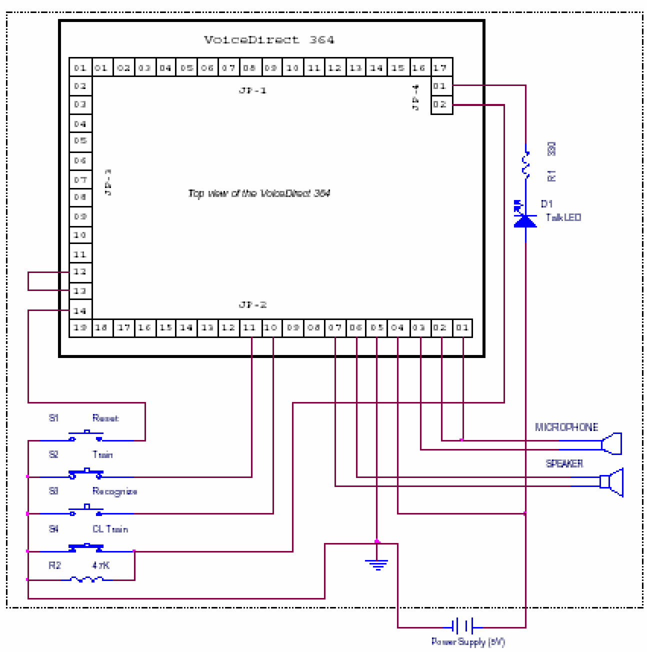
The following table describes the analog values obtained for the different combinations of bump switches.

Sensors Hit	Atmel A/D Value (+-1)
Front	46
Back	88
Front Left	131
Front Right	24
Front and Front Left	144
Front and Front Right	62

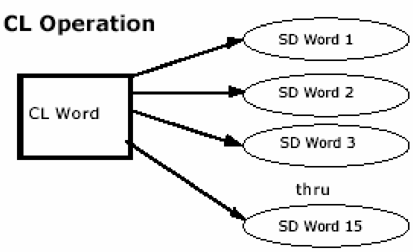
For some of the bump switch combinations, the A/D reading would not stabilize at any one value. Instead, it would toggle between the value +/- 1. This is probably because of the lack of resolution for the A/D result. The A/D was configured for only 8 bits of resolution and the bump sensors were sampled at 23 kHz.

The circuit used to test the voice kit is shown below.

Single Word CL Configuration



Single Word CL Operation



This circuit configures the voice chip for single word continuous listening mode. In this mode, the circuit is continuously listening for the gateway word. Once the gateway word is spoken, the voice kit listens for any of 15 different words. To test this configuration, I trained the word "Chester" for the continuous listening and trained the speaker dependent words "come here" and "go away". These I trained at three different distances and then I tested the recognition accuracy at various positions. The results of these tests are given by the following table.

Training Distance	**Accuracy at 3 ft**	**Accuracy at 6 ft**	**Accuracy at 9ft**	**Accuracy at 12 ft**
3ft	70 %	60%	60%	40%
6ft	60 %	70%	50 %	40%
9ft	40%	40%	60%	50%
12ft	30%	30%	40%	50%

Note: Accuracy based on 10 trials

The CMUcam comes with a Graphical User Interface written in Java. Using this interface I tested the various capabilities of the camera. I was able to track various colored object such as my hand and a blue ball. The camera also dumped the mean color and the variance. Dumping frames is also possible and I used this feature to properly focus the lens.

Once I had the camera in focus, and was able to see data with the CMUcamGUI I began interfacing the camera with the microprocessor board. To interface the CMUcam, I found that removing the max232 chip and taking non-level shifted serial data from the camera to the non-level shifted pins of the ATMega323 worked the best.

The following psuedocode is what I used to test the CMUcam:

```
Reset CMUcam
Put camera into poll mode and turn on raw data mode for returned packets from camera
Call Track Window
LOOP_START
Call Track Color
If # of Pixels > 250 And Confidence > 50 Then Go Backward
If Middle Mass X > 55 And Confidence> 25 Then Go Right
If Middle Mass X< 35 And Confidence > 25 Then Go Left
If # of Pixels < 120 And Confidence > 25 Then Go Fwd
GOTO LOOP START
```

To test this algorithm I used the setup shown in the image below:

