Baskin Engineering
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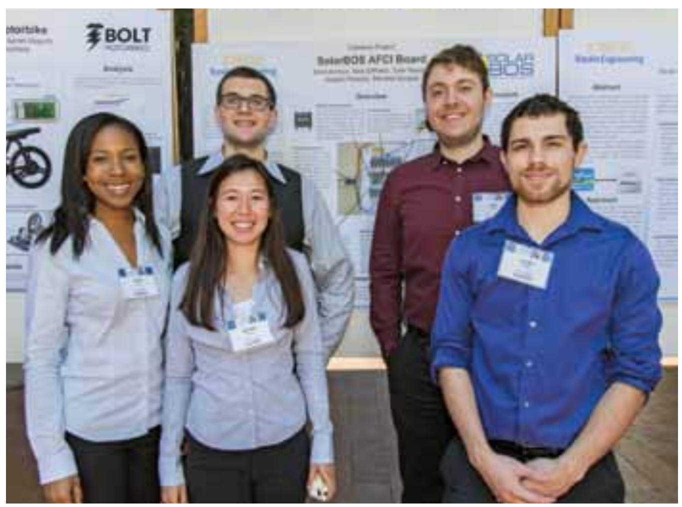
CORPORATE SPONSORED SENIOR PROJECTS

2017 PROGRAM



Introduction

This publication highlights the sixth year of the **Corporate Sponsored Senior Project Program (CSSPP)** at the Baskin School of Engineering. The publication also includes a selected group of this year's capstone projects from student teams in Computer Science, Computer Engineering and Electrical Engineering working on faculty/student initiated projects.

CSSPP provides students with a unique opportunity to experience working on real-world engineering projects as part of their undergraduate education. Throughout the academic year, students interact with teammates; some make visits to their corporate sponsor's worksite, and all are required to solve problems along the way.

By working with mentors at corporate partner companies, students learn important skills, take on interesting challenges, and begin to understand what it means to be a professional engineer.
We appreciate our corporate sponsors for their willingness to support this year-long program, mentor our students and provide them with challenging projects to work on. And we appreciate our students, who have worked hard and have enriched our lives through their energy, intellect and determination.

Alexander L. Wolf
Dean
Baskin School of Engineering

Acknowledgements

We would like to acknowledge and thank the faculty, teaching assistants and staff who have been so instrumental in the Corporate Sponsored Senior Project Program:

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Sponsors

SPECIAL THANKS TO OUR SPONSORS for your generous support of our Corporate Sponsored Senior Projects Program. Your time, experience and financial support were beneficial to our students and the success of their Senior Design Projects.

Capstone Project

Amazon RFID Dash

John Hockel, Julia Warner, Yu-hsiang Lo,
Andrea David, Cameron Schaefer

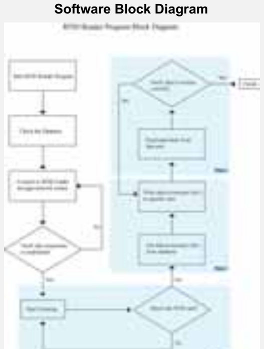
Abstract

The primary objective of our project is to establish proof-of-concept of the feasibility of incorporating RFID technology to Amazon's many distribution centers. Amazon's motivation in interfacing with RFID tags on certain products is based in the ability to preload RFID enabled devices with specified customer information prior to shipping. This capability would allow Amazon to add several convenience features to many of their devices, enhancing the customer experience by pre-programming devices prior to distribution and saving the hassle of initializing their new device with personal data. Amazon's primary motivation for this technology is "to make things easier for the customer".

Approach

Hardware Block Diagram

Software Block Diagram



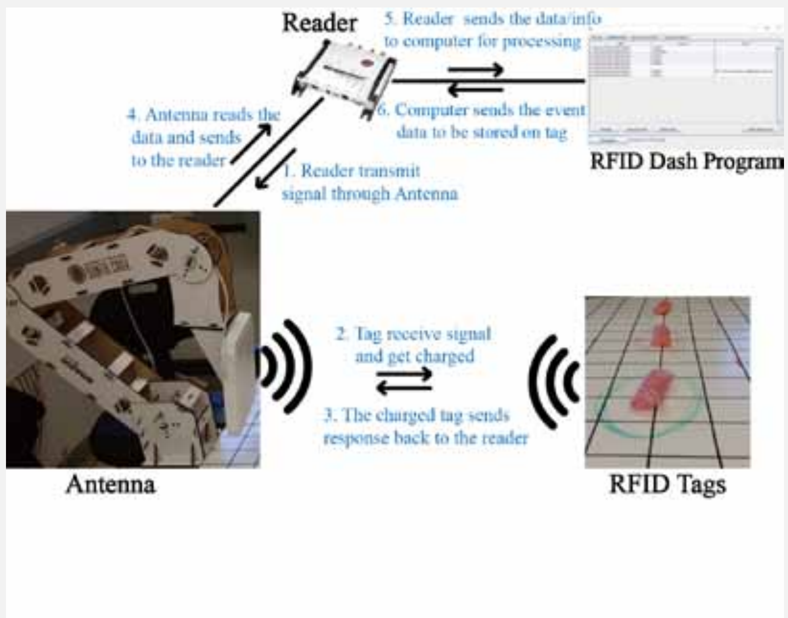
Overview

Hardware

The team crafted an antenna mounting solution that offers the greatest chance for success at interfacing with the embedded RFID chips within a variety of standard cardboard shipping boxes. The mounting solution is fully adjustable, but it provides the maximum amount of radio coverage when and where possible as determined by the testing.

Software

The group created software that can read and write data to the Impinj RFID tags. The data to be written is unstructured, but falls within the confines of the tags' memory. The software is robust enough to read the contents of the tags, write data to the same tags, and then read it again to determine whether the data was successfully written. The goal for the interface software was to be user-friendly and intuitive on first sight.

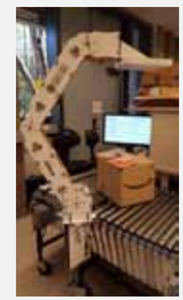


Acknowledgments

The team would like to thank Michael Lee, from Amazon Lab126, for being a helpful and enthusiastic sponsor throughout the project. We would also like to thank Professor Stephen Petersen and Becker Sharif, from UC Santa Cruz, for advice on the engineering process.

Analysis

Given the nature of RFID tags, it was very likely that there would be a blind spot of some sort where the antennas would be unable to read the RFID tags. To check for blind spots, a small foam stand was made to hold a single dash button in set positions. The foam stand worked best at dealing with perpendicular configurations. Since the antennas themselves are circularly polarized, all blind spots at close range are either attributed to the tags themselves or due to gaps in the transmitted wave. For these tests, the antenna was laid flat, facing up.



Results

Impinj Antenna Controller

The team has tested the basic capabilities of the Impinj Speedway Revolution Antenna Controller, including its range, spread, power capabilities, and its suitability for the project according to Amazon Lab126's intended use for the project.

Antenna Mount

The team has designed and created adjustable holders for the antennas that may be mounted on the conveyor belt and adjusted for several different antenna array configurations.

The User Interface

The team has designed a graphical user interface (GUI) program that illustrates the capabilities of the RFID antenna array reading and writing to multiple devices as they pass on the Amazon distribution center conveyor belt. It clearly pictures the success or failure of live reads and writes to RFID tags as well.

Conclusion

The team assembled an antenna array configuration and developed a GUI interface to test a coherent demonstration of the RFID technologies and give a report of its accuracy, reliability, and any possible problems. The end goal of the demonstration is to show to Amazon executives the reliability of the RFID interface as it would be incorporated in the distribution centers.

Image-Based Quality Control for OLED Printers

Kevin Johnson, Daniel Ruatta, Richard Pham, Paloma Fautley

Jack Baskin School of Engineering, University of California, Santa Cruz, CA, 95064

Abstract

1. General Background: In order for OLED manufacturers to continually improve the quality of their phone and TV screens, the manufacturing equipment that produces them needs to be incredibly precise. The motion systems involved are highly complex, and require constant improvement in order to ensure that screen quality can improve (e.g. 720p vs. 1080p).

2. Specific Background: Our system is a proof of concept image capturing system that could be run on a Kateeva inkjet printer. It is designed to capture high quality images of the screen substrate as they run through the printer at speeds up to 1m/s. Image capturing speed is critical. Keeping the camera exposed to light for too long (in our case, around 10us of blur) will ruin the quality of our image.

3. Statement of Problem or Knowledge Gap: We don't understand how to maximize the luminance exposed to our camera while also minimizing the amount of time that the LED is on.

4. Here we show: We have optimized both our LED position relative to the camera and our LED parameters (strobe pulse length and strobe controller input voltage) while also utilizing image processing software in MATLAB to give the highest quality image possible.

5. Results: We have proved that it is possible to take an image 10x faster than our minimum 10us spec that Kateeva outlined for us and still determine the pixel well locations.

6. Implications: With this proof of concept, we are able to give Kateeva a strong enough foundation to integrate our system onto their tool. Having the ability to capture images of micron sized pixel wells while the printer is moving will allow Kateeva to locate their precise location. By know their precise location, Kateeva can drop OLED droplets in the right pixel wells.

Background and Motivation

This system will allow Kateeva to run quality control tests on their motion systems. By taking images of certain critical points on sample glass screens while moving, Kateeva can determine if their motion system accuracy is below their expectations and they can make adjustments accordingly.

Methods

Mechanical Design

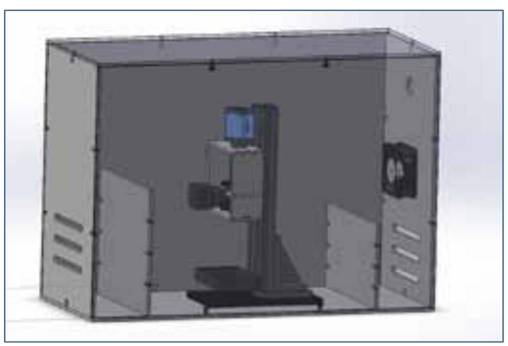


Figure 1: After meeting with UCSC's Environmental Health and Safety department regarding our two 60V 50A power supplies and the potentially blinding LED connected to them, we created this safety enclosure for the system in SolidWorks and wrote standard operating procedure to ensure safe operation of the system.

