UMass Amherst

Comprehensive Design Review

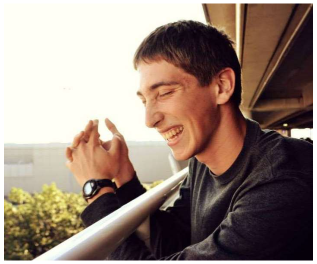
Team 1 (AutoUmp)

March 9th, 2017

Department of Electrical and Computer Engineering

Advisor: Wolf

The Team



Timothy Adams
CSE

Justin Marple
CSE

Jason Camiel
EE

Matt Barnes
EE

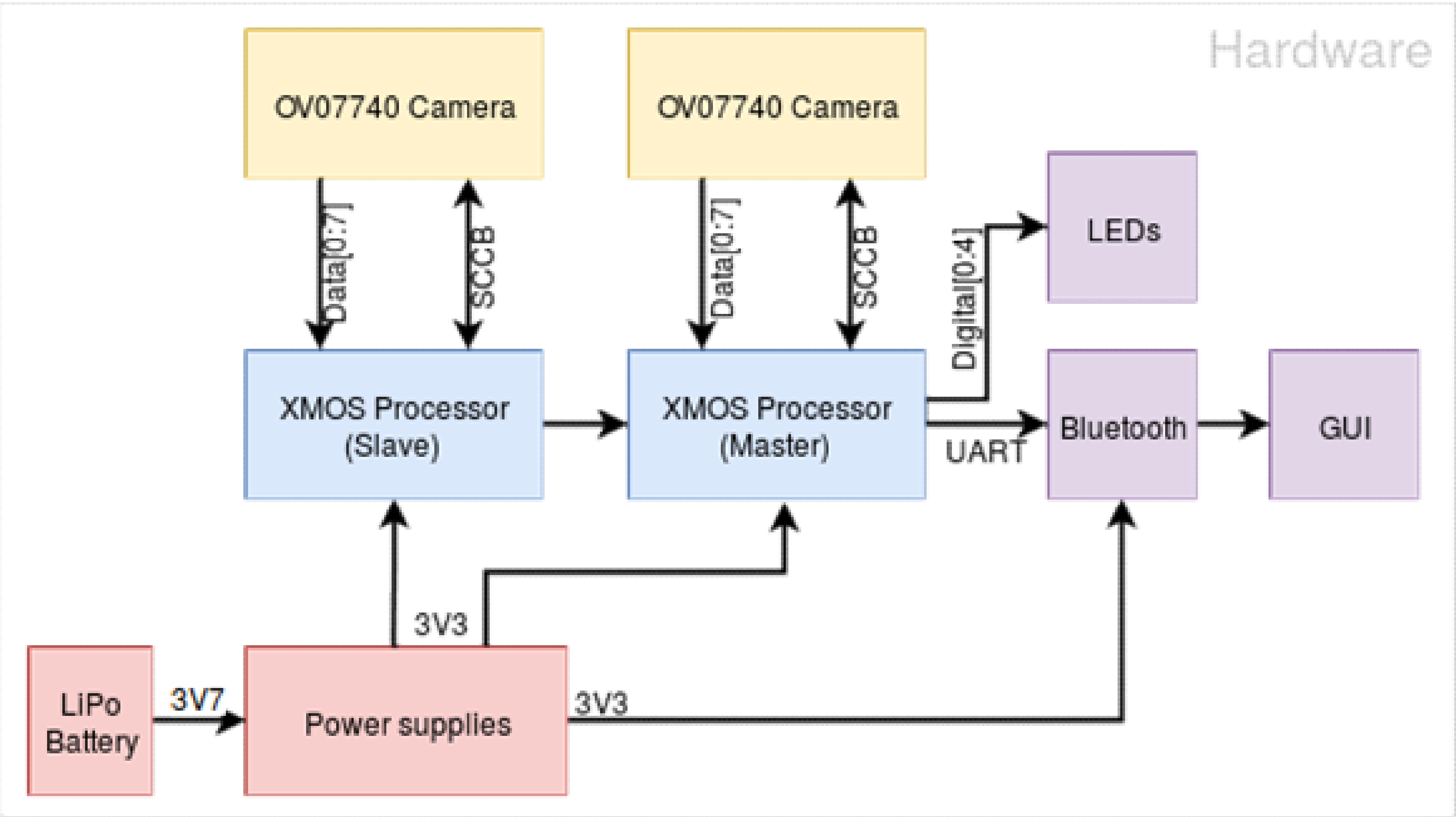
The Problem

- Determining strikes and balls without a professional umpire is difficult and inaccurate
- Current technology solutions are expensive and require extensive set-up
- Incorrectly called pitches lead to angry players

The Solution

- Use a stereo camera and image processing system built into the home plate to determine the baseball's location
- Challenges:
  - Time restrictions for bulk of image processing (16.2ms)
  - High accuracy required for successful use (~95%)
  - Ball detection vs. object detection (e.g. bat)

Block Diagram - Hardware



CDR Deliverables

- Demonstrate complete system functionality
  - Implement ball detection, strike zone intersection, and baseball height functions in C (Tim)
  - Functioning PCBs (Justin)
  - Capable of detecting balls/strikes with hardware at 60fps
- Implement full app functionality (Jason)
  - 2-way Bluetooth communication established
    - App receives ball/strike information including XY position of ball
    - Plate receives batter height
- First iteration of enclosure built (Matt)

Background Subtraction and Denoise

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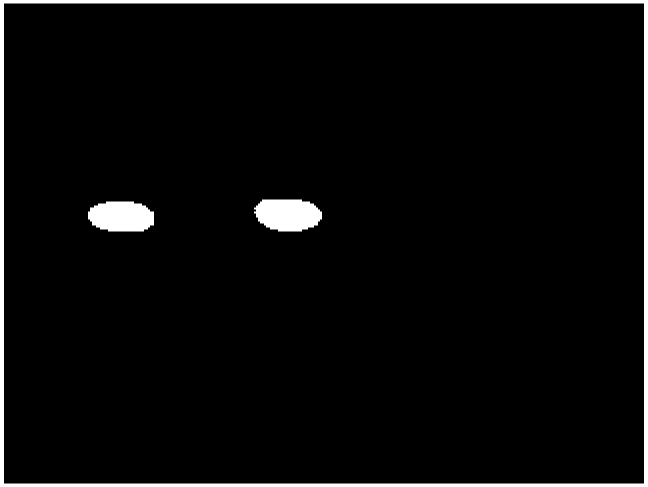
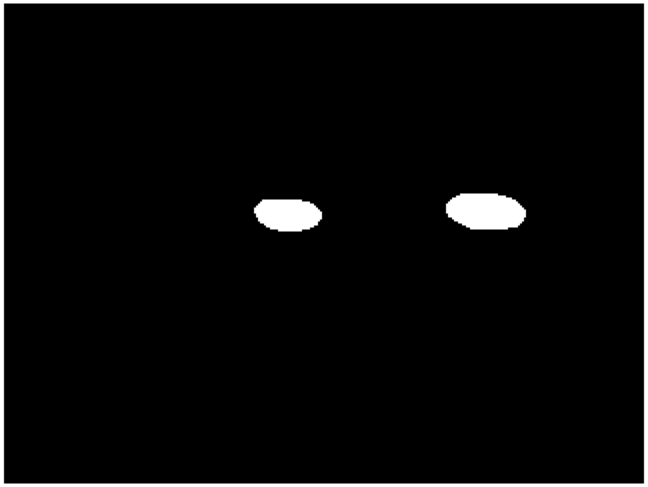
Background Subtraction and Denoise

Background Subtraction and Denoise



Background Subtraction and Denoise



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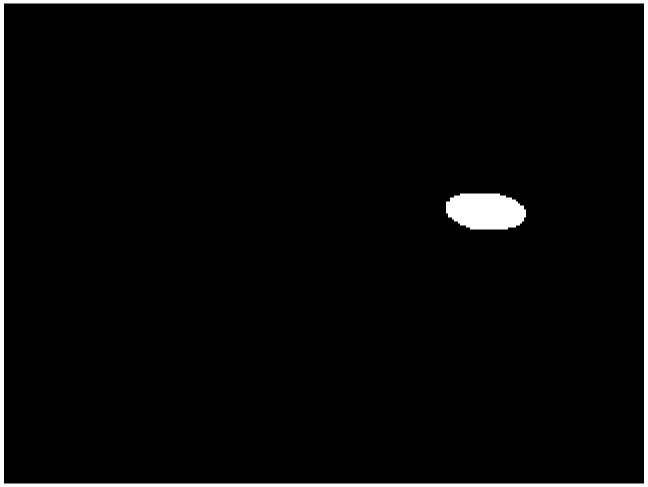
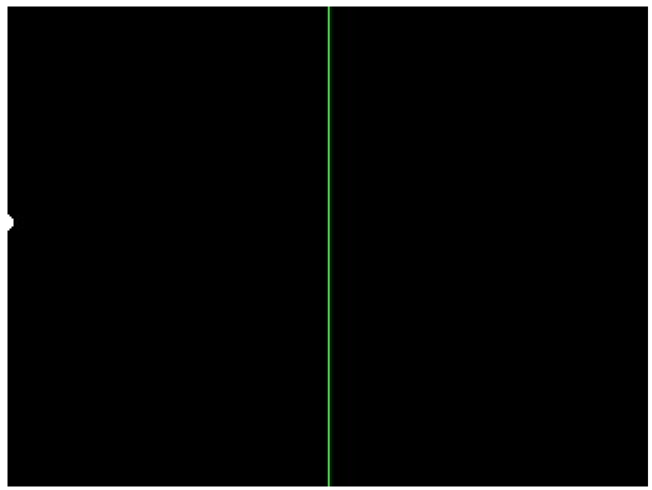


