DriMix 4ics – Mobile Autonomous Bartending

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ABSTRACT
This paper outlines the design methodology, sensor configuration and final implementation of the DriMix 4ics robot. The DriMix 4ics is an automated bartending robot whose gross motor functions can be controlled via color segmentation and recognition, while menu driven drink mixing commands are driven by Quick Response Code. The aim of the robot is simplify the ordeal of what at times can be complicated, mixing of cocktails. Then once the mixing is complete return the cocktail to the appropriate order location

Keywords
QR Code, Color Recognition, Drink Mixing, Bartending, DriMix 4ics, Atmel, Android

1. INTRODUCTION
Drimix 4ics, the Drink Mixer for Alcoholics, was constructed for the Intelligent Machines Design Lab course at the University of Florida. The goal of the robot was to combine two things, creating an autonomous robot and making a drink mixing machine. The main objective of the project was to create a mobile robot that could go to a drink station, mix drinks, and then return to a user with the mixed drink.

This paper will cover: the overall system interaction of the DriMix 4ics, the movement and actuation of the robot, the sensors and their testing conditions, software design principle of the robot, the rudimentary power distribution system, the behavior of the robot, the experimental changes, and the lessons learned. An image of the complete set up can be seen in the Appendix.

2. DRIMIX 4ICS SYSTEMS
The systems of the DriMix 4ics can be divided into three main interaction areas; coding, the mobile platform, and the stationary platform. Coding can further be broken down into three main areas, Android, Matlab, and C on the Atmel. The mobile platform is the robot and the stationary platform is the drink mixing station.

2.1 Integrated systems
The DriMix 4ics uses the Epiphany DIY board [1]. This board is based on the ATXMega64A1 Microcontroller. The platform consists of several sensors, servos, DC motors, wireless communication, batteries, and a drink mixing station. The block diagram shown in Figure 1 describes the basic interactions of the platform as a whole.

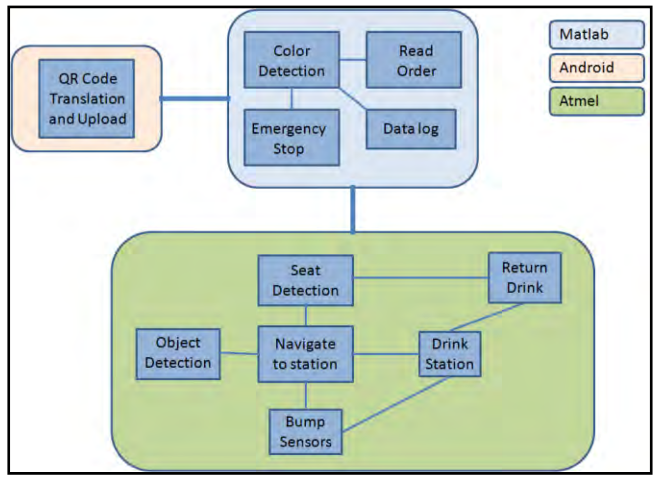

Figure 1. DriMix 4ics systems block diagram

The code in the pink box is controlled by the Android OS on a mobile phone. The communication link between Android and Matlab is either a WiFi, cellular, or LAN connection. The code in the blue box is handled by Matlab on a computer. Matlab would be considered the main "traffic conductor" as it handles the decoded QR orders, the color recognition, data logging, and issuing wireless commands to the robot. The link between Matlab and the Atmel chip on the robot is a simulated RS232 link sent over RF between two XBee modules. The coding in the green box is handled by the Atmel chip on the robot and controls the basic navigation and mixing routines on the robot.

2.2 Mobile platform – the robot
The mobile platform is composed of several layers. Each layer hosts a different sensors, motors, or actuators. The top two layers hold the adjustable servo array. The layer beneath that hosts the infrared rangers. Attached to this layer is the channel for the sliding drink return cart. The layer under this holds the microcontroller, bump switches, and guide rails. The very bottom of the robot hosts the battery packs, switches, DC motors, wheels, and an infrared array. The overall setup can be seen in Figure 2.