Electrical Block Diagram

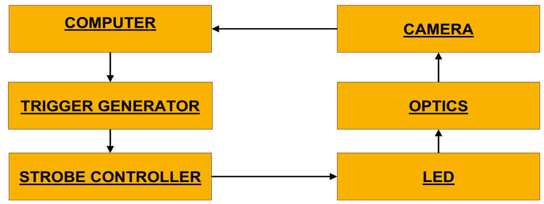


Figure 2: Our computer tells our trigger generator board when to send a pulse that aligns the camera exposure and strobe controller pulses. While our camera exposure is on, the LED pulses for a brief period through the optics, which allows the camera to absorb enough light to create an image. The camera then sends the image to the computer for storage.

Software Block Diagram

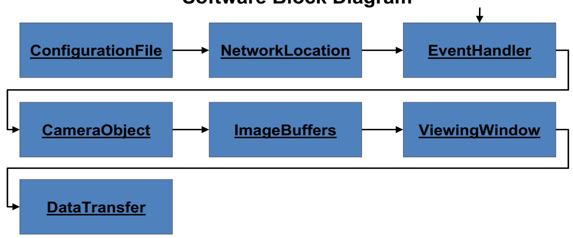


Figure 3: Software Block Diagram of our system using DALSA's built in Sapera Camera Library. Using the Sapera's software manual, we were able to capture images using an external trigger using Microsoft Visual Design Studio.

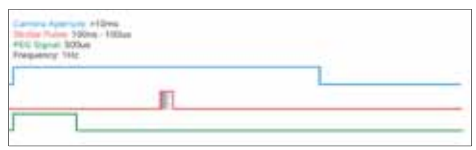


Figure 4: Timing Diagram using Kateeva's PEG signal generator to trigger camera and strobe our LED.

Results

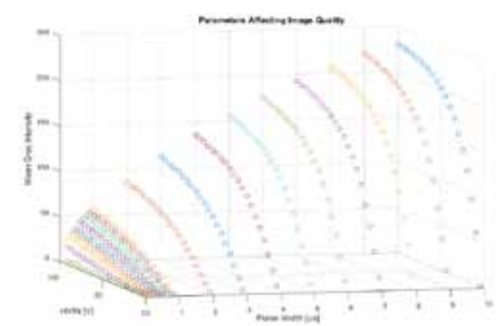


Figure 5: Using gray intensity, we quantified the image quality of our photos. In this scatter plot, we find the correlation between pulse width, high input voltage, and image intensity using several combinations of LED configurations.

Smallest possible strobe pulse width while maintaining image quality

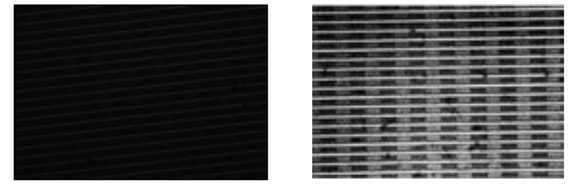


Figure 6: A faster pulse width (1us) and higher voltage (55V) with quad LEDs and medium beam optics provides us with a usable image after histogram equalization, locally adaptive thresholding, and a 3x3 averaging filter in MATLAB

Finding each pixel well's location in MATLAB

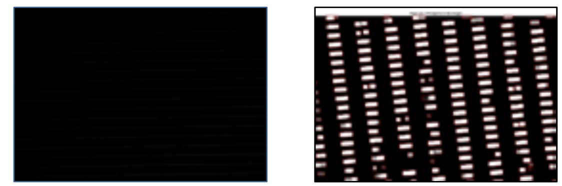


Figure 7: In addition to histogram equalization, locally adaptive thresholding, and a 3x3 averaging filter, we used morphological opening and connected component labeling in MATLAB to determine the approximate location of each pixel well in the image above (11V, 200us). This algorithm can be fine tuned to ensure that every pixel well is correctly located, and this data can be sent to Kateeva's motion controllers to minimize motion system error.

Conclusion

1. Shorter pulse widths correlate to less illumination at low voltages.
2. Longer pulse widths cause motion blur.
3. Higher strobe controller input voltages give us more brightness.
   a. We noticed an anomaly around certain voltages that unexpectedly decreased our brightness levels.
4. Image processing can be used to help us identify the locations of the pixel wells.
5. Adding beam optics to our LEDs gave us a more concentrated beam of light which gave us better image quality.
6. Our gray intensity (brightness) improved when we switched from single LEDs to quad LEDs.
   a. Adding more quad LEDs further improved our gray intensity
7. We chose red LEDs because other wavelengths can damage the photosensitive OLED ink.

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EH&S: Project Safety Supervisor
Mike Baker & Tim O'Brien: Sponsor Liasons

Capstone Project

MaxExchange

Josh Bernfeld, Taylor Futral,
Philip Guther, Cameron Johnson

Abstract

The objective of this project was to demonstrate the capabilities of a software based stock exchange and then transition the product to a hardware based FPGA implementation. A large volume of orders would need to be sent to a stock exchange server for matching while also measuring the performance of the matching engine without impacting its performance. The resulting data would then have to be displayed in an understandable way.

Approach

Use Bots to Generate Orders

Create bots which run in parallel and will send upwards of 10,000 orders per second to the stock exchange.

Measure Performance Without Degrading Performance

Add code to track the number of orders being processed and the time it takes to process each order. Write to a database without slowing down the exchange.

Visualize Collected Data

Display collected data as charts that update in real-time via web browser using Pentaho.

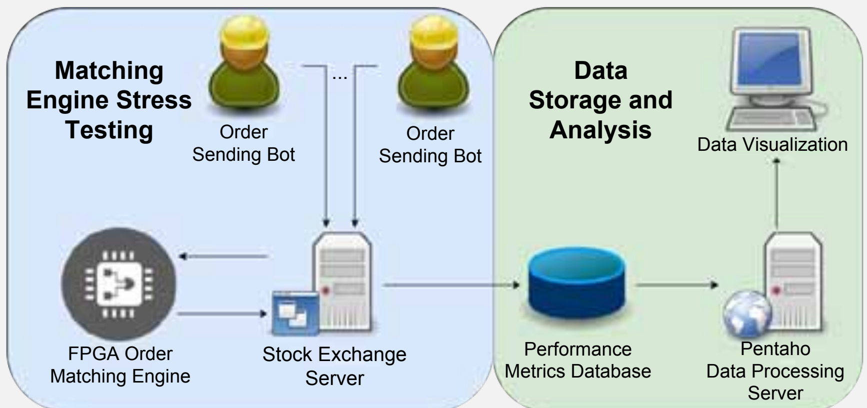
Integrate FPGA matching engine

Replace the software matching engine with a streamlined FPGA implementation.

Overview

Maxeler provides high performance computing solutions using Field Programmable Gate Arrays (FPGAs), which have a significant speed advantage over regular processors because they are configured to perform a single task efficiently instead of general purpose computing. Maxeler has developed an FPGA-based stock exchange order matching engine that can handle 1 million orders per second. **Project goal.** The goal of this project was to demonstrate the performance of the Maxeler platform by generating a large volume of stock exchange trade orders, collecting performance data for the order matching engine, and visualizing the performance data through a web interface. The current implementation is built on a software matching engine which can be swapped with an FPGA hardware version.

Architecture



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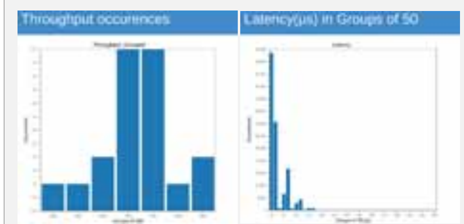
A special thanks to Richard Veitch (rveitch@maxeler.com) and Maxeler for the unique chance to work with them. We could not be more appreciative of the time Richard set aside to work with us, and the knowledge and expertise he brought to the table. We would also like to thank our professor Richard Jullig and TA Morteza Behrooz for their all-important advice and guidance. Lastly, we would like to thank the Jack Baskin School of Engineering for providing us with this great opportunity.

Results



The histogram on the left shows the performance of the exchange in terms of throughput, specifically each bar represents the number of times a certain trading frequency was reached. The prominent bars in the middle show that 7000-7500 orders per second were the most common, occurring a total of 12 times for the session.

The histogram on the right shows the number of times a specific latency was achieved. Latency is the time it takes for an order to be processed by the exchange. The most commonly occurring latencies were in the 0-40 μs range.

These metrics greatly outperform our initial metrics, which were around 80 orders per second and 100 μs latency per order. The increased performance is a result of minimizing the number of cycles needed for recording data and introducing multithreading.

Conclusion

We delivered a framework that generates a high volume of orders to stress test Maxelers matching engine, collects data without degrading performance, and displays the data in an intuitive manner, while also providing a basis for native implementation under an FPGA architecture.

Capstone Project

Acoustic Source Location by Time Delay Estimation

Luong Truong, Sahil Singh, Tanvir Heer,
Leo Chen, Pranav Yerabati, Alec Marin

Abstract

This project focuses on the problem of locating acoustic sources using a microphone array by comparing the amplitudes of the signals from these microphones. The primary objective is to automate the location of a speaker inside a confined area (e.g. inside an automobile). With additional signal processing, further enhancements are envisioned, including voice recognition and support for speaker identification in teleconferencing. The approach in this project employs an array of microphones and a microprocessor implementing digital signal processing to analyze the audio signals, calculating phase and relative distance that the detected speaker is away from a selected location. The implementation is an embedded system with analog inputs from a set of microphones and with digital signal processing configured to allow monitoring and management of algorithms through an API. Input signals and results from signal processing are displayed via a GUI that shows the computed position of the speaker and the characteristics of the data that is assisted in optimization and debugging.

Approach

At a high level, the problem was approached by digitizing the audio input through a PIC32 from which the digital signal processing takes place. The processed data is then sent to a configurable UI environment over an Ethernet communication to visualize the data. Off the shelf microphones with pre-amplification stages were preferred as it allows easier reproducibility. The analog input obtained from the microphones are then discretized using pulse code modulation for digital signal processing.

