ARK
SDP18 | Team 21

MDR
12/07/2017
Team

Matteo Bolognese, EE
Device Design, Assembly
PCB Design, & Power

Chad Klinefelter, CSE
User Interface & Backend
App Development

Jackie Lagasse, CSE
Augmented Reality
App Development

Ethan Miller, EE
Device Communication
Sensor Interfacing

Department of Electrical and Computer Engineering
Advisor: Professor Holcomb
PDR Feedback / Problem Statement

- Our previous design (OmniRoll) could not find a niche to separate from other low-cost omnidirectional treadmills made for home use.
- Instead, decided to pivot focus to Augmented Reality (AR).
- **Problem Statement:**
  - AR users are unable to incorporate extremities into a game unless their device camera can directly face them.
  - There are no inertial sensing products for extremity tracking that can be used in AR gaming.
Augmented Reality (AR)

What is Augmented Reality?

- Computer responds to physical environment through object recognition or computer vision
- User requires view of physical world through goggles or screen
- World is augmented through overlaid visuals, sounds
- Distinct from Virtual Reality (VR)

http://www.solidapps.co.uk/blog/2013/02/now-available-edrawings-for-ios-with-augmented-reality/
Background Information

ARK (Augmented Reality Kick) is an augmented reality gaming device with an accompanying Android App.

- Soccer is played by roughly 265 million people worldwide (FIFA survey).
- AR is capable of running on most new smart phones (iPhone, Galaxy, Pixel, etc.) with APIs directly from OS developers.
- Why a separate foot attachment?
  - To overcome current limitations in AR gaming. In particular, being unable to incorporate extremities into the game unless the phone camera directly faces the extremities.
  - Sensor on foot can transmit data to phone, where it can then be acted upon.
Our Vision

On demo day we plan to present the following:

- Bring user to an open space
- User wears headset and kick tracker
- Start ARK app on phone
- App displays virtual soccer ball and goal
- User kicks foot, observes movement of soccer ball
System Requirements

- App must have clean and user friendly interface, must create virtual soccer goal and ball, must allow ball to move when kicked
- App must properly determine user’s kick speed, direction
- Ball must move realistically in relation to user's movement (should miss if kicked in wrong location, consistent speed)
- System delay must be low enough to retain immersion (satisfactory at less than 300ms, ideally less than 100ms)
- Kick tracker must be lightweight, enclosed, and easy to calibrate
- The device must be rechargeable, last for a few hours of continuous use on one charge, and be as inexpensive as possible
Concept Diagram

Kick Tracker
- Inertial Sensor
- Microcontroller
- Bluetooth Module
- Battery

Bluetooth LE

Signal Processing
- Process Environment with Camera
- Process Ball Movement

AR Game
- Data Rx
- Represent Motion in Game Environment

Smartphone with Headset
All components in foot attachment will be connected together in PCB.

Battery will be rechargeable.

User data consists of user's score count, i.e., how many goals earned in this play through.
Microcontroller

Atmel AVR ATMega32

- Have experience from using in ECE 353, easily obtain programming hardware and AVR Studio
- Has several communication interfaces including
  - USART for Bluetooth module
  - ADC and I2C for sensor data
- Clock rate up to 16MHz means higher data throughput
- Inexpensive, about $6 each

Bluetooth Module

HC-05 Wireless Bluetooth Serial Transceiver

- Contains USART module to communicate with ATMega32 processor
- Uses standard Bluetooth functionality
- One line BT Tx to uProc Rx, another line uProc Tx to BT Rx
- Inexpensive, about $9 each

Sensors

Bosch BMI160 Shuttle Board

- Includes BMI160Accelerometer / Gyroscope and BMI150Magnetometer sensors
- High quality, currently used in high end mobile phones for augmented reality applications
- Can use SPI or I2C communication
- Many included features such as step counter, power management, timestamping data, capable of integrating external sensor data

Sensors

Adafruit ADXL335

- 5V Triple-axis Analog Accelerometer
- Small, thin, low-power, temperature stability
- On-board 3.3V regulator
- Minimum full scale range of ±3g
  - -3g is at 0V output
  - 0g is at 1.65V output (half of 3.3V)
  - 3g is at 3.3V output
- Can measure dynamic acceleration
  - Motion, shock, and vibration

https://www.adafruit.com/product/163
Battery

- Strongest option: LiPo 18650 cell (~$5 per)
  - Single cell outputs 3.7V, nominal capacity 2600mAh (dependent on manufacturer)
  - 44g weight, slim packaging useful for placement on leg
  - Will be in enclosure to protect cell from damage

- Cheaper alternative is NiMH cell, safer to store, however lower voltage (1.2V) would require more cells to power devices

https://www.orbtronic.com/vtc5-18650-battery-imr-2600mah-us18650vtc5
### Power System Analysis

#### Device

<table>
<thead>
<tr>
<th>Device</th>
<th>Average Current</th>
</tr>
</thead>
<tbody>
<tr>
<td>ATMega32L @8MHz, 3.3V, no PicoPower</td>
<td>~6 mA</td>
</tr>
<tr>
<td>HC-05 Bluetooth (no power savings)</td>
<td>~8 mA</td>
</tr>
<tr>
<td>Bosch BMI160 (no low power)</td>
<td>~1.1 mA</td>
</tr>
<tr>
<td>Adafruit ADXL335, 3.3V</td>
<td>~0.45 mA</td>
</tr>
</tbody>
</table>