Object Detection and Find Intersection



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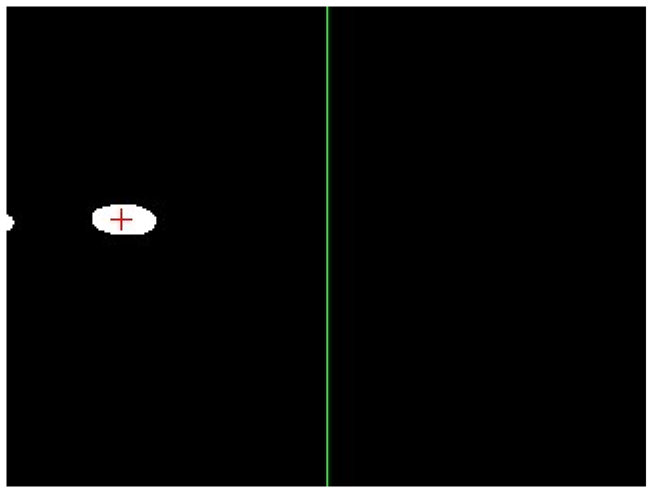

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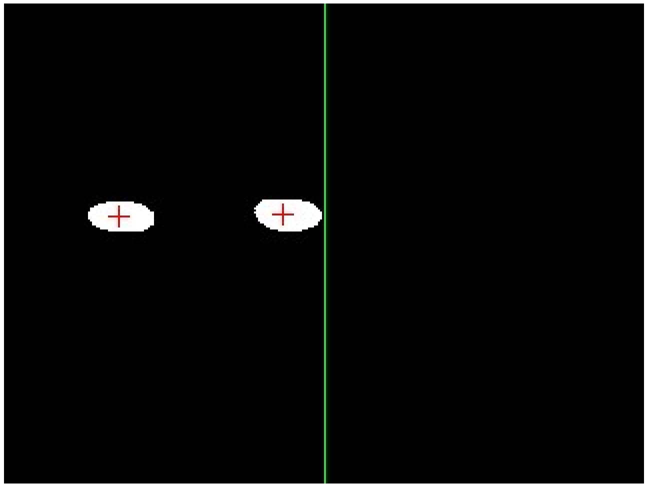

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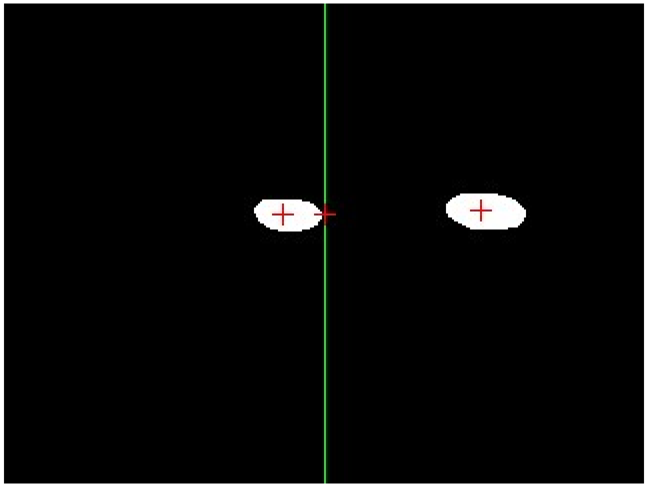
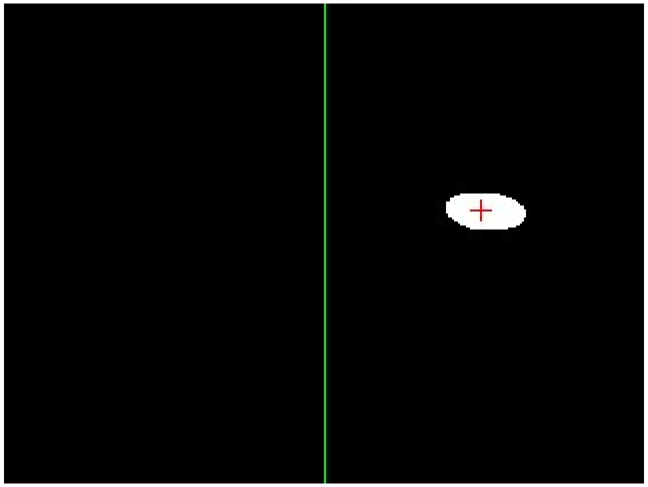


Object Detection and Find Intersection



Processing Results

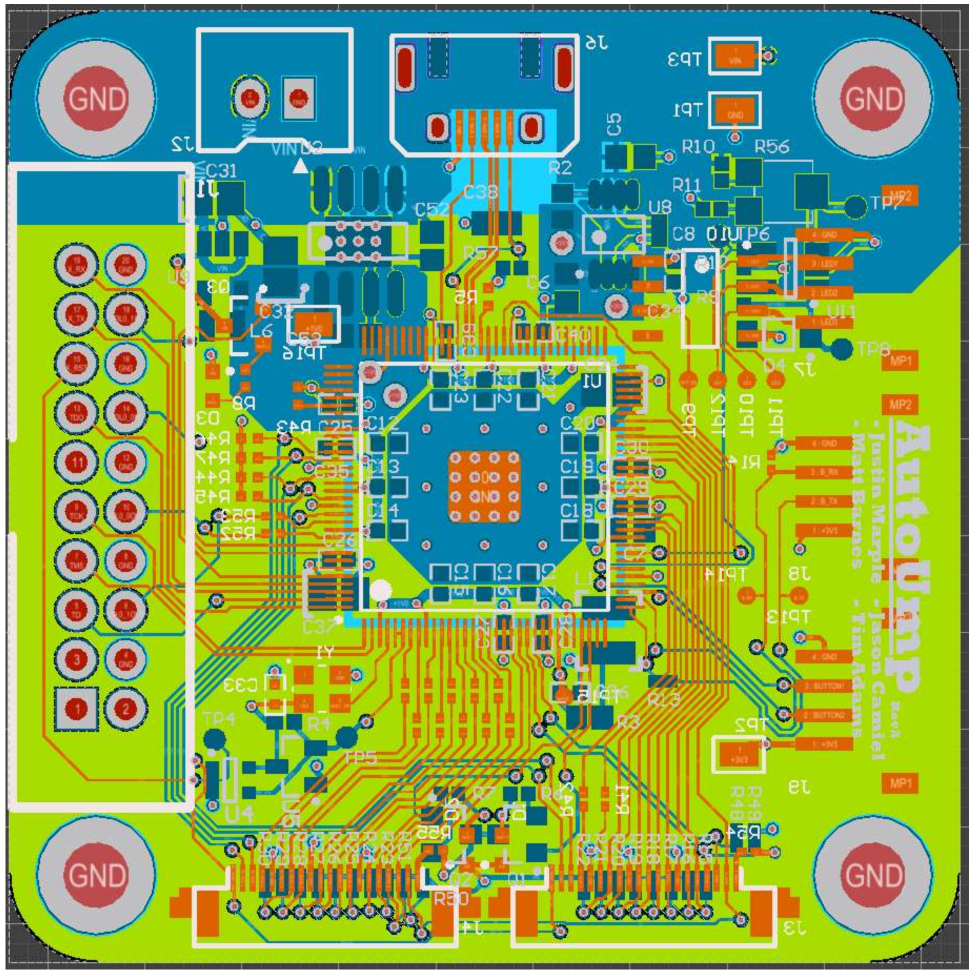
(Units in Inches)	Recorded		Calculated, Matlab		Calculated, C Code	
Pitch	**Width**	**Height**	**Width**	**Height**	**Width**	**Height**
1	**0**	**24**	-0.1	23.99	-0.191	19.07
3	**5.5**	**33.75**	5.4	28.2	5.72	23.09
4	**-3.5**	**31.25**	-2.2	27.8	-2.187	20.85

PCB's

- XMOS PCB
  - 49mmx49mm 4 layer board
  - 2000MIPS with 16 cores
  - 256kB of RAM, 2MB of FLASH

- Image Sensors PCB
  - 26x26mm 4 layer board
  - 0.65mm BGA pads requiring 4mil trace/spacing
  - Stencil was built to aid in the soldering of the BGA

