Team 03
Diesel Coffee Table

Tuesday, February 10th, 2015
15-549

Shilpa Murthy
Shivam Naik
Anuj Patel
Adhish Ramkumar

Table of Contents

Project Description

The Diesel Coffee Table is a musical entertainment system that is intended to provide recreational delight to users by revolutionizing the simple construct of the coffee table. The system consists of a hand-crafted glass table that acts as a singular interfacing environment to the users. Users have to place their drinks on this table using the custom coasters that we have created. Based on which coaster they use and where the coffee cup is placed on the table different musical and visual effects will be produced. The system is preloaded with a set of audio clips from four basic instrument categories: string, percussion, woodwind, and brass. These categories are mapped to shapes on the bottom of the coasters: square, circle, triangle, star. These shapes will be recognized by a IR sensing camera place on the ground below the table. The system will play the particular instrument, that each shape that it recognizes, maps to. The distance of each cups from the center of the table will also be calculated via further image processing. This distance will be used to determine the volume of the corresponding instrument. To accompany the audio feedback, we aim to provide visual feedback as well. This will be performed by a projector that will be placed adjacent to the camera underneath the table. The project will display a audio visualizer on the coffee table surface. The light will be captured and diffused by a vinyl cover (coated with silicon) that is placed over the glass.

Our main goal for this project is to be able to create a unique, interactive musical and visual experience for people in cafes, restaurants, bars, and other places where you can sit and place a food or drink on a table. We want to achieve building an accurate yet relatively inexpensive system that will allow users to seamlessly control their ambiance with their food or beverage.

