RevMetrix Capstone I

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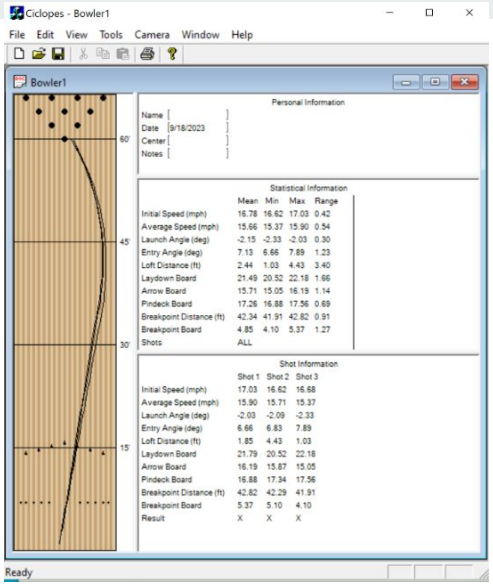
Background

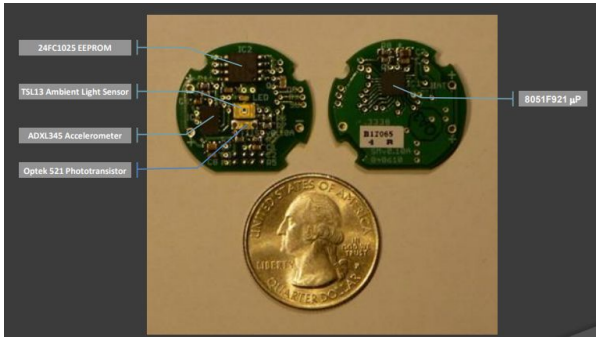
What problem are we trying to solve?

Absence of a unified, user friendly system for collecting, organizing, and analyzing bowling performance data.

Founding Technologies

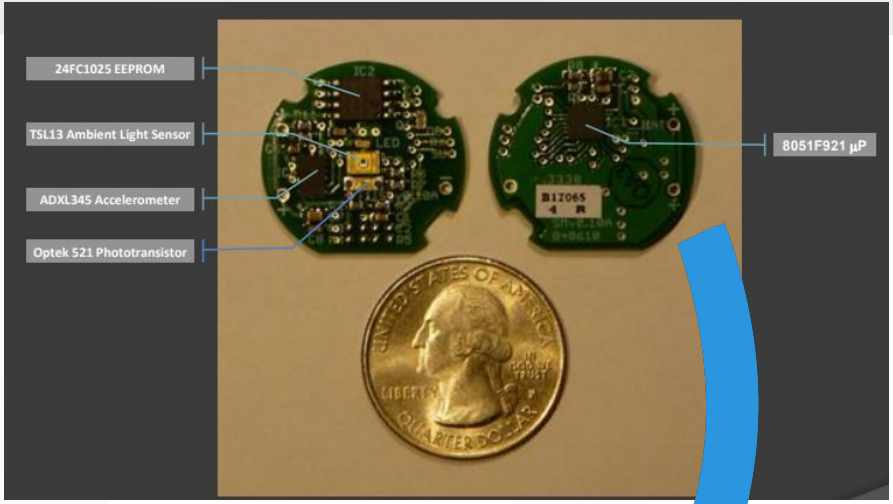
- Creation of Prof. Hake and Dr. Babcock
- Key Components
  - SmartDot module
  - Ciclopes software

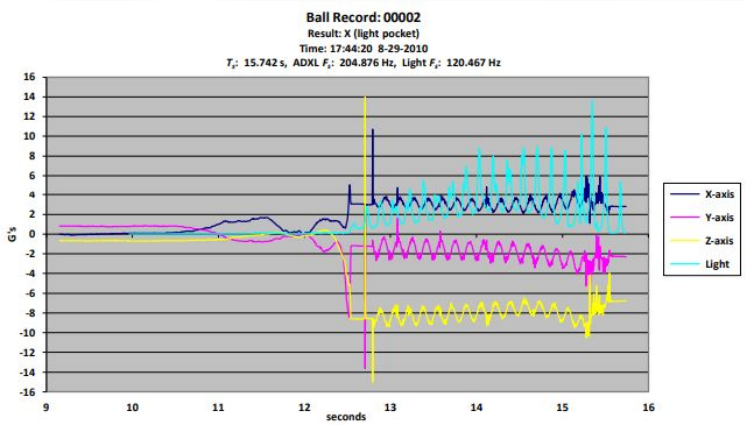


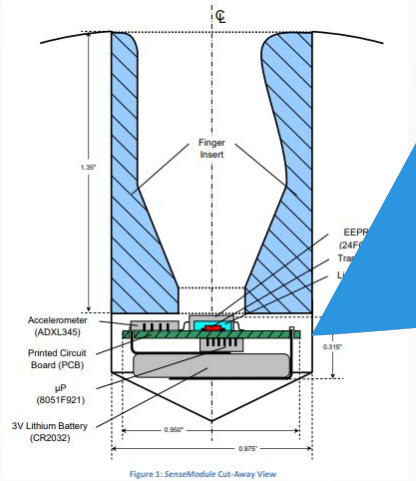


What is SmartDot?

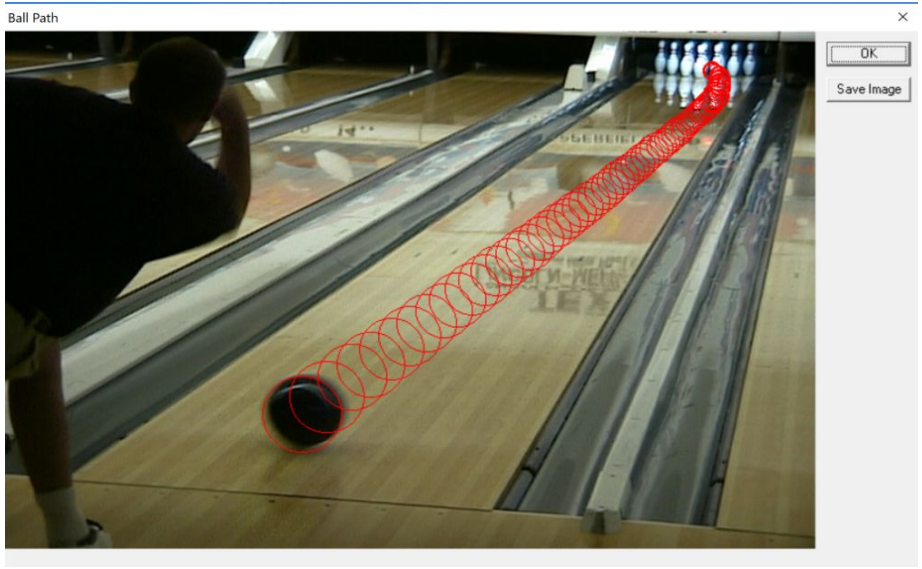
- Professor Hake's Brain-Child
- Light Sensor + Accelerometer







What is Ciclopes?



Ciclopes - Bowler1

File Edit View Tools Camera Window Help

Bowler1

60'
45'
30'
15'

Personal Information

Name [ ]
Date [9/18/2023]
Center [ ]
Notes [ ]

Statistical Information

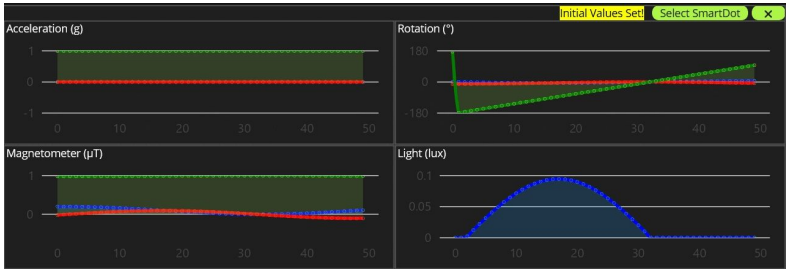
	Mean	Min	Max	Range
Initial Speed (mph)	16.78	16.62	17.03	0.42
Average Speed (mph)	15.66	15.37	15.90	0.54
Launch Angle (deg)	-2.15	-2.33	-2.03	0.30
Entry Angle (deg)	7.13	6.66	7.89	1.23
Loft Distance (ft)	2.44	1.03	4.43	3.40
Laydown Board	21.49	20.52	22.18	1.66
Arrow Board	15.71	15.05	16.19	1.14
Pindeck Board	17.26	16.88	17.56	0.69
Breakpoint Distance (ft)	42.34	41.91	42.82	0.91
Breakpoint Board	4.85	4.10	5.37	1.27
Shots	ALL			

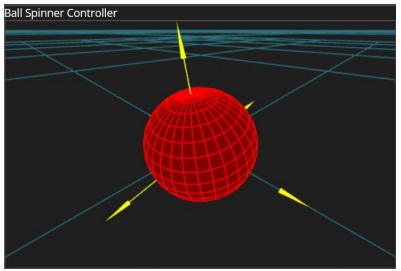
Shot Information

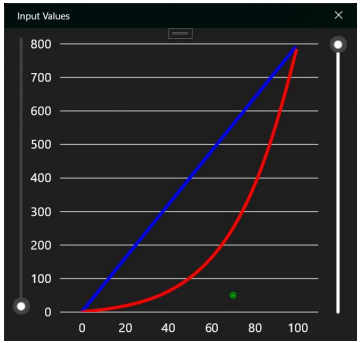
	Shot 1	Shot 2	Shot 3
Initial Speed (mph)	17.03	16.62	16.68
Average Speed (mph)	15.90	15.71	15.37
Launch Angle (deg)	-2.03	-2.09	-2.33
Entry Angle (deg)	6.66	6.83	7.89
Loft Distance (ft)	1.85	4.43	1.03
Laydown Board	21.79	20.52	22.18
Arrow Board	16.19	15.87	15.05
Pindeck Board	16.88	17.34	17.56
Breakpoint Distance (ft)	42.82	42.29	41.91
Breakpoint Board	5.37	5.10	4.10
Result	X	X	X

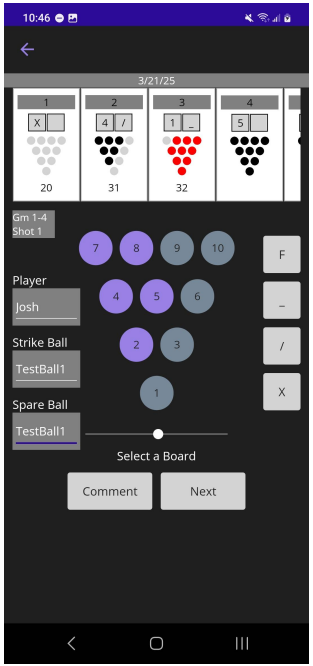
Ready

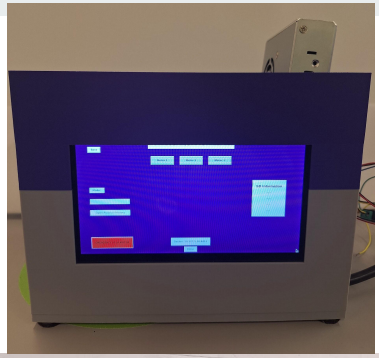
Where did last semester leave us?











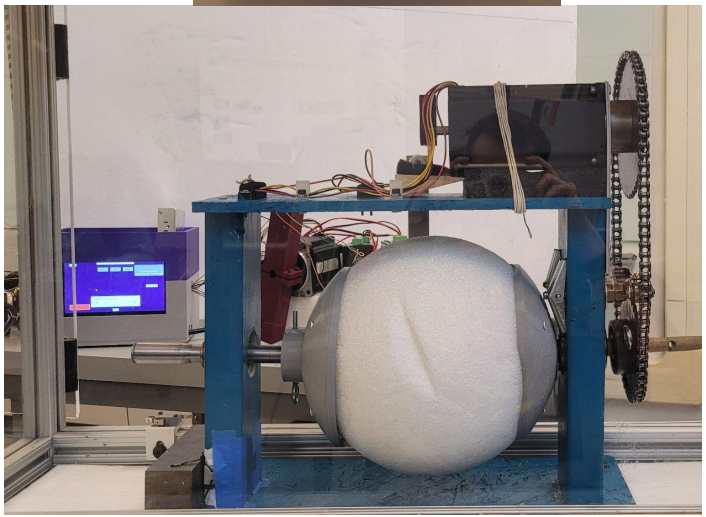
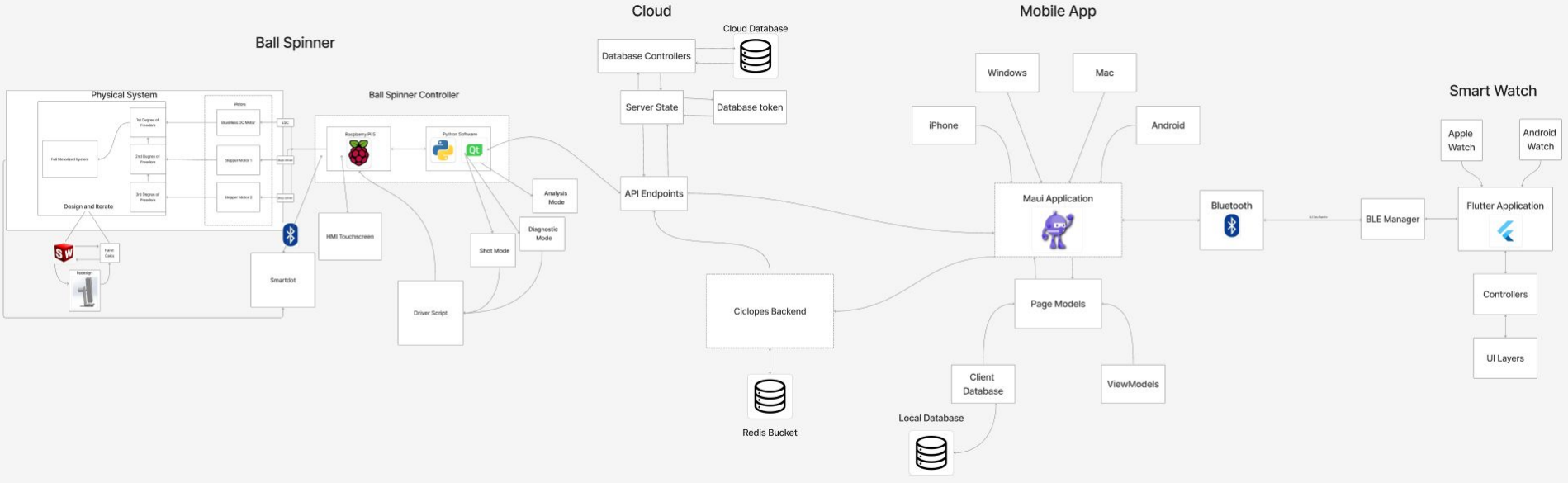


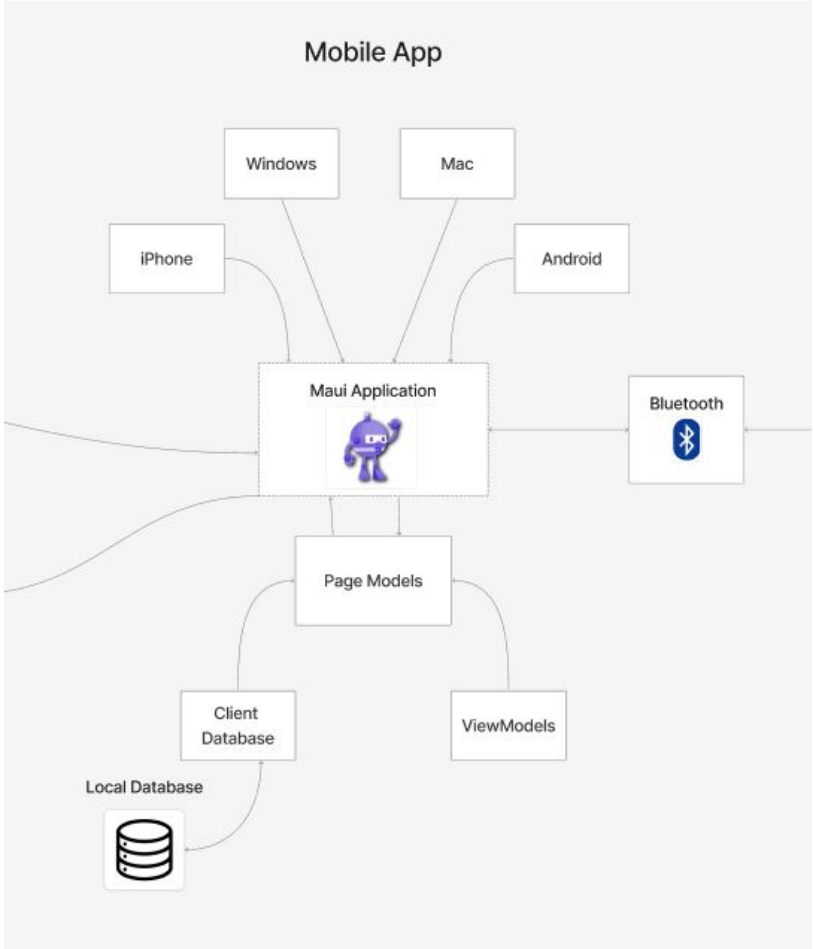
Diagram of System Overview



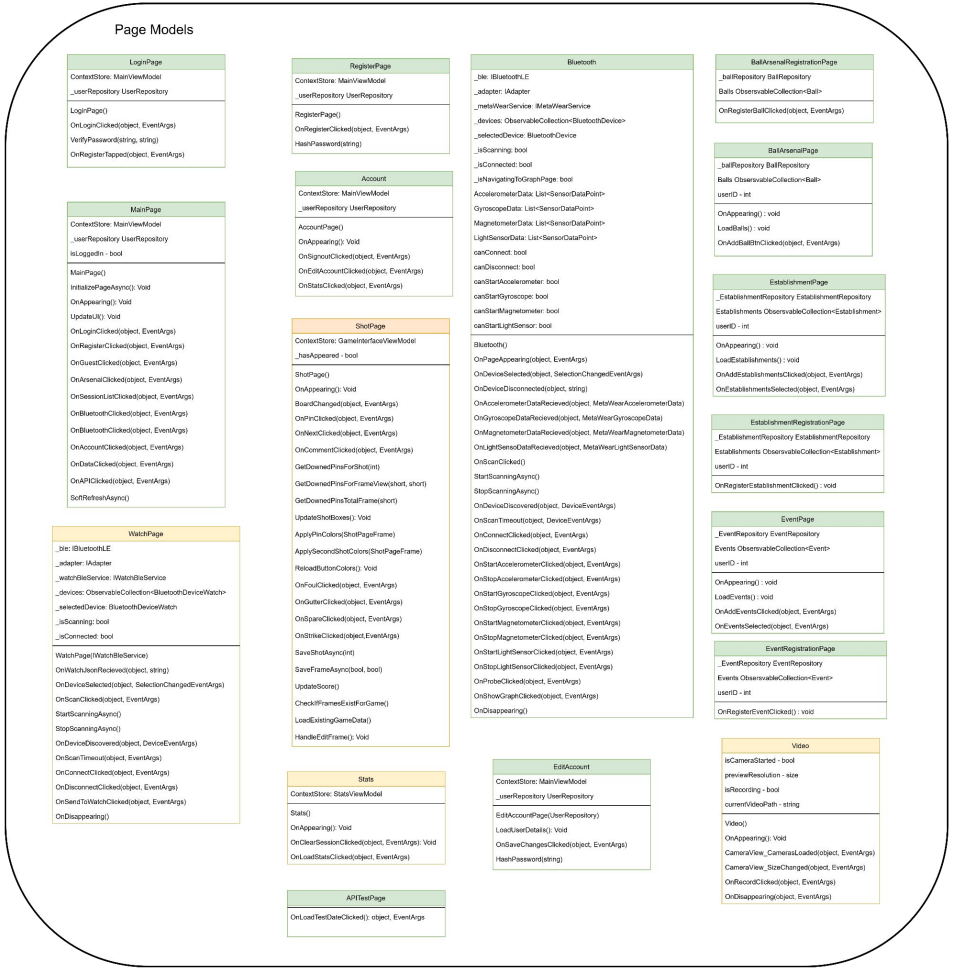
Questions?

