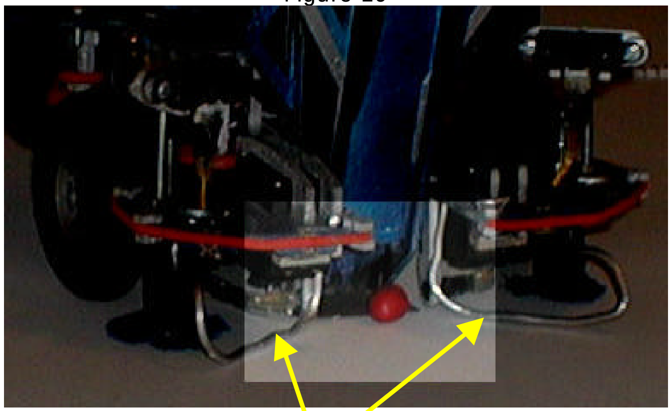
6.0 UNIQUE BEHAVIORS

6.1 Picking up the M&M's

6.1.2 The Funnel

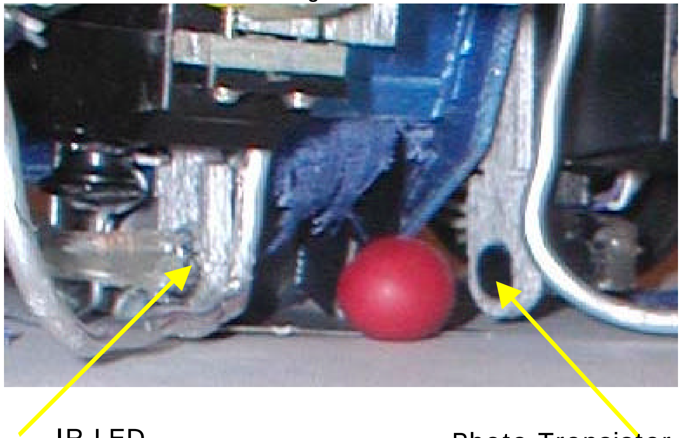
Figure 19



As EM moves forwards, M&M™ candies are funneled in towards the break beam network.

6.1.3 The Break Beam

Figure 20



Break Beam Schematic

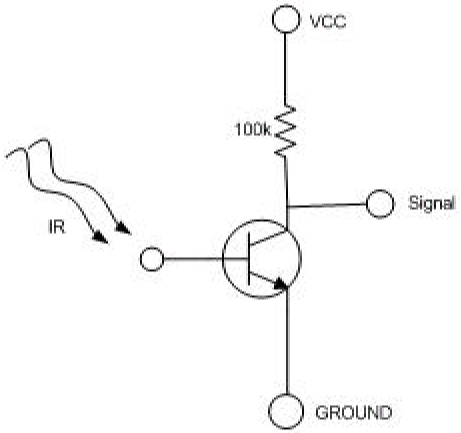


Figure 21

While IR is present on the base of the transistor, the collector has a potential of approximately 3.5 V. When no IR is present the voltage drops to approximately 0.2V . This characteristic is perfect for tying the signal right to an input bit rather than wasting an A/D port. Once the break beam is broken the arm lifts up quickly sending the M&M™ down the shaft of the sorting unit.

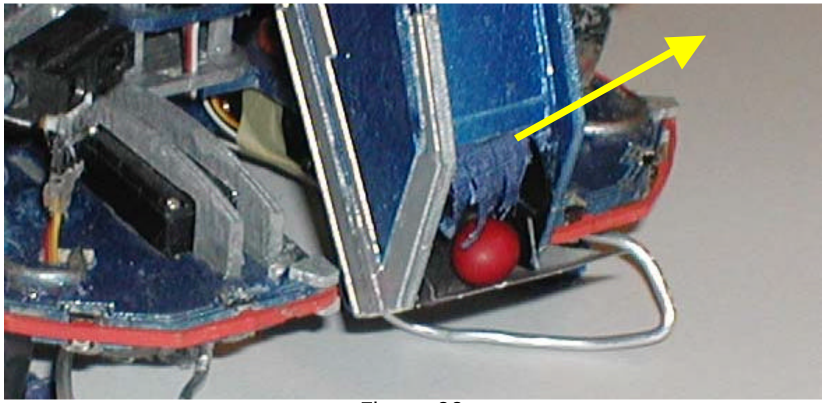


Figure 22

6.2 COLOR DETECTION

- 1 - Ultra Bright Blue LED
- 1 - Ultra Bright Green LED
- 1 - Ultra Bright Yellow LED
- 1 - Ultra Bright White LED
- 1 - CDS Cell
- 1 - 47k Ohm Resistor
- Electrical Tape, or Heat Shrink Tubing

Cost:
$9 for Ultra Bright LEDs
Resistors and CDS cell are free in lab

The idea behind color detection is simple. Different colors reflect different amounts of light. A blue M&M™ for example, when exposed to green light shines very brightly, however in the presence of red light appears to be black. Theoretically if one could just measure the amount of light reflecting off the surface of an object being exposed to different colors of light, one should be able to determine its color. That's exactly what I did.