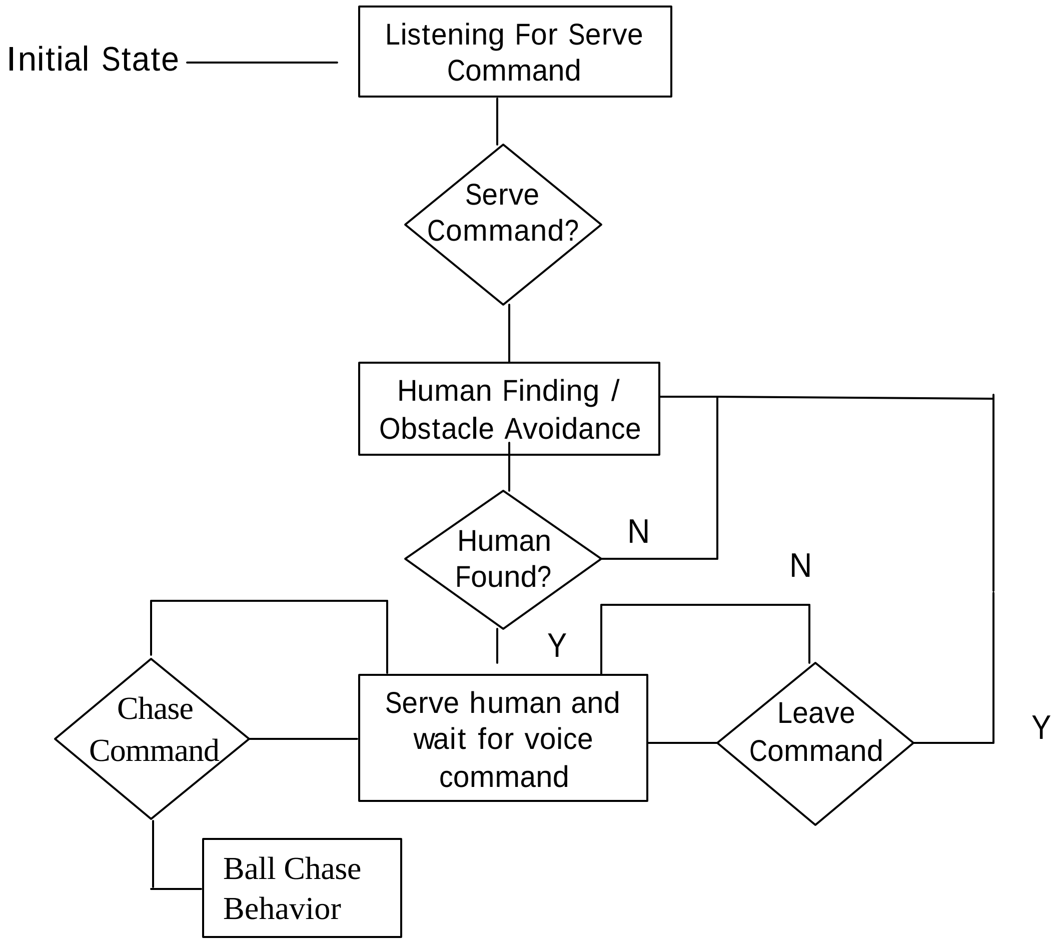
What I discovered when testing this code was that lighting is vital to the success of the CMUcam. Standard incandescent lighbulbs worked ok, but florescent lighting such as that in the lab works much better. In the lab environment, Chester recognizes objects from 7-9 feet away while in my apartment Chester will recognize objects from only 3-5 feet away. These results were much better than several other people in the class perhaps b/c I bought my camera from Acroname rather than Seattle Robotics. The camera from Acroname comes with an IR filter already installed while I believe it's a special order from Seattle Robotics.

Behaviors

Chester will perform the following behaviors:

- Listening behavior
- Obstacle avoidance behavior / human tracking behavior
- Human tracking behavior
- Dispensing / pause nehavior
- Ball chasing behavior

The following flow-chart relates all the behaviors and gives an overview of the operation of Chester:



<u>Listening behavior</u>

When Chester is first turned on it will immediately enter listening behavior. In this state, Chester is awaiting a voice command to commence serving. Once the human gives the voice command to serve, Chester will enter Obstacle Avoidance / Human tracking behavior. While in this behavior, Chester is calibrated to his environment. To calibrate the camera, the object to be tracked is placed about 5 inches away from the CMUcam.

The rear bumper is then pressed and the camera captures the color of the object with the track window command. It is also very important in this behavior to train the voice sensor to the environment that it will be used in. If the voice sensor is not trained the robot likely will not operate properly.