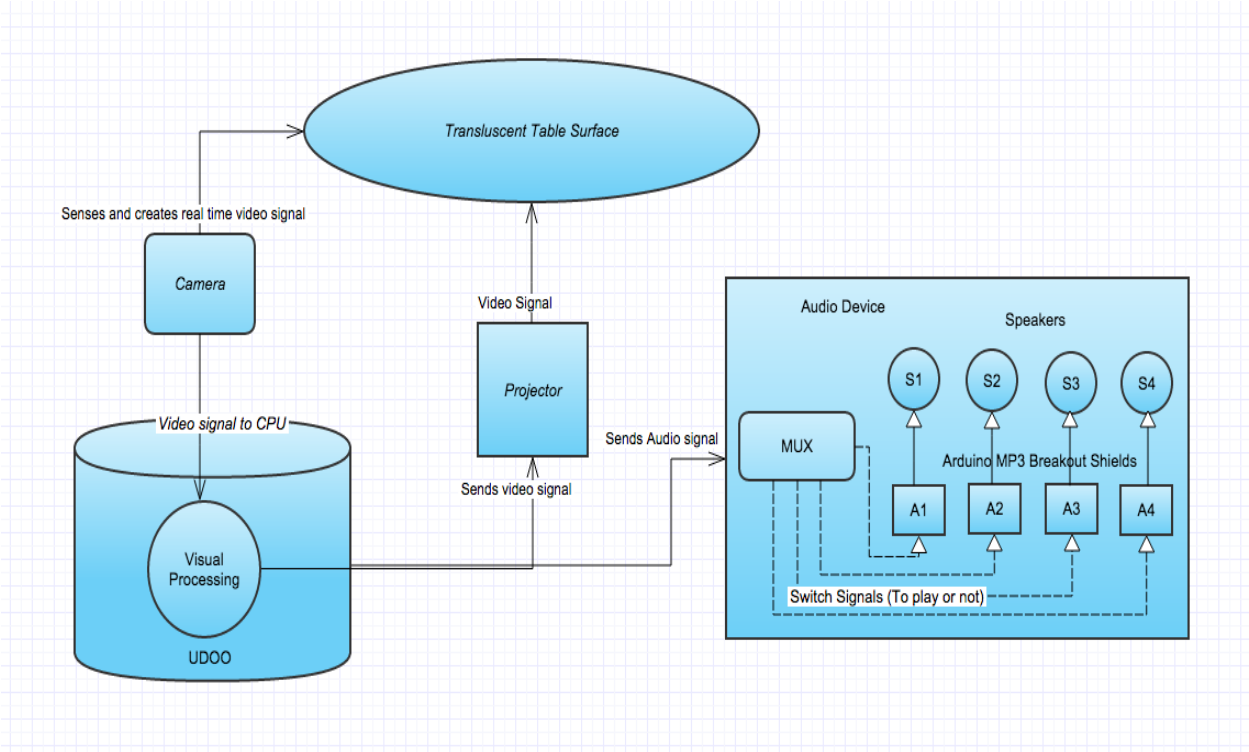
Design Requirements

Our core functionality includes a speaker and projector that respectively provide audio and visual feedback to complement the coffee consumption experience. The preliminary functionality of this service is to have people place their drinks on coasters on arbitrary parts of the table and have the system play different audio tracks based on different shapes that will be carved out on the bottom of the coaster. The volume of the audio feed should dynamically change as users move their coffee cups to and away from the center. Additionally the projector will display an audio visualizer. Keeping these functionality in mind, we should be able to use cameras to capture the table space in real time. We would ideally use a transluscent material to build the surface of the table since we need to caputre the table space with the camera as well as be able to project on the table. We should then be able to use computer vision to ascertain the

markings on each coffee cup and the distance of these individual cups from the center of the table. This would serve as the selection criteria for the audio feed and the pace of the audio feed as discussed in the project description.

As a reach goal, we want to be able to add a thermal sensor to each coffee cup and have that sensor directly communicate with the system that creates the projections for the projector. This will allow us to sense the temperature of the drinks in each cup. Based on the cup temperature, the color of the visual animation from the projector will change. This will add a very stimulating dimension to our coffee table. One of our main concerns is to integrate the real time aspect of the system flawlessly. Ideally we want to be able to process the table space in real time and apply our computer vision algorithms on the video feed and send real time updates to our audio and visual output systems.

Architecture



Our architecture can be described by 5 main subsystems that interact with each other to produce the audio and visual effects that we desire.

Subsystem 1, Table: This subsystem consists of a custom-built Frustrated Total Internal Reflection (FTIR) table. This tranluscent surface will be ideal to detect whenever an object is placed on it (specifically blob detection) and for projection. This is the main interfacing surface for users.

Subsystem 2, Camera: This subsystem consists of the IR sensitive camera that will capture the table space in real time and provide this feed to UDOO for image processing.

Subsystem 3, UDOO: The UDOO t will recieve real time video feed from the camera. All of the image processing will be done here and we have two processed outputs. One output is a video feed that will be sent to the projector and the other is a number that will be sent to our audio device.

Subsystem 4, Projector: The projector gets real time video feed from the UDOO and projects it onto the FTIR table.

Subsystem 5, Audio Device: Our audio device subsystem consists of a multiplexer, four MP3 Arduino Sheilds and 4 speakers each connected to one Arduino MP3 breakout Shield. Each shield and its corresponding speaker corresponds to one class of the four classifications of intruments (i.e. string, percussion, woodwind and brass). Our audio device receives a number between 0 and 15 (inclusive). The audio device then processes this number in the following way. We have a multiplexer that will take the number as input and produce a boolean value for each of the 4 Arduino breakout shield which will act as an indicator input to whether output the class of sound to its corresponding speaker or not. This number essentially guides the creation of music through the mux.

Design Trade Studies

We had to do a lot of literature review of the parts we are using in order to choose the best of the lot. A lot of review was spent in choosing the type of board we would be using, the type of materials needed to build our multi-touch table and the type of camera we would be using.

UDOO:

We chose UDOO as our single board PC for several reasons. Initially when we came up with this idea, we considered integrating a computer to the system because we needed a system with a lot of computational power since we are doing a lot of image processing. However, keeping costs in mind, we had to come up with an alternative solution that would offer us significant processing and computation power. We initially looked into an Arduino and

Raspberry PI for our image processing and ended up using the UDOO. The UDOO is also highly compatible with the IR sensitive camera that we are using to capture our FTIR table space, hence it sets up an ideal environment for image processing.