There are two main pitfalls which hinder the accuracy of any color detection scheme, they are:

1.) The Presence of Ambient light
2.) Inconsistent Positioning of the objects.

These two problems are the by far the biggest obstacles one must overcome when attempting color detection. The actual color detection process is very straightforward and easy to reproduce once the previous 2 conditions are met. In fact, I personally think it is a good practice to sit back and spend some time working out these type of problems before jumping in and getting your hands dirty. It is good practice to ask yourself: *"How can somebody screw up my robot's behavior?".* Solving these type of problems early in the development phase will save you a lot of time and headache later on.

6.2.1 Blocking out Ambient Light

Why do I need to block out the ambient light, and how can I do it?

If you plan on demonstrating your robot in more than one room (and I'm sure you are) then you must account for the various lighting conditions. Moreover, the brighter the ambient light, the less accurate your color readings will be. Think of a glass of fruit juice as your brightly colored M&M™. Start pouring water into it and the vibrant red of the juice begins to dilute losing its color.

The way I overcame this obstacle was by placing the M&M™ inside a controlled pitch black environment. The sorting unit I built is enclosed on all sides (Refer to Figures 16 & 17) and the inside is spray painted black to stop all reflections of light from the entrance and exit.

This works very well for small objects but what if you wanted to do color detection on large ones. My suggestion is to carry out color detection beneath your robot, using the chassis of the robot as a shield to ambient light. And then on top of that, design the color sensor so that it will be positioned completely flush with any object that you wish to carry out color detection.

6.2.2 Positioning

It is important that the object is consistently positioned in front of the color sensor. Spherical objects, such as M&M™'s, are easiest since they are relatively the same in all positions. Because of this I did not have to worry too much about the orientation of the m&m's as they fall in front of the color sensor. However, If you plan on applying color detection on something with an awkward shape you must devise a method to not only place the object in front of the sensor in a consistent manner but orientate the object so the same side is facing the sensor as well.

6.2.3 Color Sensing

The Color Sensor

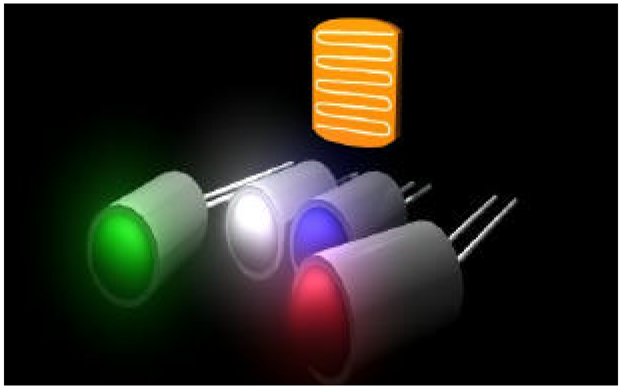


Figure 23

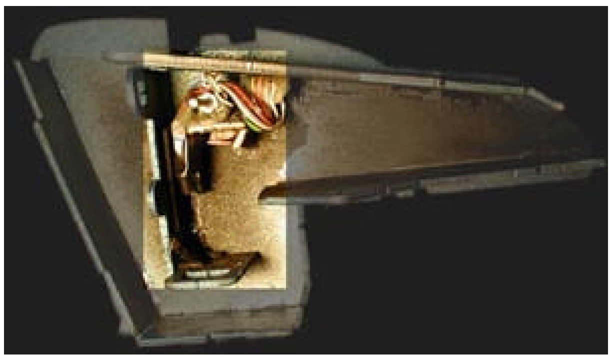
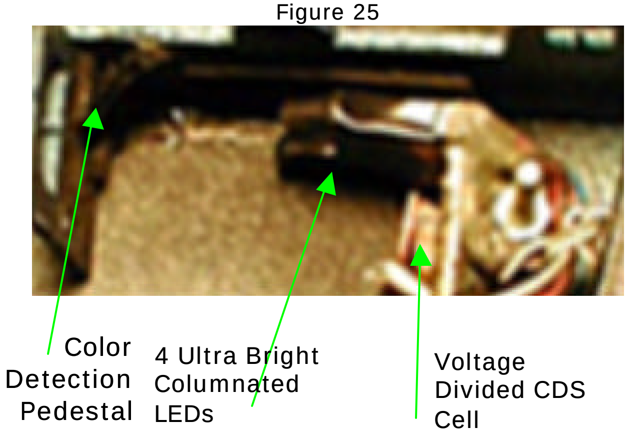