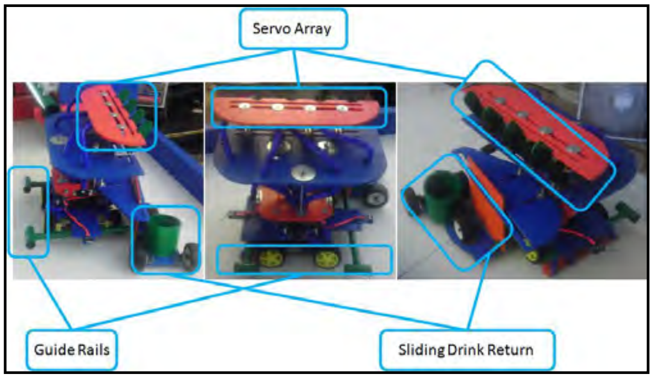

Figure 2. Mobile platform principle components

2.3 Stationary platform – the drink station

The stationary drink mixing station hosts plastic containers that hold various mixable drinks. On top of the levers of each of the spigots are lever guides that ensure the cams from the servo motors do not slip off while pressing down. The down spouts from the spigots are channeled into a larger collector that is angled and open at one end. This allows all of the liquid to be collected in the cup on the return cart. The mixing station can be seen in Figure 3.

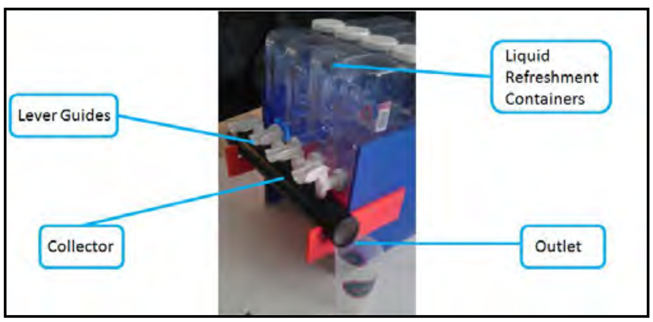

Figure 3. Mixing station principle components

3. MOVEMENT, ACTUATION, DRINK RETURN CART

This section covers the gross movement controls of the mobile platform. Covered first is the movement control of the platform, then the actuation system of the cam lobed servos, and finally the drink return cart.

3.1 Movement

The movement of the DriMix 4ics is controlled by four DC motors, movement is also guided by two guide bars that slide over a larger guide bar running the length of the table top. The guide rails can be seen in Figure 2. The mounting of the DC motors, as well as the specifications of the motors, can be seen in Figure 4. The four DC motors easily have the power to move the platform.

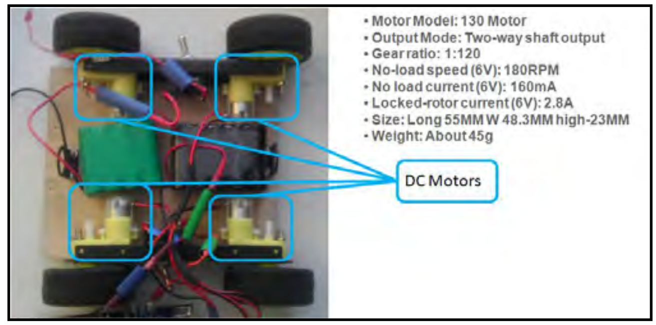

Figure 4. DC motors

Testing revealed that at only a fraction of the rated power was required for movement. In order to avoid the main guide rail becoming actuated, solid bar stock was run through its center.

3.2 Actuation

When docked next to the mixing station, the servo array mounted atop the mobile platform is brought into alignment with the levers of the spigots of the plastic liquid containers. Four Hitec servos [2] mounted in an adjustable servo array were fitted with cam lobes. The cam lobes were profiled to allow easy lever actuation when actuating the spigots of the drink station. The arrangement of the servos as well as the cam lobes can be seen in Figure 5.

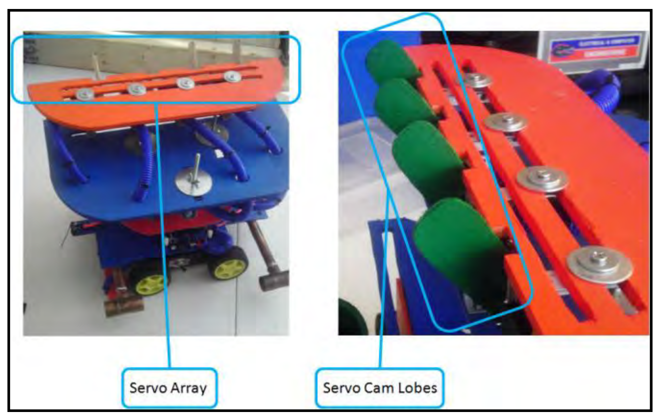

Figure 5. Servo array and cam lobes

3.2.1 Servo Alignment

In addition to cam lobes on the servos and lever guides on the spigots of the drink containers, the servo array is adjustable along the X, Y, and Z axis. This allows for overall and individual adjustment of servos to ensure proper alignment. Figure 6 shows the servo array and cam lobes in alignment with the spigot levers. Figure 6 also shows how the cams can be individually moved allowing for 3 degrees of freedom.