PCBs



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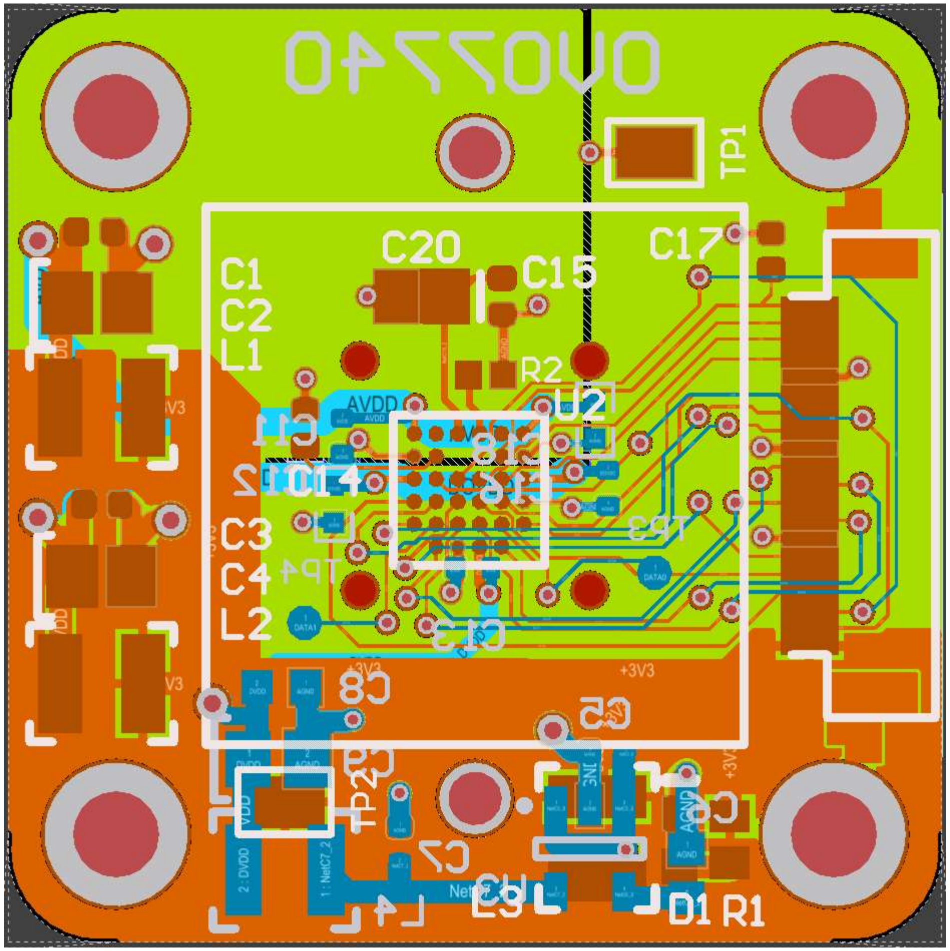
PCBs



Low level implementation

- Steps:
  - Outputs a 25Mhz CLK signal to cameras
  - Retrieves a 50Mhz Pixel-CLK signal back from cameras
  - Retrieves Horizontal and Vertical sync lines
  - Reads 8-bit data bus on falling edge of Pixel-CLK and saves into 32-bit buffer
  - 32-bit buffer is split into only the “Y” components of “YUYV” format
  - Run background subtraction for every pixel

Low level implementation – difficulties

- The XMOS board has horizontal and vertical sync signals are all on the same port
  - Each camera needs their own core. Very difficult to share a port event over two cores.
- A master thread is used to look for changes on the sync port
  - XMOS “channels” are used to communicate when a sync signal changes. Port counters are used to ensure that each core samples their respective camera at the correct time.

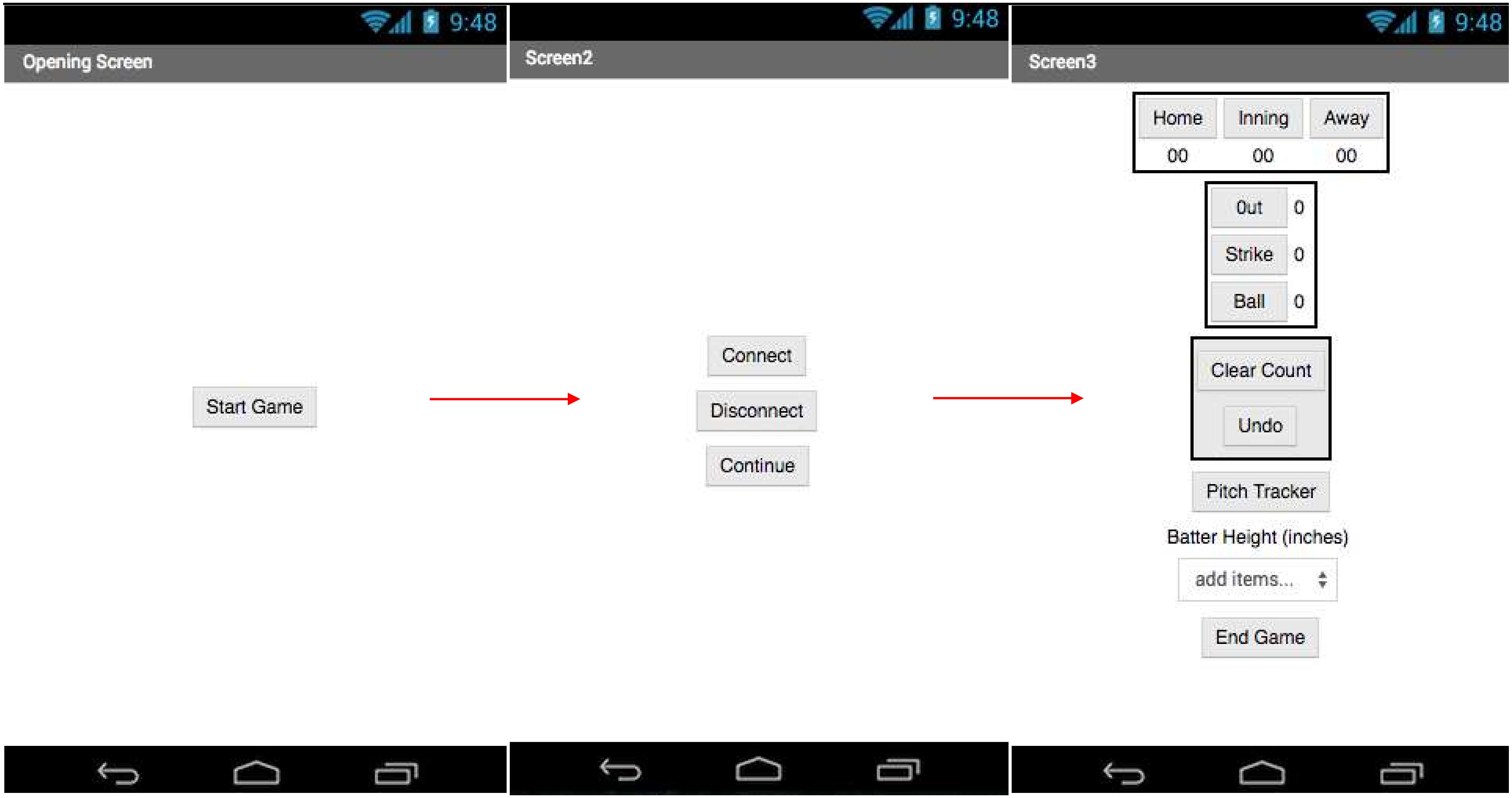
Low level implementation – difficulties

- Sync Frame Input pin is used to ensure the PCLK, data-bus, and sync signals are perfectly synchronized
  - Knowing one HREF/VSYNC of one camera means we'll know the HREF/VSYNC of the other
  - Critical for running the two cameras together reliably

Two way Bluetooth communication

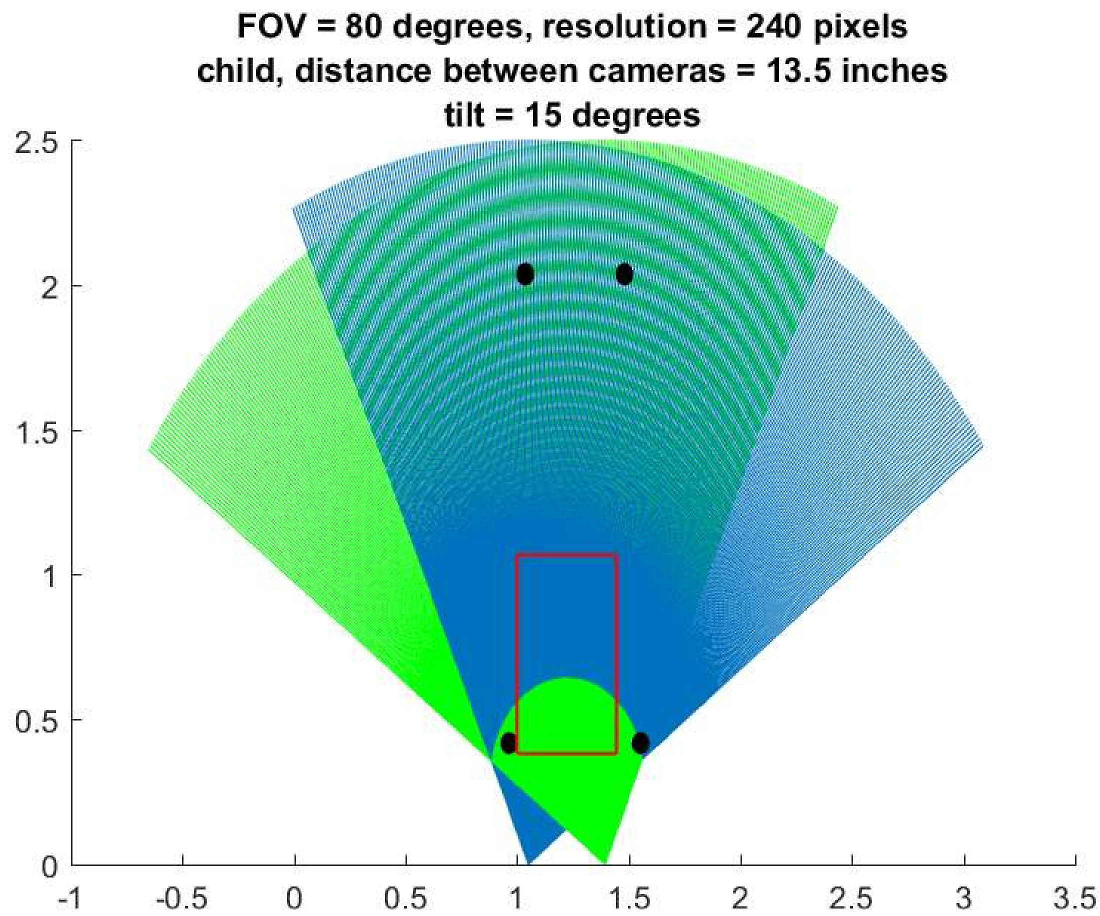
- Batter height is set per batter within in the app; this data is promptly sent to XMOS
- The XMOS drives the app with updates on ball count, strike count, and location
- With each set of updated data the app display is changed automatically
- In event of error, user may interact with the app to make adjustment or undo; updated data is sent to the XMOS