Figure 24

Figure 25



Once an M&M™ is securely positioned in front of the color sensor, the method I use for color detection is as follows:

1.) Turn on the green LED turn OFF all others - RECORD
2.) Turn on the white LED turn OFF all others - RECORD
3.) Turn on the blue LED turn OFF all others - RECORD
4.) Turn on the red LED turn OFF all others - RECORD
5.) Pass the 4 recorded values into a color detection function. The function runs my color detection algorithm and returns the correct M&M™ color.

The following is a schematic of my color sensor. (See figures 23-25)

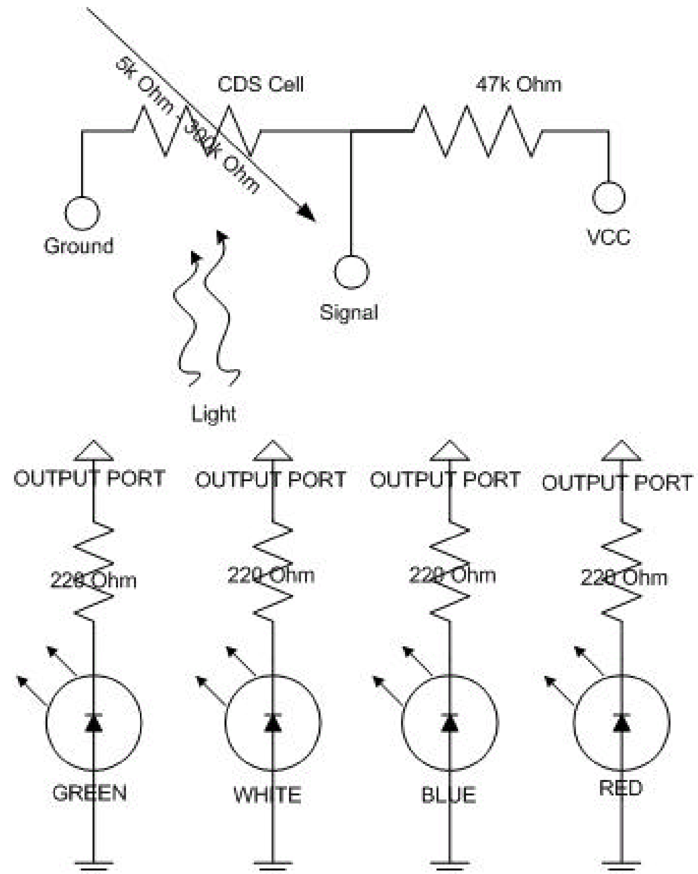


Figure 26

6.2.4 Data Collection

Figure 27

	Green	White	Blue	Red	G+W+B+R	G+W+B-R	Red	G+W+B+R	G+B-R	W+R-B-G	G+W+B	G+W+B+R
Yellow	55	175	117	193	540		193		-21	196	**347**	
Yellow	72	177	124	192	565		192		4	173	**373**	
Yellow	83	182	123	191	579		191		15	167	**388**	
Yellow	70	178	120	189	557		189		1	177	**368**	
YELLOW	**70**	**178**	**121**	**191**	**560.25**		**191.25**		**-0.25**	**178.25**	**369**	
	Green	White	Blue	Red	G+W+B+R	G+W+B-R	Red	G+W+B+R	G+B-R	W+R-B-G	G+W+B	G+W+B+R
Red	2	85	89	164	340		164		-73		176	340
Red	2	72	75	160	309		160		-83		149	309
Red	4	83	85	166	338		166		-77		172	338
Red	3	80	84	160	327		160		-73		167	327
RED	**2.75**	**80**	**83.3**	**163**	**328.5**		**162.5**		**-76.5**		**166**	**328.5**
	Green	White	Blue	Red	G+W+B+R	G+W+B-R	0	G+W+B+R	G+B-R	W+R-B-G	G+W+B	G+W+B+R
Blue	8	88	125	68	289	153	**68**	**289**				
Blue	16	95	120	56	287	175	**56**	**287**				
Blue	15	88	127	54	284	176	**54**	**284**				
Blue	8	80	115	46	249	157	**46**	**249**				
BLUE	**11.75**	**87.75**	**122**	**56**	**277.25**	**165.25**	**56**	**277.25**				
	Green	White	Blue	Red	G+W+B+R	G+W+B-R	Red	G+W+B+R	G+B-R		G+W+B	G+W+B+R
Green	81	157	139	104	481		104	481	**116**	**41**		
Green	62	136	123	84	405		84	405	**101**	**35**		
Green	84	157	134	101	476		101	476	**117**	**40**		
Green	85	153	127	106	471		106	471	**106**	**47**		
GREEN	**78**	**150.8**	**131**	**99**	**458.25**		**98.75**	458.25	**110**	**40.75**		
	Green	White	Blue	Red	G+W+B+R	G+W+B-R	Red	G+W+B+R	G+B-R	W+R-B-G	G+W+B	G+W+B+R
Brown	1	42	64	71	**178**	**36**						
Brown	6	72	96	76	**250**	**98**						
Brown	6	60	75	80	**221**	**61**						
Brown	6	60	79	72	**217**	**73**						
BROWN	**4.75**	**58.5**	**78.5**	**75**	**216.5**	**67**						
	Green	White	Blue	Red	G+W+B+R	G+W+B-R	Red	G+W+B+R	G+B-R	W+R-B-G	G+W+B	G+W+B+R
Orange	5	124	88	187	404		187		-94		217	**404**
Orange	12	149	108	191	460		191		-71		269	**460**
Orange	5	132	104	187	428		187		-78		241	**428**
Orange	8	133	106	179	426		179		-65		247	**426**
ORANGE	**7.5**	**134.5**	**102**	**186**	**429.5**		**186**		**-77**		**243.5**	**430**

The first 4 columns of the table represent the data recorded from the CDS Cell through the A/D when the corresponding LED is turned on. For example, starting from the top left, the CDS cell measures 55 units for a yellow M&M™ in a green light, 175 in white light, 117 in blue, and 193 in red. The program I wrote called "CLRTST.C" was used to quickly obtain test data and can be found in APPENDIX B . This is a sample screenshot of that program.

```
+==========================================+
|            Color Testing Program         |
| 't' To Begin     +/- To Change Light Delay |