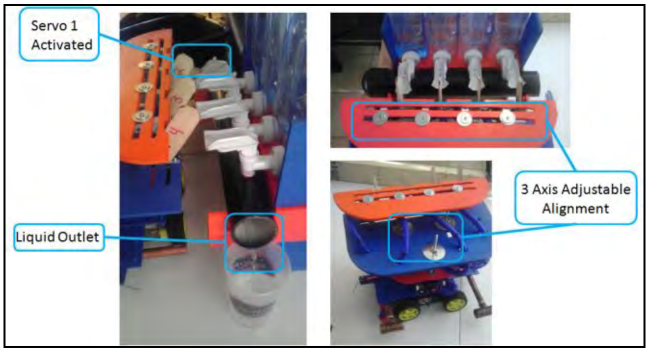

Figure 6. Cam alignment and adjustability

3.3 Drink return cart

A drink return cart needed to be fabricated due to the size and location of the drink mixing station, the ends of the bar, and the robot itself. The return cart and its attachment to the mobile platform were designed to allow extra clearance to compensate for the aforementioned size and placement issues. The design was achieved by creating an adjustable platform with a guide channel. The drink cart has a rigid guide wall that slide into the guide channel attached to the robot. This allowed for linear motion on 1 axis. This can be seen in Figure 7.

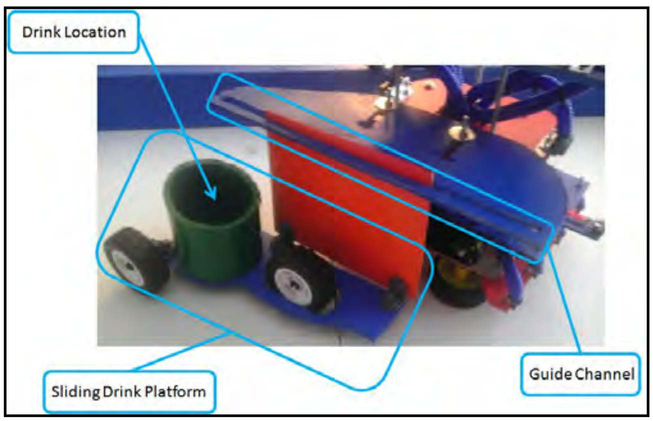

Figure 7. Drink return cart and platform mount

4. SENSORS AND POWER

The sensors of the DriMix 4ics consist of five main sensors groups along with Radio Frequency communication for updating the mobile platform with a variety of information. All sensors were tested under multiple conditions to ensure operation in most lighting conditions. The sensors used for the DriMix 4ics are detailed and explained in this section.

All of the sensors are summarized and described in Table 1. The table describes the function of each sensor and how the values of the sensors are used.

Table 1: Sensors descriptions

	EVO 3D	Ranging IR	IR Array	Switch	RF	Webcam
General Purpose	QR Code Decoding	IR Distance Sensor	Location Under Array	Physical Contact Detection	Radio Comm	Streams Video
How it Performs Function	Decoded MSG Sent to Dropbox	Return Alters Voltage Signal	Return Toggles High/Low	Allows Voltage Signal	Receive and Transmit	Video Streams to Matlab
What it Controls	Order Choice	Avoid Collisions	Line Following	Docking	Comm with laptop	Robot Control

4.1 Android phone

Cellular phones are very quickly becoming laptop replacements. As technology increases the computing power and battery life of these devices, they can quickly take on more and more roles. The average smart phone now has GPS, WiFi, video capturing, accelerometers, gyroscopes, and magnometers, all functioning together in a very small package. In an effort to leverage some of these features that already exist, sitting in most everyone's pocket; the video capture and WiFi functions were used. The particular phone used with this platform is he EVO 3D. However the model is not terribly important as most smart phones can access and use the two applications that are needed to interface with the DriMix 4ics. This is true for both Android and iOS operating systems. The two applications used were Dropbox and any of the numbers of Quick Reaction code readers available on the Android market.