UI


9:48
Opening Screen
Start Game
9:48
Screen2
Connect
Disconnect
Continue
9:48
Screen3
Home
Inning
Away
00
00
00
Out
0
Strike
0
Ball
0
Clear Count
Undo
Pitch Tracker
Batter Height (inches)
add items...
End Game

Enclosure

- Cameras are placed 13.5 inches apart, tilted 15 degrees to have coverage of the strike zone and surrounding area



Enclosure

- The camera boards are placed on 3D printed mounts that tilt the cameras the desired 15 degrees
- The mounts are attached to a single surface to prevent them from rotating relatively to each other
- Aluminum sheet (3mm thick) is cut to fit inside outer edge of plate to prevent injuries
- Two support ridges are removed from plate to make room for cameras

Enclosure

- 30mm holes are cut into the plate slightly less than 13.5 inches apart
  - This prevents the “home plate” from blocking the camera’s field of view
- 34mm sapphire watch crystals will be inserted into a ridge cut 2mm below the top of the hole
- The cameras will be mounted so that the lenses are 4mm from the bottom of the lens

FPR Goals

- Code optimized and fully running on XMOS
  - Implement filtering algorithm to consistently isolate balls
  - Object detection and pitch determination each < ~16ms
- Detection accurate, sent to app
  - Primary issue, we believe: distortion. Calculate distortion coefficients.
  - Report pitch location and determination to app
- Complete enclosure
  - Insert sapphire crystals
  - Update camera mounts/fix to aluminum to create mount that can be secured underneath the plate

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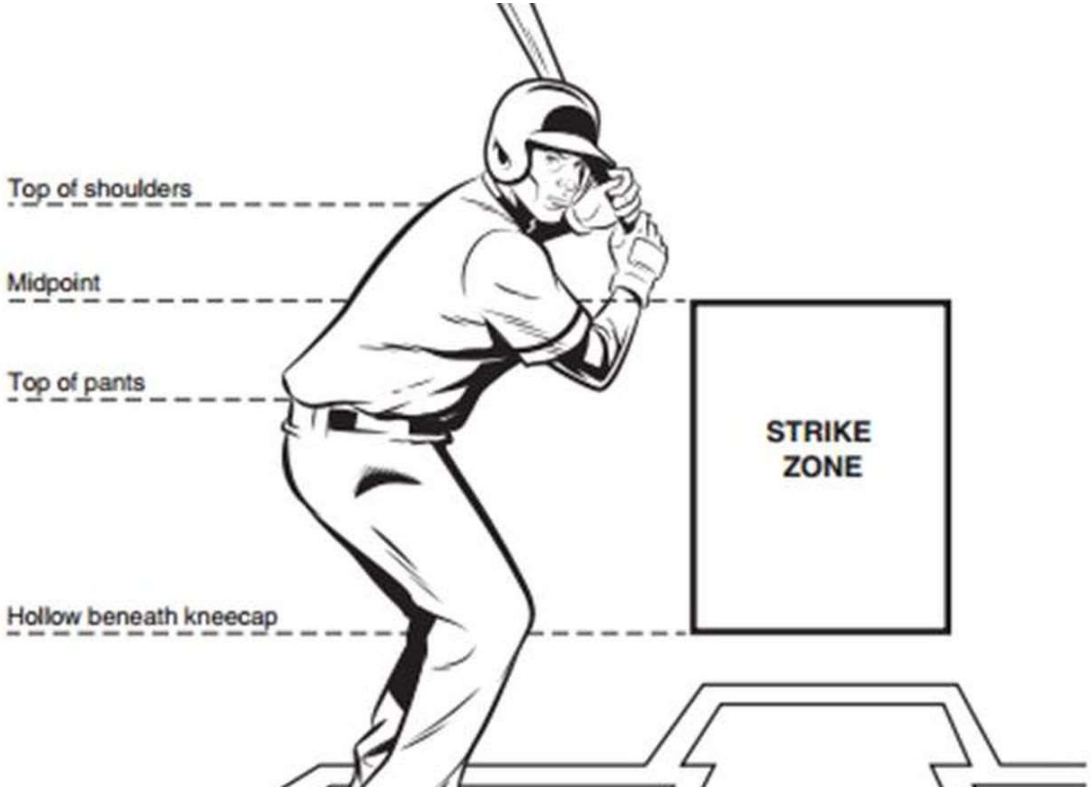
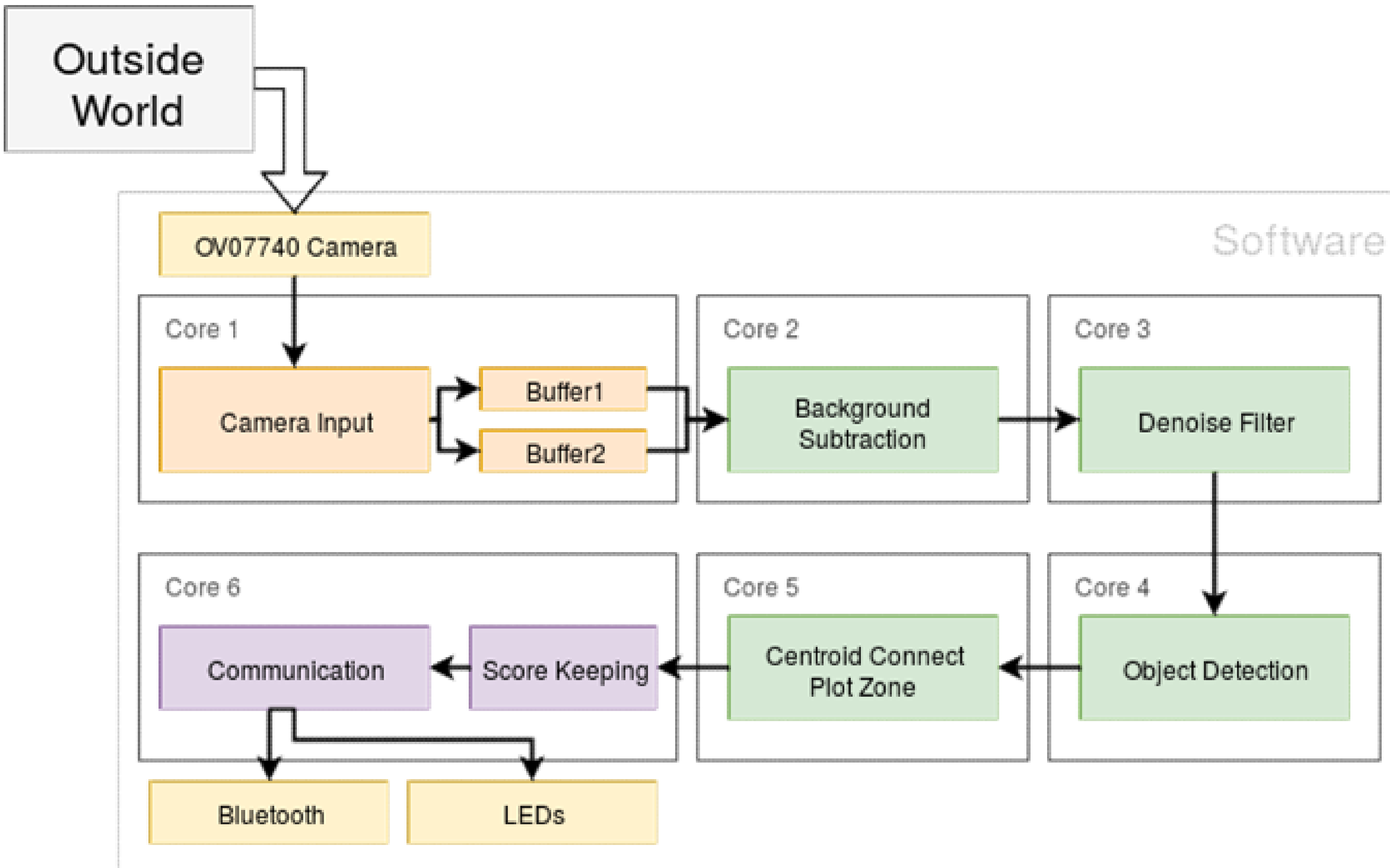
Strike Detection Concept