Analysis and Design

Mobile: High-Level Overview



Mobile: Page Models



Implemented

Partially Implemented

Not Yet Implemented

Mobile: Page Models - Shot Page

ShotPage

ContextStore: GameInterfaceViewModel

_hasAppeared - bool

ShotPage()

OnAppearing(): Void

BoardChanged(object, EventArgs)

OnPinClicked(object, EventArgs)

OnNextClicked(object, EventArgs)

OnCommentClicked(object, EventArgs)

GetDownedPinsForShot(int)

GetDownedPinsForFrameView(short, short)

GetDownedPinsTotalFrame(short)

UpdateShotBoxes(): Void

ApplyPinColors(ShotPageFrame)

ApplySecondShotColors(ShotPageFrame)

ReloadButtonColors(): Void

OnFoulClicked(object, EventArgs)

OnGutterClicked(object, EventArgs)

OnSpareClicked(object, EventArgs)

OnStrikeClicked(object,EventArgs)

SaveShotAsync(int)

SaveFrameAsync(bool, bool)

UpdateScore()

CheckIfFramesExistForGame()

LoadExistingGameData()

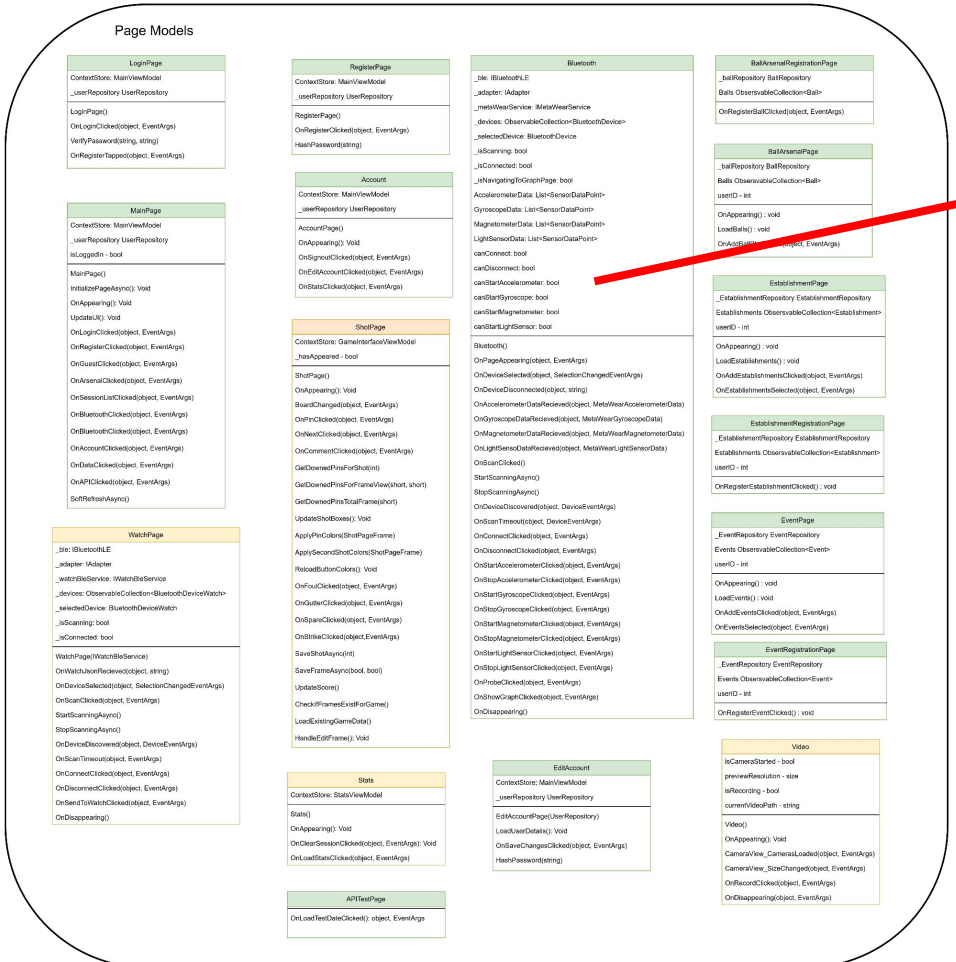
HandleEditFrame(): Void

Implemented

Partially Implemented

Not Yet Implemented

Mobile: Page Models - Bluetooth



Implemented

Partially Implemented

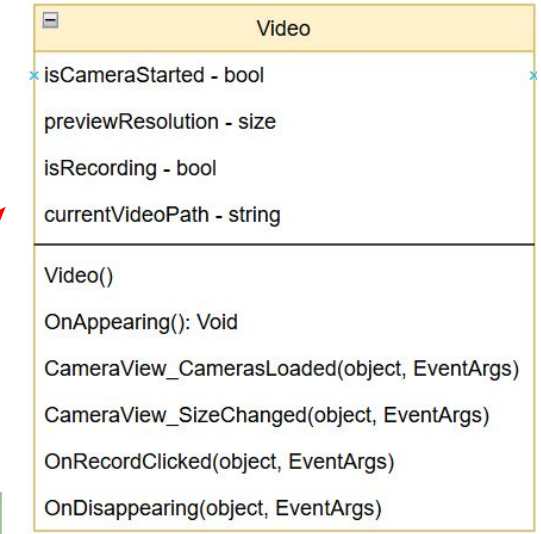
Not Yet Implemented

Bluetooth

_ble: IBluetoothLE
_adapter: IAdapter
_metaWearService: IMetaWearService
_devices: ObservableCollection<BluetoothDevice>
_selectedDevice: BluetoothDevice
_isScanning: bool
_isConnected: bool
_isNavigatingToGraphPage: bool
AccelerometerData: List<SensorDataPoint>
GyroscopeData: List<SensorDataPoint>
MagnetometerData: List<SensorDataPoint>
LightSensorData: List<SensorDataPoint>
canConnect: bool
canDisconnect: bool
canStartAccelerometer: bool
canStartGyroscope: bool
canStartMagnetometer: bool
canStartLightSensor: bool

Bluetooth()
OnPageAppearing(object, EventArgs)
OnDeviceSelected(object, SelectionChangedEventArgs)
OnDeviceDisconnected(object, string)
OnAccelerometerDataRecieved(object, MetaWearAccelerometerData)
OnGyroscopeDataRecieved(object, MetaWearGyroscopeData)
OnMagnetometerDataRecieved(object, MetaWearMagnetometerData)
OnLightSensoDataRecieved(object, MetaWearLightSensorData)
OnScanClicked()
StartScanningAsync()
StopScanningAsync()
OnDeviceDiscovered(object, DeviceEventArgs)
OnScanTimeout(object, DeviceEventArgs)
OnConnectClicked(object, EventArgs)
OnDisconnectClicked(object, EventArgs)
OnStartAccelerometerClicked(object, EventArgs)
OnStopAccelerometerClicked(object, EventArgs)
OnStartGyroscopeClicked(object, EventArgs)
OnStopGyroscopeClicked(object, EventArgs)
OnStartMagnetometerClicked(object, EventArgs)
OnStopMagnetometerClicked(object, EventArgs)
OnStartLightSensorClicked(object, EventArgs)
OnStopLightSensorClicked(object, EventArgs)
OnProbeClicked(object, EventArgs)
OnShowGraphClicked(object, EventArgs)
OnDisappearing()