4.1.1 Quick Reaction code

Creating QR code can be accomplished from literally thousands of locations on the web or with Android or iOS applications. The same is true for decoding QR code. The only caveat for use with the DriMix 4ics is the application must be able to output the decoded QR message via ASCII text file. Again, this is available via multiple applications in the marketplace.

With four drink containers at the mixing station there were theoretically 24 combinations of mixable drinks. However, there realistically aren't too many people that mix vodka and whiskey in the same drink. By limiting the mixing combinations to actual drinks or combinations that would potentially taste good, the number dropped to 11.

QR codes were created to correspond with an ASCII representation of the drink name. These were then printed and tested to ensure accuracy. The generated QR codes can be seen in the Appendix.

4.1.2 Dropbox

Dropbox is a service that allows file backup and sharing across multiple platforms. What makes it ideal is that when one platform updates a file, the changes are immediately pushed out to all the other platforms. The disadvantage of this system is that a WiFi, LAN, or cellular network connection is required.

When a QR code is translated into an ASCII text file on the phone and put in the phone's Dropbox application, the results can be seen nearly instantly in the Dropbox application running on a computer or other cell phones.

This functionality allows Matlab to continually monitor the status of a file used as a drink order repository.

4.2 Webcam

A Gigaware webcam [3] was used to feed video of colored control cards to Matlab for processing. These control cards determined the overall functioning of the mobile platform. A green card indicated an order being placed while a red card indicated a need for emergency stop. The color detection was done via multiple filtering techniques of the video stream. The results of this process can be seen in Figure 8.

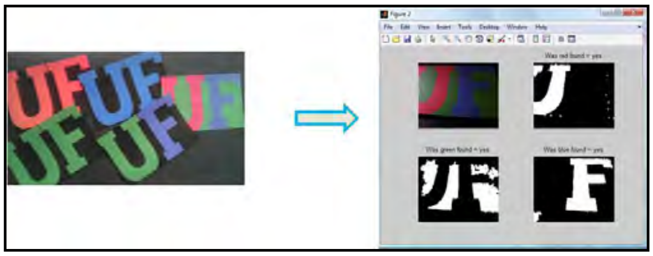

Figure 8. Control cards and filtering of an RGB example

4.2.1 Filtering operations

After pulling the video stream from the webcam into Matlab, it was split into the three principle color components of the RGB color space. Each color layer was then weighted and subtracted from the original stream, giving channels of just pure components. Each of these was then thresholded, allowing for variations of lighting conditions. With the separate RGB streams weighted and thresholded, multiple morphological operations were performed to reduce noise and increase fidelity.

First a morphological opening operation was run to remove any "salt" type noise in each channel. Then a dilation filter was used to connect adjoining pixels and emphasize remaining groups. Of the remaining groups after the filtering, contiguous pixels were counted. If the total number of pixels of a group were above a certain threshold, then it was counted as being a detection of that color group.

The result is that each color channel was effectively filtered of noise and only registered a detection if contiguous pixels of like color groupings comprised a large enough size.

Under poor lighting conditions this still allowed for adequate color detection. An example of this can be seen in Figure 7, where even with poor, uneven lighting the three color objects were still detected and classified.

4.3 Infrared rangers

Two Sharp IR range finders [4] were mounted on both ends of the mobile platform. The IR sensors allowed obstacles to be detected in the path of travel of the robot. They are set to activate over a set threshold value which can be altered according to ambient conditions or wanted activation range. Typically this range was set to be about a foot. The mounting of the sensors can be seen in Figure 9.

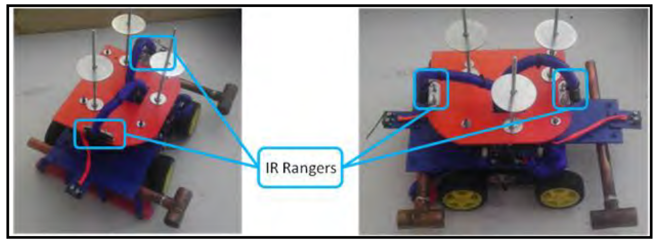

Figure 9. IR range finder mounting locations

The testing conditions of the IR rangers were focused on finding an acceptable range at which an object could be detected under most lighting conditions yet still be a safe distance from the mobile platform.