Locate point in 3D space where ball intersects with the "Strike Zone" plane

Block Diagram - Software

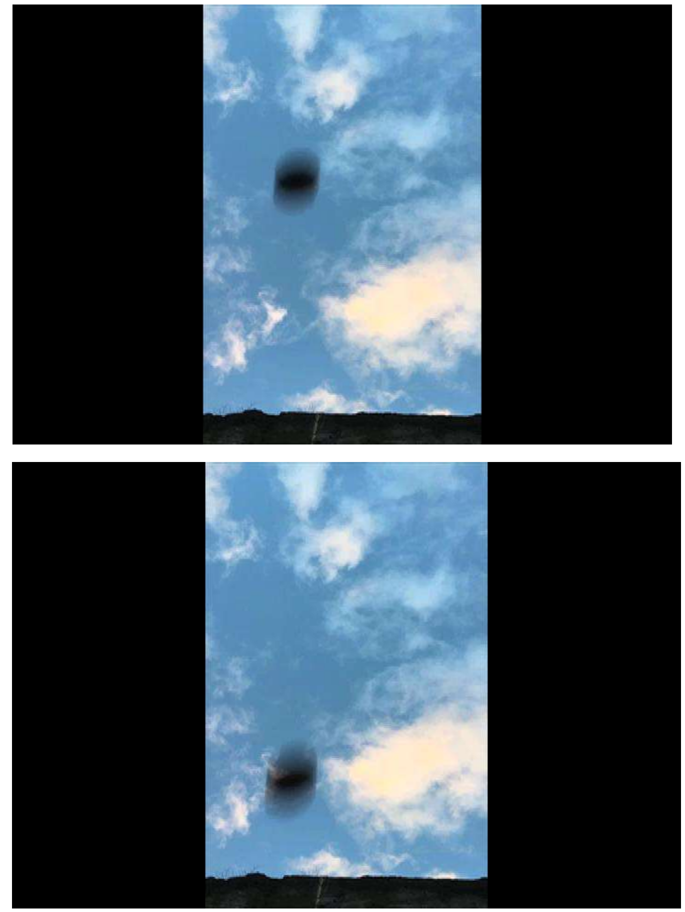


The Algorithm – Input

Left:

t

Right:



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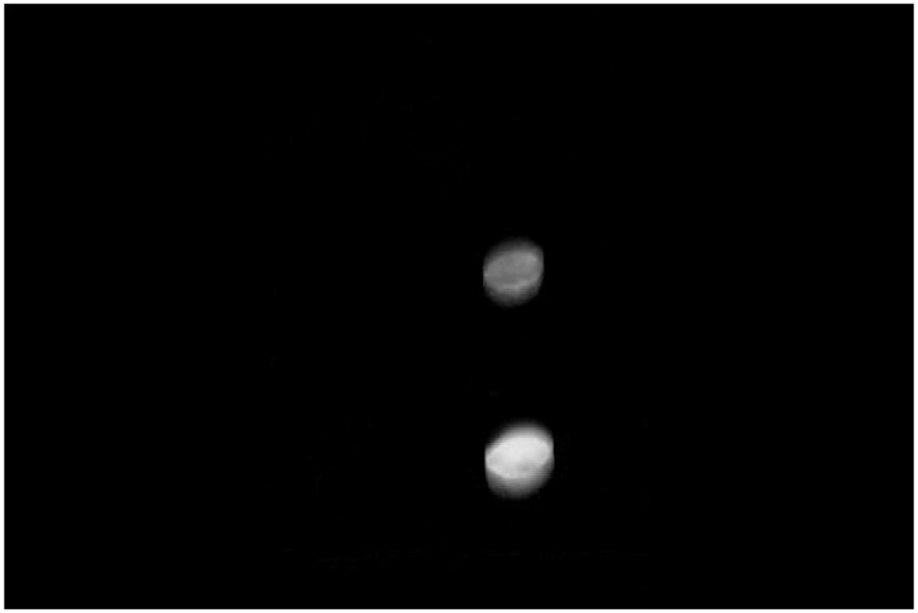
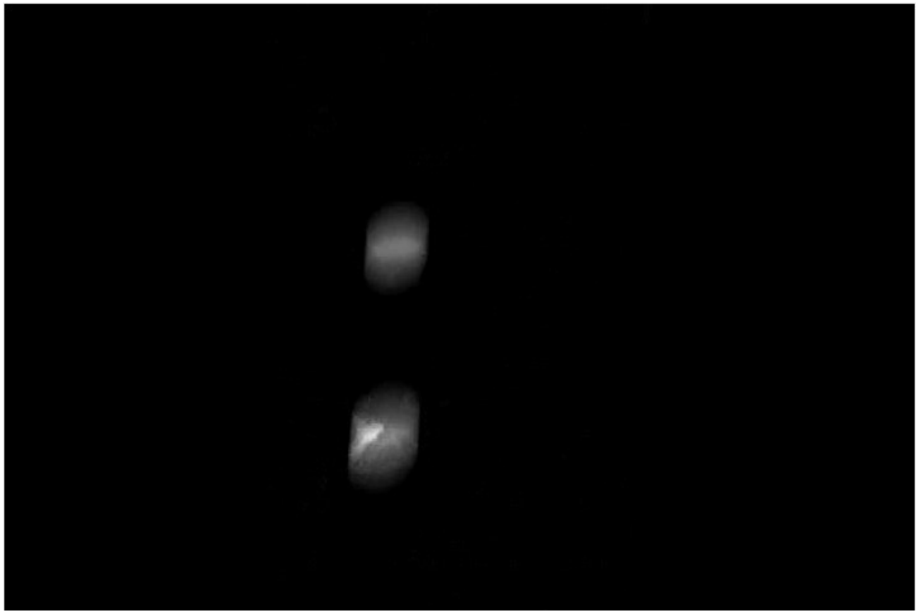
The Algorithm – Background Subtraction

Left:

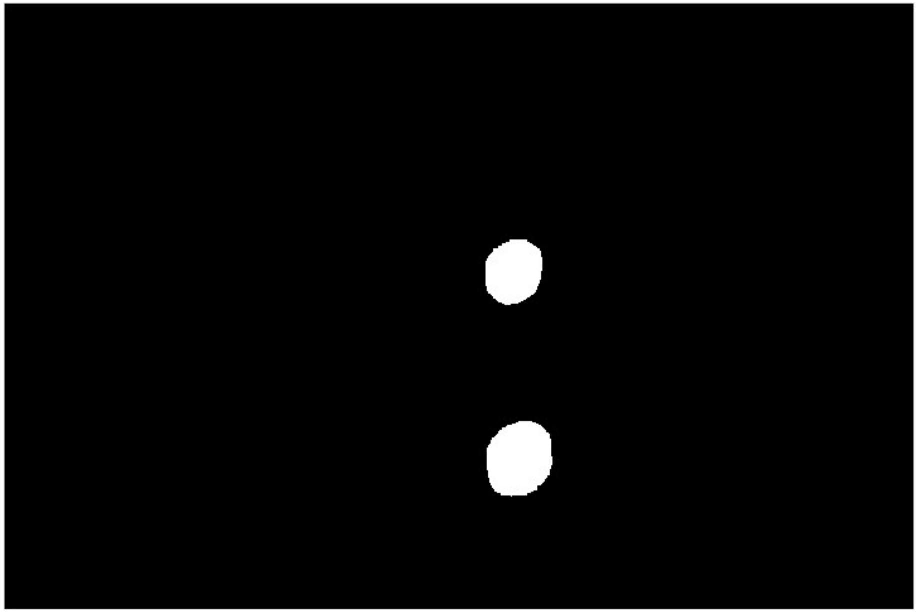


Right:



The Algorithm – Filter and Enhance

Left:



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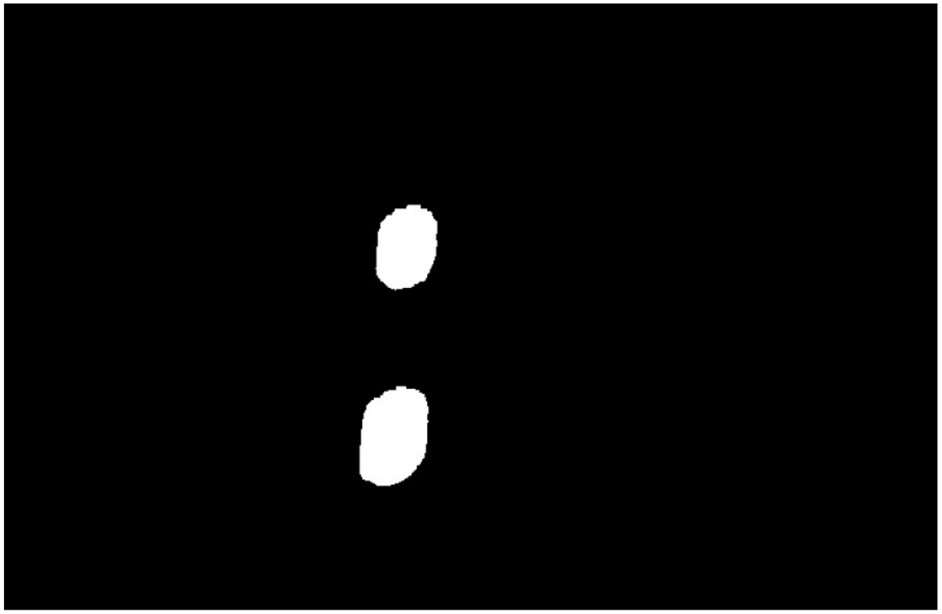
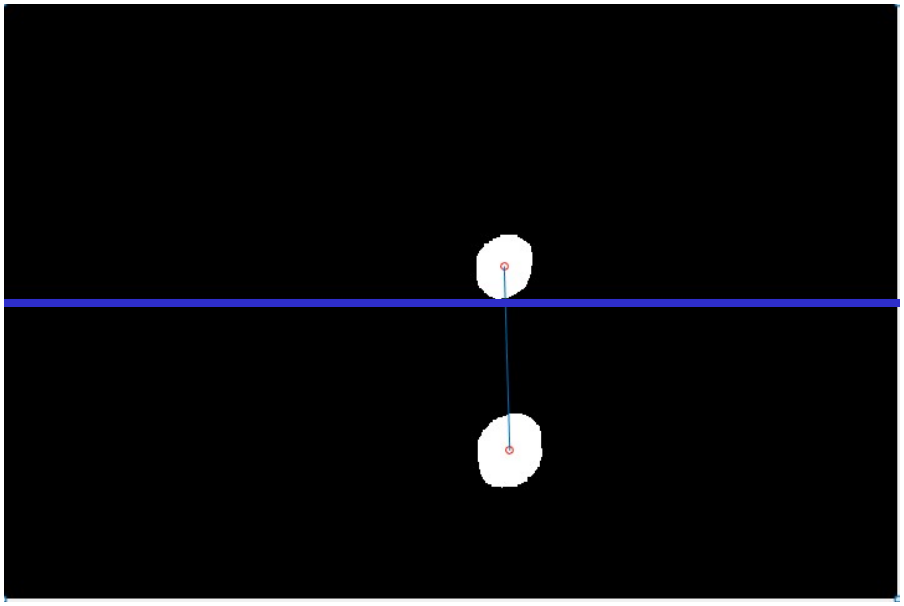
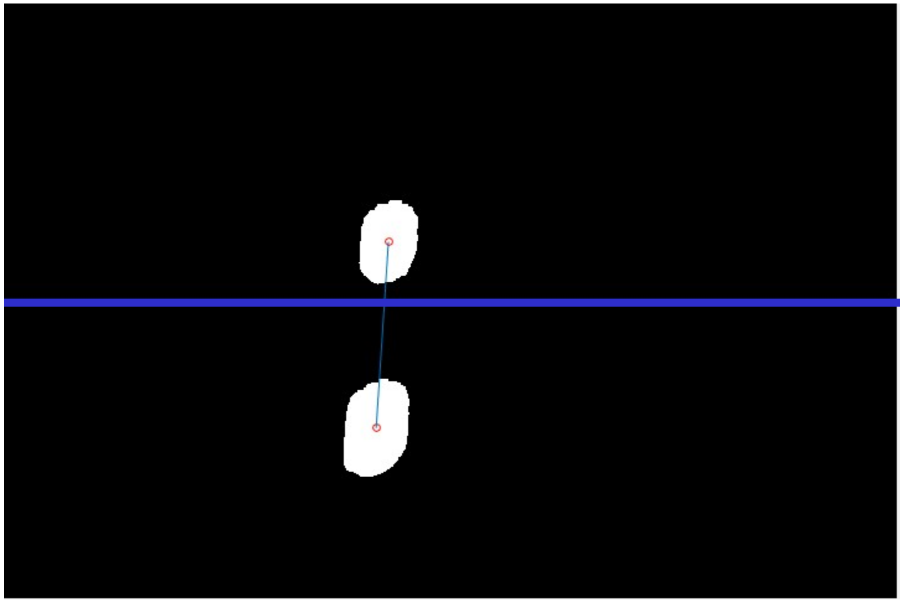


The Algorithm – Intersection with Strike Zone

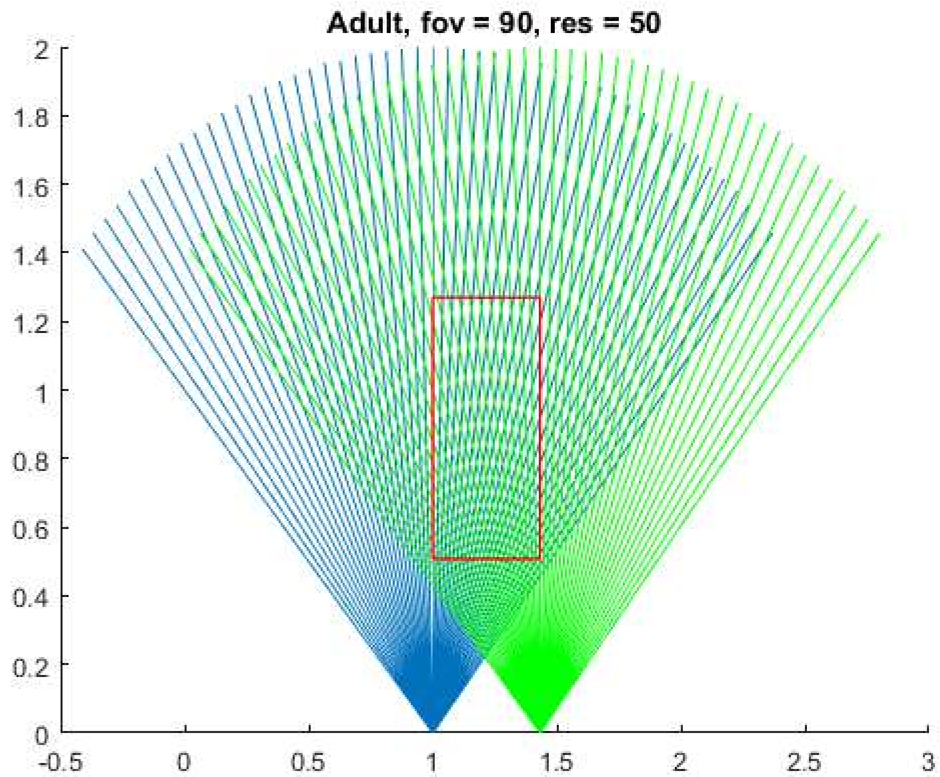
Left:



Right:



The Algorithm – Find Centroid Pixel



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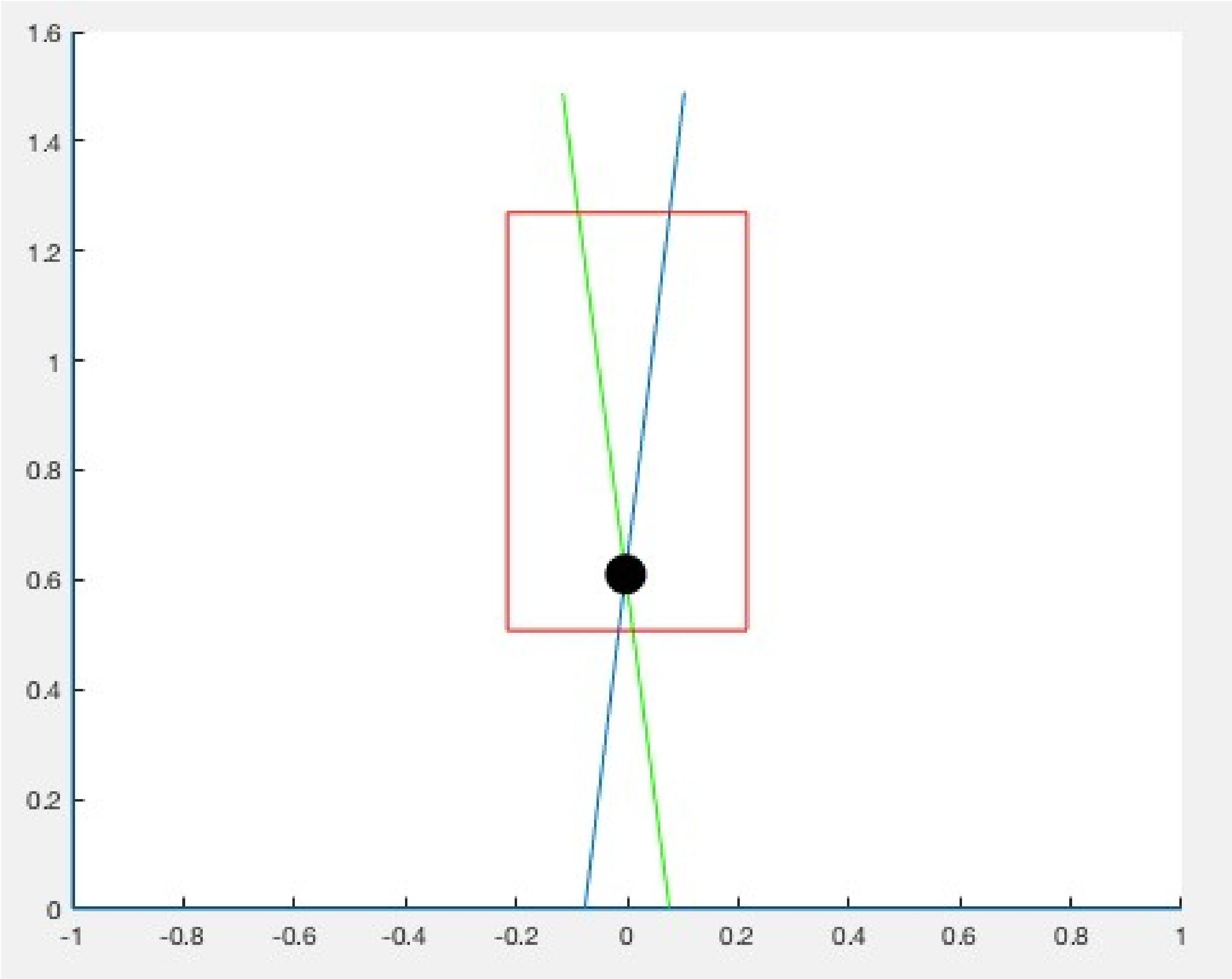
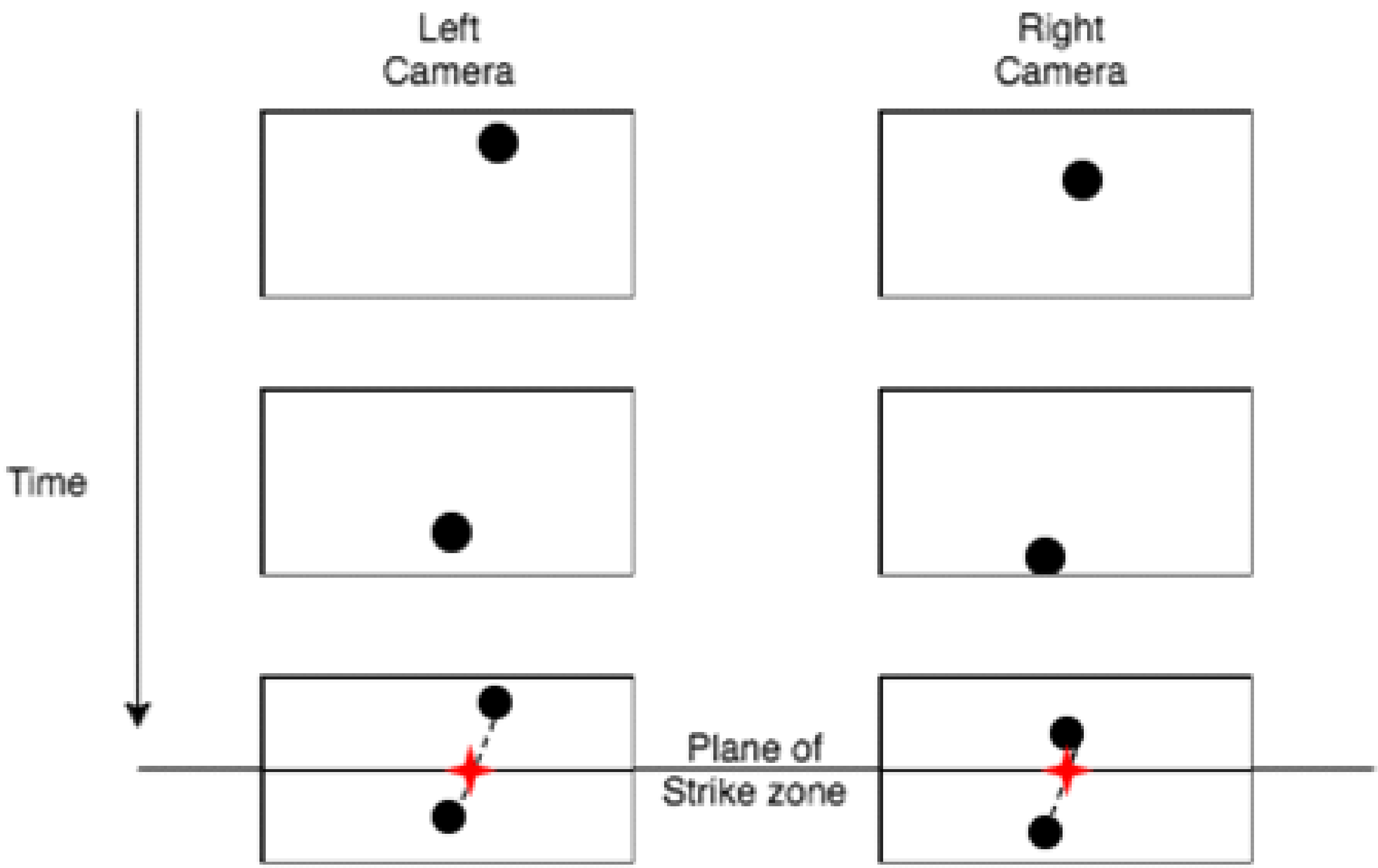
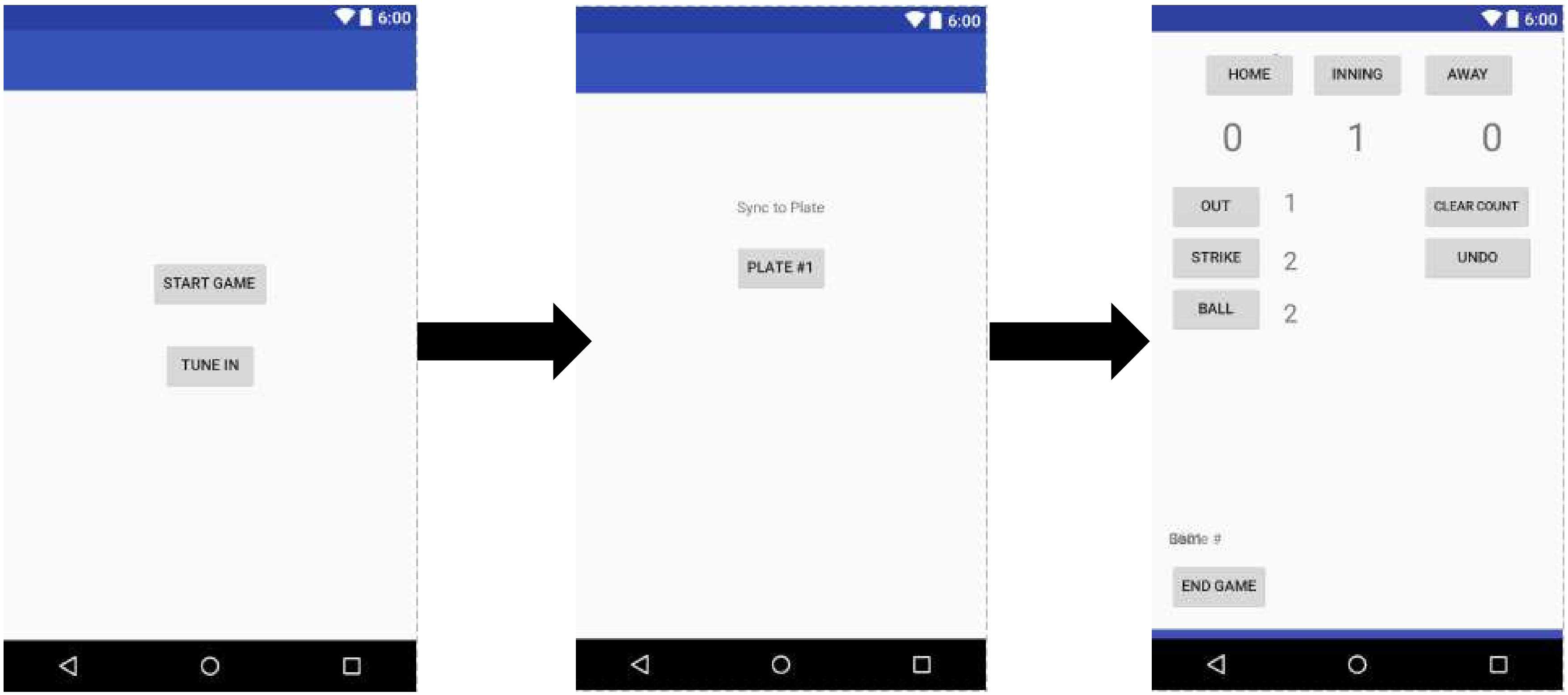
The Algorithm – Determine Ball Location