Obstacle Avoidance / Human tracking behavior

The obstacle avoidance behavior was taken from Eric Donnelly's WOMAN Robot final report Spring 2002. The algorithm, based on random numbers, seemingly gives the robot a mind of its own when avoiding obstacles. Chester will turn in random directions at random speeds for random amounts of time. This makes the robot more interesting and gives the robot better coverage of an area. While in obstacle avoidance mode, Chester's senses are checked in a priority fashion. The following is the order of priority from highest to least:

- Object Tracking
- Bump Switches
- IR Detectors

While Chester is in obstacle avoidance mode, he is collecting data from the IR detectors and bump sensors to avoid obstacles. Meanwhile, Chester uses the CMUcam to try to track the brightly colored object placed at the feet of the human. If the object is not immediately visible to Chester, he will turn 360 degrees looking for the object. If Chester still does not see the object, he will move in a random pattern around the room and then spin in place again looking for the object. This will continue until Chester finds the desired object.

Once Chester locates the object, he will move towards the object until he reaches a certain distance. Once Chester has reached the desired distance from the brightly colored object he will enter the dispensing / pause behavior. In this behavior, Chester rotates 180 degrees and aligns the gumball machine with the tracked object.

Dispensing / pause behavior

In this behavior, the robot will be positioned in front of the brightly colored object. The human can now dispense the gumballs from the robot at his/her leisure. Once the human has been served, he/she gives Chester either the leave command or the ball chase command. If the ball chase command is given, Chester turns around faces the ball and will chase the ball around.

Ball Chasing Behavior

In this behavior, Chester will turn around and face the ball or object and will follow the object as long as the object is held in view of the camera tracking window.

Conclusion

This concludes my final report for Chester the autonomous waiter robot. The robot worked as specified and was a success. This project has given me the confidence to pursue other projects and I now feel well equipped to solve more difficult engineering problems.