These are the comparative advantages of UDOO over Arduino and Raspberry PI:

	Arduino	Raspberry Pi	UDOO
CPU	ATMEGA328 16MHz	ARM1176JZF-S 700 MHz	Freescale i.MX6 ARM Cortex-A9
GPU	Inbuilt	VideoCore IV GPU	Complies with Complies with OpenGL ES 2.0/1.1
RAM	32KB	512MB	1 GB DDR3
Onboard Storage	N/A	No	Not Specified .
Video Output	14 digital I/O pins, 6 PWM outputs	RCA, HDMI	HDMI and LVDS + Touch (I2C signals)
OS	N/A	Backtrack, Kali Linux, XMBC , ETC.	Every OS supported by Arduino and Raspberry Pi, Android, Linux
Extension Interface	14 digital I/O pins, 6 PWM outputs	GP10 Connector	76 fully available GPIO, Sata, Camera Input.
Network Interface	Attachable Shields	Ethernet Port	RJ45 Ethernet, Wifi
Price	QUAD: $135	$30	$25

FTIR Table:

When we were choosing what type of multitouch environment to build, we had several options. We had to choose between FTIR (Frustrated Total Internal Reflection), LLP (Laser Light Plane). DSI (Diffuse Surface Illumination), LED-LP (LED- Light Plane), Rear DI (Rear Diffuse Illumination) surfaces. I will discuss the advantages and disadvantages of each and then proceed to explain our choice of surface.

The advantages and disadvantages of each of these surfaces are as follows:

Multi-touch Technique	Disadvantages	Advantages
FTIR	● Requires a silicone rubber surface and an LED frame. ● Cannot recognize objects or fiducial markers	● Enclosed box is not required ● Blobs have strong contrast ● Can recognize very small objects ● Acts mainly on pressure ● Very easy and cheap to build
LLP	● No compliant silicon surface needed ● can use either glass or acrylic ● no led frame required ● enclosed box is not required ● could be slightly cheaper than other techniques ● LCD setup compatible	● Cannot track traditional objects and fiducial markers ● not pressure sensitive ● has occlusion risk ● safety hazard
DSI	● No compliant silicon surface needed ● Easy switch to FTIR ● Can detect object, hovering, and fiducial markers ● pressure sensitive ● no hotspots ● even finger object illumination throughout the surface	● Enlightened Acrylic costs much more ● Blobs have lower contrast than other methods (harder to pick up via software)
LED-LP	● No compliant silicon surface needed ● Compatible with any transparent material ● Enclosed Box is not required ● LCD compatible	● LCD frame required (intensive soldering) ● hovering can cause false blobs ● can cause occlusion ● cannot track traditional objects or fiducial markers
REAR DI	● Difficult to get even illumination	● No need for a compliant surface, just an diffuser/projection surface

	• Blobs have lower contrast (harder to pick up by software) • Greater chance of false blobs • Enclosed box is required	on top/bottom • Can use any transparent material like glass (not just acrylic) • No LED frame required • No soldering (you can buy the IR-Illuminators ready to go) • Simple setup • Can track objects, fingers, fiducials, hovering

We decided to build an FTIR surface because it is very inexpensive and easy to build. Additionally during blob detection, blobs have very high contrast which will exponentially increase the ease and accuracy of image processing. We considered building a Rear-DI surface but the illumination in Rear-DI is not even and therefore we would not be able to project onto the table properly. In addition to that Rear-DI requires an enclosed box which would be very inconvenient since we are placing most of our sensors and actuators underneath the table. We do not want our audio device to be in an enclosed box.

Camera:

The camera we decided to use was MIPI 5MP IR AF Camera. This camera is highly compatible with the UDOO interface. Additionally we want a camera that is sensitive to IR which is highly crucial for blob detection from the FTIR table. Most other cameras we looked at were either not UDOO compatible, had no sensitivity towards IR or were too huge or expensive.