+==========================================+
|                                          |
|   Lights are on for (   200) milliseconds |
|                                          |
|   NO LIGHT  VALUE:  253                  |
|   GREEN LED VALUE:    3                  |
|   WHITE LED VALUE:   65                  |
|   BLUE  LED VALUE:  114                  |
|   RED   LED VALUE:   55                  |
|   SUM   LED VALUE:  237                  |
|                                          |
|   M&M Color:           Blue              |
|                                          |
+------------------------------------------+
```

Figure 28

I tabulated 4 trial runs for each color M&M™ and then calculated the average which I then underlined to be able to see quickly. It is crucial at this point to have a database program such as EXCEL that will allow one to quickly do calculations on a large amount of data and display that data in a organized manner. It is also a big plus to be able to change the font colors so that you can hide values that you don't care for any longer.

6.2.5 The Color Detection Algorithm

To begin, please refer frequently to figure x in order to follow the color detection process. If you look at all the colors you will notice that brown has consistently smaller values for ALL lights. Using this first trend we can add all the light values (G + B + W + R) which is calculated and displayed in the next column. Notice that brown is 216, significantly less than the other colors. The next closest would be blue which is at 277. I take the average of these 2 values (approx 240) and create the first conditional of my algorithm. (See Figure 29). Now even if this conditional is met there is still a SLIGHT chance that the M&M™ could still be blue. So what I need is one more nested conditional that does nothing but distinguish between blue or brown. Looking back at the table we notice that the GREEN, WHITE, and BLUE readings for the brown M&M are less than the blue M&M, however the RED reading for brown is greater. Using this data we create one more column (G + W + B - R) and we notice that there is a very nice gap between the blue and brown. Using this data we now have a way to determine if the M&M™ is brown.

At this point we can assume that if any readings get pass our first conditional than the color can not be brown. And so in excel we can ignore all values of brown. With one color already gone it becomes even easier to find minimum or maximum light trends for the various M&M™'s. Let us do one more example. Now that brown is out of the equation we look back at our data and see that BLUE now has the smallest RED value by far (56)! So to keep things consistent I make a column for just red (R). We notice that the next closest M&M™ is green with a value of 98. So we take the average of these 2 values (56 + 98 / 2 = 76) and create our next conditional. Now all we need is a way to distinguish between blue and green and we can then take blue completely out of the picture. So looking back at the table we notice blue is smaller than green for all color readings. With this information we create one more (G + W + B + R) column, take the average for blue and green and create yet another nested conditional that will distinguish blue from all the rest of the M&M™'s.