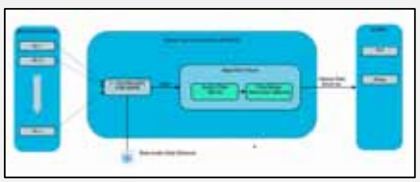


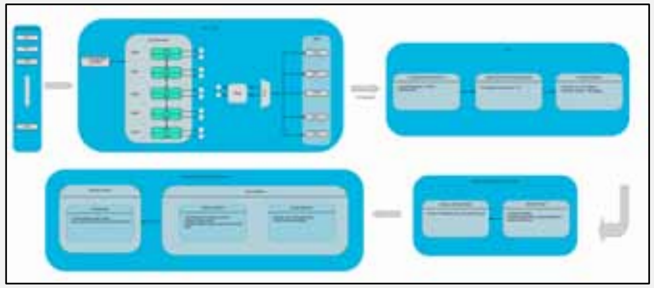
Figure 1: High Level Systems Diagram

Each microphone signal is passed through an ADC to digitize the signal and then processed through an audio filter in the embedded system to filter out background noise and mitigating aliasing. The signals are passed through an Energy-Detector to attain only the signals of interest before filtering the signals. These signals are processed by a time-delay estimation algorithm to locate the emitter. A second TCP server is spawned in order to handle sending the audio data from the active microphone channel.

The embedded system passes this data onto the GUI and Debug module in Qt/QML. The debug module allows the user the capability to send function commands back to the embedded system in order to turn on/off certain microphone streams and view algorithm related debugging information.

Overview

Top-Level Systems Diagram



Time Delay Estimation: Cross-Correlation and Filtering Design

- Fourth-Order Infinite Impulse Response (IIR) Filter, carried out by cascading two biquad stages.
- Cross-Correlation is a measure of how similar two signals are to each other.
- We can determine which microphone is the first to pick up an acoustic signal, and thereby determine where a speaker is in a car.

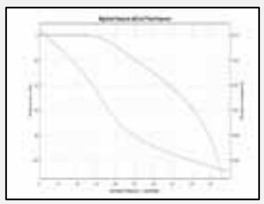


Figure 2: Frequency Response of IIR Filter

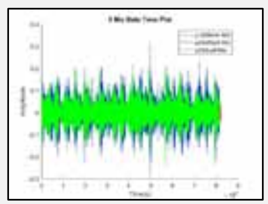


Figure 3: Cross-Correlation plot of 3 microphones

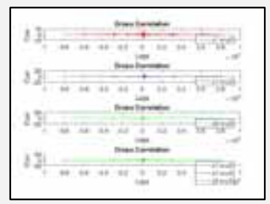
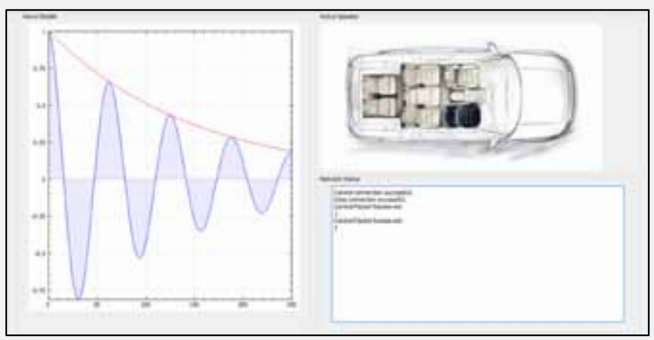


Figure 4: Cross-Correlation of 3 microphones

Graphical User Interface



Analysis & Results

The Microchip PIC32MZ2048EFH144 microcontroller is the embedded platform of choice due to it having a 252 MHz MIPS processor with Floating Point Unit allowing sufficient processing capability and having necessary on-board peripherals, such as suitable ADCs, DMAs, UART, and Ethernet. Microphones chosen for this project were Electret Condenser microphones with a pre-amplification stage. Testing and analysis were done on these microphones through a DAQ using LABVIEW. Adequate frequency response testing concluded that these microphones are a suitable candidate for this project.

As an initial test plan, we started with 5 microphones (one for each seat in a Mercedes-Benz sedan). The microphone signals are digitized by a 12-bit High Speed SAR ADC. Each ADC has paired dedicated and alternate channels which are multiplexed to allow up to 10 independent audio input channels. Independent sample and hold circuits permit synchronous sampling of analog signals. Configurable sampling rates up to 18 MSPS allows us to meet Nyquist Criterion for standard 44.1kHz audio format quality. The audio signals are processed through a chain of digital signal processing algorithms (Neyman-Pearson detection, IIR preprocessing, and cross-correlation).

Through use of DMA channels to transport the data from peripherals to memory, stress is taken off the processor during algorithm computations. Once the data has been processed, it is transported over the host system through TCP/IP to display on a front-end GUI, where the MCU is acting as the server. The GUI client reflects the location of the emitter source and displays debugging information to the console.

Future Work

The signal processing methods which have been mentioned thus far serve as adequate solutions to the problem, but with further research we wish to develop less processing intensive techniques such as adaptive filters, and implement beamforming algorithms to capture angle information of the sound source.

Conclusion

The goal of the in-car audio input framework project was to solve the problem of locating acoustic sources using a microphone array by comparing the signals from a set of microphones. Testing of our algorithms, hardware, and network systems demonstrates that the preliminary system is functioning as intended. This project has plenty of room for advancements, such as the algorithms and hardware architecture.

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The Mercedes-Benz Team would like to thank the following:

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Ethan Papp – MBRDNA, Project Advisor

John Burr – MBRDNA, Project Advisor

Eric Cao – Electrical Engineering Graduate Student, Project TA

Capstone Project

Sun Light

Brian Tang, Connor Barnes, Scott Davis,
Alina Syrtsova, Roman Sodermans

Abstract

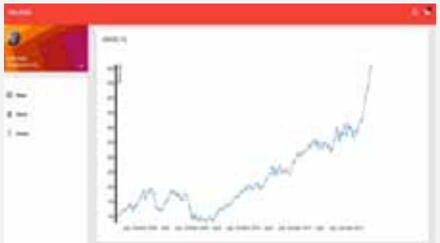
The goal of this project was to provide Mira Bella Energy a data management system for their solar-powered street lights. Each street light is part of a DigiMesh network that is connected to the internet, and each street light uses this connection to send data to a cloud-based web server where it is stored in a database. This data can be accessed by Mira Bella customers and personnel via a web application. The web application provides an intuitive interface for viewing performance data and configuring street lights.

Solar-powered street light

Street Light Management

The web application is designed to be an easy-to-use interface for displaying and analyzing large amounts of data in a meaningful way. The website is organized into four major tabs:

- **Maps** display the location of each street light using Google Maps, making it easy to determine where each street light is located.
- **Alerts** contain notifications regarding the status of different street lights that keep the user informed of the performance of their street lights. Also alerts the user of any issues that may exist so that the user can deal with them quickly and effectively.
- **Assets** list all the street lights owned by the user and provides an easy way to view the most recent data collected from each street light.
- **Home** shows graphs such as savings over time for a single street light, a consumer's chosen grouping of street lights, or all the street lights at a given location.



Home page with graph of usage percentage over time

Overview

Street lights consume energy during peak hours when electricity is in higher demand. During these peak hours, the total maximum demand for electricity is increased. Mira Bella Energy's solar powered street lights aim to reduce both monetary and environmental costs as well as electricity consumption as a whole. Sun Light provides Mira Bella Energy with a management system that **stores data** for multiple street lights, allows for their **power consumption configuration**, and provides meaningful **analysis** of each street light's state/performance.

The **project goals** included connecting Mira Bella's street lights through a **mesh network**, transferring data to and from a **server**, and interfacing with both the collected data and the configurations of each street light through a **web application**.

Architecture

Proprietary Hardware

Every street light has a microcontroller, a battery, and a connection to the power grid. The battery stores the energy collected by the solar panels, and the microcontroller manages the operation of the street light. For example, the microcontroller controls when the light turns on, when the light turns off, the brightness of the light when it is on, when to run on battery power, when to run on power from the grid, and other things. The microcontroller also collects data from built-in sensors, which is sent to the database server for storage. Each microcontroller also has an XBee radio, which it uses to send and receive data over the DigiMesh network.

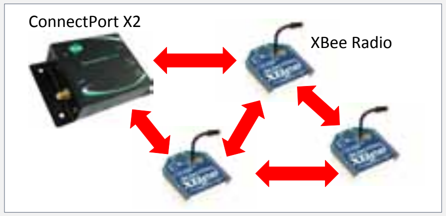
Microcontroller for solar-powered street light

Acknowledgments

Special thanks to Jim Meringer from Mira Bella Energy, Babandeep Singh for his hardware expertise, and Professor Richard Jullig and Morteza Behrooz for providing advice throughout the course of the project.

The DigiMesh Network

- Every node in a DigiMesh network consists of a street light with an XBee radio.
- All nodes are routers, which expands the range of the network and allows the network to find different routes between nodes in the case of node failure.
- The ConnectPort X2 acts as a router, but also acts as a gateway between the DigiMesh network to the internet.
- The street lights send data to the ConnectPort X2, which reformats the data and uploads it to the Digi Device Cloud.



Results

The point-to-point communication (i.e. street light to PC) was replaced with the DigiMesh network (i.e. street light to gateway). The DigiMesh network allows one gateway to communicate with multiple street lights, which gives the web application the ability to send and receive data from any street light that is a part of the DigiMesh network. A database server was created to store the data sent by every street light so that it can be retrieved, manipulated, and interpreted later. A web application was also created to let users easily view and analyze live data as 0well as historic data (e.g. power consumption over time, solar panel voltage over time, etc.). The web application also gives users the ability to remotely configure certain settings for each of their street lights.

Future Work

- **Remote Firmware Updates:** Implement the ability to update the street light firmware remotely so that bug fixes and additional features can be deployed easily
- **Custom Procedures:** Allow users to define custom protocols for individual or groups of street lights to execute in response to events (e.g. set all nearby lights to full brightness when a motion sensor detects movement)
- **Additional Peripherals:** Add support for controlling and reporting data collected from custom peripherals added to a street light

Capstone Project

RT-2M Audio Analyzer Replacement

Matthew Ardito, Daniel Catbagan, Carlo Figueroa,
Ethan Harte, Matthew Menning, Ian Perrigo

Abstract

As part of Plantronics' commitment to their customers, the company tests every product that they manufacture to ensure that no defective devices will reach the consumer. Audio signals are tested to ensure the device's speaker and microphone meet required performance levels. Currently, Plantronics uses the Neutrik RT-2M Audio Analyzer; however, this device is now obsolete and bottlenecks the testing procedure.