The test conditions of the IR Range finders can be seen in Table 2. Of note about the table, there was no lumen count measurement for the lighting conditions. The lighting was very much a subjective test as to "it's bright in here" or "it's dark in here," as values from sensor returns were read over an X-CTU terminal window.

Table 2. IR ranging sensor test conditions and results

Metric	Lights Off	Lights On	Blinds Open	Outside
Baseline	250-290	260-290	260-290	260-290
Δ500 Distance	~17 in	~17 in	~17 in	~17 in
Break 1200	~ 12 in	~12 in	~ 12 in	~ 12 in
FoV @ 12 in	~3 in	~ 3 in	~ 3 in	~ 3 in

4.4 Infrared array

The IR reflectance sensor array originally tested was a QTR-8A [5] array. The conditions of testing can be seen in Table 3. However the QTR-8A was not used in the project. A custom spaced array was constructed. The individual IR transmit/receive pairs of this custom array are the same as those used in the QTR-8A, so retesting was not needed and the sensor test conditions would remain the same for the custom array. Testing for the IR Array was much like the testing conditions of the IR Rangers. The focus was to find the ideal range for accurate sensor measurement. The lighting conditions did not have a particularly large effect on the sensors. However there is a very small range for which the sensors are reliable, less than an inch of workable area. The table showing the testing conditions of the IR transmit and receive pairs can be seen in Table 3.

Table 3. IR array sensor test conditions and results

Metric	Lights Off	Lights On	Blinds Open	Outside
Min Range	1/8 in	1/8 in	1/8 in	1/8 in
Max Range	1 in	1 in	1 in	1 in

The custom array that was constructed using four pairs of individual IR transmit/receive pairs. The array can be seen in Figure 10. As can be seen the array is much wider than a standard QTR-8A.

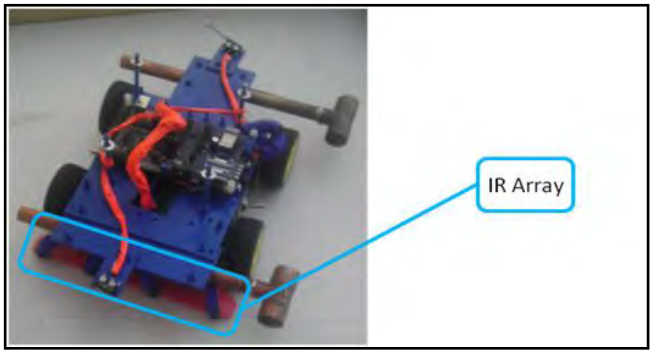

Figure 10. IR Array

4.5 Bump switches

Two bump switches were used on the DriMix 4ics, one on each end. These switches extended out past the main body of the mobile robot. The switches were used both in docking and in navigation. When an order is present and the front switch is activated the robot knows that it is at the mixing station end of the bar. When the rear switch is activated the robot knows that it is at the rear of the bar. Activating the switches either changes direction of travel, during drink polling operation. Or activating the front switch with an order in the system will activate the drink mixing sequence. The mounting locations of the bump switches can be seen in Figure 11.

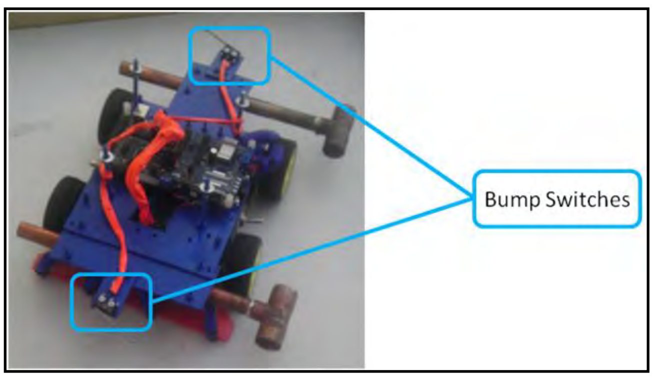

Figure 11. Bump Switches

Testing the bump switches was a simple matter of checking continuity under open and closed conditions.

4.6 Power

Power to the entire platform could have easily been supplied by a single battery pack, however two battery packs allowed for very long term testing and tuning without having to recharge. One battery pack supplied power to the Microcontroller main board while another supplied power to the motors. Each was independently controlled by a switch. This allowed for easily turning off the motors when movement was not needed. The layout can be seen in Figure 12.