So now after 6 lines of code we have already distinguished 2 of the 6 M&M™'s and it becomes easier and easier with each M&M™ we can take out of the equation. I continue my analysis for the rest of the M&M™'s the same way and produce the color detection algorithm which you see here.

```
int detectColor(int white, int red, int blue, int green) {
  if ((white + red + blue + green) <= 240) {
  /* Brown, Perhaps Blue */
    if ((green + white + blue - red) <= 116) return 1; // brown
    else return 2; // blue
  }
  else if ((red <= 78)) {
  /* Blue, Perhaps Green */
    if ((green + white + blue + red) <= 367) return 2; // blue
    else return 3; // green
  }
  else if ((green + blue - red) >= 55) {
  /* GREEN, Perhaps Yellow */
    if ((white + red - green - blue) <= 110) return 3; // green
    else return 5; // yellow
  }
  else if ((green+white+blue) >= 308) return 5; // yellow
  else if ((green + white + blue + red) >= 372) return 6; // orange
  else return 4; // red    }
```

Figure 29

6.3 M&M Positioning

Figure 30

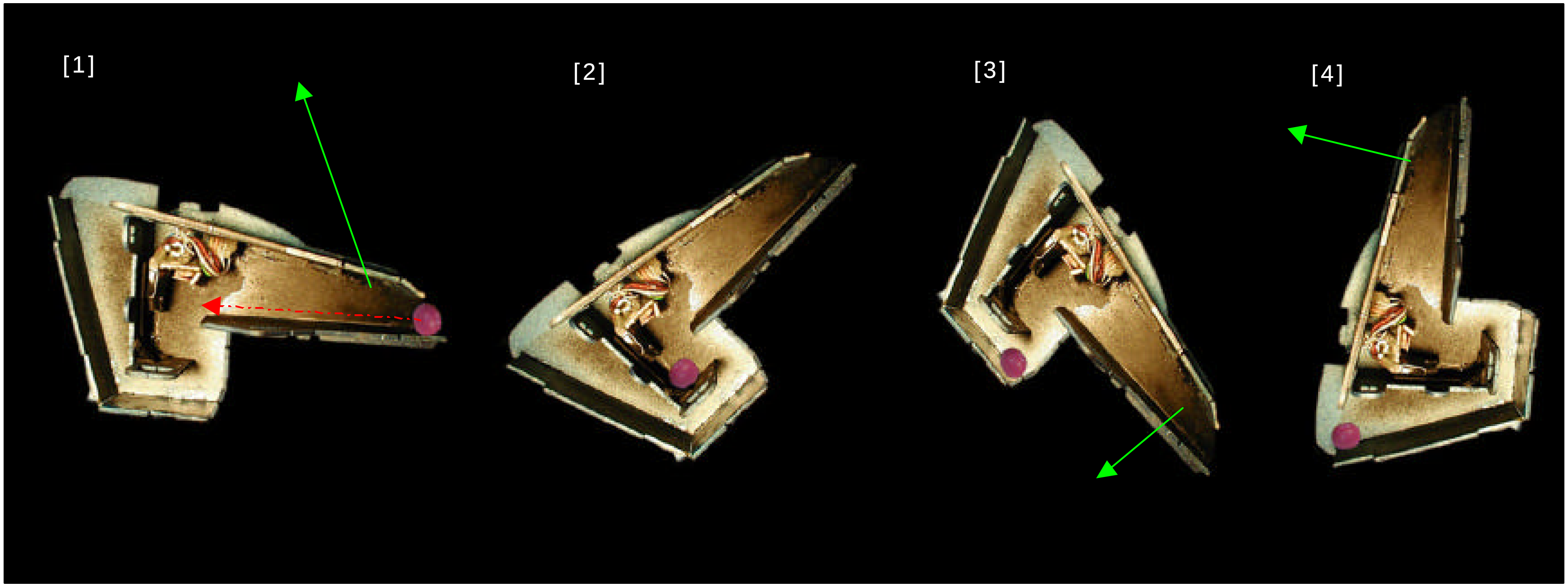


Figure 31

[1] - The M&M is lifted up and travels down the shaft of the sorting unit and onto the color detection pedestal.

[2] - This is where color detection takes place. Refer to Section 7.0 for details on the color detection sensor and how color detection is implemented.

[3] - M&M is dropped down to the bottom level of the sorting arm. At this point the arm is then positioned in front corresponding color bin.

[4] - M&M is sent down the last chute into color bins located at the back of the robot

[5] - The color bin