We developed a replacement audio tester that reduces total test time as well as implements modern technology to extend the lifetime of the tester. This new audio tester will increase the throughput of device testing across production.

Development Tools

PSpice

Allegro

National Instruments

LabVIEW

LabVIEW FPGA

LabVIEW RTOS

Slack

SmartGit

Google Drive

Overview

Audio I/O Hardware

Hardware for audio I/O was designed to provide channel selection, impedance selection, and variable gain. Selector circuits were designed using solid state relays. Programmable gain was achieved using discrete gain amplifiers that interface with the NI cRIO and the digital I/O module.

Embedded Controller

The cRIO receives the test parameters and interfaces with the digital I/O module to select channel, impedance, and gain. In parallel, the cRIO generates the multi-tone and its samples transferred using a DMA FIFO to the FPGA for audio out. The FPGA handles input before the cRIO performs signal analysis and transmits the results back to the testing PC.

Audio Power Amplifier

An audio power amplifier was designed to allow for acoustic tests. The amplifier used a class AB design to meet the 20W average power specification with increased efficiency. The amplifier uses op amps with negative feedback to maintain bias points.

Testing PC

The core of the testing PC software includes the GUI for test specification and the connection manager which uses LabVIEW's stream reader and writer methods for communication between PC and cRIO. The test parameters are transmitted to the cRIO where they are unbundled and executed for the audio test. After, the test results are sent back to the PC for the user to view.

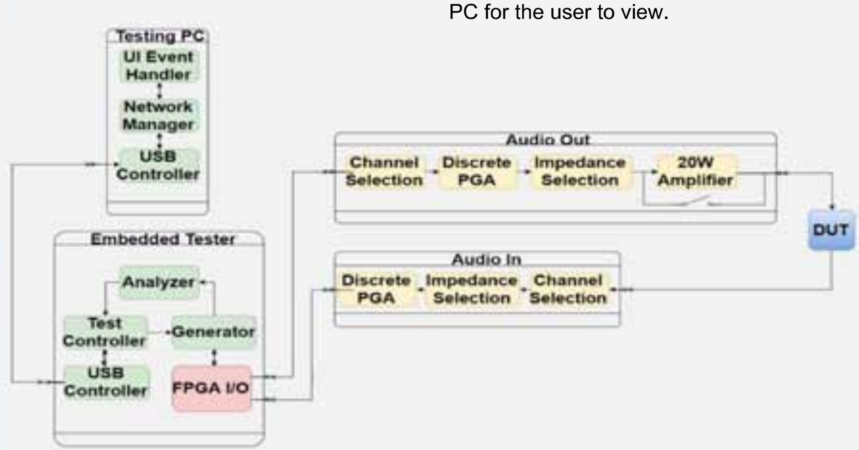


Figure 1: Block diagram of tthe audio tester system. Testing PC and embedded tester are programmed in LabVIEW, while the audio in and out modules are physical hardware.

Approach

The design of the audio testing system was divided into two sections: software and hardware. Software was implemented in LabVIEW for effective interfacing with the embedded controller: the National Instruments CompactRIO seen in *Figure 2*. Software was developed to communicate between PC and cRIO and to generate and analyze audio signals. Hardware was designed to interface the embedded tester with the device under test (DUT). The audio signals go through hardware stages: channel selector, programmable gain amplifier (PGA), impedance selector, and a 20W audio amplifier. The system flow is shown in the block diagram seen in *Figure 1*.

Figure 2: National Instruments CompactRIO to generate and analyze multi-tone singals as well as serve as the control interface between the PC and DUT.

Conclusion

This project provides a proof of concept for a replacement audio tester and outperforms the RT-2M. This provides Plantronics a long-term, modernized audio testing system. Future system development includes frequency sweep testing and support for additional channels.

Acknowledgments

Prof. Petersen for hardware design mentorship
Becker Sharif for team guidance
Russ Evans for LabVIEW advising

Capstone Project

Calm Response

Connor King, Gabriel Larwood, Henry Tran, Brent Hickey, Justin Chizer

UC SANTA CRUZ Baskin Engineering

POLICE STRATEGIES

Abstract

- Calm Response is a conflict de-escalation simulator designed for use by police departments in training their officers. The simulation is run in a virutal reality environment and involves the officer verbally interacting with a 3D avatar in real time. Programmed to emulate the behavior of a person suffering from a schizophrenic episode, the avatar will drastically alter its mood and response depending on what the officer says or gesticulates. Our goal is to provide officers with a tool to learn and practice appropriate de-escalation techniques in such an encounter.

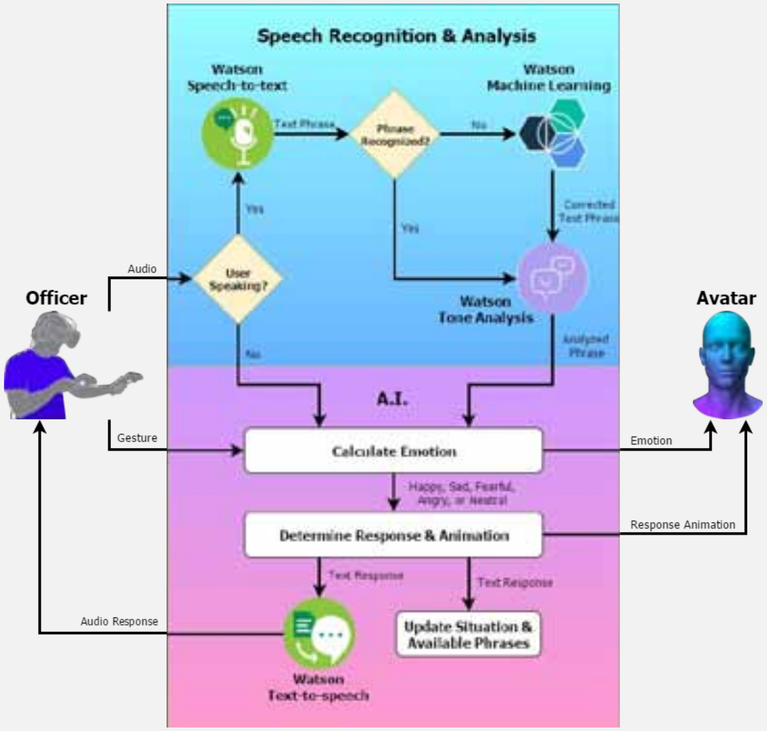
Approach

- Calm Resopnse was built with the Unity 3D engine. Utilizing the HTC Vive, we immerse the officer in a scenario where the officer is called to respond to a public disturbance at a subway station.
- For speech recognition and analysis we call upon multiple IBM Watson systems to convert the officer's voice to text, to analyze the tonal qualities of the text, and to help recognize the text as a meaningful phrase.
- The information from Watson is then fed into the A.I. as input, where it determines the best emotional, physical, and verbal response to what the officer said or motioned.
- As the interaction proceeds, the A.I. moves between various situations, which maintains context throughout the dialogue.

Overview

- The images above illustrate Calm Response in action. On the left is a glimpse of the subway scene with the avatar in motion. On the right is the officer interacting with the avatar using the HTC Vive and a microphone.

Architecture



Results

- Calm Response includes a fully rigged 3D avatar with lip-sync, animations, and eye tracking. In addition, while wearing the Vive headset, an officer can see their body in an animated police uniform.
- We constructed a functioning A.I. that generates accurate responses and can ask the officer questions.
- Calm Response supports basic multiplayer, where a second officer may enter the game and adopt the role of the avatar.
- Upon reaching a terminating dialogue, such as calling an ambulance or arresting the avatar, the officer may choose to review a detailed transcript of the interaction.

Acknowledgements

- We would like to express our gratitude to our sponsor Bob Scales for his leadership and support. We would also like to thank Professors Richard Jullig and Patrick Mantey for their guidance throughout the project.

Conclusion

- Through training with Calm Response, an officer can gain an improved understanding of how to de-escalate a crisis situation. As the project continues, we would like to incorporate more scenarios, new avatars, and voice acted recordings of the avatar's responses.

UC SANTA CRUZ
Baskin Engineering

Capstone Project

Calm Stop

Talal Abou Haiba, Annisa Karaca, Douglas Silva
Howard Ting, Maria Vizcaino

POLICE STRATEGIES

Abstract

We have developed an application for Android and iOS to alleviate the apprehension which shrouds a typical traffic stop. This is done by allowing the officer to conduct the majority of a traffic stop through the use of a mobile app, negating the need to approach the driver's vehicle. Both the driver and the officer can communicate via voice and text entirely through the app, and the driver can securely transfer their documents, such as their driver's license, registration and insurance to the officer. All interactions through the app are stored and can be later retrieved and analyzed.

Approach

Connection. A connection is established between an officer and driver through the use of a Google Nearby beacon. The beacon is used to emit a Bluetooth Low Energy (BLE) signal detectable by both the driver and officer.

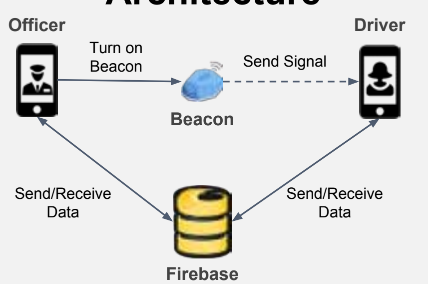
Data Sharing. Through the use of the live database Firebase, the officer's information (age, name, gender, badge number, department number) is shared with the driver, and the driver's information (age, name, gender) is shared with the officer.

Document Transmission. The officer can request a driver's documents. Once the request is made, the driver can securely transmit their documents to the officer with the touch of a button.

Communication. The officer can communicate with the driver via a text chat. All messages sent using the chat are preserved and can be viewed at a later date.

Feedback. Following a stop, both the driver and officer can securely upload feedback on the stop. If necessary, the driver can also submit a complaint to the officer's department.