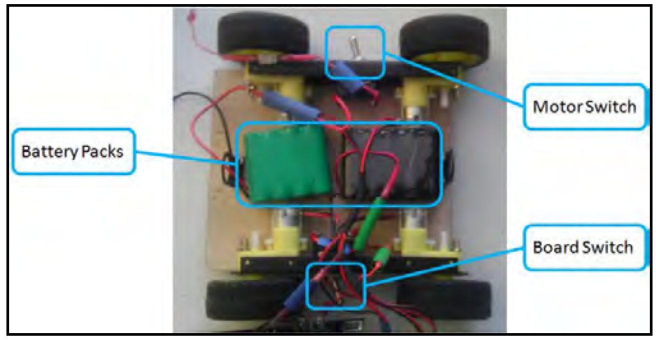

Figure 12. Battery packs and power switches

5. PLATFORM BEHAVIORS, EVOLUTION

The logic of the DriMix 4ics can be overall separated into five main behaviors. Matlab with the color recognizing control cards represent overriding controls of placing an order or stopping the mobile platform, but should not be considered behaviors.

5.1 Navigation

The DriMix 4ics essentially cycles back and forth on the bar top, stopping at each seating location, waiting for an order. Different seating locations on the counter top are marked by black bars of different lengths. The DriMix 4ics uses the IR array to determine the length of the array and thus order location. This is how the robot knows where a drink was ordered and where to take a drink after it is mixed.

5.2 Docking

Based on the direction of travel and activation of bump sensors, the robot knows which end of the bar it is located. Prior to activation the adjustable servo array is properly aligned with the mixing station. This way when the robot reaches the end of the bar with a drink order, activation of the drink levers will be aligned with the drink container spigots.

5.3 Mixing

After the process involved with transmitting the order and tracking the order location and docking at the drink station, mixing can begin. After docking the proper servos will be activated based on the order received. The servos correspond to the drinks in the mixing station. The activation angle of the cam as well as the amount of time the cam remains in that position has been measured to ensure pouring a double shot. After activation of the servo and pressing of the spigot, fluids pour into the collector then into the cup on the drink return cart.

5.4 Object avoidance

There are three forms of object avoidance on the DriMix 4ics. IR rangers, bump sensors, and the emergency stop triggered by the webcam and “red” card. The IR rangers will cause the mobile platform to stop if they detect any object a foot in front of the path of travel. The red card causes a stop in motion, no matter the direction of motion. The bump switches will cause a reverse in direction of travel.

5.5 Updating drink orders

An order can be scanned and sent to Dropbox at any time. It is only after a green order card is detected, that the value of the order is scanned in and sent to the mobile platform. The Matlab control is what processes this. On the robot, unless the “waitfororder” value is 1 (indicating a green card was detected) any order value received is disregarded. Data logging occurs after the drink order has been processed and delivered, and the green card withdrawn. The format of the data logging in excel can be seen in Figure 13.

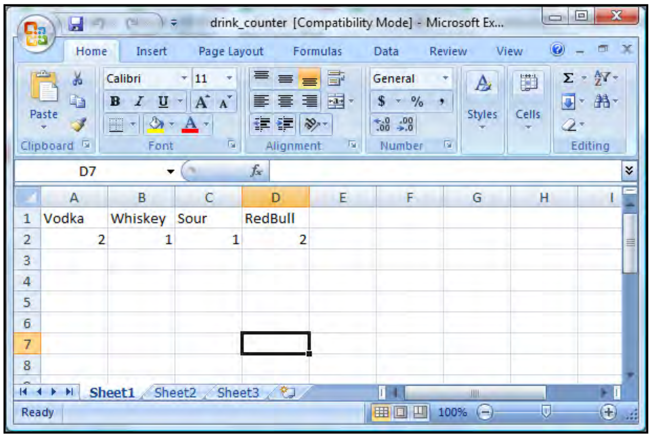

Figure 13. Data logging in Excel

5.6 Platform evolution

The original chassis used for the DriMix 4ics was the DFRobot 4WD Arduino Mobile Platform [6]. The platform was chosen because it is light weight, inexpensive and has a four wheel drive system with four DC Motors. It was only during the course of the project that the platform was discovered to be inadequate for the required tasks. The DC Motors, wheels, and motor mounts were the only things that were kept from the platform. The base chassis was about expanded three inches wider and two inches longer than the original DFRobot. The chassis also had multiple tiers added to accommodate all of the sensors and servos used. Figure 14 shows an early iteration of the DriMix 4ics as well as the original DFRobot chassis.