Mobile: Page Models - Video

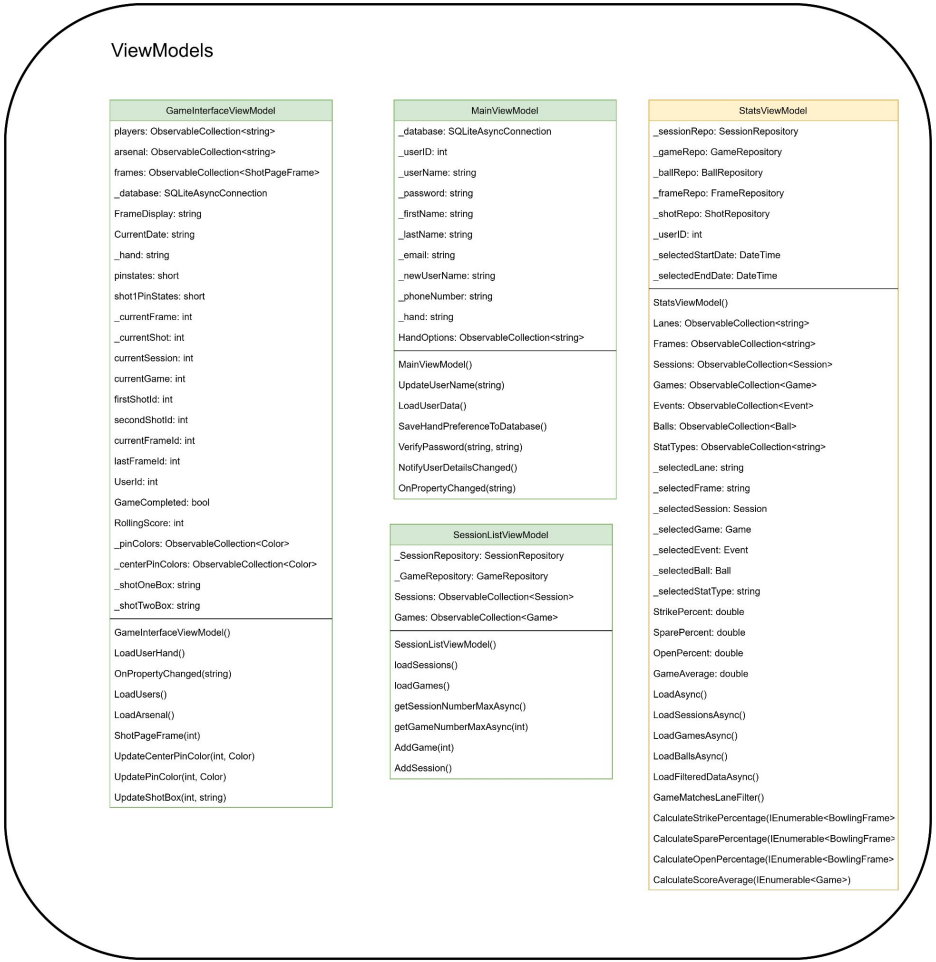


Implemented

Partially Implemented

Not Yet Implemented

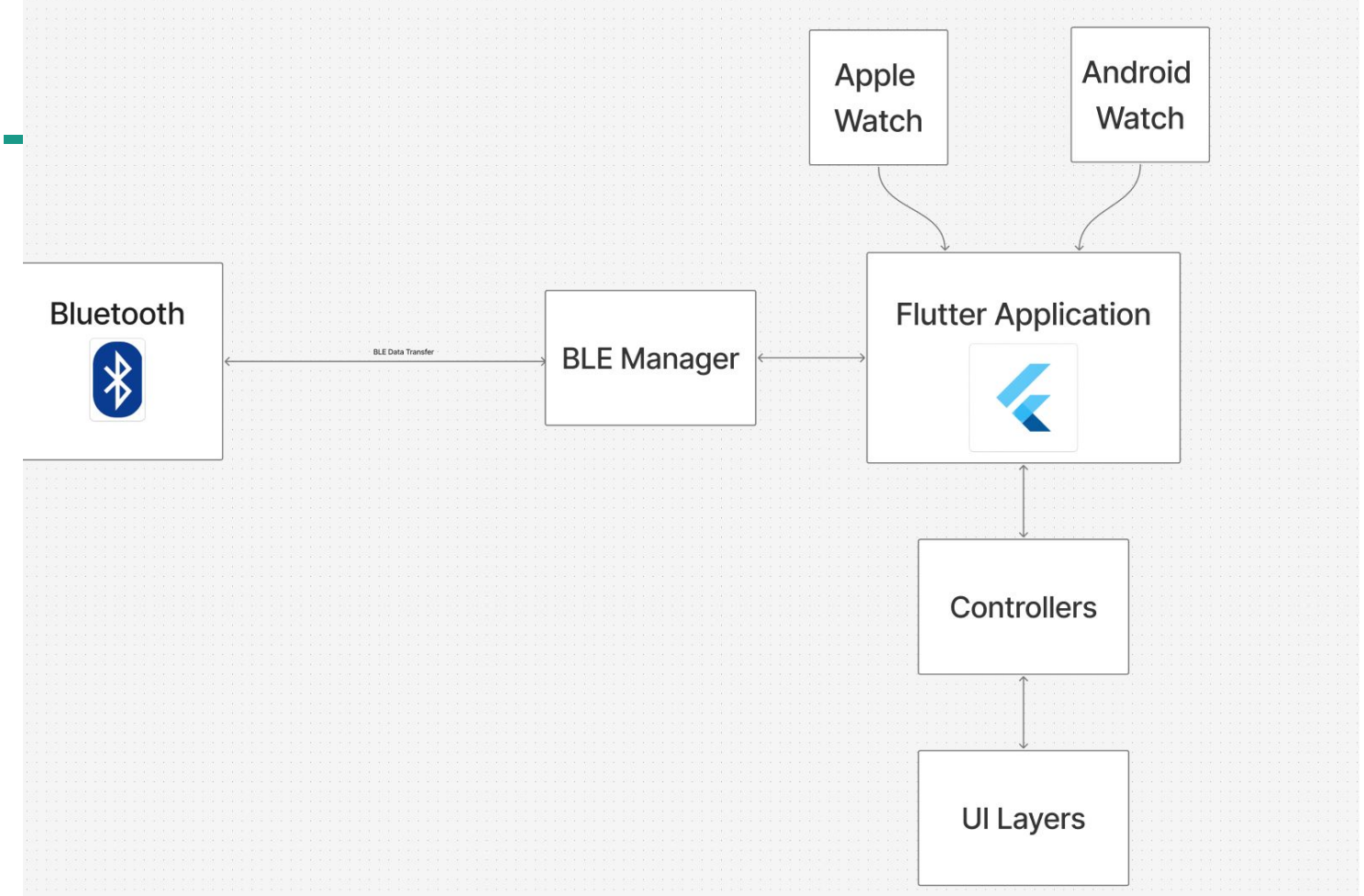
Mobile: View Models



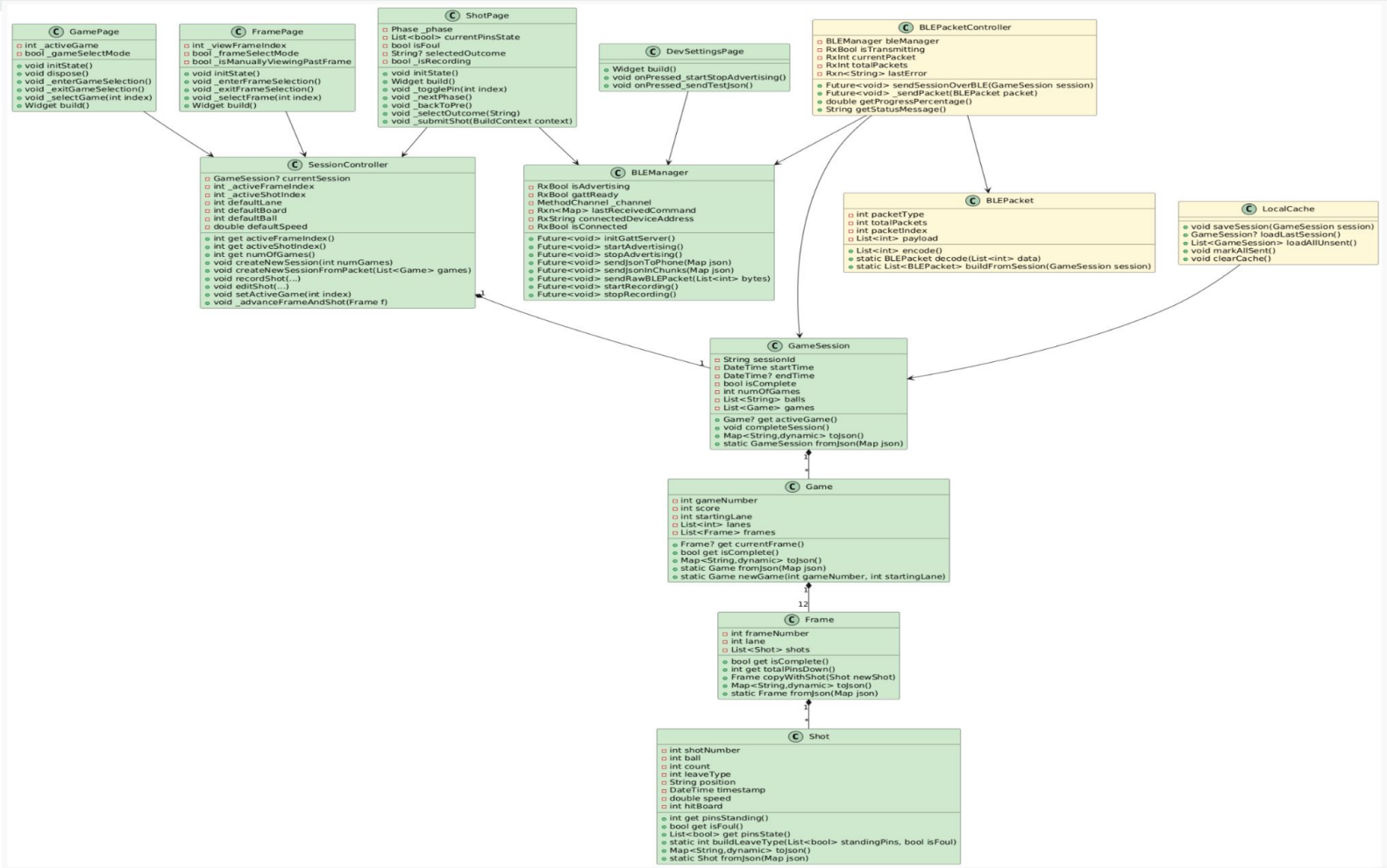
Mobile: Client Database

Client Database

Watch High-Level Overview



Watch UML


GamePage
- int _activeGame
- bool _gameSelectMode
+ void initState()
+ void dispose()
+ void _enterGameSelection()
+ void _exitGameSelection()
+ void _selectGame(int index)
+ Widget build()
FramePage
- int _viewFrameIndex
- bool _frameSelectMode
- bool _isManuallyViewingPastFrame
+ void initState()
+ void _enterFrameSelection()
+ void _exitFrameSelection()
+ void _selectFrame(int index)
+ Widget build()
ShotPage
- Phase _phase
- List<bool> currentPinsState
- bool isFoul
- String? selectedOutcome
- bool _isRecording
+ void initState()
+ Widget build()
+ void _togglePin(int index)
+ void _nextPhase()
+ void _backToPre()
+ void _selectOutcome(String)
+ void _submitShot(BuildContext context)
DevSettingsPage
+ Widget build()
+ void onPressed_startStopAdvertising()
+ void onPressed_sendTestJson()
BLEPacketController
- BLEManager bleManager
- RxBool isTransmitting
- RxInt currentPacket
- RxInt totalPackets
- Rxn<String> lastError
+ Future<void> sendSessionOverBLE(GameSession session)
+ Future<void> _sendPacket(BLEPacket packet)
+ double getProgressPercentage()
+ String getStatusMessage()
SessionController
- GameSession? currentSession
- int _activeFrameIndex
- int _activeShotIndex
- int defaultLane
- int defaultBoard
- int defaultBall
- double defaultSpeed
+ int get activeFrameIndex()
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+ int get numOfGames()
+ void createNewSession(int numGames)
+ void createNewSessionFromPacket(List<Game> games)
+ void recordShot(...)
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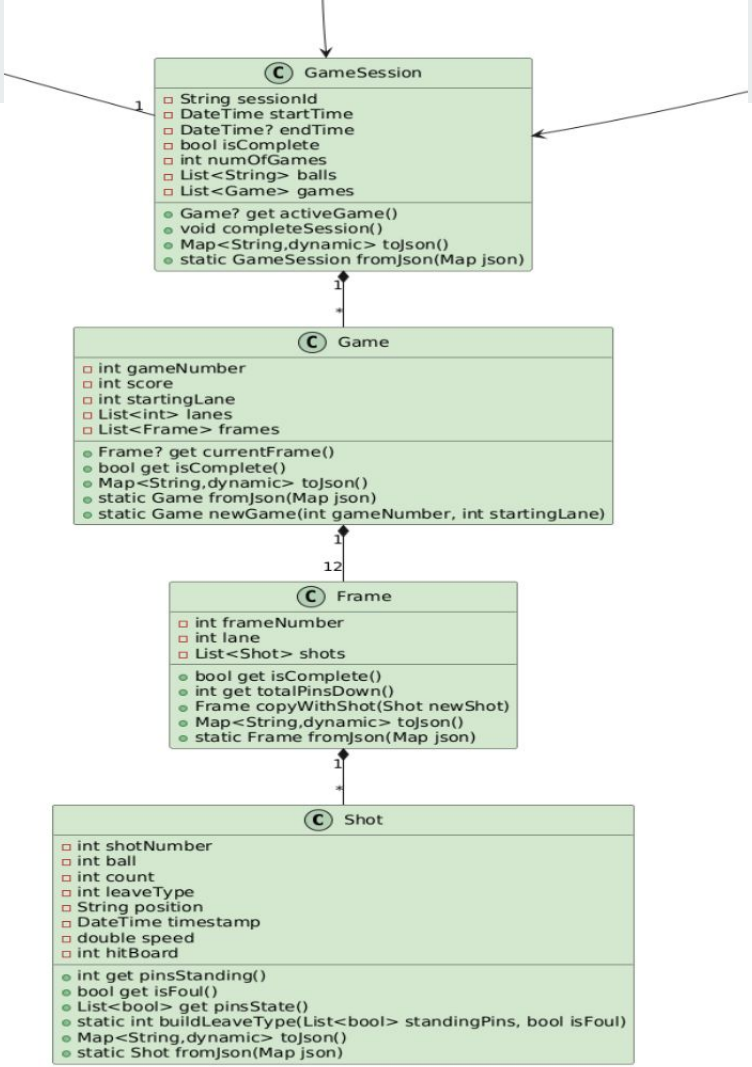
+ void setActiveGame(int index)
+ void _advanceFrameAndShot(Frame f)
BLEManager
- RxBool isAdvertising
- RxBool gattReady
- MethodChannel _channel
- Rxn<Map> lastReceivedCommand
- RxString connectedDeviceAddress
- RxBool isConnected
+ Future<void> initGattServer()
+ Future<void> startAdvertising()
+ Future<void> stopAdvertising()
+ Future<void> sendJsonToPhone(Map json)
+ Future<void> sendJsonInChunks(Map json)
+ Future<void> sendRawBLEPacket(List<int> bytes)
+ Future<void> startRecording()
+ Future<void> stopRecording()
BLEPacket
- int packetType
- int totalPackets
- int packetIndex
- List<int> payload
+ List<int> encode()
+ static BLEPacket decode(List<int> data)
+ static List<BLEPacket> buildFromSession(GameSession session)
LocalCache
+ void saveSession(GameSession session)
+ GameSession? loadLastSession()
+ List<GameSession> loadAllUnsent()
+ void markAllSent()
+ void clearCache()
GameSession
- String sessionId
- DateTime startTime
- DateTime? endTime
- bool isComplete
- int numOfGames
- List<String> balls
- List<Game> games
+ Game? get activeGame()
+ void completeSession()
+ Map<String,dynamic> toJson()
+ static GameSession fromJson(Map json)
Game
- int gameNumber
- int score
- int startingLane
- List<int> lanes
- List<Frame> frames
+ Frame? get currentFrame()
+ bool get isComplete()
+ Map<String,dynamic> toJson()
+ static Game fromJson(Map json)
+ static Game newGame(int gameNumber, int startingLane)
Frame
- int frameNumber
- int lane
- List<Shot> shots
+ bool get isComplete()
+ int get totalPinsDown()
+ Frame copyWithShot(Shot newShot)
+ Map<String,dynamic> toJson()
+ static Frame fromJson(Map json)
Shot
- int shotNumber
- int ball
- int count
- int leaveType
- String position
- DateTime timestamp
- double speed
- int hitBoard
+ int get pinsStanding()
+ bool get isFoul()
+ List<bool> get pinsState()
+ static int buildLeaveType(List<bool> standingPins, bool isFoul)
+ Map<String,dynamic> toJson()
+ static Shot fromJson(Map json)

Watch UML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1
1
*
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int score
int startingLane
List<int> lanes
List<Frame> frames
Frame? get currentFrame()
bool get isComplete()
Map<String,dynamic> toJson()
static Game fromJson(Map json)
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12
Frame
int frameNumber
int lane
List<Shot> shots
bool get isComplete()
int get totalPinsDown()
Frame copyWithShot(Shot newShot)
Map<String,dynamic> toJson()
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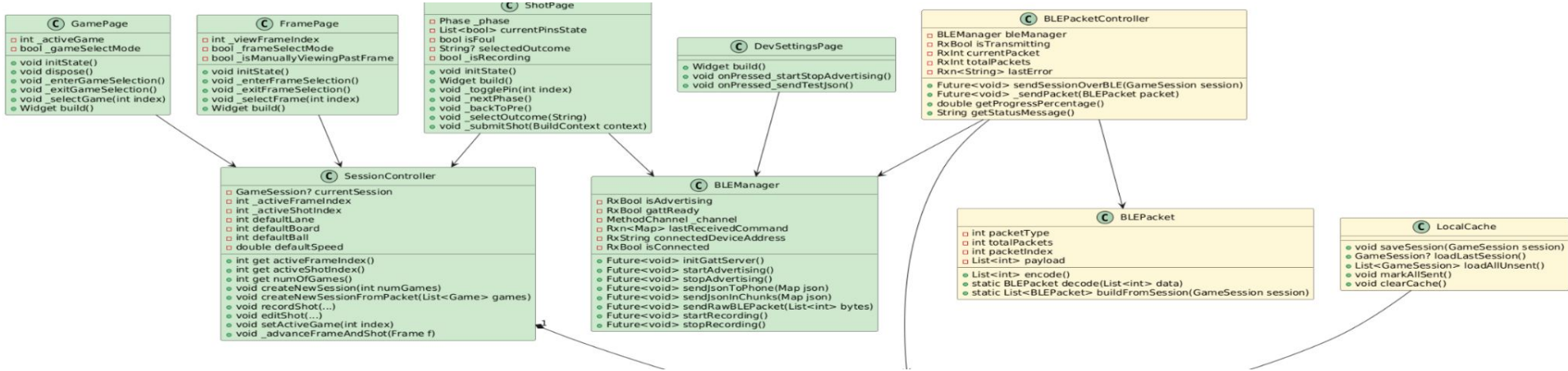
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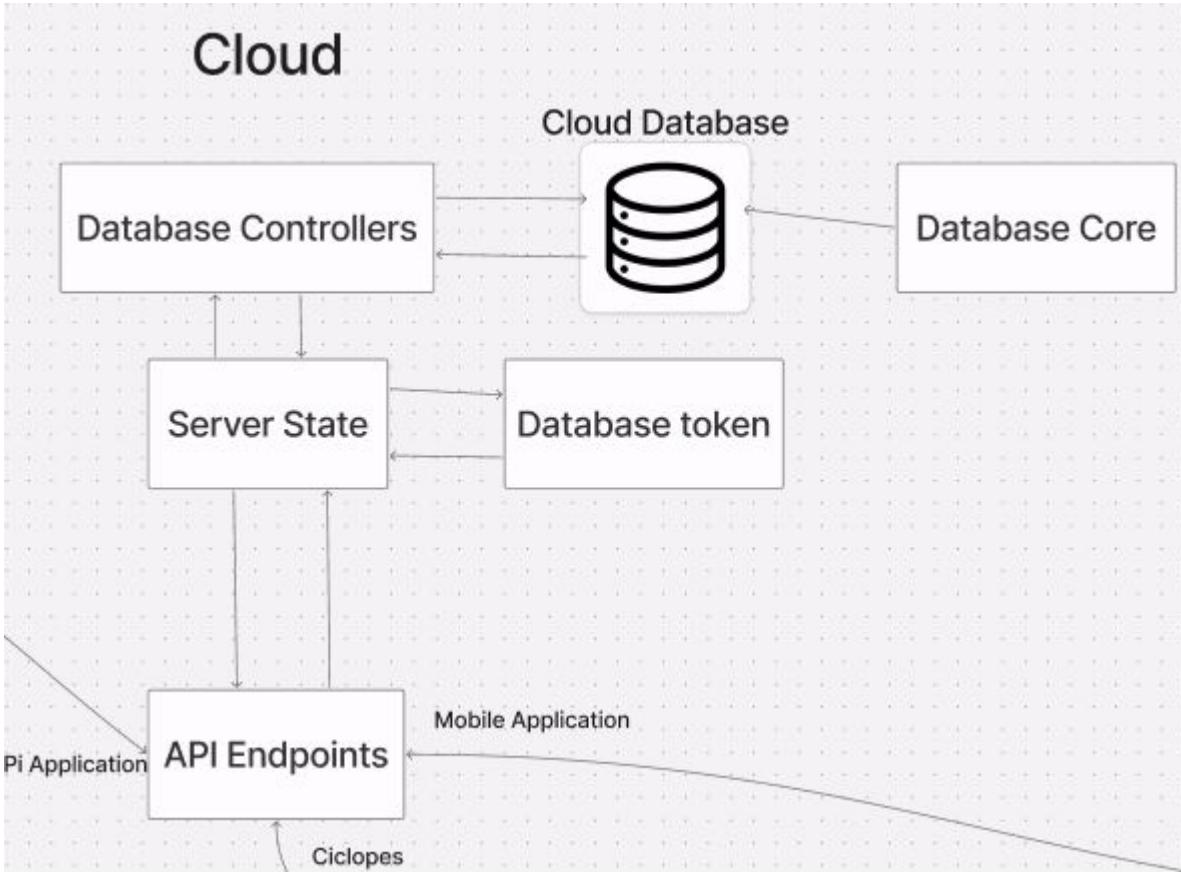
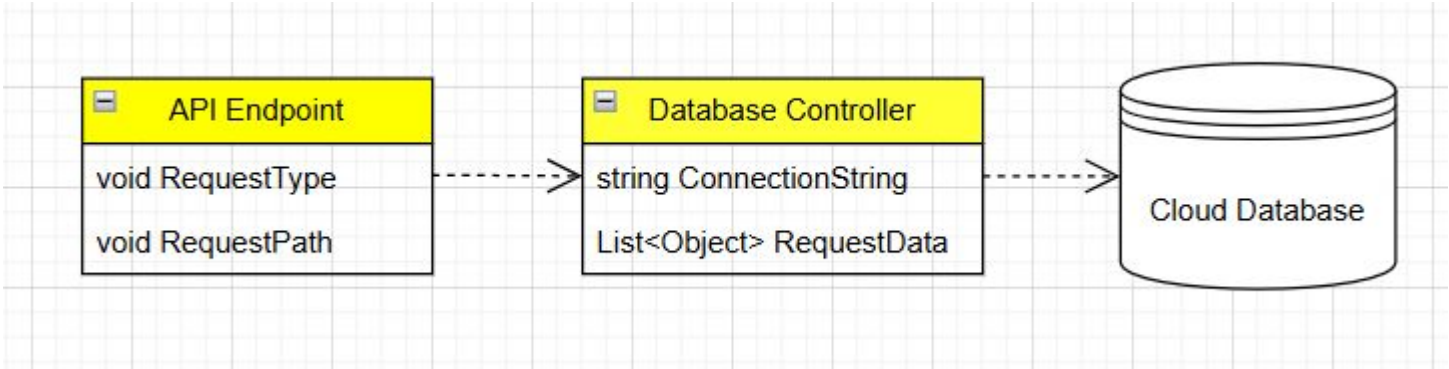
1