Architecture



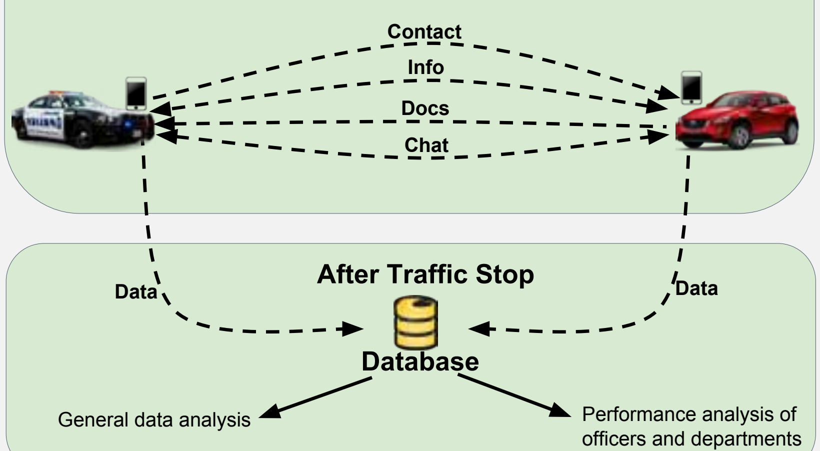
Overview

Every year, millions of drivers are involved in traffic stops across the country. With each traffic stop comes a bundle of anxiety and fear - fear for both the officer and the driver. The officer is left in the dark, wondering what will happen when he approaches the car, while the driver is forced to wait and hope that the officer will treat him correctly. Why should such a common occurrence be so tense and stressful?

A recent study has shown that over 75% of Americans own smartphones - by leveraging this spread of smart-devices and using them to facilitate the contact between the officer and the driver, we can remove the need for a face-to-face confrontation. By creating a mobile application which can allow the officer and driver to communicate, transfer documents, and record the interaction, we believe that we can help make traffic stops safer across the country.

During Traffic Stop

1. **Contact**: Officer connects with driver.
2. **Info**: Driver accepts connection, and basic profile info is exchanged.
3. **Docs**: Driver sends driver's license, vehicle registration, insurance to officer's app.
4. **Chat:** Text chatroom is shared for communication; a phone call is also possible.
5. **Data**: Data from the stop is stored (e.g. location, time, dialog record, survey/feedback).



Acknowledgments

Special thanks to our sponsor, Bob Scales, and our teaching staff, Richard Jullig and Morteza Behrooz.

Conclusion

The Calm Stop mobile app is in beta, with two separate versions available - one for police officers and one for drivers. Both versions are available on Android and iOS. Calm Stop is a tool to be used during traffic stops in order to reduce the tension between the officer and driver, and as a conduit for community members to easily give direct feedback to police departments.

De-escalation Tool. Upon connection, drivers receive basic profile information about the officer who stopped them, and officers can view the driver's prior history and comments from officers who have stopped him previously. Equipping officers with a background of the driver enables them to make informed decisions on how to proceed with the stop. The app also allows the driver to wirelessly send their documents, so that officers will not need to take the risk of approaching a vehicle to obtain these documents. After the documents have been shared, the officer can establish communication with the driver via the app. This aids in de-escalation by allowing communication to occur in a more calm and controlled manner for both parties.

Community Feedback. After the traffic stop, drivers are invited to complete a survey about how the stop was conducted. By providing the community with an easy way to submit feedback on the officers, this app has the potential to improve police-community relations. Widespread use of this app will provide a police department with a quantifiable metric of public perception of its officers. From this feedback, departments can make data-driven decisions in regards to their training programs and make individualized decisions for officers.

Future Work

Police Testing. Working directly with the Santa Cruz Police Department and getting feedback from the officers is a natural next step for the completed beta. Through this we can obtain feedback on the app and better prepare for a full release.

Beacon Emulation. Newer Android devices have the ability to emulate a beacon, removing the need for a physical beacon entirely. This would be a major improvement in terms of convenience, as the officer would not have to keep track of a small bluetooth beacon which is easily misplaced.

Phone Number Anonymization. A service to anonymize phone numbers would improve the privacy of the app's users by ensuring that calls made using the app don't share a user's personal cell phone number.

UC SANTA CRUZ Baskin Engineering

Capstone Project

Participant Data Tracking System

Mitchell Etzel, Darius Sakhapour,
Austin Shelton, Cedric Linares, Bereket Haile

SMART REVENUE

Abstract

SmartRevenue is a Market Research Firm of ethnographers who work to provide advanced analytics, field research staff, and data collection technologies to several well-known corporations. The project we developed for our sponsor is a digital system that can help them better track what they call a consumer's "path to purchase". An important part of this means to collect relevant data the average consumer has on their different digital devices to derive new and improved insights into the interactions they have with their electronics and the information sources used when deciding to make a certain purchase, online or in-store.

Approach

Chrome Browser Extension

A Chrome Browser extension allows us to unintrusively interact with the participant's browser on their Desktop or Laptop and track the data they generate from visiting sites such as Amazon, Jet, Target, and others. The data is collected by generating a chronological log of all visited URLs and periodically sending it to our Background Web Services. Using Google Account Sync capabilities we can also log URLs visited on the participant's Mobile Chrome Browser as well.

Android Mobile Application

The Android Application we built takes advantage of the built-in data tracking processes of the operating system to create a stream of use-data for all the Applications installed on a participant's phone. This then goes to our Web Services including data such as the last time a certain application was used, the total time the app has been open, and how many times it has been opened.

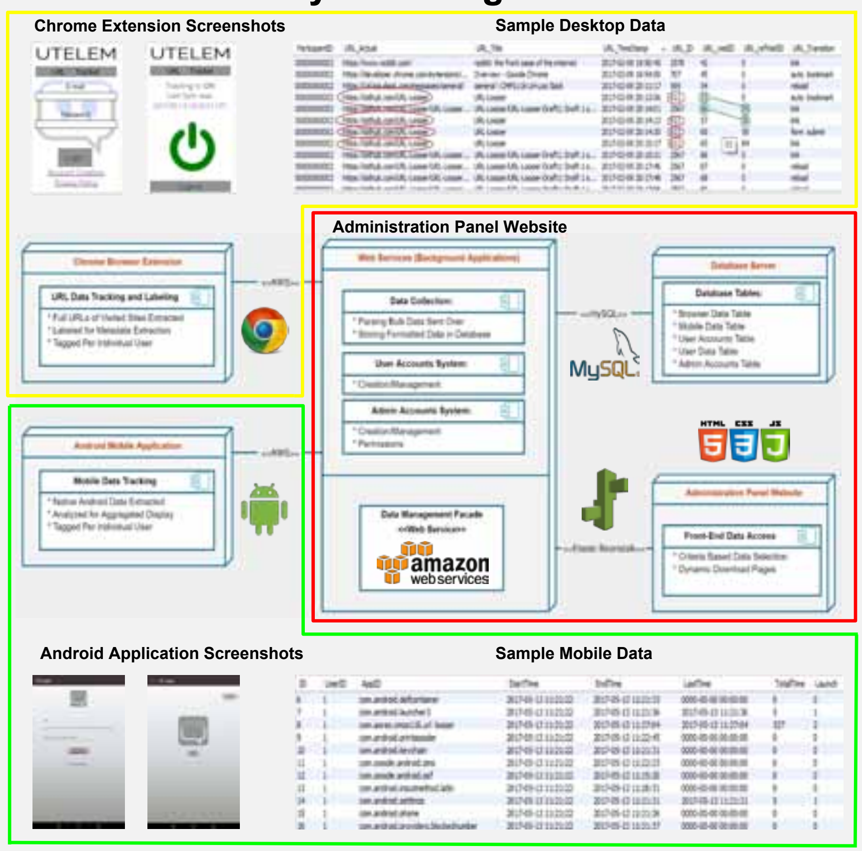
Administration Panel Website

This website is the backbone of our entire system. It hosts our Web Services that collect, format, and store the generated data in our database. In addition, it provides a Front-End system for our Sponsors to dynamically filter and download the data. Finally it allows for management of Participant/Admin Accounts.

Overview

In order to reach as many of SmartRevenue's pre-existing participants as possible we researched into both the capabilities of the different desktop and mobile operating systems as well as their respective market share figures. We discovered that with well documented APIs as well as over fifty percent of the market share, Google's Chrome Browser and Android Mobile Operating System were the best choices for our developmental path. We have created a three pronged approach for a system that grabs participant data from both the Desktop and Mobile Form Factors then arranges it for presentation to our sponsor. This is so that our sponsor can look at how the devices were used to supplement their participants' path to a purchase, as well as cross reference and examine the experiences of several of their participants in a similar context.

System Diagram



Analysis

The Administration Panel Website allows our sponsor to dynamically filter the data generated from all of their participants using our system so that it is within SmartRevenue's power to decide the scope of the data they access, view, and download. This means that their talented, pre-existing team of ethnographers and anthropologists can create their own differentiated insights, winning strategies, and comprehensive cost-effective solutions using the data generated from the system we created.

Results

Our Market Data Tracking System supports our project goals of developing software to help SmartRevenue make a new digital foray into data tracking so that they can have more valuable observations into their participants' "path to purchase". While we had to take in mind the different security constraints of the available data in the different operating systems and API's we used in our development, we believe there is a fair balance between the data SmartRevenue wanted and what data is currently available to be tracked.

Conclusion

In conclusion, this project was an amazing learning process for every member on the team. Moving forward, we believe a lot more analyses can be done digitally in the Web Services part of the project. For example, scraping aggregate data per participant, for both their URL and App data, then displaying it all in one place.

Acknowledgments

SmartRevenue
Dard Neuman
James Rizzo
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Patrick Kinkead

UC Santa Cruz
Professor Richard Jullig
TA Morteza Behrooz

Capstone Project

UTELEM

Research Panel Management System

Robert Pence, Adam Paz, Henry Chang,
Savanna Jordan, Sushil Patel, Joshua Pena

Abstract

SmartRevenue is home to over 1,000 trained ethnographers who collect data and perform analytics regarding a consumer's path to purchase and purchase experience in today's market.

Why? SmartRevenue advises clients on tactics to improve their marketing, merchandise, and sales plan.