Audio Device:

For the Audio Device we decided to use an Arduino Breakout Shield for MP3 and connect it to speakers. This was the best and most feasible way we could convert our numerical output from the UDOO to select what classification of sounds to output. Initially we had a computer outputting the audio signal after processing the video feed from the camera. But this turned out to be very infeasible and expensive.

System Description

Our entire project can be broken up into three main subsystems which are the sensing, audio, and visual subsystems.

Sensing

Our sensing system will consist of

We have an IR sensing camera that will

1. **IR Sensing camera** which takes shape information from coaster by running a computer vision program on **Udoo** written using OpenCV. Shape information will be converted into a number and sent to the audio subsystem.
2. track movement on the table. Proximity to center will be cent to audio subsystem. Tracked movement will be sent to the visual system

Audio

Our audio subsystem consists of

1. **Multiplexer** which picks a combination of speakers
2. **4 Arduino MP3 breakout shields**, each of which will hold a classification of instrument. We will have multiple mp3 files for each instrument. The shield's primary function is to pick which mp3 file will be played.
3. **Speaker** associated Arduino MP3 breakout shield will play specified beat.

Visual

Our visual subsystem will consist of

1. **Projecter** which will project a visual animation. If we reach our stretch goals, we may change color as a function of time.

Project Management

Schedule

Date	Week #	
2/15-2/21	6	Start project website template. Get table materials and build physical table.
2/22-2/28	7	Build the multi touch part of the table and get a demo program so we can interact with the table and ensure that multi touch works.
3/1-3/7	8	Create audio visualizer and use OpenGL to communicate images to projector via laptop. Start working on shape detection on coasters using IR Camera and computer vision algorithms.
3/8-3/14	9	Spring Break
3/15-3/21	10	Finish audio visualizer and coaster sensing. Align shapes with instrument type and start porting all code over to Udoo.
3/22-3/28	11	Make sure we have error handling for everything that needs it

		including having undetectable shapes. Use this week to catch up on any unfinished items in prior weeks.
3/29-4/4	12	Finish porting all code over to Udoo test that individual components still work.
4/5-4/11	13	Tie in sensing, audio, and visual all together.
4/12-4/18	14	Tie in sensing, audio, and visual all together. Make sure app works in real time.
4/19-4/25	15	User test system before system demo.
4/26-5/2	16	Start final report and bug fixes for demo encore.
5/3-5/9	17	Finish up final report touches.
5/10-5/11	18	Make sure entire website is finished.

Budget

Parts	**Count**	**Cost**	**Link**
MIPI 5MP IR AF Camera	1	39.00	http://tinyurl.com/omkxa82
60 Watt 12vt DC Power Supply for LED Reel	1	40.30	http://tinyurl.com/69x6bsk
ACRYLITE® extruded (FF), sheet, Colorless 0A000 GT	1	36.4	http://tinyurl.com/orjuya7
Vinyl Sheet VINWHTPM.010	1	16.45	http://tinyurl.com/nksegwh
Silicone I 9.8-oz. Clear Window and Door Caulk	1	5.21	http://tinyurl.com/nsjwx79
1-qt. Xylol Xylene	1	6.98	http://tinyurl.com/lonzogo

9 in. x 3/8 in. High Density Woven Roller Cover (3-Pack)	1	10.98	http://tinyurl.com/nwc6hry
9 in. Roller Frame Acme Cage Frame	1	1.78	http://tinyurl.com/oqrr3jo
16-oz. Plastic Paint Cup	1	2.97	http://tinyurl.com/oxmdkzl
0.94 in. x 60 yds. Painter's Tape	1	3.93	http://tinyurl.com/ojy2m5d
4 in. x 4 in. x 8 ft. #2 SYP Pressure-Treated Timber	8	7.87	http://tinyurl.com/ov3ko6a
UDOO Quad	1	135	http://tinyurl.com/k9b8ddq
SparkFun MP3 Player Shield	1	39.95	http://tinyurl.com/m7g2b7l

Team member responsibilities

We plan on working on each component together but we will have primary and secondary point persons for the responsibilities.