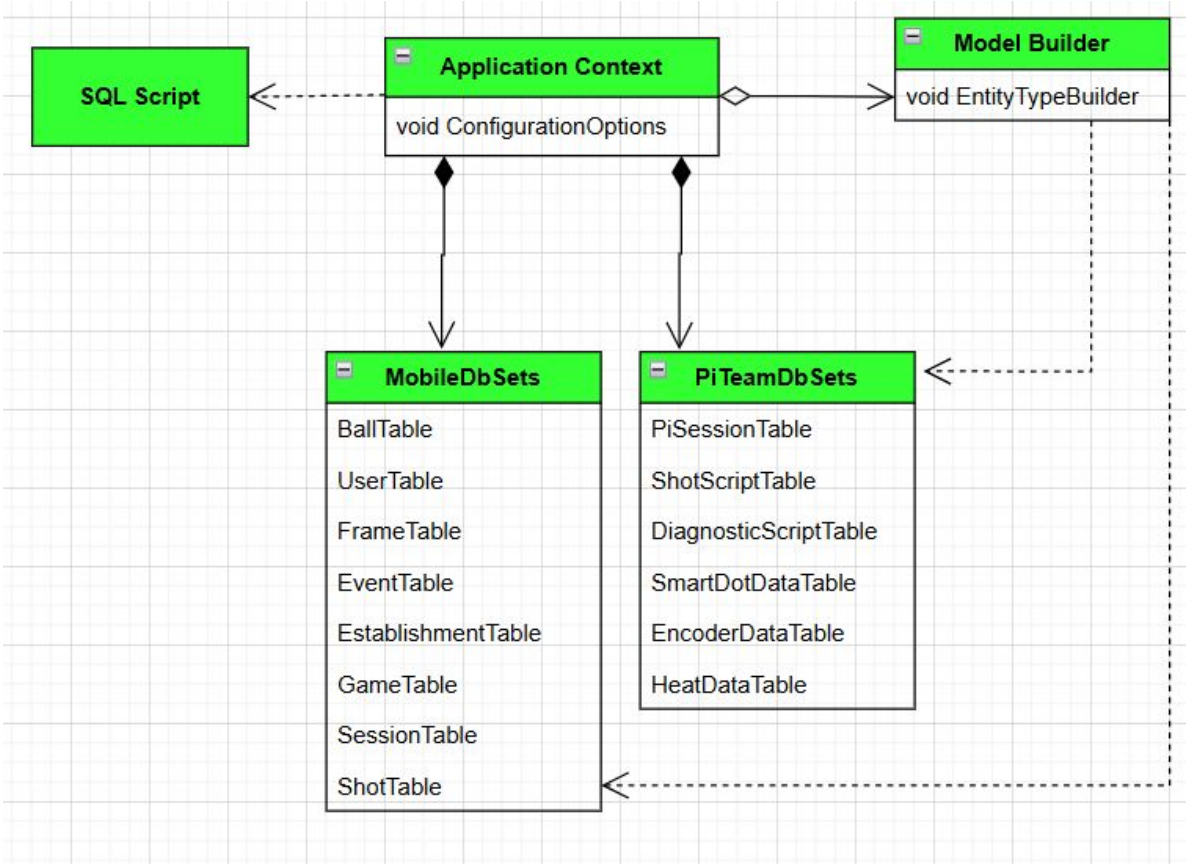
Cloud
High-Level Overview



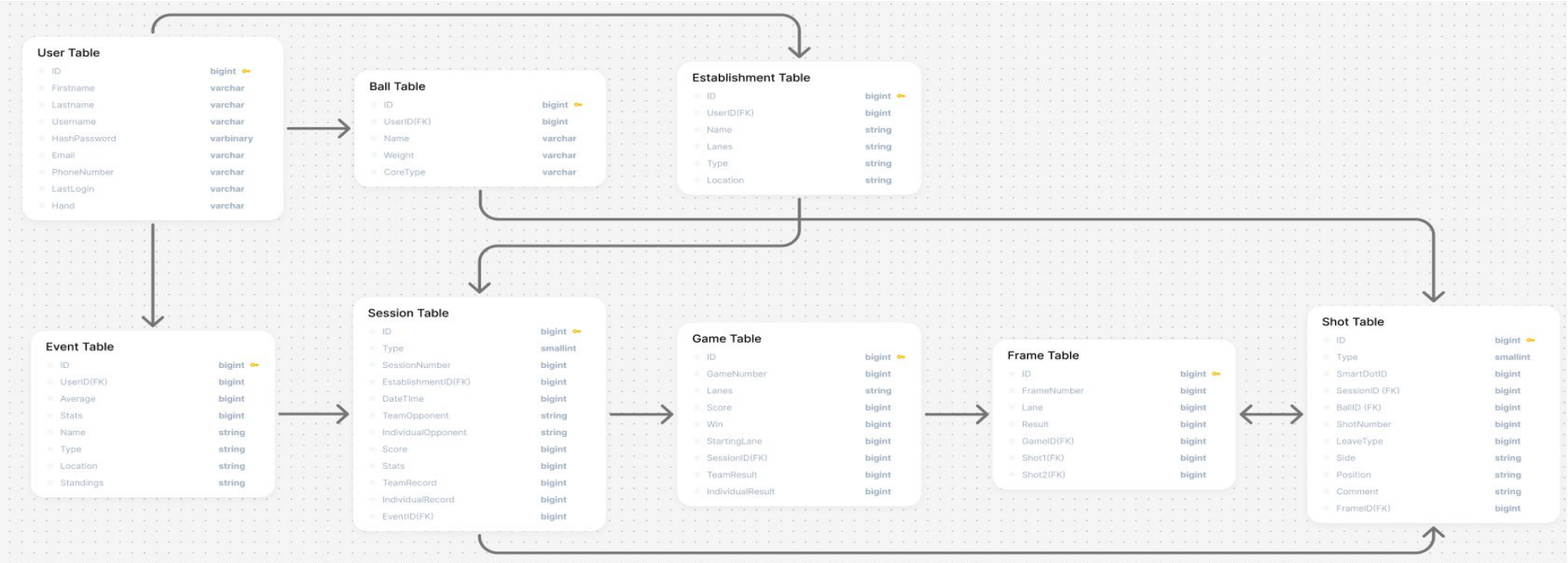
Cloud - Cloud Application UML Diagram



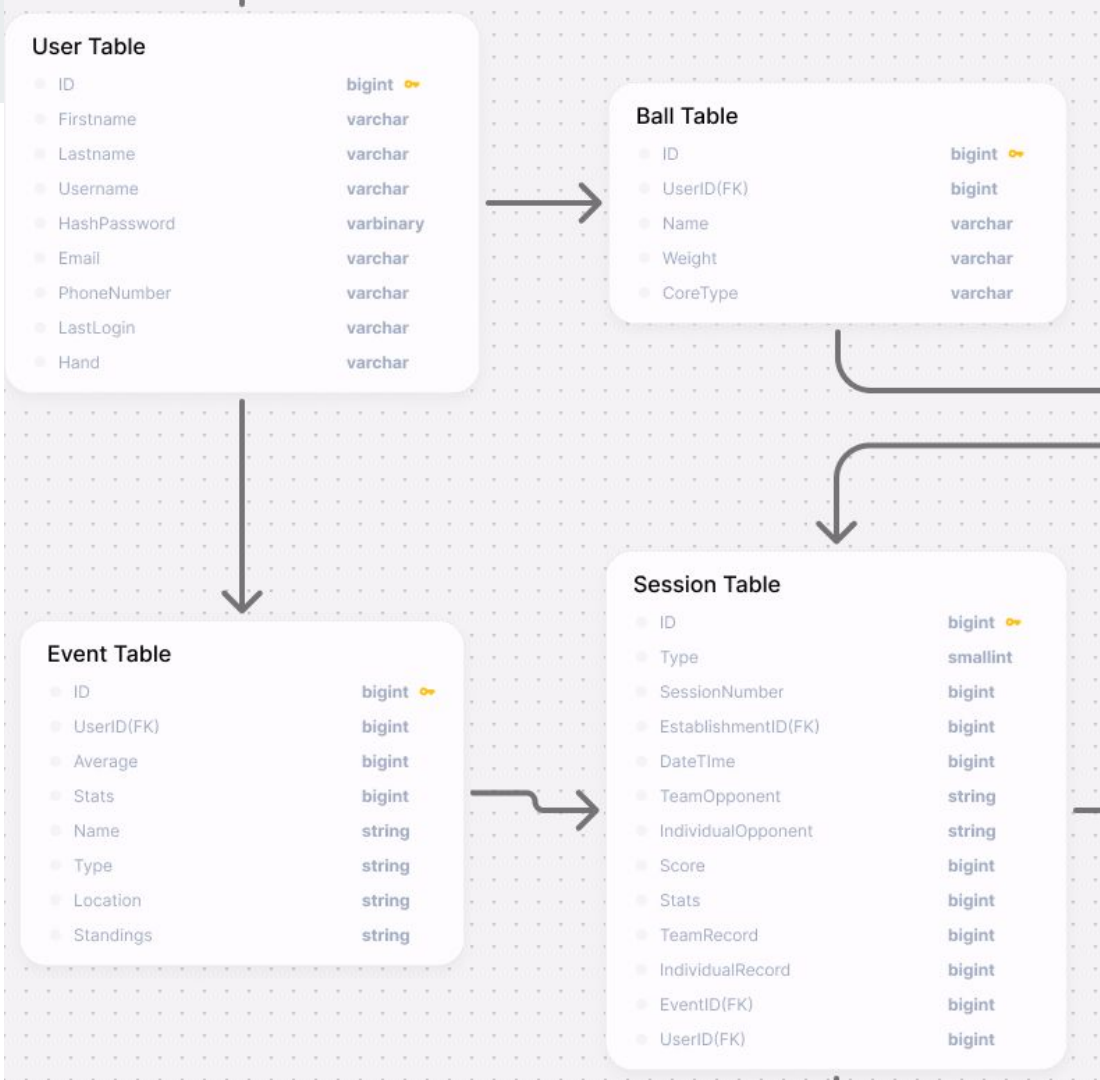
Cloud - DBCore UML Diagram



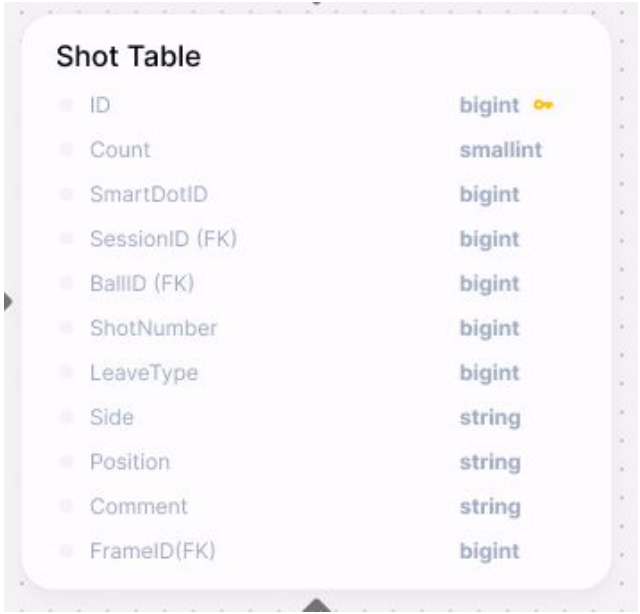
Cloud - Mobile Database Schema

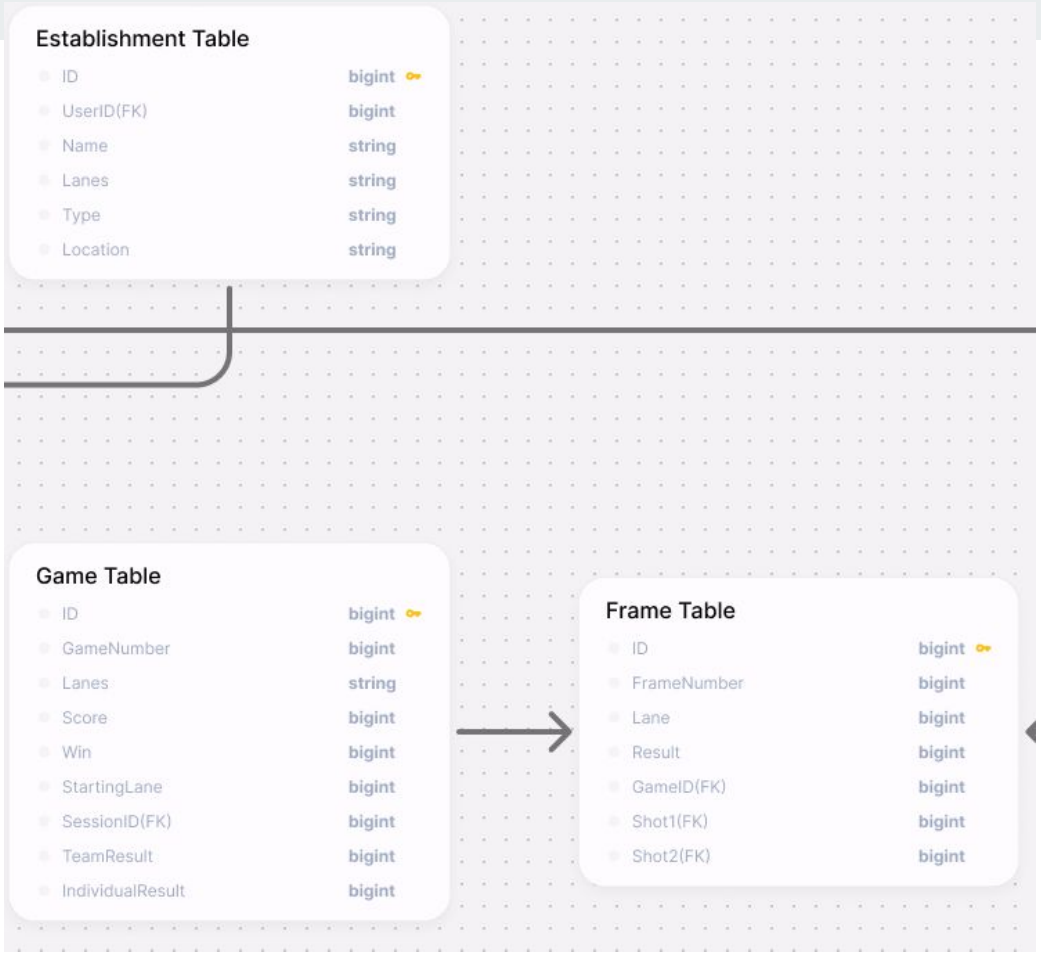


Cloud - Mobile Schema Zoomed In

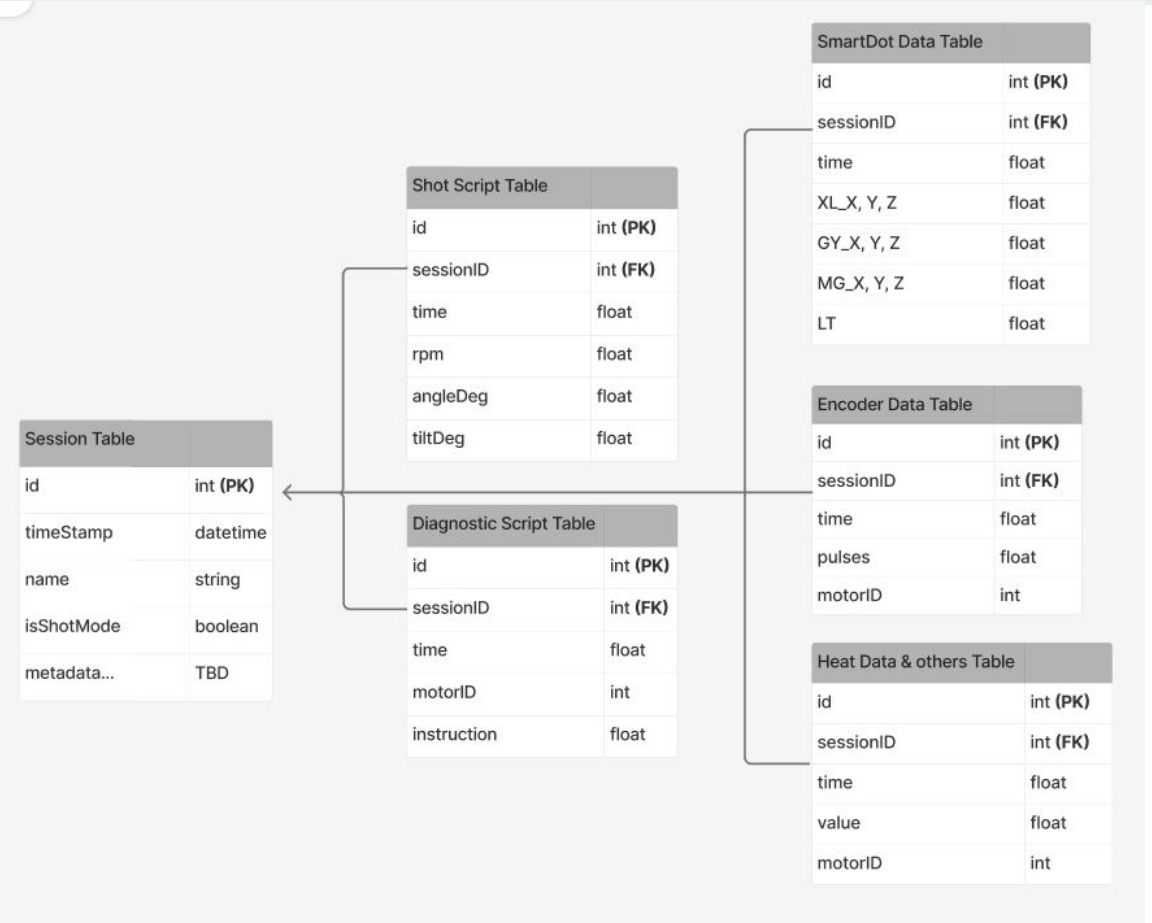


Cloud - Mobile Schema Zoomed In





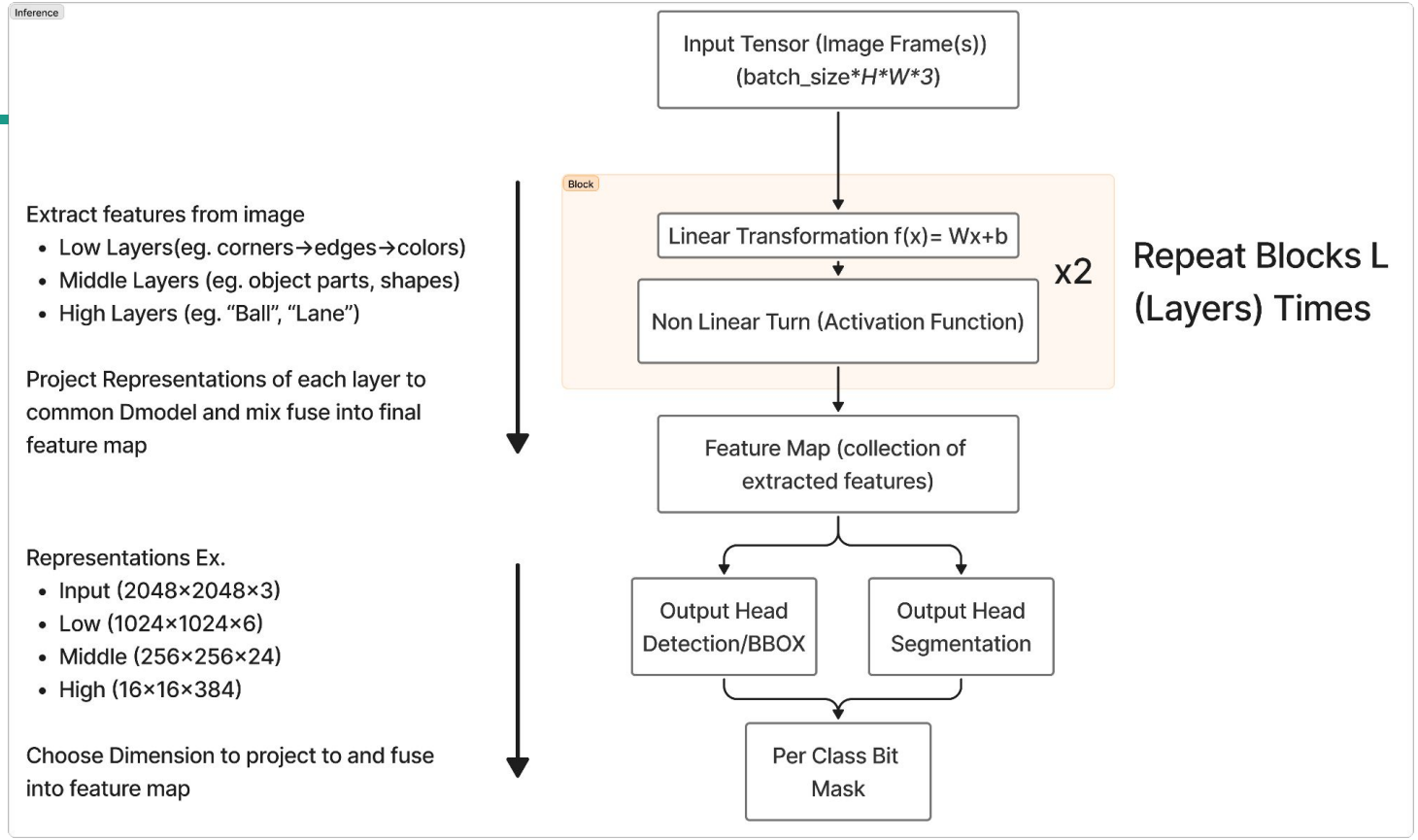
Cloud - Pi Team Schema



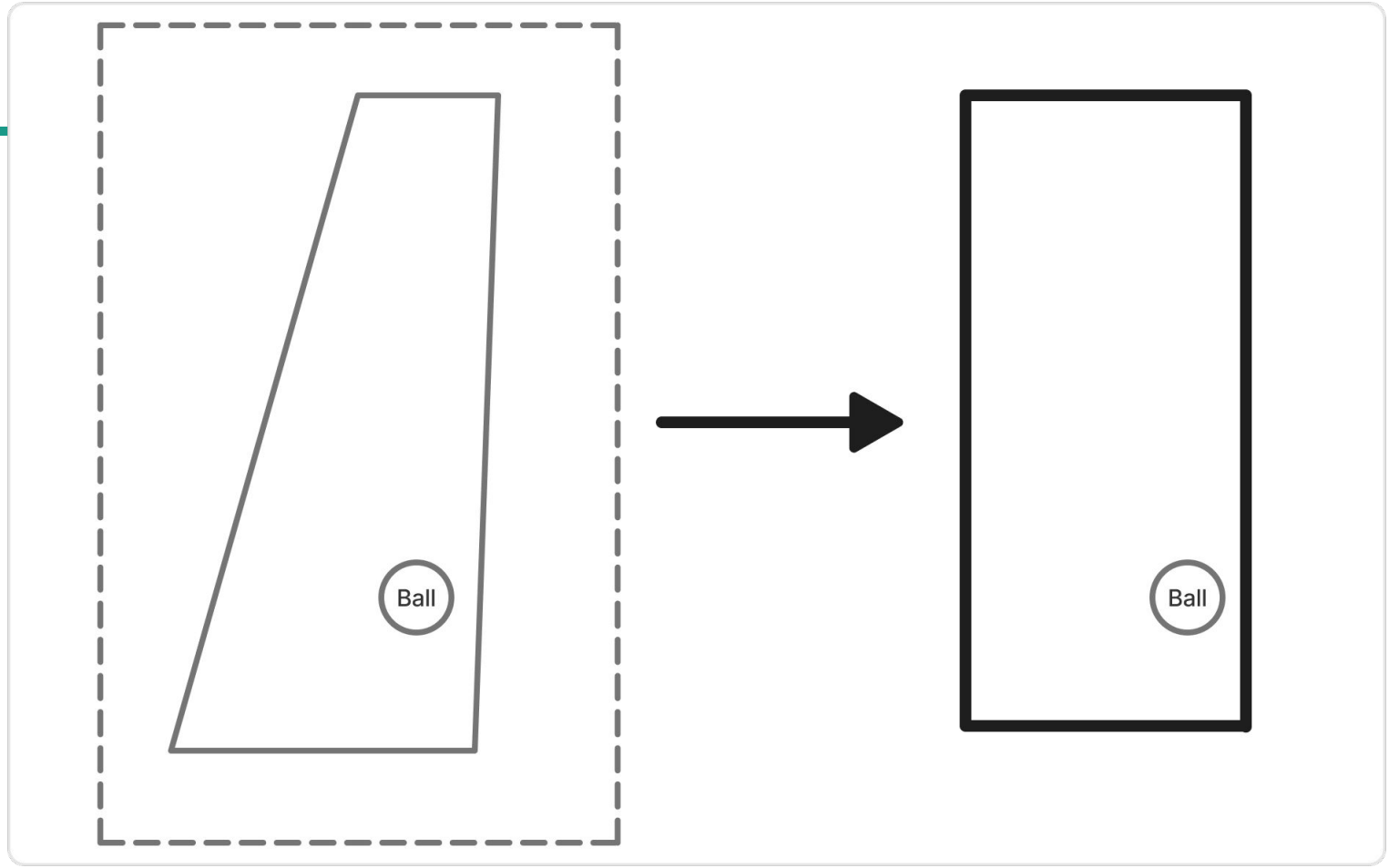
Ciclopes - Overview From First Principles

1. Preprocessing
    1.1. Video Intake
    1.2. Computer Vision Model Object Detection/Segmentation
2. Postprocessing
    2.1. Use lane and known size to calculate the transformation from its shape in the image to a top down view of it as a rectangle
    2.2. Reuse this transformation on the contact point of the ball on the lane to transform it onto the top down view of the lane
    2.3. Optionally apply interpolation (predicting points between the known points)
    2.4. Use coordinates of the ball per frame to do kinematics calculations / render trajectory