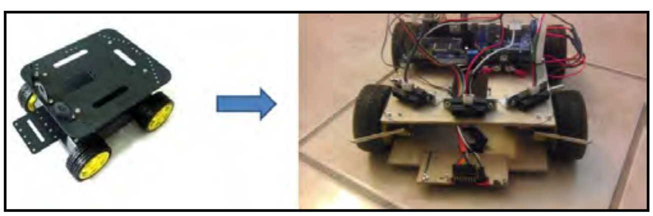

Figure 14. DFRobot chassis and early DriMix 4ics model

The original platform ended up have little in common with the finished product. Seen in Figure 14 is the original set up of the DriMix 4ics. In this configuration the DriMix 4ics was a much more mobile platform. The code at the time allowed the platform to “dodge and weave” as well as line follow. This was done with the intention of having the platform deliver the drink in a crowded room. However, none of those functions were required on a bar top serving drinks

6. CONCLUSIONS

The DriMix 4ics is able to take drink orders, accurately mix them, and return the drinks to the location they were ordered from.

6.1 Lessons learned

There were multiple lessons learned of the course of building the DriMix 4ics. Some of them will be listed below in no particular order.

- Gainesville humidity will warp thin wood. Mount everything to either sturdy wood or metal.
- Order backups of all sensors. You don’t have time to wait for a sensor in the mail.
- Work with HSV, not RGB. HSV is much more lighting invariant than RGB. Thus more robust.
- Make sure that sensors and moving part mounts are adjustable. Easy tweaking is the key to rapidly fixing problems.

6.2 Enhancements

One of the best ways to improve this project for the future would be to create a sturdier base chassis (see comments above about thin wood) and mount motors with metal shafts. Not only would a sturdier base fix the issues encountered with the wheels canting toward the center, but it would also aide in accurate sensor readings. The base that is starting to warp also affects the mounting of the IR array, causing one end of the array to be 1-2 mm lower than the other end. This does not affect sensor readings currently, because it is still within the sensor envelope.

Changing to the HSV color map would also be a much more robust implementation of color detection. The HSV map is much less sensitive to changes in lighting. Whereas the RGB color map is very sensitive to lighting conditions. I am sure that the general code could be improved as well, coding can always be improved.

7. AKNOWEDGEMENTS

Without the use of the Android marketplace the robot’s ordering system would have been much less “slick.” Multiple QR applications were tested and used to ensure a wide variety of sources could be used to send an order.

Also, without the help of the TA in the IMDL class I’m certain development would not have been finished within the single semester time frame. Or the robot would not have been as complex as it is now.

8. REFERENCES

[1] T. Martin. "Epiphany DIY board" Available: https://sites.google.com/site/epiphanydiy/ [Accessed: 30-Apr-2012].

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[4] "Sharp GP2Y0A21YK0F Analog Distance Sensor 10-80cm " Available: http://www.pololu.com/catalog/product/136 [Accessed: 30-Apr-2012]

[5] "QTR-8A Reflectance Sensor Array" Available: http://www.pololu.com/catalog/product/960 [Accessed: 30-Apr-2012]

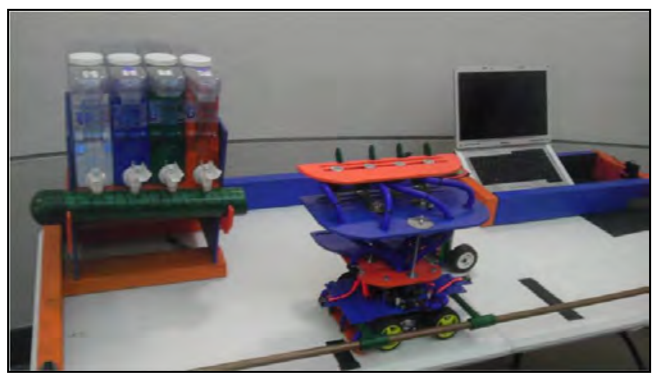
[6] "DFRobot 4WD Arduino Mobile Platform" Available: http://www.robotshop.com/dfrobot-4wd-arduino-mobile-platform-3.html [Accessed: 30-Apr-2012]

9. APPENDIX

The appendix contains the QR codes created for the menu and a picture of the complete set up.

Appendix Figure 1. Menu items

Appendix Figure 2. Menu items



Appendix Figure 3. The DriMix 4ics