To What Scale? Over one million observations and interviews have been conducted through over 600,000 participants in 90 categories. 150 retail banners in the U.S., Canada, Latin America, Asia, Europe, and Middle East.

UTELEM is a web application that allows the 50,000+ current and future panel members to actively participate in surveys, as well as provides SmartRevenue with an easy way to manage member accounts and survey data by replacing unscalable excel spreadsheets with a scalable software system.

Implementation

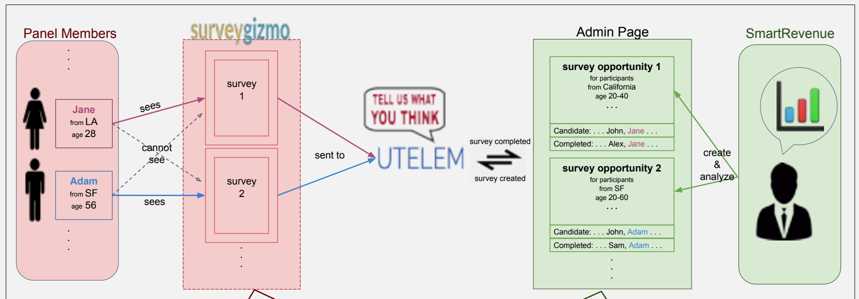
Panel Members are matched to surveys based on a set of demographic information that users fill in on signup and SmartRevenue employees set during survey creation. Our system matches the users to the surveys using a matching algorithm that allows users to view the surveys that match their demographic information.

SmartRevenue Employees can manage panel members through the UTELEM platform; It provides an easy to use admin interface that allows them to keep track of participant activity and data.

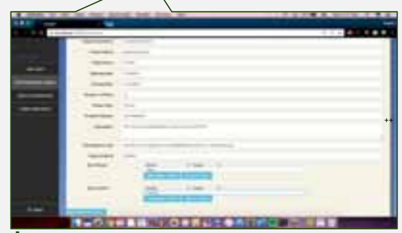
UTELEM utilizes a MySQL relationship database that is currently hosted on Amazon Web Services. It links panel member information, survey details and the criteria that SmartRevenue employees created, in order to match surveys to qualifying members.

Overview

UTELEM - An automated scalable solution for SmartRevenue to distribute surveys to qualified respondents selected from a large user base for easier data analysis process

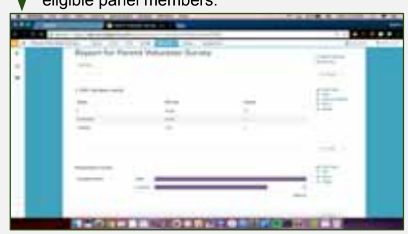


The landing page invites panel members to sign in or to create an account.



The admin page allows SmartRevenue to create surveys with demographic criteria matching eligible panel members.

The panel member page displays announcements and available surveys the member is eligible for, and allows user to edit their information.



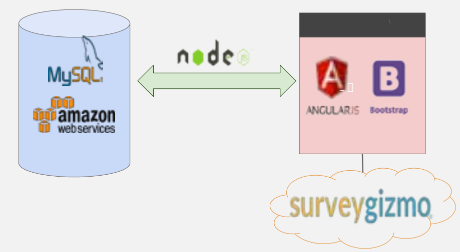
After panel members have completed surveys, SmartRevenue can collect and analyze the results on the survey page.

Acknowledgments

Thanks to Dard Neuman, James Rizzo, David Howard, Patrick Kinkead, and Angela Klepach for sponsoring and for providing directions as the SmartRevenue group. Thanks to Richard Jullig for his support and guidance as course professor throughout the development process.

Architecture

Database ←→ Server ←→ Website



A full-stack system that heavily utilizes Javascripts as communication languages and a scalable back-end based on relational database to maintain data field flexibility.

Project Goals

To **display information** appealingly**,** a simple and intuitive user interface is deployed for a large amount of demographic and survey information. A filterable table displays user information cleanly and concisely. SmartRevenue can also easily export the table to a external CSV file.

To achieve data **scalability**, the team created a criteria system which uses basic logic operations; This provides SmartRevenue employees with the ability to efficiently filter their database of panel members based on an extensive variety of demographic information. Using this system, SmartRevenue can target a highly specific group of users for each survey, improving the quality and correctness of their data, regardless of the number of participants involved. When a panel member logs onto the UTELEM platform and their demographics match the criteria requirements of a survey, the survey will be advertised and available for the member to take.

To **integrate SurveyGizmo** as part of the project requirements, the team faced a challenge in the form of 120 requests per minute API request limit. To combat this restriction, a request is only made to confirm whether or not a member has completed a survey. In addition, a queue was implemented to store requests in the event that the request limit is reached.

Capstone Project

TiVo Automated Video Testing

Arthur Chiao, Viraj Patel,
Aidan Gadberry, Xing Cao, Gerardo Espinoza

Abstract

TiVo produces set-top boxes that allow viewers to record content and stream it to any device, anywhere in the world. This project supplements the existing testing tools and frameworks TiVo engineers use for quality assurance and analysis, particularly regarding video transcoder hardware. This project consists of two major parts:

The first half of the project addresses the lack of automated self-validating tests in TiVo's current toolset. These tests are essential in analyzing video transcoding capabilities under various network loads.

The second half of the project tackles the development of Android and iOS applications, which allows us to test video transcoding capabilities on multiple mobile platforms.

Approach

We developed an automated testing toolset that evaluates the reliability and stability of video streaming from in-home TiVo devices to computers and mobile devices. For the first half of the project, we redesigned current TiVo quality assurance tests to be automated for Mac and PC testing through the use of Selenium, an automation webdriver framework. For the second half, we developed Android and iOS mobile applications and extended the automated tests using Appium, a test automation framework, to interact with these testing apps.

As the tests run on the TiVo devices, performance data is generated in the form of log files. These log files are then aggregated into a database and indexed. Splunk, a big data analyzer, was used to create charts and graphs to visualize the performance logs of the TiVo hardware to better assist TiVo engineers.

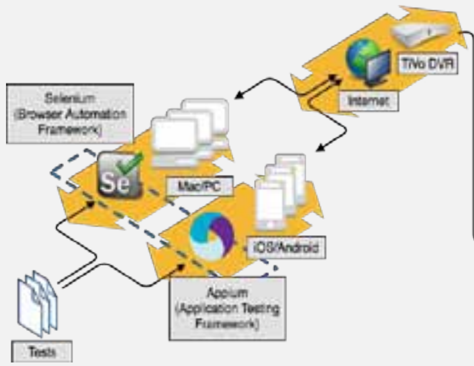
Overview

The basis of this project revolves around analyzing TiVo set-top box behavior under varying network conditions. The idea is to aggregate data from set-top boxes to determine the behaviors and correlations of streaming and transcoding capabilities. The focus of this project is to create a scalable automated test harness for which meaningful data can be mined and interpreted. This data is ingested into Splunk, an application capable of visualizing and analyzing the data, providing engineers with useful information about the device's transcoder capabilities.

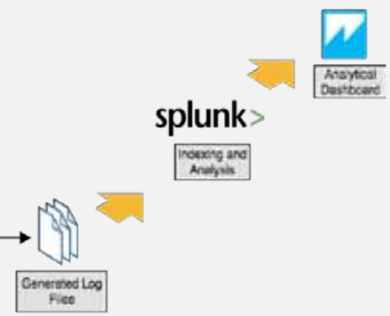
This test framework gives TiVo engineering and quality assurance teams the ability to scale tests that hinge on various network and bandwidth conditions. With the ability to simulate a variety of network conditions as well as fine-tune various parameters for video playback, we are able to generate meaningful data that we can then use to isolate transcoder failures and analyze its performance under various network loads.

Architecture

System Diagram



Data Analysis Diagram



Acknowledgments

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Dr. Tela Favaloro, Faculty Sponsor, UC Santa Cruz
Frank Howley, Senior Director, UC Santa Cruz
Morteza Behrooz, Teaching Assistant, UC Santa Cruz

Implementation

Our initial approach entailed rewriting the preliminary tests that were included for the video playback webpage. Tests were redesigned to self-validate for video playback events. Selenium is used in conjunction with pytest, a Python test framework, to automate our video playback tests. For mobile devices, we developed native applications for Android and iOS to stream video from the set-top boxes. We use Appium to automate our tests for both Android and iOS devices. Log data, generated by the tests and stored on the set-top box, is mined and analyzed with Splunk, allowing us to visualize and monitor set-top box performance. This provides automated testing and data analysis for TiVo developers across all three major platforms.

Results

The redesigned tests for both the video streaming web page and native mobile applications provide a more modular and robust approach when compared to the preliminary tests provided. Our framework expands on areas of the tests where coverage initially fell short, such as evaluating transcoder capability under sparse network bandwidth conditions. The testing framework allows us to map out the behavior of the streaming and transcoding capabilities of the set-top boxes.

Conclusion

Through all the challenges and impediments, we were able to successfully accomplish the goals set out for us. Expansion of the toolset to test video streaming to mobile devices was achieved in the second half of the project, creating a more modular testing system while maintaining the scalability. With improved quality assurance tests, TiVo engineers now have a mechanism to generate test data automatically and analyze it for hardware faults.

Capstone Project

WebScan Explorer

Austen Barker, Scott Brenner, James Garbagnati
Kevin Mai, Huimee Sanchez

Abstract

WebScan Explorer is a web application designed to run on traditional and mobile devices. It allows users to look up Cyber Security Threat Assessment Ratings (CSTAR) from the cyber security company UpGuard.

This application relieves UpGuard developers from the task of manually looking up data and gives journalists and other interested parties world-wide convenient access to UpGuard security scores and other relevant data.

Requirements

- The website must be able to run on multiple platforms for wide access and ease of use.
- The website must be able to serve a large number of users to meet the demand of the data.
- It must be easy to look up the data you are interested in.
- The data needs to be displayed in a way that is easy to understand.