	Shilpa	Shivam	Adhish	Anuj
Audio Device	2nd			1st
Audio Visualizer			1st	2nd
Camera/OpenCV	1st	2nd		
Projector/OpenGL	2nd	1st		

Table Construction			1st	2nd
Website		2nd	1st	

Audio Device:
Anuj has most experience with hardware so he is taking lead on audio devices. Shilpa comfortable enough to be the secondary point person.

Audio Visualizer:
Adhish felt he could finish this part of the project with a little help. Anuj felt he could contribute to this part of the project.

Camera/OpenCV:
Shilpa has worked on a project using OpenCV and felt comfortable taking the lead on this. Shivam has also worked on a project using OpenCV.

Projector/OpenGL:
Shivam has worked on projects using OpenGL. Considering Shivam and Shilpa are working on OpenCV and camera together it made sense to pair the two, which is why Shilpa is secondary point person.

Table Construction:
Adhish has researched this topic very deeply and feels he can do a good job of it with a little help. Anuj volunteered to be secondary point person.

Website:
Adhish has been a webmaster for Bhangra in the Burgh and has taken webapps and loves CSS more than life itself. Shivam has taken webapps.

Risk Management

1) Our biggest risk right now is the fact that all four team members feel most comfortable in software. We are going to try to mitigate this through two avenues.
    a) Firstly, we have spaced out or schedule so we are working on getting individual components working with udoo and allotting the last three weeks to making sure the individual components work together

seamlessly. We have also allotted a catch up week in case of pitfalls in making the individual components work.

b) Secondly, we have extracted as much of the project as we can into the software side and will try to deal with problems via software first.

2) Another risk we face is using an Udoo because we have never worked with it before and there is not as much documentation on it as other resources such as an Arduino. Two of us have never worked with Arduinos/Raspberry Pi's and so on so we will face a learning curve. Currently, one of the team members is a student of the creator of the Udoo. We are hoping if we cannot figure something out and have exhausted our resources that we can talk to him about it directly. Lastly, we do not know if our audio and visual processing will be too much for the Udoo to handle. If we try and fail, we can still demo with our lapop. Considering, Linux can run on Udoo, we believe it will be okay.

Related Work

ReacTable. This project build an interactive DJ Table where the user could add place and move different objects on it to create electronic music. The table was also equipped with a screen that displayed visualizations of the tempo and volume of the sounds. Our project is similar to this in the way we detect objects on the table and output audio and video.
https://www.youtube.com/watch?v=Mgy1S8qymx0

LED Interactive Table
These tables integrate infrared sensors under a translucent table to display visual effects. We plan to use a similar method to detect objects on the table. However to make it geared toward our skills, we will use an infrared sensing camera and hook it up to a backend microprocessor. Our video will be handled by a projector rather than leds
http://www.becausewecan.org/LED_coffee_table_Ripple
https://www.youtube.com/watch?v=OLfF4b49MLs

Milan Screen Table
Microsoft's interactive computer table that supports integration with devices such as phones and tablets sitting on it. We plan to use the same infrared sensing technology that they use.

In summary, there are many related projects that all use some piece of our planned architecture. Our project aims to build a simple, complete table using only a few key devices. Unlike other projects, we plan to keep most of our work in software and image processing. This gives us the confidence that we can succeed.

References

RasPi vs Arduino vs Udoo: http://realhackerspoint.blogspot.com/2013/07/raspberry-pi-vs-arduino-vs-cubieboard.html

FTIR table: http://www.peauproductions.com/ftir.html

Udoo Opencv: http://highsineburgh.com/udoo-camera-and-opencv.html

Udoo openGL: http://www.udoo.org/udoo-supports-full-opengl-hardware-acceleration/