Pegasus-21
Midyear Design Review

Senior Design Project
Fall 2016
Our Team

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Our Mission

We aim to create a turret-mounted system capable of transmitting audio in a directed beam that tracks the listener.
Acoustic Directionality

- Directionality of sound correlates with the size of speaker compared to wavelength. The formula for far field directivity of a flat circular piston in an infinite baffle is

\[
p(\theta) = \frac{p_0 J_1(k_a \sin \theta)}{k_a \sin \theta}
\]

where...

\[k_a = \frac{2\pi a}{\lambda}\]

- Piezoelectric transducers approximate the ideal acoustic piston

- Directionality is achieved by maximizing the piston radius and minimizing the wavelength

(“Loudspeaker” n.d.)
Sound From Ultrasound

Technology to create directional, highly focused soundbeams:

- An array of transducers emits ultrasonic carrier waves in the direction of target
- Air, as a nonlinear medium, acts as a demodulator (no need for receiver)
- When the modulated wave reaches a person the modulated sound becomes audible

(Nema, “Ultrasonic Directive Speaker”)
Sound From Ultrasound

http://www.soundlazer.com/what-is-a-parametric-speaker/
Demonstrate the functionality of the individual stages

- Range of motion in X and Y direction for Turret
- Directionality of piezo-array speaker
- Face detection and recognition
System Block Diagram

Mobile Phone App
- user interface
- rapid image capture
- image compression
- volume/language adjustment

HTTP over Wi-Fi/LTE

Data Server
- Web Server
- Database
- Neural Net Trainer
- Process Engine

Pegasus Turret Mount
- Servo Motors XY
- Arduino
- Nvidia Jetson TK1
- Power Supply
- Webcam

TCP over WIFI

Soundlazer
- Audio Pre-Amp
- DSP
- Oscillator
- Transducer Array
- Power Supply
- PWM Modulator
- Ultrasonic Amplifier

Analog/Digital
Pegasus Turret: Block Diagram
Arduino

- Communicates with NVIDIA Tegra TK1 over I2C
- Receives new position data from NVIDIA
- New data arrives every time an image is processed on the NVIDIA
- Turns the servos, controlling the turret to the desired position
- Upon request, sends back turret position to NVIDIA
Hardware: Minor Components

**Servo Motors**
- Input Voltage: 6V
- Operating Speed: 0.15sec/60deg
- Stall Torque: 3.95 kg-cm

**Arduino Nano**
- Input Voltage: 7-12V
- Logic Level: 5V
- Clock Speed: 16MHz
- PWM Capable

**Webcam**
- 3.0 Megapixel
- 1280 x 720 pixels
- RightLight Technology
Soundlazer

- 12VDC power input
- 120dB ultrasonic output
- Usable range indoors: 30.0 feet
- Beam size of around 3 feet
- 40 GHz Carrier Wave
- Pulse Width Modulation
- Digital Signal Processing
- 5 Watt Carrier Wave
NVIDIA Jetson TK1

- GPU: NVIDIA Kepler GK20a with 192 CUDA cores (326 GFLOP)
- CPU: Quad-Core Cortex-A15 32-bit ARM Processor
- DRAM: 2 GB DDR3
- Storage: 16GB fast eMMC 4.
NVIDIA Jetson TX1

- GPU: NVIDIA Maxwell GPU with 256 CUDA cores (1 TFLOP)
- CPU: Quad-Core Cortex-A57 64-bit ARM Processor
- DRAM: 4 GB DDR4
- Storage: 16GB fast eMMC 4.51
- Wi-Fi
iphone App: Block Diagram

1. User interface
2. Rapid image capture
3. Compression framework
4. Language & volume adjustment
5. Protocol
6. Data connection
7. Cloud connection
iPhone App System Requirements

**Images**
- 720p image standard

**Frameworks**
- RealmSwift
- .tar.gz compression
- sockets
- notifications

**Targeting**
- Override turret position
- Videofeed with aiming reticule
Server: Block Diagram

- Web Server
- Process Engine
- Neural Net Trainer
- Turret TCP Socket

Database
Server System Specifications

Database
- SQLite will suffice for prototyping purposes

Neural Net Training
- Train 2-person neural net in under 5 minutes for demos
- Send push notification
**Tracking**

**CAMShift + Kalman Filter**

- Currently utilizing a CAMShift algorithm for face tracking

- Next step to integrate Kalman Filter as described in *Improved CAMshift Algorithm Based on Kalman Filter* ("Advanced Science and Technology Letters."")
System Performance Test
Looking Forward

- 3D Print an acoustic horn Array to increase speaker directionality
- 3D Print turret chassis and casing
- Implement algorithms on NVIDIA TX1
- Build App
- Full Integration of subsystems

http://www.thingiverse.com/thing:45649/apps/#apps
CDR Deliverables

**Keith:**
- Fully working software pipeline for tracking, interfaced with the turret

**Trevor:**
- Design and 3D print acoustic horn and turret chassis
- Design universal power supply

**Istvan:**
- Build iPhone application skeleton
- PCB for power supply
Web. Cam-Shift Info

Soundlazer abstract


Questions

THERE WILL BE NO QUESTIONS

ARE THERE ANY QUESTIONS?
Backup Slides

NEEDS BACKUP

DOESN'T CALL AVENGERS
Mathematics of Secondary Waves

\[ \nabla^2 p_s - \frac{1}{c_0^2} \frac{\partial^2 p_s}{\partial t^2} = -\rho \frac{\partial q}{\partial t} \]

\( p_s \) is the secondary wave sound pressure, \( p_1 \) is the primary wave sound pressure, \( \beta \) is the nonlinear fluid parameter, and \( c_0 \) is the small signal sound velocity.

The solution for Eq. (2.2) may be expressed by the superposition integral of the Green's function and the virtual second source [right side of Eq. (2.2)] as shown in Eq. (2.4).

\[ p_s = \frac{1}{4\pi} \iiint_v \frac{1}{|\mathbf{r} - \mathbf{r}'|} \frac{\partial^2}{\partial t^2} q(\mathbf{r}t - \frac{\mathbf{r} - \mathbf{r}'}{c_0}) d\mathbf{r}' \]

Where \( \mathbf{r} \) is the observation point position vector, \( \mathbf{r}' \) is the source position vector and \( v \) is the nonlinear interaction space.
Ultrasonic Directional Speaker Circuit
MDR Deliverables

**Sound Spear:**
- Functioning amplifier and signal generator prototype capable of driving an ultrasonic waveform through a piezoelectric transducer

**Pegasus Turret:**
- Functioning turret with transducer array mounted

**iPhone App:**
- Version b.1.0
- Successfully sends pictures and preferences to the server

**Server Cluster:**
- Trains the neural net
- Protocols created to communicate with the app and turret
Compacted System Overview

Data Server
- Web Server
- Turret TCP Socket
- Database
- Process Engine
- Neural Net Trainer

TCP over Wi-Fi

Pegasus Turret Mount
- Servo Motors XY
- Arduino
- Nvidia Jetson TK1
- Sound Lazer
- Power Supply
- Webcam
How can it be done?

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