- Assuming the highest power consuming sensor, average current will be roughly 15.1 ma.
- Assuming a 2500mAh cell,

\[
2500\text{mAh} / 15 \text{ mA} = 166.7 \text{ h of battery life per charge}
\]

- Energy storage is not critical aspect of design

[https://www.orbtronic.com/vtc5-18650-battery-imr-2600mah-us18650vtc5](https://www.orbtronic.com/vtc5-18650-battery-imr-2600mah-us18650vtc5)
Application Development

- App being developed in Android Studio
- Data primarily transferred over BT sockets (similar concept to TCP sockets)
- Augmented Reality code will be based off the free ARCore API from Google
- Will be using Google Pixel XL and / or Samsung S8 phones, both compatible with ARCore API

Headset

Starlight SL-001 VR Headset

- Compatible with AR and VR applications
- Expands to fit various phone sizes, can fit both phones we are interested in using
- Lenses are adjustable for different eye distance and optical focus
- Inexpensive, $12-$25 per pair

http://www.starlightvr.com/
## Budget & Cost Analysis

<table>
<thead>
<tr>
<th>Items to Date</th>
<th>#</th>
<th>Total Cost</th>
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</thead>
<tbody>
<tr>
<td>Ball Bearings</td>
<td>30</td>
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<tr>
<td>ATMega32</td>
<td>2</td>
<td>$15 (with shipping)</td>
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<tr>
<td>HC-05 Bluetooth</td>
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<td>$18</td>
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<td>BMI160 Board</td>
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<td>$79 (with shipping)</td>
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<tr>
<td>Adafruit ADXL335</td>
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<td>$15</td>
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<tr>
<td>Battery</td>
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<td>$11</td>
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<tr>
<td>PCB Manufacture</td>
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<tr>
<td>Starlight Headset</td>
<td>1</td>
<td>$12</td>
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<tr>
<td><strong>Total:</strong></td>
<td></td>
<td><strong>$212</strong></td>
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<table>
<thead>
<tr>
<th>Items per Device</th>
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<th>Bulk Cost</th>
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<tr>
<td>ATMega32</td>
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<td>$4.46</td>
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<td>HC-05 Bluetooth</td>
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<td>Inertial Sensor</td>
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<td>Battery</td>
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<td>Starlight Headset</td>
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<td><strong>Total:</strong></td>
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<td><strong>$44.21-64.21</strong></td>
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</table>

Even cheaper if user has their own headset!
# MDR Deliverables

<table>
<thead>
<tr>
<th>Deliverable</th>
<th>Status</th>
<th>Team Member</th>
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<tbody>
<tr>
<td>Select and purchase inertial sensor, microcontroller, Bluetooth module, and battery</td>
<td>Completed (except battery)</td>
<td>Matteo &amp; Ethan</td>
</tr>
<tr>
<td>Assemble purchased components together</td>
<td>Completed</td>
<td>Matteo, Jackie, Chad, &amp; Ethan</td>
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<tr>
<td>Send data from inertial sensors to phone over Bluetooth</td>
<td>Completed</td>
<td>Matteo, Jackie, Chad, &amp; Ethan</td>
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<tr>
<td>Display data from sensors in Android App</td>
<td>Completed</td>
<td>Jackie &amp; Chad</td>
</tr>
</tbody>
</table>
Proposed CDR Deliverables

App
- Augmented reality must be implemented to show soccer goal and soccer ball (Jackie)
- Backend of app must store sensor data, model data to analyze foot movement (Chad & Ethan)

Device
- Kick accuracy measurement (Ethan)
- Design PCB, send for fabrication (Matteo)
- Design foot mount structure and enclosure (Matteo)
# Gantt Chart

<table>
<thead>
<tr>
<th>Assignee</th>
<th>Task</th>
<th>Start</th>
<th>Bench</th>
<th>CDR</th>
<th>Break</th>
<th>Bench</th>
<th>FDR</th>
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<tr>
<td>Matteo</td>
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<td>Jackie</td>
<td>Develop App, Soccer Goal</td>
<td>Jan. 29</td>
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<tr>
<td>Chad</td>
<td>Develop App, Backend</td>
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<tr>
<td>Ethan</td>
<td>Integrate Sensor w/Backend</td>
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<tr>
<td>Matteo</td>
<td>Design Foot Mount, 3D Print</td>
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<td>Jackie</td>
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<tr>
<td>Chad</td>
<td>Develop App, UI</td>
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<tr>
<td>Ethan</td>
<td>Assess Accuracy of App</td>
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<tr>
<td>Matteo</td>
<td>Assemble PCB, Foot Mount</td>
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<tr>
<td>Jackie</td>
<td>Develop App, Motion Accuracy</td>
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<td>Chad</td>
<td>Develop App, Motion Accuracy</td>
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<tr>
<td>Matteo</td>
<td>Assess Accuracy of App</td>
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<tr>
<td>All</td>
<td>Final Integration of System</td>
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</table>
Thank You!

Questions?
Bulk Pricing References

ATMega32
https://www.mouser.com/ProductDetail/Microchip-Technology-Atmel/ATmega32-16PU/?qs=aqrrBurbvGdpkmgj7RWmsQ%3D%3D

HC-05
https://www.dhgate.com/product/hc05-jy-mcu-anti-reverse-integrated-bluetooth/401037278.html#s1-1-1b;srp|2321066803

LiPo Battery
https://www.dhgate.com/product/hot-vtc5-18650-us18650-3-7v-30a-2600mah-vtc5/402133835.html#s1-0-1b;srp|0029339464

PCB
https://www.pcbcart.com/quote