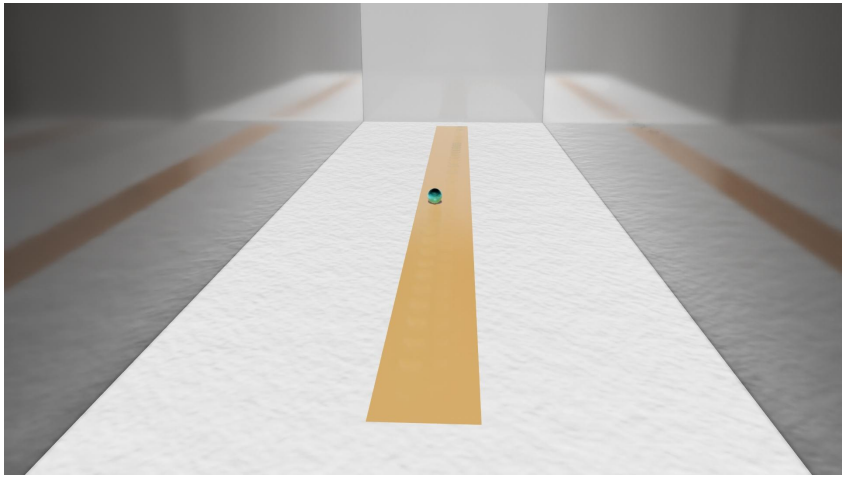
Ciclopes - Deep Learning Overview

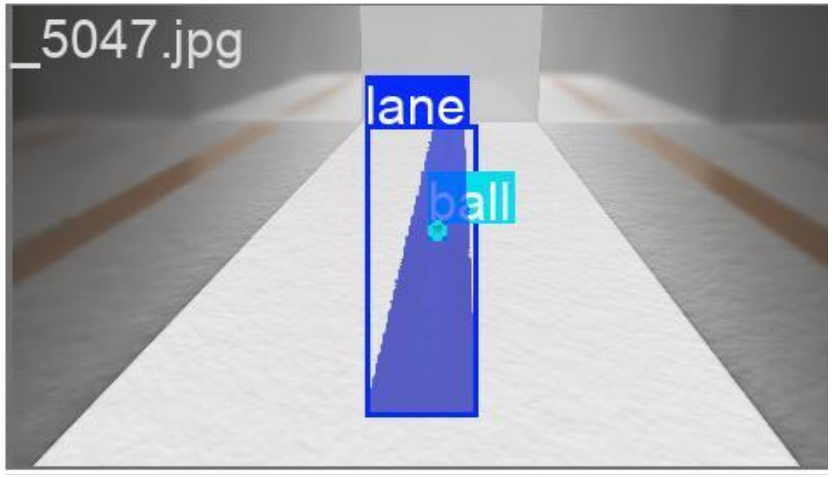


Ciclopes - Homography Example

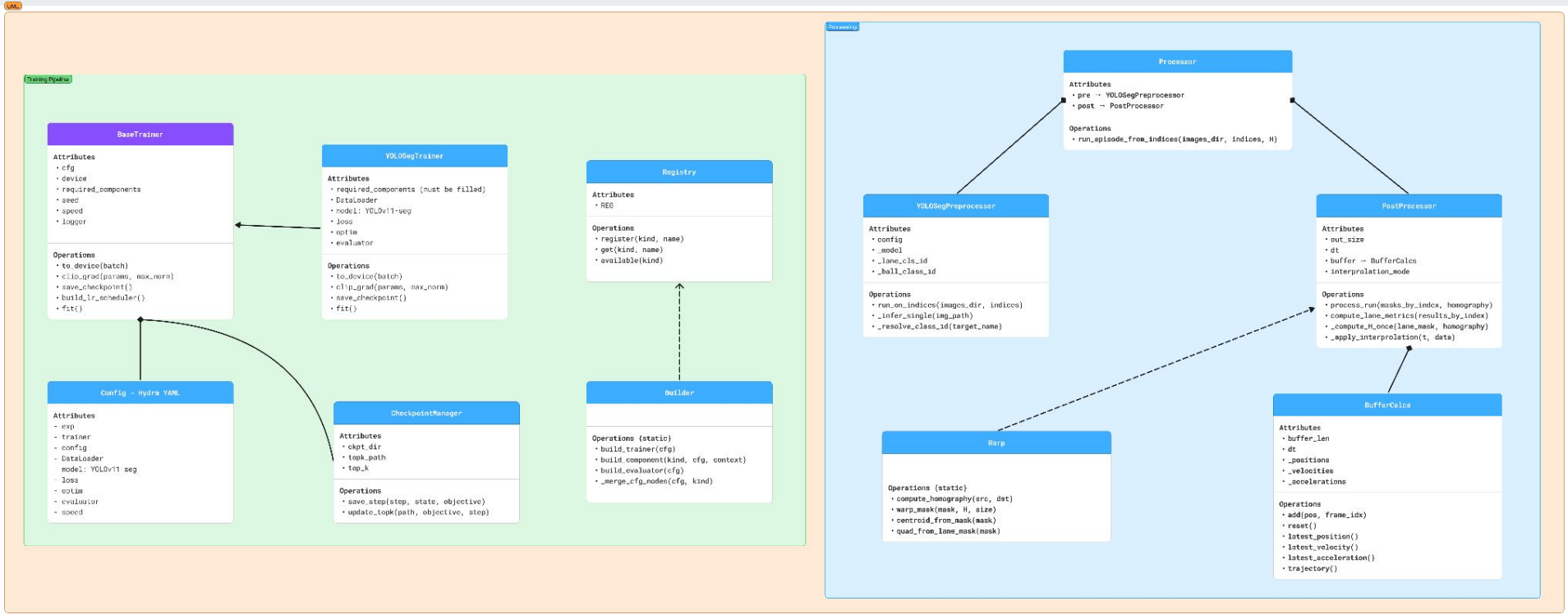


Ciclopes - IsaacSim Synthetic Data

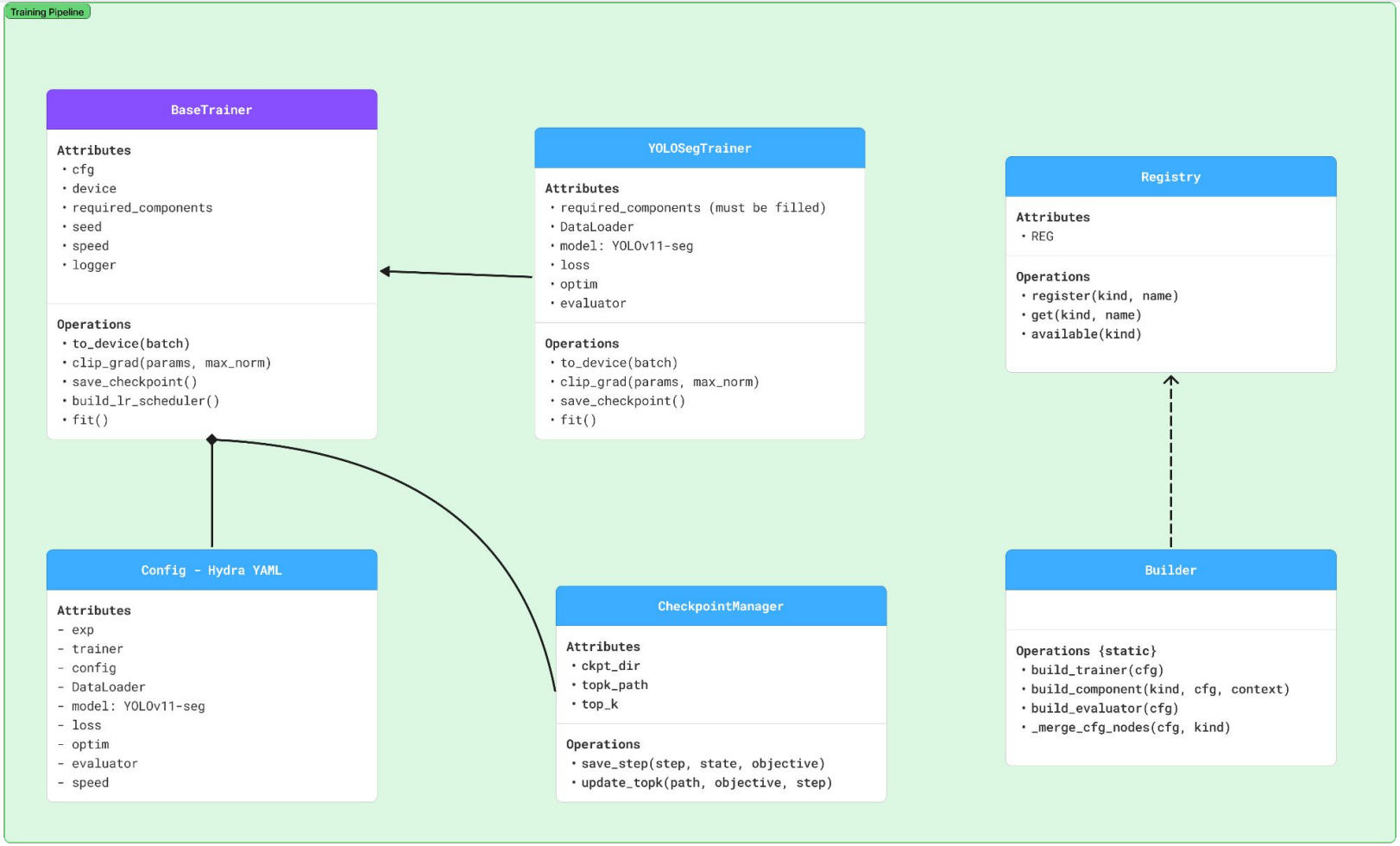




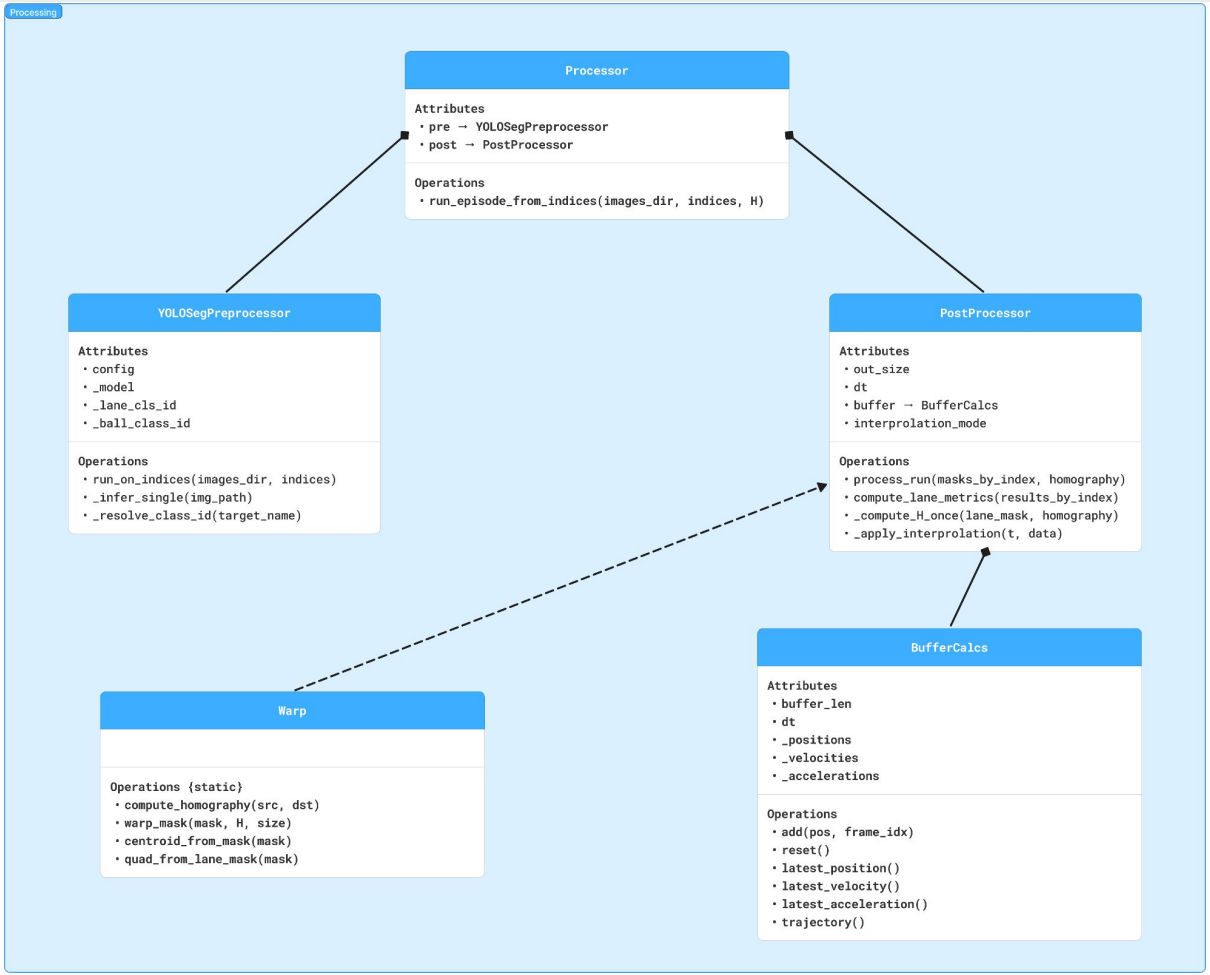
Ciclopes - Full UML



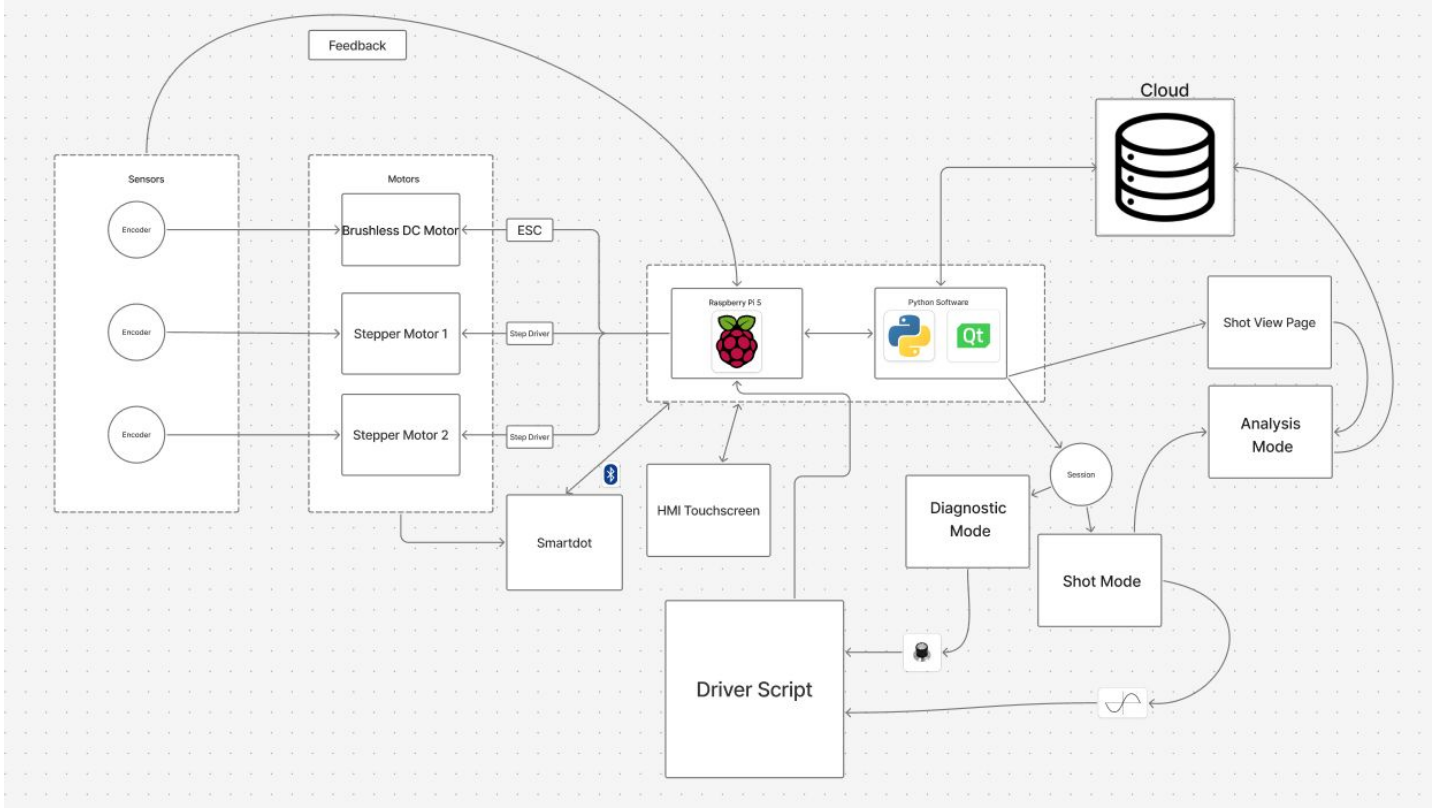
Ciclopes - Training Pipeline



Ciclopes - Processing

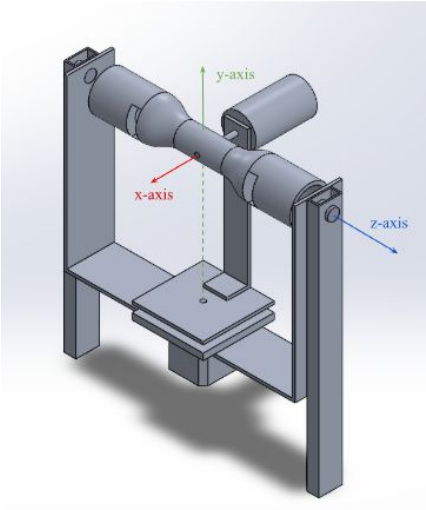


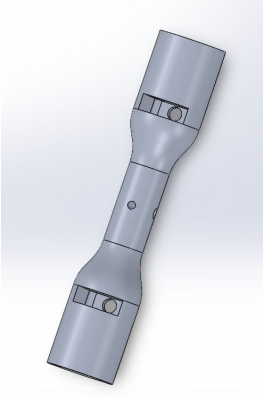
Ball Spinner Mechanical System High Level Overview



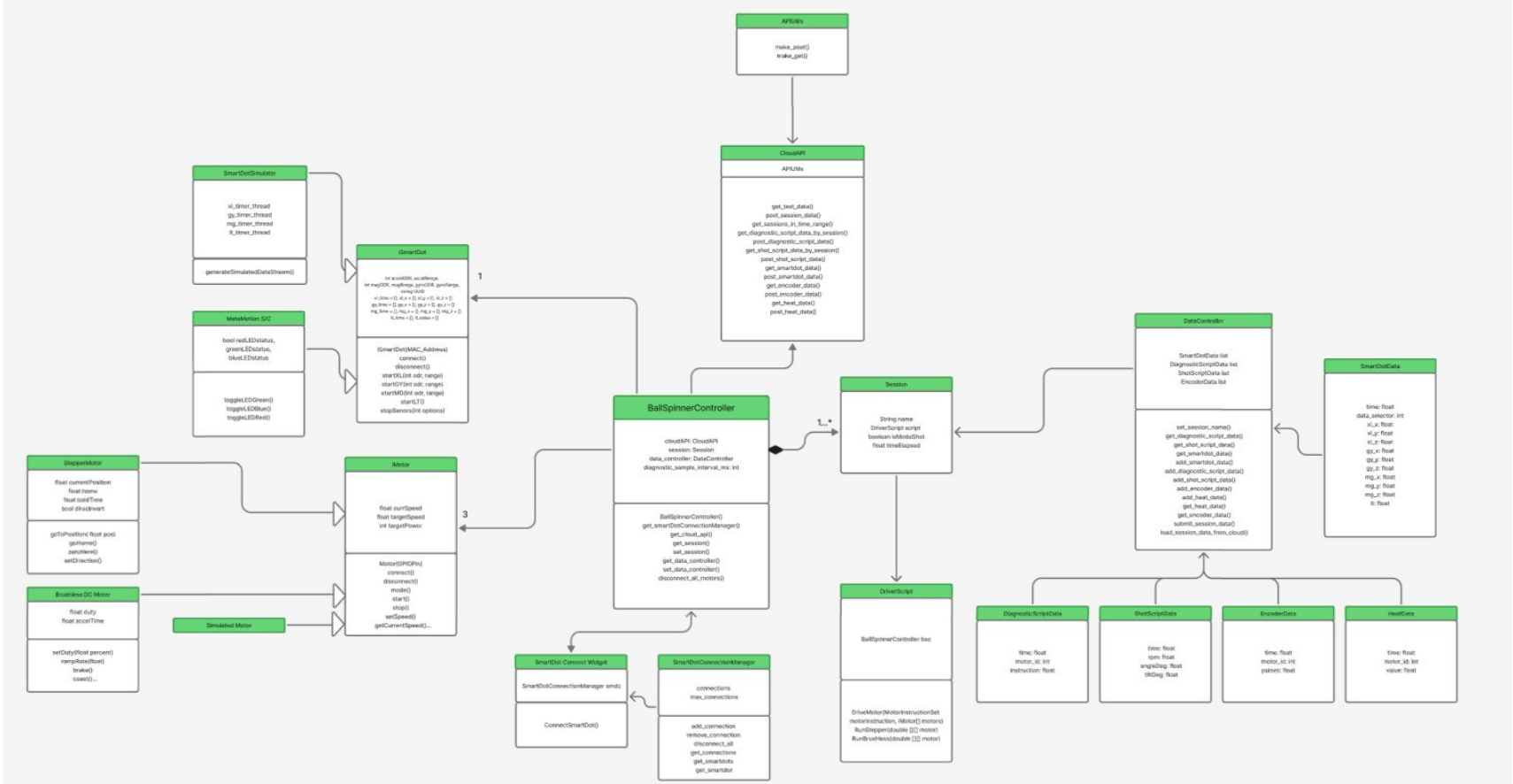
Ball Spinner Mechanical System

- **3 axes of rotation controlled independently**
  - X-axis: 1st DOF, Smart Dot Holder attached to motor by friction fit and set screw
  - Y-axis: 2nd DOF, rotating plate holding 1st dof
  - Z-axis: 3rd DOF, U-bracket which rotates 1st and 2nd
- **SmartDots mount into SmartDot Holder by a friction fit**
  - Allows for collection of light, acceleration, and positional sensor data
  - Easy removal for charging or replacement
- **Calculated torques based on required speed and angle**