Appendices

The following is the final version of the code for Chester. The program was written using CodevisionAVR C compiler:

```
/*********************************************
Project : Chester Final Code
Version : 3.0
Date    : 12/05/2002
Author  : David Winkler

Chip type           : ATmega323
Clock frequency     : 6.000000 MHz
Internal SRAM size  : 2048
External SRAM size  : 0
Data Stack size     : 512
*********************************************/

/******************************************
Trying to get the robot to spin in place to look for red ball...
also attempting to get the robot to stop once it thinks it finds the ball,
spin in place and then back up towards ball to dispense gumballs
******************************************/

// INCLUDES
#include <mega323.h>
#include <delay.h>
#include <stdio.h>


// CONSTANTS
#define ADC_VREF_TYPE 0xE0
#define L_EYE_TOLERANCE 50
#define R_EYE_TOLERANCE 50
#define FIRST_ADC_INPUT 0
#define LAST_ADC_INPUT 4
#define BACK_BUMP 88
#define FLEFT_BUMP 131
```

```
#define FRIGHT_BUMP 24
#define CENTER_BUMP 46

// GLOBAL VARIABLES
unsigned int adc_data[LAST_ADC_INPUT-FIRST_ADC_INPUT+1];
unsigned int count=5;
short int speed_temp_l=0;
short int speed_temp_r=0;
short int speed_val_l=0;
short int speed_val_r=0;
int temp;
bit sense=0;
bit initiated=0;
unsigned char random_num;
unsigned char cpacket[10];
bit homelock=0;
int count1=0;
bit camera_init=0;
bit ball_chasing=0;
bit stopped=0;
bit skip=0;



void check_ir(void);
void drive(int,int);
int random(char);
void bumper(void);

void disable_pwm()
{
        TCCR1A=0x01;
}

void enable_pwm()
{
        TCCR1A=0xA1;
}

void check_camera(void)
{

        PORTC.0=0;
        count1=0;
        printf("TC\r");
```

```
	while (count1<11) {
	 cpacket[count1]=getchar();
	 count1++;
	}
	PORTC.0=1;
	if (cpacket[9]>40) homelock=1;

	if (homelock)
	{
		// 45 is H center
		if (cpacket[8] > 250 && cpacket[9] > 50) {
			drive(-1,-1);
			if (!ball_chasing)	{
				delay_ms(300);
				drive(-1,1);
				delay_ms(1600);
				drive(-1,-1);
				delay_ms(400);
				drive(0,0);
				delay_ms(10);
				disable_pwm();
				stopped=1;
			}  // robot stops and waits for voice command
			else {
				delay_ms(300);
				drive(0,0);
				delay_ms(10);
				disable_pwm();
			}
		}
		if (cpacket[2] > 55 && cpacket[9] > 25) drive(0,1); //Right
		if (cpacket[2] < 35 && cpacket[9] > 25) drive(1,0); //Left
		if (cpacket[8] < 120 && cpacket[9] > 25)drive(1,1);  //Fwd
	if (cpacket[9] <=25 && !skip) {
		drive(0,0); //Stop
		delay_ms(10);
		disable_pwm();
	}
	}
	delay_ms(25);
}

// Timer 1 overflow interrupt service routine
interrupt [TIM1_OVF] void timer1_ovf_isr(void)
{
```

```
        if (!camera_init || !initiated) return;
   if (count--==0) {
        check_camera();
                if (homelock) {
                        count=3;
                        return;
                }
        check_ir();
        bumper();

        if (sense==1) {
                drive(speed_temp_l,speed_temp_r);
                delay_ms(175*(random(7)+2));
                sense=0;
        }
        count=3;
   }
}


#pragma savereg-
interrupt [ADC_INT] void adc_isr(void)
{
#asm
   push r26
   push r27
   push r30
   push r31
   in   r30,sreg
   push r30
#endasm
register static unsigned char input_index=0;
// Read the AD conversion result
adc_data[input_index]=ADCH;
// Select next ADC input
if (++input_index > (LAST_ADC_INPUT-FIRST_ADC_INPUT))
  input_index=0;
ADMUX=(FIRST_ADC_INPUT|ADC_VREF_TYPE)+input_index;
// Start the AD conversion
ADCSR|=0x40;
#asm
   pop  r30
   out  sreg,r30
   pop  r31
   pop  r30
```

```
   pop  r27
   pop  r26
#endasm
}

/***********************************************
Function: drive
Inputs: Two integers between -2 and 2 representing
the speed of the motors. A speed > 0 is forward,
while a speed < 0 is backward. The greater the
magnitude of the inputs the faster the motors will
turn.
Outputs: none
Notes: A 100 ms delay is implemented when changing
motor speeds to protect the motors from burnout.
***********************************************/
void drive(short int speedl, short int speedr){
	enable_pwm();
	if(speedl > 2) //can't overdrive servos
		speedl =2; //.8 sec max total to change speeds
	if(speedl < -2)
		speedl = -2;
	if(speedr > 2)
		speedr = 2;
	if(speedr < -2)
		speedr = -2;
	while(speed_val_l != speedl || speed_val_r != speedr){
		if(speed_val_l > speedl){
			OCR1BL = OCR1BL -1;
			speed_val_l--;
		}
		if(speed_val_l < speedl){
			OCR1BL = OCR1BL +1;
			speed_val_l++;
		}
		if(speed_val_r > speedr){
			OCR1AL = OCR1AL +1;
			speed_val_r--;
		}
		if(speed_val_r < speedr){
			OCR1AL = OCR1AL -1;
			speed_val_r++;
		}
		delay_ms(25); //delay on each increment to protect motors
	}
```

```
}

int random(unsigned char range){
//generates random numbers between 0-254
	range++;
	return TCNT0 % range;
}

void check_ir(void){
	if(adc_data[1] > L_EYE_TOLERANCE || adc_data[0] >
R_EYE_TOLERANCE){
		sense = 1;
		temp= random(3) - 2; // random speed between -2 and 1
		if(adc_data[1] > adc_data[0] + 10) {
			speed_temp_l= temp;
			speed_temp_r= temp + random(3)+1; // always point away from
obstacle
		}