Visit our project at

https://www.webscanexplorer.info/

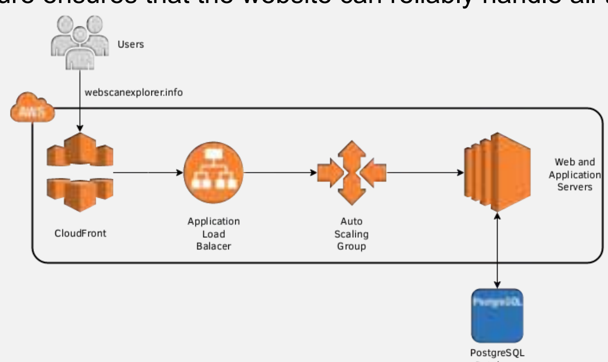
Overview

The image on the left shows a sample graph of the CSTAR values of two companies over a period of time.

The second image shows how the query builder automatically scales to fit onto a mobile device.

Design Choices

- *Reactive Design* - ReactJS was chosen to allow the application to resize to different specifications based on user devices and settings.
- *Clarity and Usability* - We decided to use D3 for data-visualization because of the native ReactJS support as well as the ability to implement user interaction.
- *Scalability and Reliability* - The Amazon Web Services-based architecture ensures that the website can reliably handle all traffic.



Functionality

Constructing a Query

Users enter relevant data for their query at the top of the website, such as the size of the company, time frame, or types of companies.

Processing the Query

After submitting the query, the query is processed in the back-end and retrieves a response from the database using a series of API calls.

Receiving the Data

The back-end synthesizes the response into a JSON package which is relayed back to the front-end.

Displaying the Data

The front-end receives the package of information and dynamically constructs spreadsheets or graphic representation of the data. The resulting information is displayed to the user.

Acknowledgements

We'd like to give a special thanks to Greg Pollock, Paul McCarthy, and UpGuard for giving us the opportunity to develop for WebScan Explorer.

We would also like to thank Richard Jullig and Morteza Behrooz for being our advisors during the course of this project.

Capstone Project

UC SANTA CRUZ
Baskin Engineering

Process Dashboard

Ion Fong Chan, Geoffrey Herz, Robert James,
Christian Kempis, Eunika Wu, Calvin Yang

xactly

Abstract

Xactly Corp provides a sales performance management solution as a multi-tenant Software-as-a-Service (SaaS). These services calculate incentive compensation for Xactly's enterprise clients, with batches of these services referred to as "jobs." Xactly's clients need timely and accurate calculations, which requires any problems in Xactly's processing of these jobs to be quickly identified and resolved. Xactly processes these jobs across a distributed computing infrastructure, making detection of issues a nontrivial task.

We created the Process Dashboard as a scalable visualization tool to assist the Xactly support team in identifying problematic jobs in their processing pipeline. Through highlighting long-running or halted processes in the dashboard, the support team can more quickly address issues and increase service efficiency.

Technologies

- **Maven:** Build automation tool Java development.
- **Spring** with Springboot: A framework to allow for dependency-injection. Springboot facilitates quick and easy deployment of Spring based applications.
- **JPA:** Java Persistence API.
- **React:** A javascript library for building user interfaces.
- **Node.js:** Event-driven I/O environment for executing JavaScript code server-side.
- **Oracle Database**

Approach

We replaced the cumbersome manual query process that the support team previously used to search for problematic jobs, using Java functions to automate individual SQL queries. The resulting table of long-running job statuses is rendered in realtime to the UI as an interactive, filterable, and searchable table. This increases efficiency in finding and addressing problematic jobs when a client notifies the support team of processing stalls.

We used a Gantt chart to display the processes over time, allowing the support team to visualize each process pipeline and predict when a process is likely to fail.

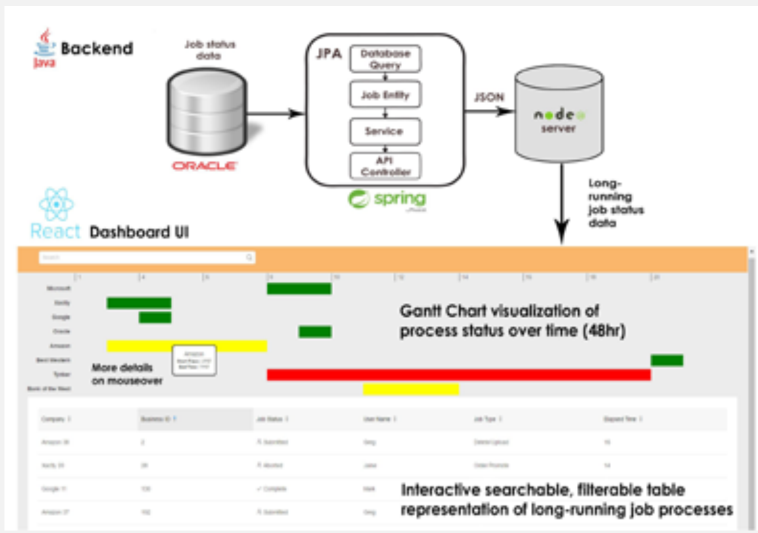
Overview

Xactly is a rapidly expanding business that provides a powerful processing service for companies that require enterprise business calculation. Specifically, Xactly processes their clients' sales data to compute incentive compensation solutions, such as calculating bonuses and commissions. These calculations are each considered a "job" that needs to be processed by Xactly across a distributed computing infrastructure. These job processes can stall and fail, and Xactly wants a tool to organize and visualize the jobs and their process statuses.

Process Dashboard is a web application support tool for Xactly that visualizes the process pipeline and allows for easy rectification of processing failures. It was our task to provide this tool to Xactly in order to assist their internal support team in identifying, servicing, and fixing issues within their system.

Our goal was to replace Xactly's previous text-based log system with an intuitive real-time visual interface that allows for their support team to (i) quickly identify a problematic job when a client calls in about a long-running job, and (ii) predict when a job is likely to fail (i.e. whether a job is long-running because the batch size is large or because the process stalled). We achieved both goals through (i) creating a filterable and searchable table and (ii) visualizing the process data with a Gantt chart.

Architecture



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Jean Xu, Sr. Software Engineer, Xactly Corp.
Anil Kona, Sr. Director of Engineering, Xactly Corp.
Swati Bhosale, Software Engineer, Xactly Corp.

Richard Jullig, Faculty Advisor, UC Santa Cruz
Morteza Behrooz, Teaching Assistant, UC Santa Cruz

Analysis

Gantt Chart

The Gantt chart visualizes Xactly's processes across time (48 hrs) to indicate where in the process pipeline a job stalls. This gives the dashboard a predictive capability. The support team can identify at a glance processes that are likely to fail and take proactive action, which was impossible with Xactly's previous text-based log system.

Table view of long-running jobs

The job status data of all long-running processes within a given processing server is represented as a visual table. We automated and streamlined the individual SQL queries the support team needed to make in their prior system and display the results in an interactive, real-time table in the Process Dashboard.

Filterable & searchable columns of the table

This visual table replaces the tedious methods required in the prior system with an intuitive interface. For example, the support team may now sort processes by business, process id, start-time, or time elapsed, or search for specific processes, whereas in the previous system they had to manually search through log data obscured by noisy information.

This allows for more timely support when the support team receives complaints from their customers on stalled or long-running jobs.

Conclusion

Process Dashboard allows Xactly's internal support team to effectively manage its processing pipeline, thereby allowing more timely support for customers and increasing productivity for the support team. The dashboard visualizes all processes and highlights problematic processes in an interactive UI, allowing the support team to quickly identify and rectify errors.

This dashboard vastly improves on Xactly's prior system for identifying problematic processes by automating previously manual SQL queries and visualizing the processes saliently with an interactive UI. The modular setup of Process Dashboard allows for additional services to be added to the program in the future.

Other future directions include using machine learning on historical data to predict and preemptively resolve jobs that are likely to fail.

We are very pleased to include posters for the Senior Design Projects that were done without industry sponsors. Some of these projects were instigated and/or sponsored by research at the Baskin School while others were created by students with the assistance of faculty mentors and TAs. We have selected three of these projects for presentation in the program, and all were invited to display their posters that summarize their projects.

Cube Set
Hummingbird
Smart Phone Fluorescence Microscope

Capstone 2017 Deans Award

UC SANTA CRUZ
Baskin Engineering

UCSC SlugSat

Matt Carberry, Matt Moranda, Eric Ortega
Eric Wells, Marcel Tress, Navneet Kaur

Introduction

Following in the trail of the many educational satellites that have already been launched, the UCSC CubeSat project is working towards placing a satellite into low earth orbit. The main payload of this satellite will be a linear transponder for communications use by amateur radio operators.

Our team will develop the overall mission specifications for the satellite and design a linear transponder subsystem of the project. The final deliverable will result in an operational linear transponder to provide a foundation for future students to continue on the satellite.

Envisioned Future

The future of this project depends on student participation beyond this senior design project. There are many other concerns for the satellite, including mechanical, thermal, and power system design to name a few. The team's success depends on new student involvement so we are reaching out to clubs on campus. Anyone is welcome and encouraged to participate!

Launch Opportunities

Purchasing a launch is well outside the means of the project budget, consequentially the UCSC CubeSat is looking for a launch opportunity through government or corporate sponsored educational launch programs. Educational launch providers in the past have consisted of United Launch Alliance (ULA), NASA's CubeSat Educational Launch of Nanosatellites initiative and the US Air Force's University Nanosat Program. In the future as space becomes more accessible, our team believes that there will be more opportunities for educational institutions to launch small satellites. ULA has stated that in the future they have a goal to add university CubeSat slots to nearly every Atlas and Vulcan Centaur rocket launch. We plan to have UCSC students ready to compete for those opportunities.

Transponder Design

Our team developed a stronger foundation in RF design principles and electromagnetic theory. These valuable skills were then used for the design which included antennas, frequency mixing, local oscillators, phase locked loops, preselect/image/channel/output filters, IF/low-noise/power amplifiers, and automatic gain control.

Design Considerations

Designing an operational linear transponder required considerations to orbit, frequency operation, regulation, attitude control, ionosphere propagation, and antenna design.

UC SANTA CRUZ
Baskin Engineering

Capstone Project

Hummingbird: Acoustic Control for Electronic Musical Instruments

Joey Devoto, Marcus Gronberg, Andre Marquez, Jason Vance

Abstract

There are numerous tools that allow artists to create electronic music. However, the primary method of composition is either some type of digital piano or mouse-and-keyboard composition in a Digital Audio Workstation. Our goal is to deliver a system that makes the process of creating digital music more intuitive and easy.