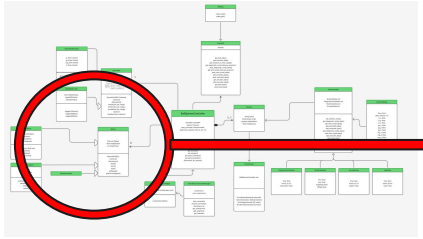


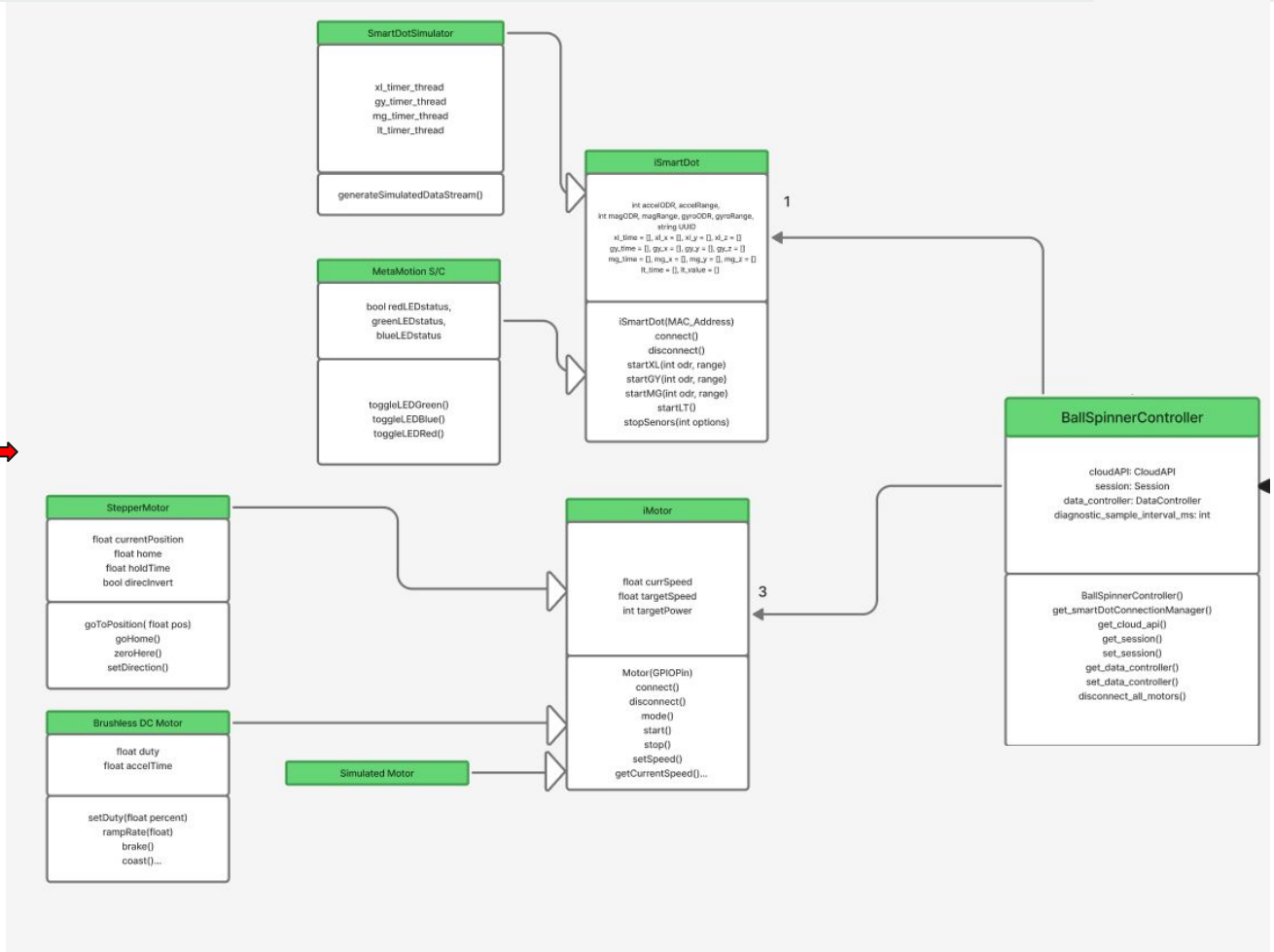


Ball Spinner Controller UML

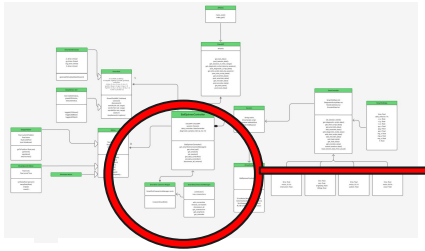


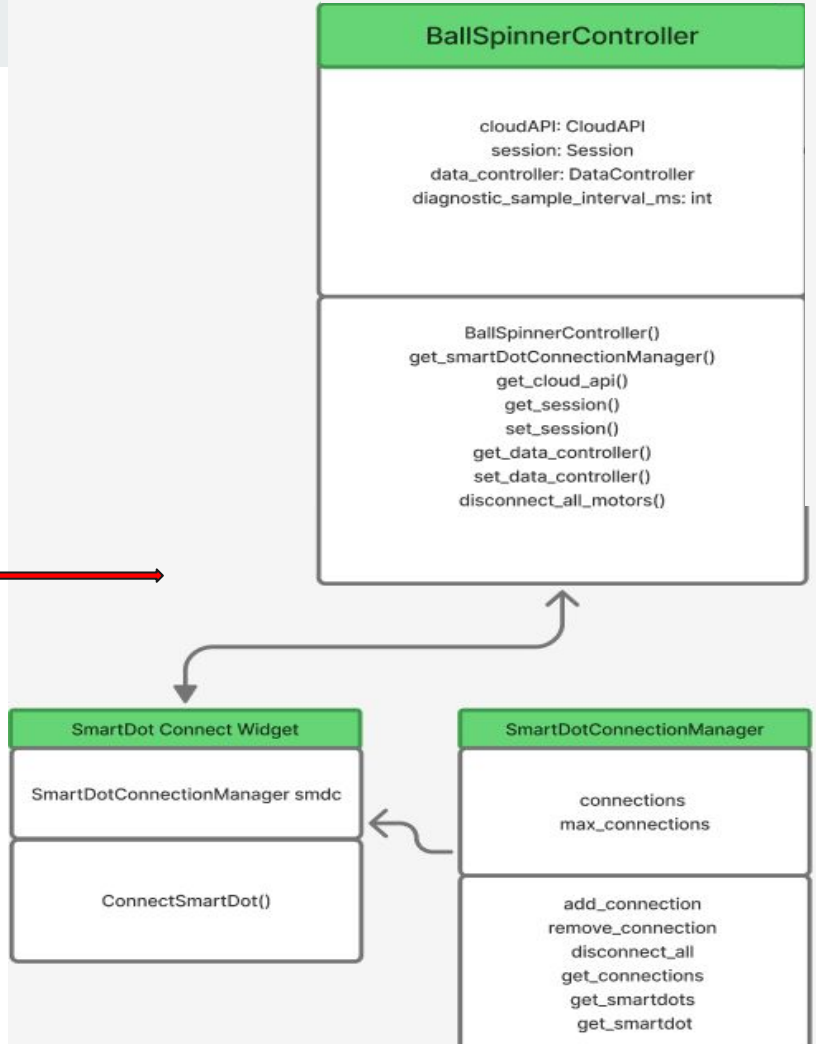
Ball Spinner Controller UML



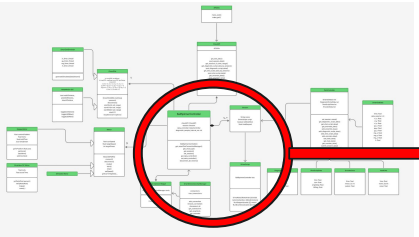


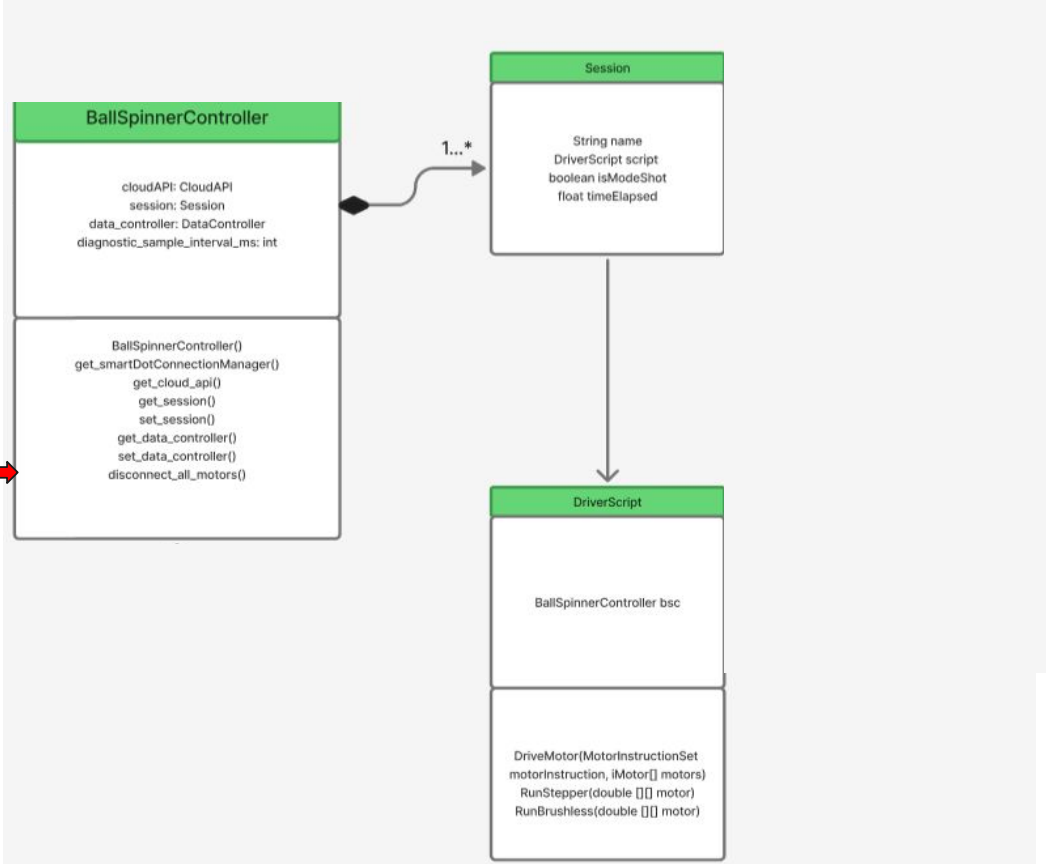
Ball Spinner Controller UML



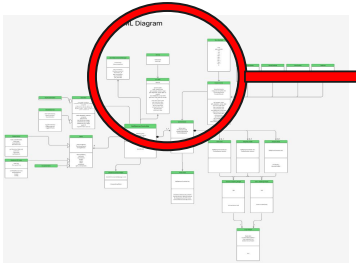


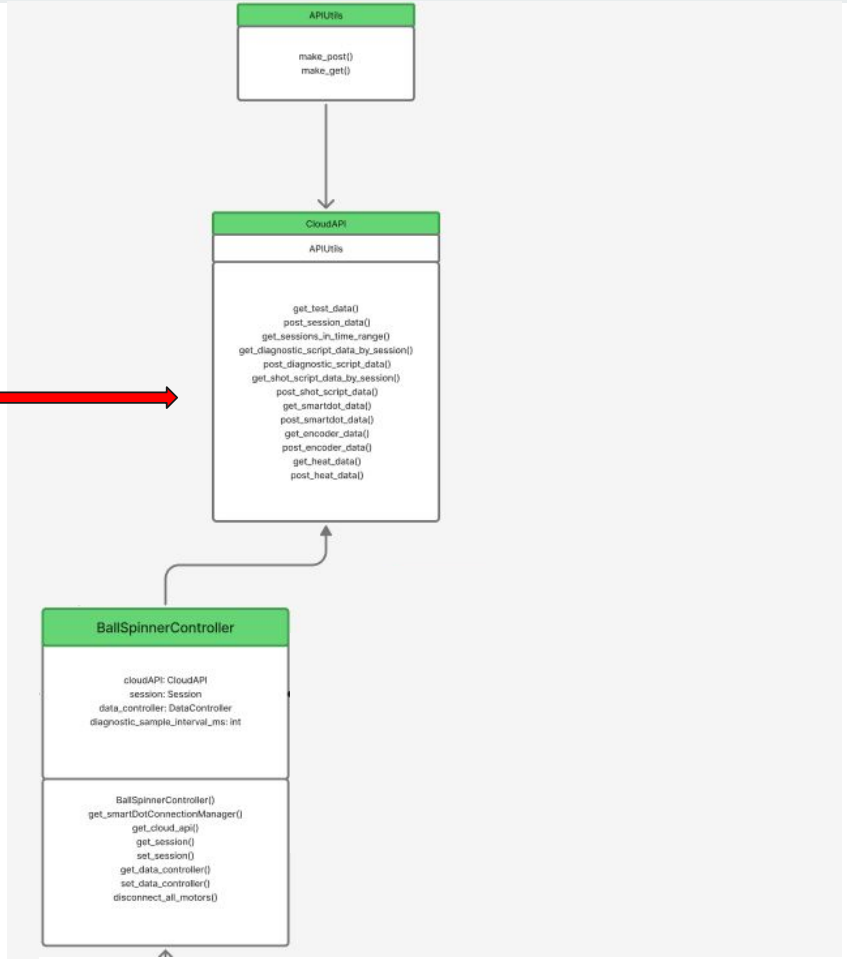
Ball Spinner Controller UML



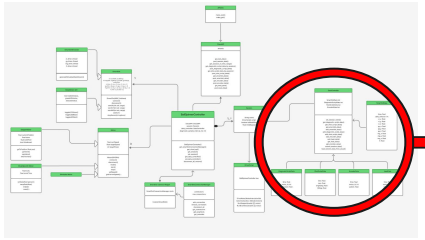


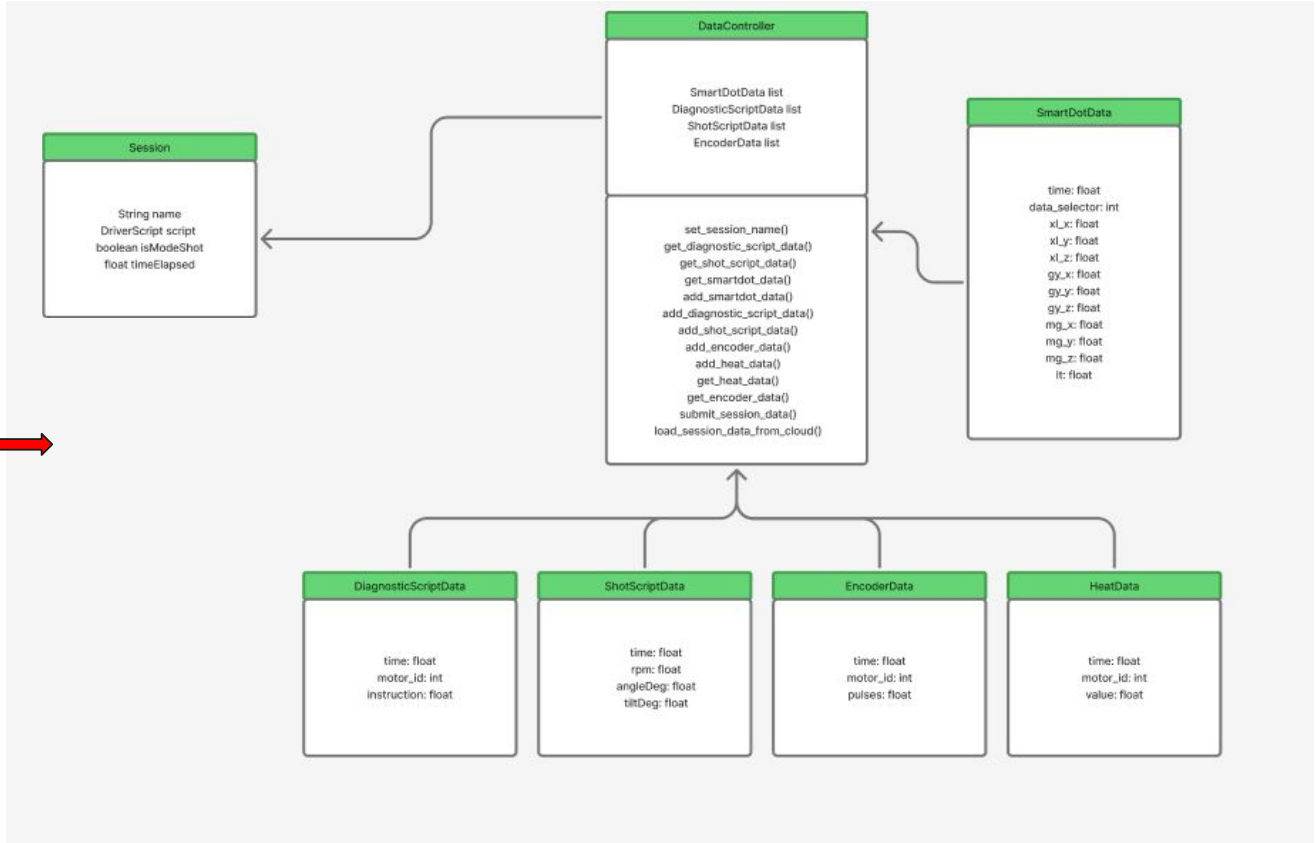
Ball Spinner Controller UML



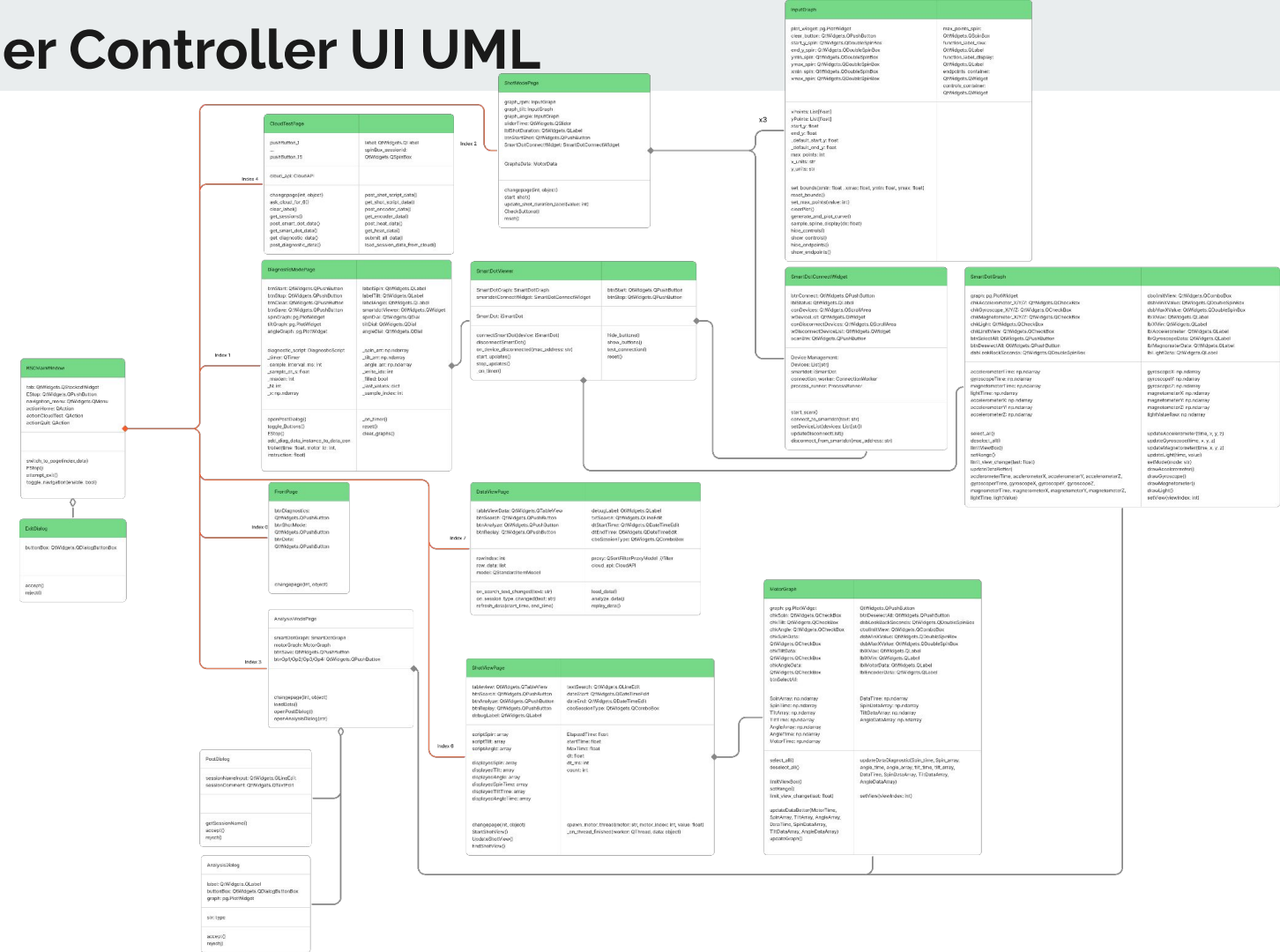


Ball Spinner Controller UML

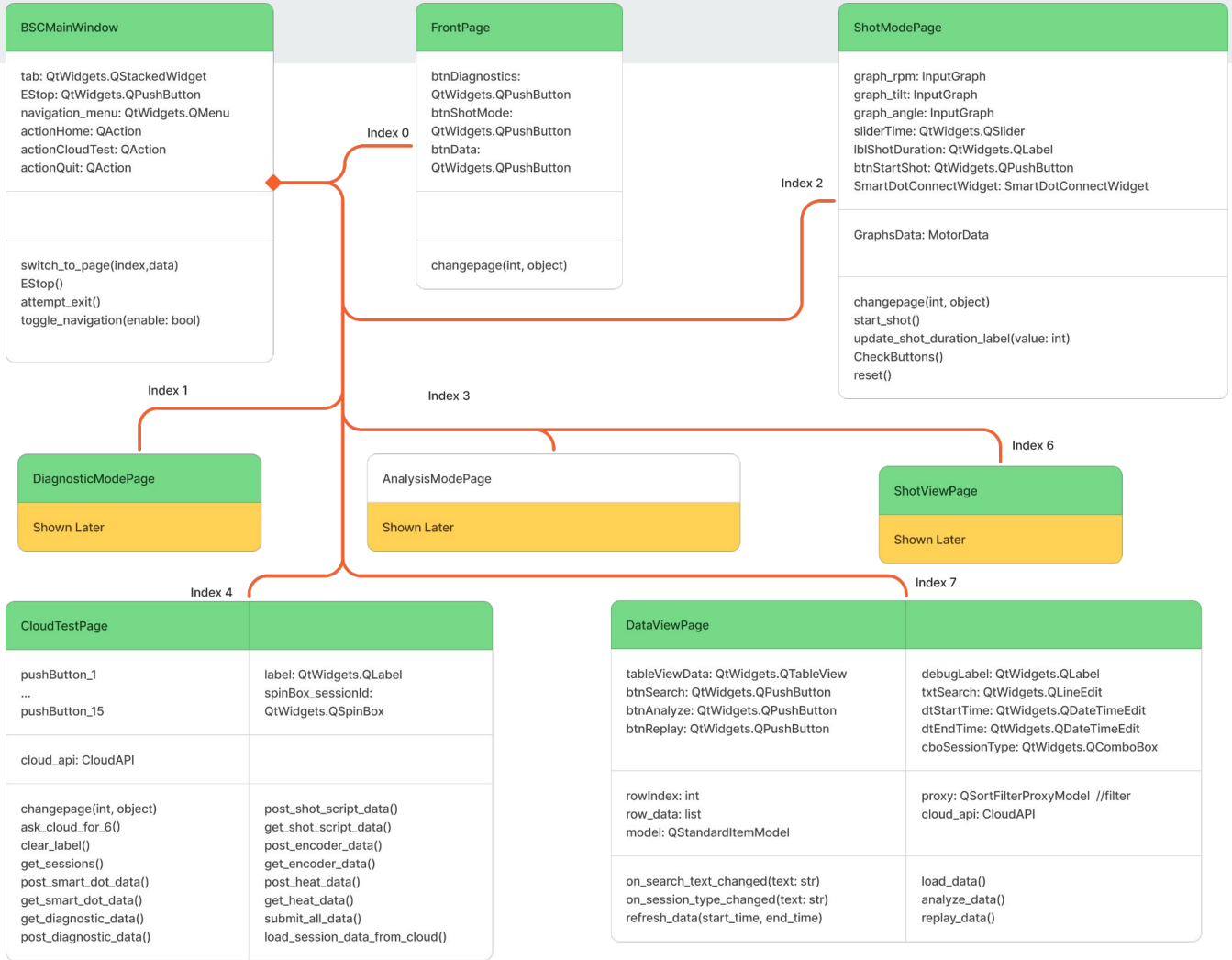




Ball Spinner Controller UI UML



BSC Ui UML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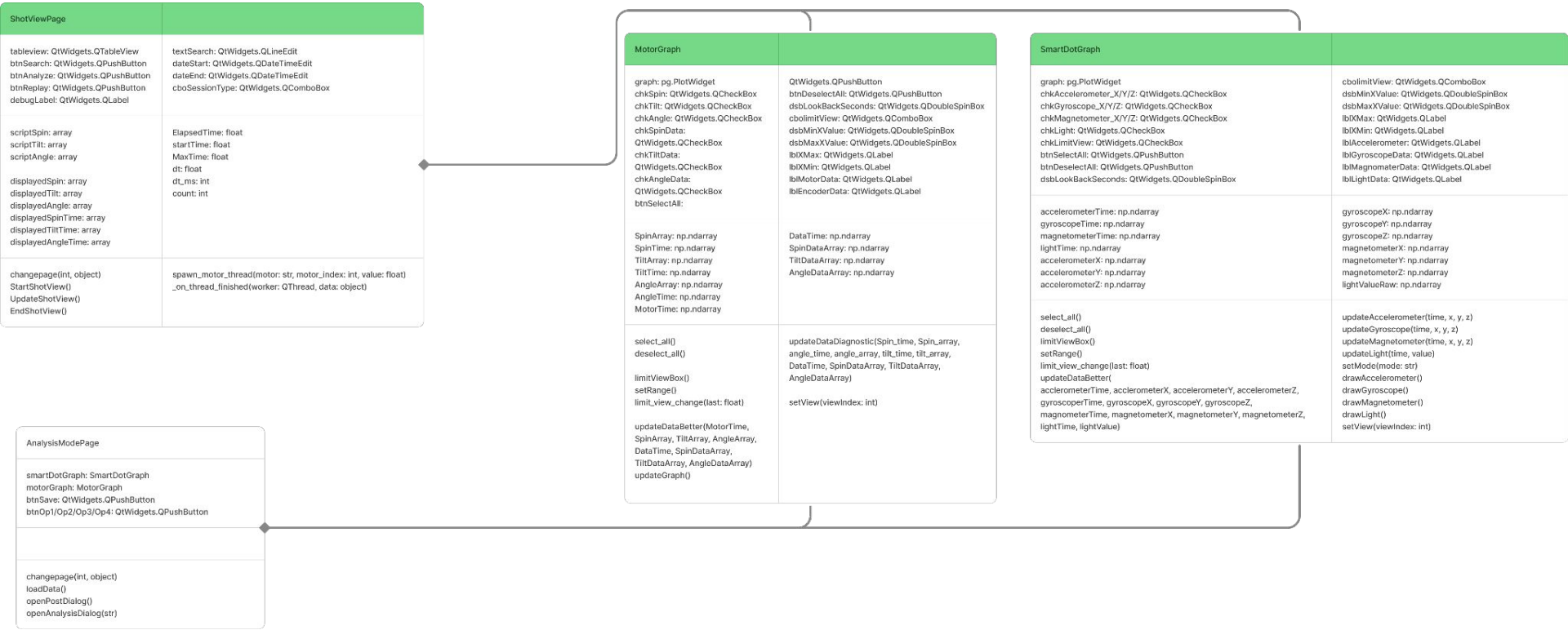
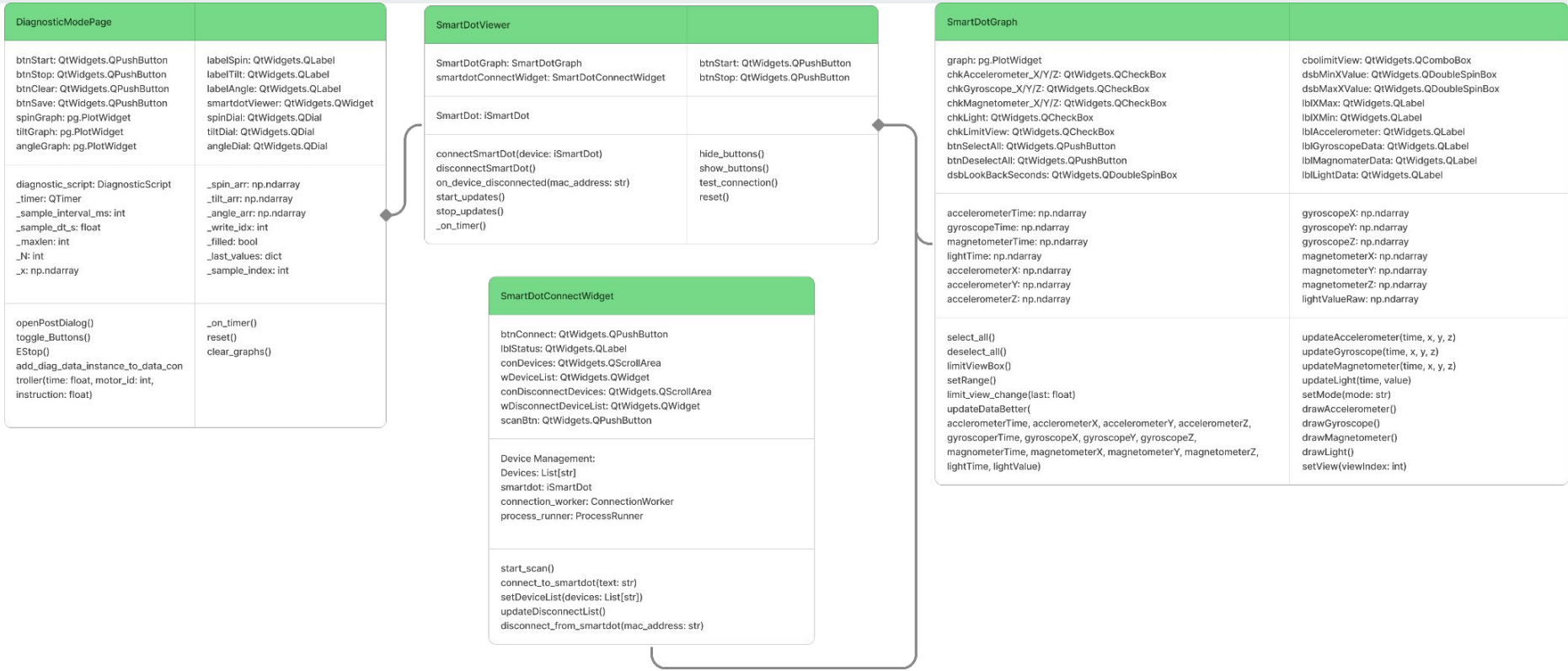
tab: QtWidgets.QStackedWidget
EStop: QtWidgets.QPushButton
navigation_menu: QtWidgets.QMenu
actionHome: QAction
actionCloudTest: QAction
actionQuit: QAction
switch_to_page(index,data)
EStop()
attempt_exit()
toggle_navigation(enable: bool)
Index 0
FrontPage
btnDiagnostics: QtWidgets.QPushButton
btnShotMode: QtWidgets.QPushButton
btnData: QtWidgets.QPushButton
changepage(int, object)
Index 2
ShotModePage
graph_rpm: InputGraph
graph_tilt: InputGraph
graph_angle: InputGraph
sliderTime: QtWidgets.QSlider