		else if(adc_data[0] > adc_data[1] + 10) {
			speed_temp_l= temp + random(3)+1;
			speed_temp_r= temp; //always point away from obstacle
		}
	   else {
			speed_temp_l = random(4) -2; // straight ahead turn in place
			speed_temp_r = -speed_temp_l;
		}
	}
}

void bumper(void){
	if(adc_data[2]==0 || adc_data[2]==1) return;
	sense =1;
	while(1){
		if(adc_data[2]==45 || adc_data[2]==46 || adc_data[2]==47 ||
		  adc_data[2]==143 || adc_data[2]==144 || adc_data[2]==145 ||
		  adc_data[2]==61 || adc_data[2]==62 || adc_data[2]==63){ //front
			drive(-1, -1); //back up
			delay_ms(300);
			speed_temp_l = random(4) -2; //turn in place if straight
			speed_temp_r = -speed_temp_l; //forward
			break;
		}
		else if(adc_data[2]==130 || adc_data[2]==131 || adc_data[2]==132){ //left
front
			speed_temp_l= -1; //right will reverse harder
```

```
                speed_temp_r= -2;
                break;
            }
            else if(adc_data[2]==23 || adc_data[2]==24 || adc_data[2]==25){ //right
front
                speed_temp_r= -1; //left will reverse harder
                speed_temp_l= -2;
                break;
            }
            else if(adc_data[2]==87 || adc_data[2]==88 || adc_data[2]==89){
//forward!!
                speed_temp_r= random(1)+1;
                speed_temp_l= random(1) +1;
                break;
            }
            else return;
        }
}


/*******************************************
Function: chester_init()
Input: None
Output: None
Purpose: Set up A/D, I/O Ports, UART, Interrupts, and Timers
*******************************************/
void chester_init(void)
{

   // Input/Output Ports initialization

   // Port A initialization
   PORTA=0x00;
   DDRA=0x00;

   // Port B initialization
   PORTB=0x00;
   DDRB=0x00;

   // Port C initialization
   PORTC=0x00;
   DDRC=0xFF;
   // Port D initialization
   PORTD=0x00;
   DDRD=0x30;
```

```
// Timer/Counter 0 initialization
// Clock source: System Clock
TCCR0=0x01;
TCNT0=0x00;

// Timer/Counter 1 initialization
// Clock source: System Clock
// Clock value: 23.438 kHz
// Mode: Ph. correct PWM top=00FFh
// OC1A and OC1B output: Non-Inverted
// Input Capture on Falling Edge
TCCR1A=0xA1;
TCCR1B=0x04;
TCNT1H=0x00;
TCNT1L=0x00;
OCR1AH=0x00;
OCR1AL=0x18;
OCR1BH=0x00;
OCR1BL=0x18;

// Timer 1 Overflow Interrupt Enabled
TIMSK=0x04;

// USART initialization
// Communication Parameters: 8 Data, 1 Stop, No Parity
// USART Receiver: On; USART Transmitter: On
// USART Mode: Asynchronous; USART Baud rate: 9600
UCSRA=0x00;
      UCSRB=0x18;
      UCSRC=0x86;
      UBRRL=0x26;
      UBRRH=0x00;

// Analog Comparator initialization (Unused)
ACSR=0x80;
SFIOR=0x00;

// ADC initialization
// ADC Clock frequency: 93.750 kHz
// ADC Voltage Reference: AREF pin (Internal 2.56 V)
// Only the 8 most significant bits of
// the AD conversion result are used
ADMUX=ADC_VREF_TYPE;
ADCSR=0xCE;
```

```
}
// GLOBAL VARIABLES

void init_camera(void)
{
        printf("RS\r");
        delay_ms(100);
        printf("\r");
        delay_ms(100);
        printf("PM 1\r");
        delay_ms(100);
        printf("RM 3\r");
        delay_ms(5000);


        while(adc_data[2]!=88);
        while (UCSRA.7) temp=UDR; //flush the receive buffer
        printf("TW\r");
        delay_ms(2000);
        while(adc_data[2]!=88); // wait for back bumper press to begin
        camera_init=1;
        PORTC=~PORTC;
        while (UCSRA.7) temp=UDR; //flush the receive buffer
}

void main(void)
{
        // LOCAL Variables

        chester_init();  // Initialize A/D, timers, interrupts, and USART
   disable_pwm();

        delay_ms(1500);  // Delay to give the A/D and other systems a chance to warm-up

   #asm("sei")

        init_camera();
   while (adc_data[3]<0xE0){} // Wait until voice command given
   initiated=1;

   drive(-1, 1); //begin moving
   delay_ms(1000);
   while (1) {
```

```
                random_num=random(50);
        while(random_num-- != 0 && !homelock){
        drive(2,2);
                        delay_ms(100);
                }
                if (!homelock) {
//              drive(random(4)-2, random(4)-2); //change directions
                drive(-1,1); // spin in place looking for objec
                random_num = random(15);
                }
                while(random_num-- != 0 && !homelock) delay_ms(100);
                if (stopped==1) {
                        while (adc_data[3]<0xE0 && adc_data[4]<0xE0) {};
                        stopped=0;
                        if (adc_data[3]>=0xE0) {
                                homelock=0;
                                drive(1,-1);
                                delay_ms(1000);
                        }
                        else if (adc_data[4]>=0xE0) {
                                skip=1;
                                ball_chasing=1;
                                drive(2,2);
                                delay_ms(400);
                                drive(1,-1);
                                delay_ms(400);
                                drive(0,0);
                                skip=0;
                        }
                }

        }

}
```