Approach

Platform

- Developed on a CY8CKIT-059 PSoC 5LP Prototyping Kit

Audio Acquisition:

- The signal from the microphone is fed into an analog signal conditioning circuit
- The system captures the signal using a successive approximation ADC

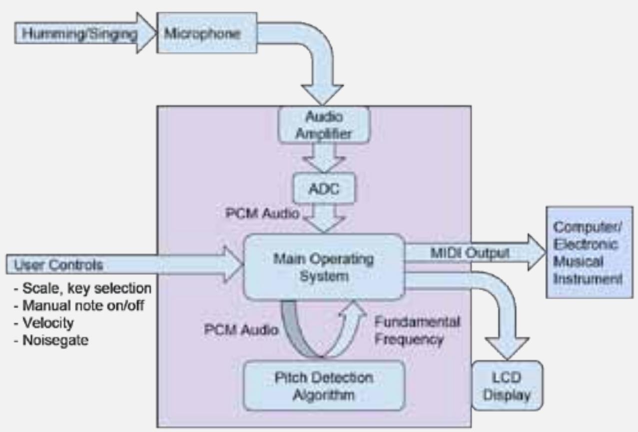
Pitch Detection Algorithm:

- The input audio is sampled at a rate of 4000 samples/second into frames of 256 samples
- Each frame is processed by the pitch detection algorithm to detect the fundamental frequency
- This frequency is converted into a MIDI note, and is output over USB or MIDI port.

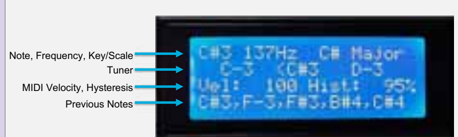
Overview

The Hummingbird is a music tool that allows the user to play musical instruments and compose music by humming. The pitch hummed is used to generate MIDI data, which can be used to play instruments or record compositions using a Digital Audio Workstation. This process happens in real-time, giving the user the sensation and control associated with playing a traditional instrument, while retaining the low skill required to hum melodies as they come to mind.

Hummingbird System:



User Interface:



To improve the accuracy of the MIDI note, the user can select a specific key and scale. Each frequency interpreted by the pitch detection algorithm is snapped to one of the notes in this scale.

Acknowledgments

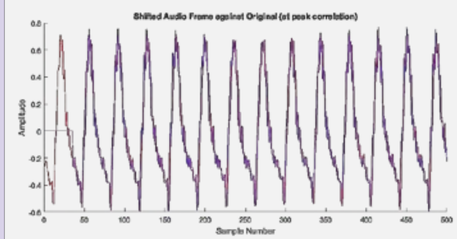
Project Mentor – Dr. Patrick E. Mantey

Peer Advisor – Eric Cao

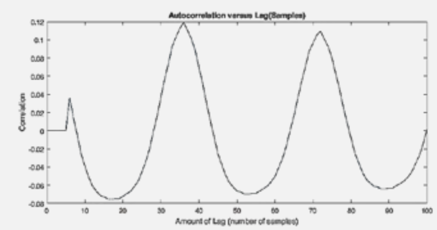
Analysis

Pitch Detection Algorithm (Autocorrelation):

- The PDA functions by comparing the original audio frame to time lagged versions of itself.



- By comparing the correlation of different amounts of lag, the period of the signal can be estimated.



Conclusion

Our team's ambition is to break down the barrier between creative thought and execution. The application of this system is not limited to music production, and might be applied towards musical education as well. We hope to move the project into commercial development in the near future.

Baskin School of Engineering Capstone Project

Smart Phone Fluorescence Microscope

Christopher Espino, Misbah Khan, Nathan Ng, Joshua Passmore

Abstract

Fluorescence microscopy has become an essential tool in biomedical science for the detection, diagnosis, and treatment of various diseases. The capability to interface with nano-sized objects far exceeds the capabilities of direct light, or brightfield, microscopy. However, optical imaging of nano-sized objects using traditional methods is challenging; Commercial fluorescence microscopy systems used for nanoscale optical imaging are cost prohibitive, require training, and are limited to lab based settings due to their large size.

This project aims to address the financial, technical, and distributive barriers that prevent individuals from utilizing a fluorescence microscopy system by designing a low cost, user friendly, and portable platform that attaches to a smartphone. The device allows nano-sized bioparticles, such as viruses, to be imaged and provides a user interface with processing software to count and categorize the imaged bioparticles.

Approach

The design of the microscopy platform falls into 3 top level categories: Optical Hardware, Mechanical Design, and Software Development.

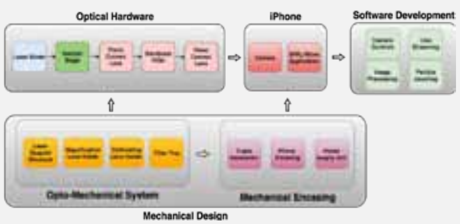


Figure 1: High level block diagram for platform characterization

Optical Hardware:

The optical team worked to reduce the necessity of multiple components found in traditional commercial microscopes. The excitation filter and dichroic beam splitter were eliminated to create a simpler, more portable solution for imaging nano sized bioparticles. Design of the compound lens system, component selection, and constant test imaging of the fully integrated system were top priorities.

Mechanical Design:

The mechanical design included fine resolution positioning of the various optical components, a laser positioning guide, and 3-axis control of the sample during testing. The complexity in mechanical features lied in the continuous evolution of the optical hardware and the need for fine imaging adjustments. These iterative designs were 3D printed with each major revision in opaque resin, which allowed optical isolation and testing of optical elements in a variety of completion states.

Software Development:

Software design focused on iOS app development that facilitated image capture, processing, and autonomous data analysis. Data analysis of fluorescent images using the iOS platform simplified the user learning curve. The user can capture a live feed and simultaneously process the image via digital focusing and exposure adjustment.

Design Overview

Mechanical design was intimately linked to optical part selection. Solid modeling and integration of optical elements into the desired form factor was done in Solidworks. Design hierarchy follows in accordance to the block diagram in the Approach section. There are 14 individual parts printed to support and functionalize the optical elements with key components discussed below:

iPhone 6/6S Case
- allows interface to phone and positioning elements for a AAA battery pack, power toggle switch, z-axis translation stage, and optical element holder

Laser Support Structure
- provides a laser mounting location with position adjustment via set screws and support for an XY-axis translation structure

XY Translation Structure
- (composed of four parts) is a custom printed, two-axis translation stage designed for modularity, efficacy, and reasonable price point. Total cost is less than $10 and supplies adjustment resolution of 600um per turn, with fine adjustment sub 50um

Figure 2: Rendered image for v6 integrated design of fluorescent microscopy platform featuring 3 axis control, laser derating to Class 1, swappable optical elements, and minimized form factor

Sample Holder
- provides containment of 1"x1" glass slides and fluidic structures for fluorescent imaging. Passthroughs for fluidic tube entry and exit and translation toleranced openings are present

Sample Tray Cover
- uses a barrel hinge with magnetic closure mechanism to shroud the sample from ambient light and prevent dissipation of laser light. This derates the excitation laser source to a class 1 emission characteristic

Swappable Optical Element Trays
- interchanging parts to alter device utilization (i.e. different emission characteristic filters, lens)

Results

Our engineering team has implemented a low cost, portable, and user friendly fluorescence microscopy platform to image marked biosamples. This design offers affordability and portability with our platform costing 300x less and weighing 200x less than commercial fluorescence microscopy systems.

Using our system, we were able to resolve and image nano-sized particles ranging from 200nm (250x smaller than the diameter of a human hair) to over 25um, with results similar to a commercial products. In addition, our system was able to quantify the image data by counting the number of particles in the image.

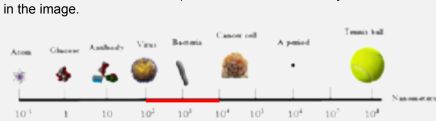
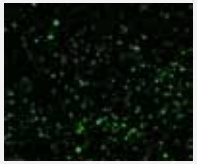


Figure 3: Relative size of objects on a Nanometer scale. Red Line (from 100nm to 1000nm) indicates size of fluorescent proteins that were tested using our microscopy platform.

The images below show a comparison between 450nm green fluorescently labeled proteins imaged using a commercial fluorescent microscopy system and our smart phone microscopy system.



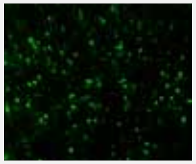


Figure 4: (Left Image) Reference image taken with a Nikon Eclipse Ti-E commercial fluorescence microscopy system, using a Zyla CMOS Camera
Figure 5: (Right Image) Sample image taken with our smartphone microscopy platform, using an iPhone 6s Camera

Analysis

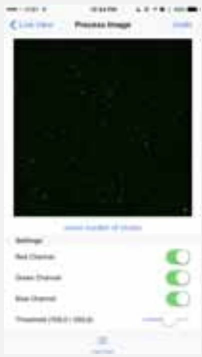


Figure 6: UI for image processing selection

The iPhone application provides an interface for manipulating the device's camera in order to bring the sample into focus. A user may then capture the view of the camera and process the image. Image processing is handled by the computer vision library OpenCV. The software performs a variety of manipulations on the image, some of which are user controllable. For example, the user can remove certain color channels from the image, and adjust the sensitivity of the particle detection.

The software is able to detect the number of particles present in a given sample, with an accuracy of 95%, as seen in the image to the right. Dynamic threshold adjustment, channel color selection, and exposure time can be adjusted to ensure count accuracy.

Figure 7: Software detection of particle number

Conclusion

Our design team has developed a smart phone fluorescence microscopy system with an accompanying application/UI for use in research applications. We have successfully reduced the cost, size, and operational learning curve of a fluorescence microscopy system considerably. The resulting product is able to excite, image, and analyze nano to micro sized particles ranging from 200nm to 25um. Added design features include 3-axis translation control, swappable laser diodes for various fluorescent protein markers, and image processing of dynamic particle count over time. These features act as tools to make data more accessible and easier to extrapolate which minimizes operation time, labor, and allows greater accuracy/consistency in results.

Future project goals include integration with the Android OS environment, creation of a more portable LED excitation system, improving mechanical platform interchangeability, test automation, and machine learning algorithms for categorizing particle trends and predictive analysis.

Acknowledgements

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