lblShotDuration: QtWidgets.QLabel
btnStartShot: QtWidgets.QPushButton
SmartDotConnectWidget: SmartDotConnectWidget
GraphsData: MotorData
changepage(int, object)
start_shot()
update_shot_duration_label(value: int)
CheckButtons()
reset()
Index 1
DiagnosticModePage
Shown Later
Index 3
AnalysisModePage
Shown Later
Index 6
ShotViewPage
Shown Later
Index 4
CloudTestPage
pushButton_1
...
pushButton_15
label: QtWidgets.QLabel
spinBox_sessionId: QtWidgets.QSpinBox
cloud_api: CloudAPI
changepage(int, object)
ask_cloud_for_6()
clear_label()
get_sessions()
post_smart_dot_data()
get_smart_dot_data()
get_diagnostic_data()
post_diagnostic_data()
post_shot_script_data()
get_shot_script_data()
post_encoder_data()
get_encoder_data()
post_heat_data()
get_heat_data()
submit_all_data()
load_session_data_from_cloud()
Index 7
DataViewPage
tableViewData: QtWidgets.QTableView
btnSearch: QtWidgets.QPushButton
btnAnalyze: QtWidgets.QPushButton
btnReplay: QtWidgets.QPushButton
debugLabel: QtWidgets.QLabel
txtSearch: QtWidgets.QLineEdit
dtStartTime: QtWidgets.QDateTimeEdit
dtEndTime: QtWidgets.QDateTimeEdit
cboSessionType: QtWidgets.QComboBox
rowIndex: int
row_data: list
model: QStandardItemModel
proxy: QSortFilterProxyModel //filter
cloud_api: CloudAPI
on_search_text_changed(text: str)
on_session_type_changed(text: str)
refresh_data(start_time, end_time)
load_data()
analyze_data()
replay_data()