A Word on Synchronization

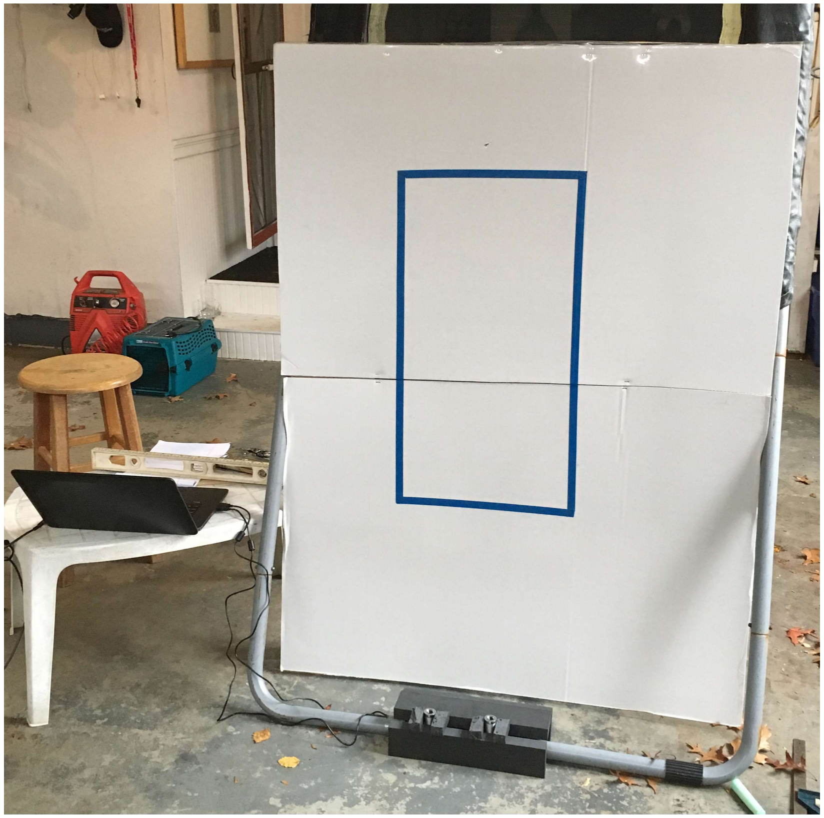


Android App UI



Indoor Garage testing

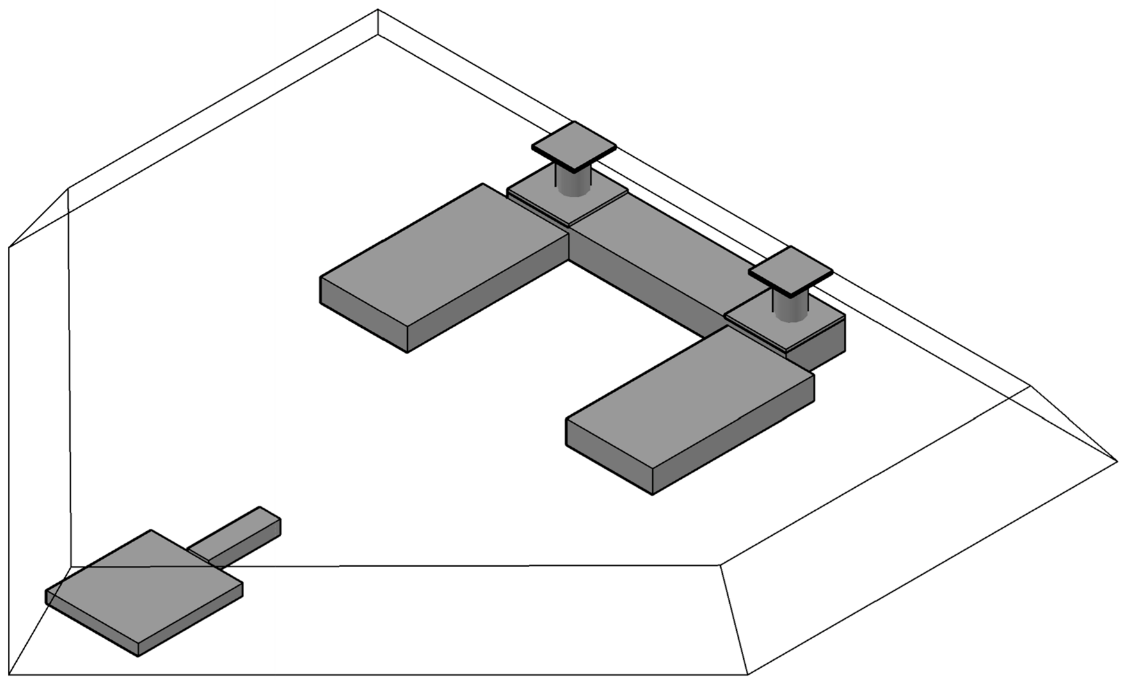
- Choose aperture and exposure time for outdoor use
- Cameras will need to be securely fastened to the plate in addition to each other
- Frame rate of 60fps required for accurate testing

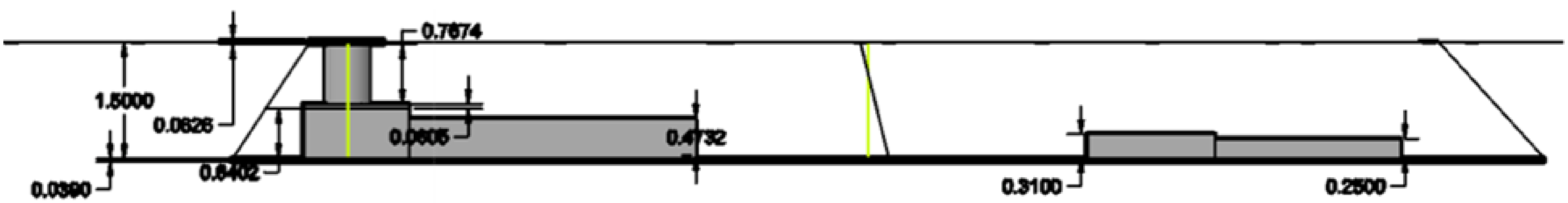


Wall Testing

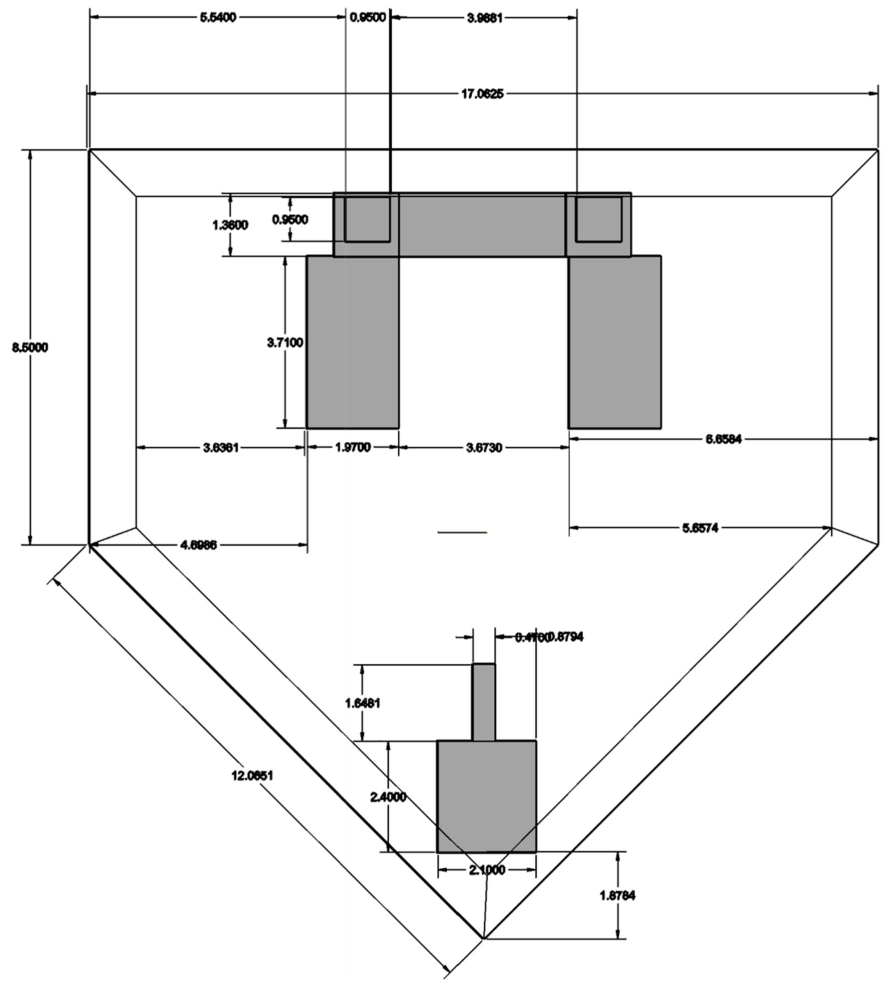
- Using two iPhones spread 6 inches apart and defined axis on a cement wall.
- Marked and measured pitches using chalk on the wall
- The data collected is used to perform validation of the location algorithm
- Sources of error that will affect perfect validation include
  - Camera movement/angle orientation
  - Ball arc between camera and mark on wall a distance of approximately 18 inches.
  - Human error in the marking of the position on wall

Enclosure





Enclosure Top View



Power Requirement

- Power consumption for processors
  - 3.7V*0.45A = 1.65W
- 4 hour game time: 6.75Wh
- Charge: 1824mAh
- Result: Choose a 2000mAh battery

Required Parts List

- OV7740 Camera Chip (x2)
  - 60fps
  - SCCB Interface
- XEF216-512-TQ128 (x2)
  - 2MB flash
  - 512kB RAM
  - 16 cores
- OV7440 Lens (x2)
- OV7440 Mount (x2)
- 2000mAh battery

CDR Deliverables

- Demonstrate complete system functionality
  - Implement ball detection, strike zone intersection, and baseball height functions in C (Tim)
  - Functioning PCBs (Justin)
  - Capable of detecting balls/strikes with hardware at 60fps
- Implement full app functionality (Jason)
  - Pair to plate, complete viewer and umpire views
  - 2-way Bluetooth communication established
    - App receives ball/strike information
    - Plate receives batter height
- First iteration of enclosure built (Matt)

Timeline

- Complete orders for final system
- Design and send out order for PCB

Dec 21^{st}

- Implement full algorithm in C
- Achieve image collection on PCB system
- Receive second round of PCB if needed

Jan 21^{st}

- Bluetooth communication established
- App functionality completed
- Implement full algorithm in XC

Feb 21^{st}

- Enclosure completed

Feb 28^{th}

Demo – Image Collection and Object Detection

- Image size: 176x144
- Frames per second: 30 -> ~33.3 ms/frame
- Limited memory space: can only store two images at a time