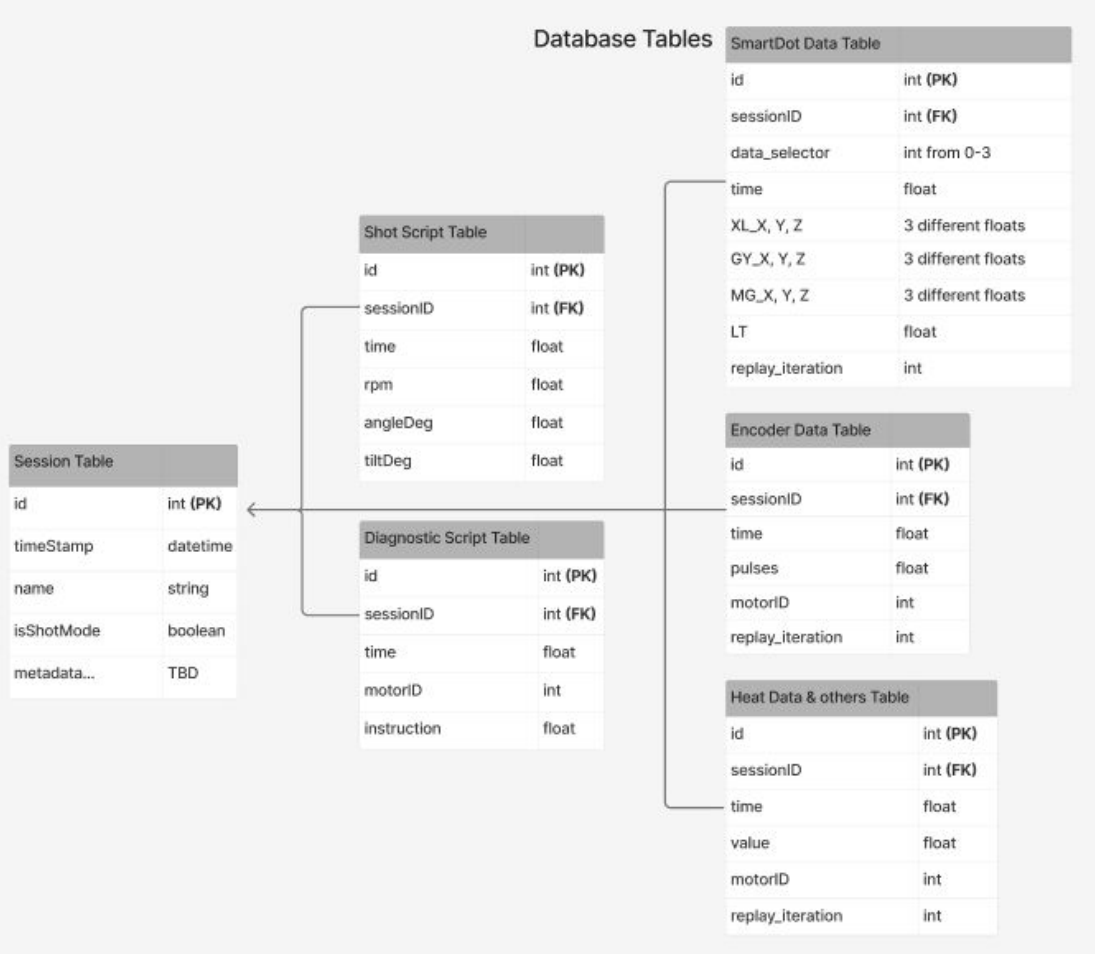
BSC Ui UML


ShotViewPage
tableview: QtWidgets.QTableView
btnSearch: QtWidgets.QPushButton
btnAnalyze: QtWidgets.QPushButton
btnReplay: QtWidgets.QPushButton
debugLabel: QtWidgets.QLabel
textSearch: QtWidgets.QLineEdit
dateStart: QtWidgets.QDateTimeEdit
dateEnd: QtWidgets.QDateTimeEdit
cboSessionType: QtWidgets.QComboBox
scriptSpin: array
scriptTilt: array
scriptAngle: array
displayedSpin: array
displayedTilt: array
displayedAngle: array
displayedSpinTime: array
displayedTiltTime: array
displayedAngleTime: array
ElapsedTime: float
startTime: float
MaxTime: float
dt: float
dt_ms: int
count: int
changepage(int, object)
StartShotView()
UpdateShotView()
EndShotView()
spawn_motor_thread(motor: str, motor_index: int, value: float)
_on_thread_finished(worker: QThread, data: object)
MotorGraph
graph: pg.PlotWidget
chkSpin: QtWidgets.QCheckBox
chkTilt: QtWidgets.QCheckBox
chkAngle: QtWidgets.QCheckBox
chkSpinData: QtWidgets.QCheckBox
chkTiltData: QtWidgets.QCheckBox
chkAngleData: QtWidgets.QCheckBox
btnSelectAll:
SpinArray: np.ndarray
SpinTime: np.ndarray
TiltArray: np.ndarray
TiltTime: np.ndarray
AngleArray: np.ndarray
AngleTime: np.ndarray
MotorTime: np.ndarray
select_all()
deselect_all()
limitViewBox()
setRange()
limit_view_change(last: float)
updateDataBetter(MotorTime, SpinArray, TiltArray, AngleArray, DataTime, SpinDataArray, TiltDataArray, AngleDataArray)
updateGraph()
QtWidgets.QPushButton
btnDeselectAll: QtWidgets.QPushButton
dsbLookBackSeconds: QtWidgets.QDoubleSpinBox
cbolimitView: QtWidgets.QComboBox
dsbMinXValue: QtWidgets.QDoubleSpinBox
dsbMaxXValue: QtWidgets.QDoubleSpinBox
lblXMax: QtWidgets.QLabel
lblXMin: QtWidgets.QLabel
lblMotorData: QtWidgets.QLabel
lblEncoderData: QtWidgets.QLabel
DataTime: np.ndarray
SpinDataArray: np.ndarray
TiltDataArray: np.ndarray
AngleDataArray: np.ndarray
updateDataDiagnostic(Spin_time, Spin_array, angle_time, angle_array, tilt_time, tilt_array, DataTime, SpinDataArray, TiltDataArray, AngleDataArray)
setView(viewIndex: int)
SmartDotGraph
graph: pg.PlotWidget
chkAccelerometer_X/Y/Z: QtWidgets.QCheckBox
chkGyroscope_X/Y/Z: QtWidgets.QCheckBox
chkMagnetometer_X/Y/Z: QtWidgets.QCheckBox
chkLight: QtWidgets.QCheckBox
chkLimitView: QtWidgets.QCheckBox
btnSelectAll: QtWidgets.QPushButton
btnDeselectAll: QtWidgets.QPushButton
dsbLookBackSeconds: QtWidgets.QDoubleSpinBox
accelerometerTime: np.ndarray
gyroscopeTime: np.ndarray
magnetometerTime: np.ndarray
lightTime: np.ndarray
accelerometerX: np.ndarray
accelerometerY: np.ndarray
accelerometerZ: np.ndarray
select_all()
deselect_all()
limitViewBox()
setRange()
limit_view_change(last: float)
updateDataBetter(accelerometerTime, accelerometerX, accelerometerY, accelerometerZ, gyroscoperTime, gyroscopeX, gyroscopeY, gyroscopeZ, magnometerTime, magnetometerX, magnetometerY, magnetometerZ, lightTime, lightValue)
cbolimitView: QtWidgets.QComboBox
dsbMinXValue: QtWidgets.QDoubleSpinBox
dsbMaxXValue: QtWidgets.QDoubleSpinBox
lblXMax: QtWidgets.QLabel
lblXMin: QtWidgets.QLabel
lblAccelerometer: QtWidgets.QLabel
lblGyroscopeData: QtWidgets.QLabel
lblMagnomaterData: QtWidgets.QLabel
lblLightData: QtWidgets.QLabel
gyroscopeX: np.ndarray
gyroscopeY: np.ndarray
gyroscopeZ: np.ndarray
magnetometerX: np.ndarray
magnetometerY: np.ndarray
magnetometerZ: np.ndarray
lightValueRaw: np.ndarray
updateAccelerometer(time, x, y, z)
updateGyroscope(time, x, y, z)
updateMagnetometer(time, x, y, z)
updateLight(time, value)
setMode(mode: str)
drawAccelerometer()
drawGyroscope()
drawMagnetometer()
drawLight()
setView(viewIndex: int)
AnalysisModePage
smartDotGraph: SmartDotGraph
motorGraph: MotorGraph
btnSave: QtWidgets.QPushButton
btnOp1/Op2/Op3/Op4: QtWidgets.QPushButton
changepage(int, object)
loadData()
openPostDialog()
openAnalysisDialog(str)

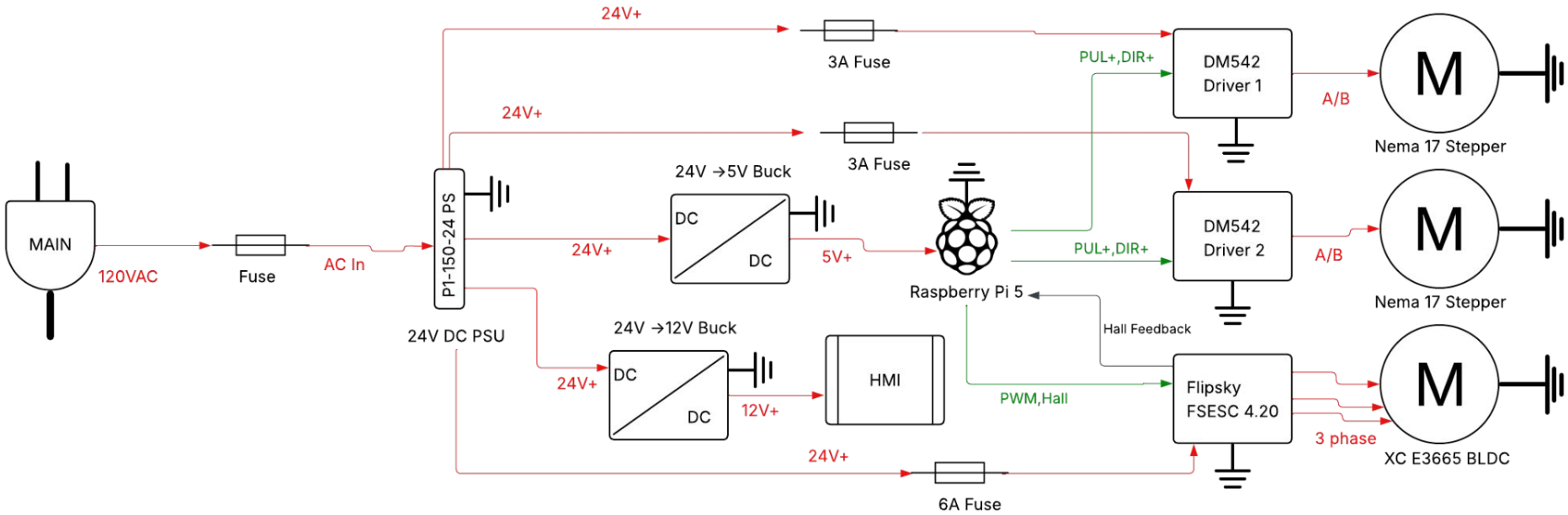
BSC Ui UML


DiagnosticModePage
btnStart: QtWidgets.QPushButton
btnStop: QtWidgets.QPushButton
btnClear: QtWidgets.QPushButton
btnSave: QtWidgets.QPushButton
spinGraph: pg.PlotWidget
tiltGraph: pg.PlotWidget
angleGraph: pg.PlotWidget
labelSpin: QtWidgets.QLabel
labelTilt: QtWidgets.QLabel
labelAngle: QtWidgets.QLabel
smartdotViewer: QtWidgets.QWidget
spinDial: QtWidgets.QDial
tiltDial: QtWidgets.QDial
angleDial: QtWidgets.QDial
diagnostic_script: DiagnosticScript
_timer: QTimer
_sample_interval_ms: int
_sample_dt_s: float
_maxlen: int
_N: int
_x: np.ndarray
_spin_arr: np.ndarray
_tilt_arr: np.ndarray
_angle_arr: np.ndarray
_write_idx: int
_filled: bool
_last_values: dict
_sample_index: int
openPostDialog()
toggle_Buttons()
EStop()
add_diag_data_instance_to_data_controller(time: float, motor_id: int, instruction: float)
_on_timer()
reset()
clear_graphs()
SmartDotViewer
SmartDotGraph: SmartDotGraph
smartdotConnectWidget: SmartDotConnectWidget
btnStart: QtWidgets.QPushButton
btnStop: QtWidgets.QPushButton
SmartDot: iSmartDot
connectSmartDot(device: iSmartDot)
disconnectSmartDot()
on_device_disconnected(mac_address: str)
start_updates()
stop_updates()
_on_timer()
hide_buttons()
show_buttons()
test_connection()
reset()
SmartDotConnectWidget
btnConnect: QtWidgets.QPushButton
lblStatus: QtWidgets.QLabel
conDevices: QtWidgets.QScrollArea
wDeviceList: QtWidgets.QWidget
conDisconnectDevices: QtWidgets.QScrollArea
wDisconnectDeviceList: QtWidgets.QWidget
scanBtn: QtWidgets.QPushButton
Device Management:
Devices: List[str]
smartdot: iSmartDot
connection_worker: ConnectionWorker
process_runner: ProcessRunner
start_scan()
connect_to_smartdot(text: str)
setDeviceList(devices: List[str])
updateDisconnectList()
disconnect_from_smartdot(mac_address: str)
SmartDotGraph
graph: pg.PlotWidget
chkAccelerometer_X/Y/Z: QtWidgets.QCheckBox
chkGyroscope_X/Y/Z: QtWidgets.QCheckBox
chkMagnetometer_X/Y/Z: QtWidgets.QCheckBox
chkLight: QtWidgets.QCheckBox
chkLimitView: QtWidgets.QCheckBox
btnSelectAll: QtWidgets.QPushButton
btnDeselectAll: QtWidgets.QPushButton
dsbLookBackSeconds: QtWidgets.QDoubleSpinBox
cbolimitView: QtWidgets.QComboBox
dsbMinXValue: QtWidgets.QDoubleSpinBox
dsbMaxXValue: QtWidgets.QDoubleSpinBox
lblXMax: QtWidgets.QLabel
lblXMin: QtWidgets.QLabel
lblAccelerometer: QtWidgets.QLabel
lblGyroscopeData: QtWidgets.QLabel
lblMagnomaterData: QtWidgets.QLabel
lblLightData: QtWidgets.QLabel
accelerometerTime: np.ndarray
gyroscopeTime: np.ndarray
magnetometerTime: np.ndarray
lightTime: np.ndarray
accelerometerX: np.ndarray
accelerometerY: np.ndarray
accelerometerZ: np.ndarray
gyroscopeX: np.ndarray
gyroscopeY: np.ndarray
gyroscopeZ: np.ndarray
magnetometerX: np.ndarray
magnetometerY: np.ndarray
magnetometerZ: np.ndarray
lightValueRaw: np.ndarray
select_all()
deselect_all()
limitViewBox()
setRange()
limit_view_change(last: float)
updateDataBetter(
acclerometerTime, acclerometerX, accelerometerY, accelerometerZ,
gyroscoperTime, gyroscopeX, gyroscopeY, gyroscopeZ,
magnometerTime, magnetometerX, magnetometerY, magnetometerZ,
lightTime, lightValue)
updateAccelerometer(time, x, y, z)
updateGyroscope(time, x, y, z)
updateMagnetometer(time, x, y, z)
updateLight(time, value)
setMode(mode: str)
drawAccelerometer()
drawGyroscope()
drawMagnetometer()
drawLight()
setView(viewIndex: int)

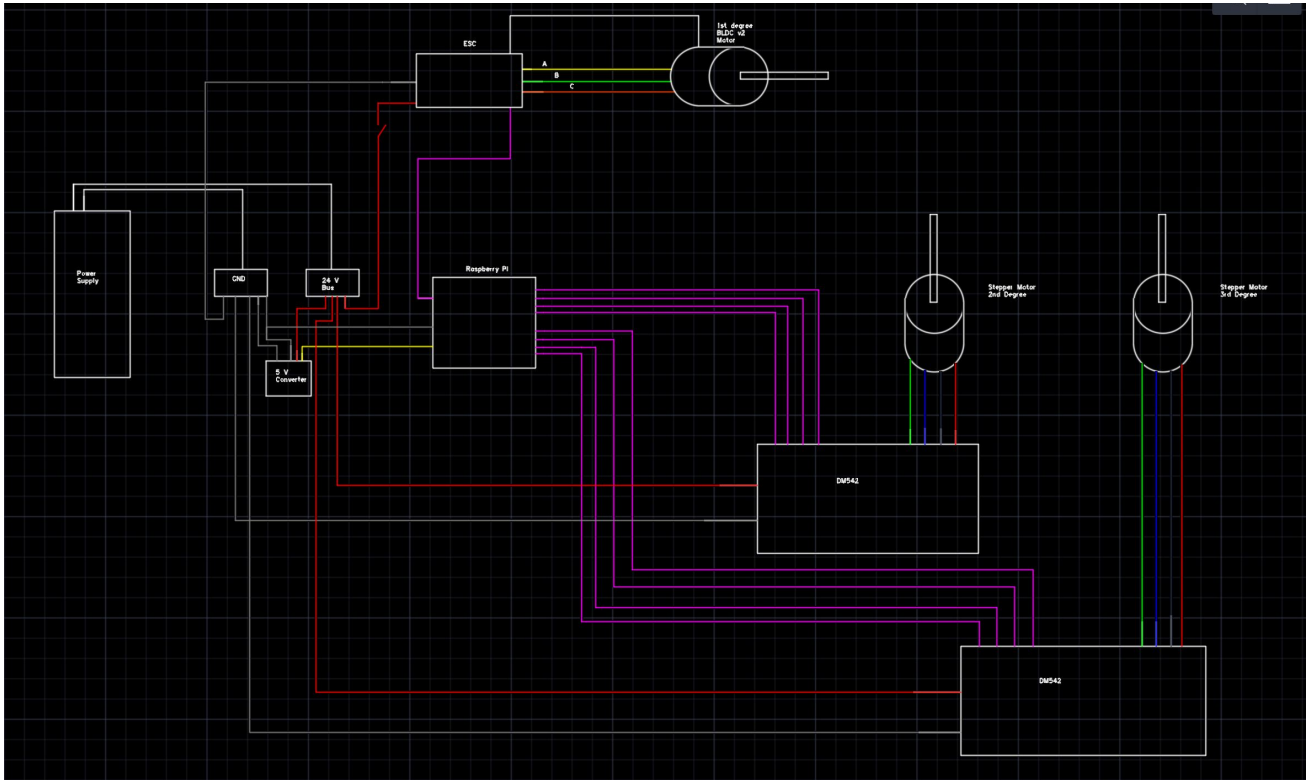
Ball Spinner Controller Database Schema



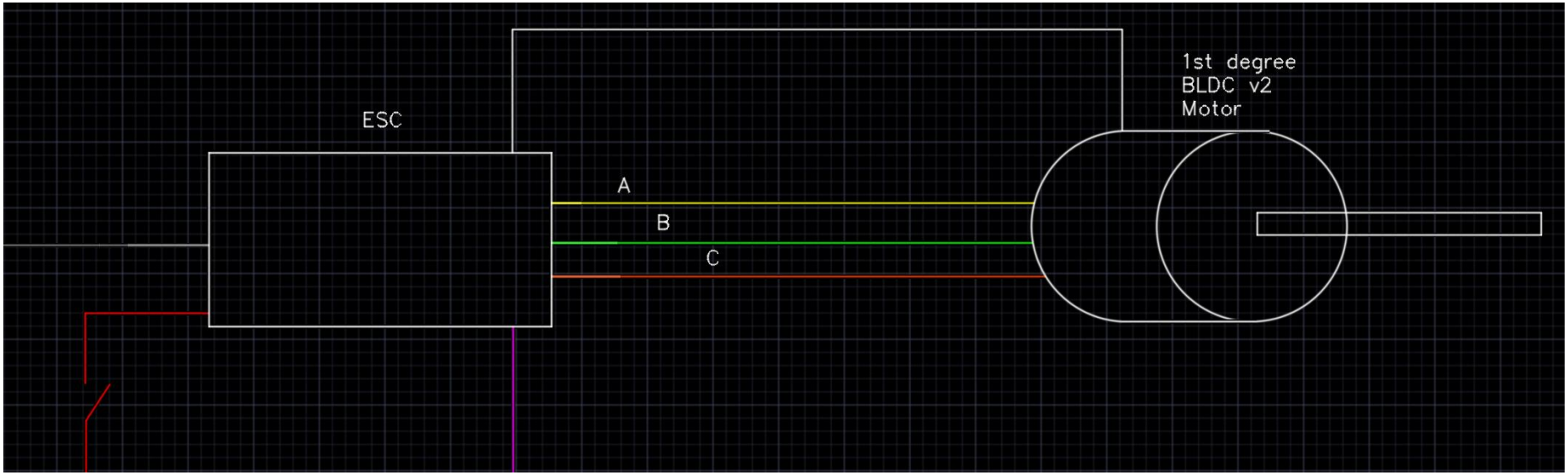
Ball Spinner Power System Design



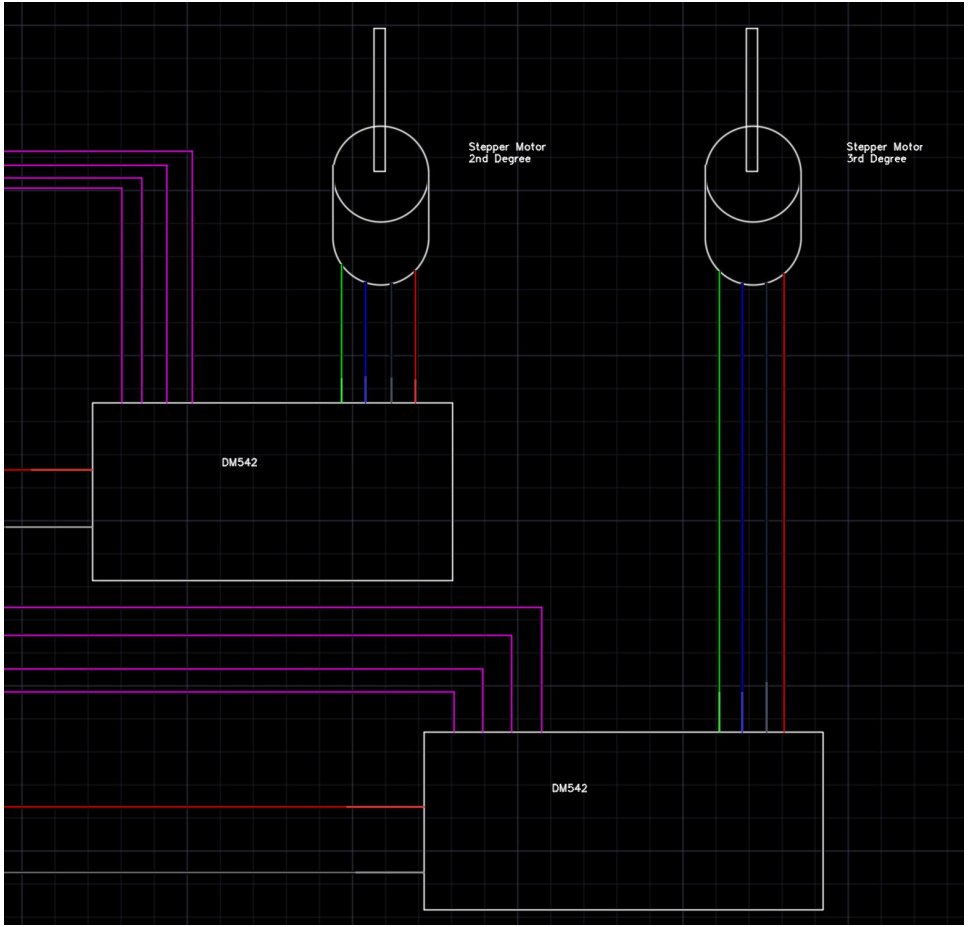
Electrical System Overview



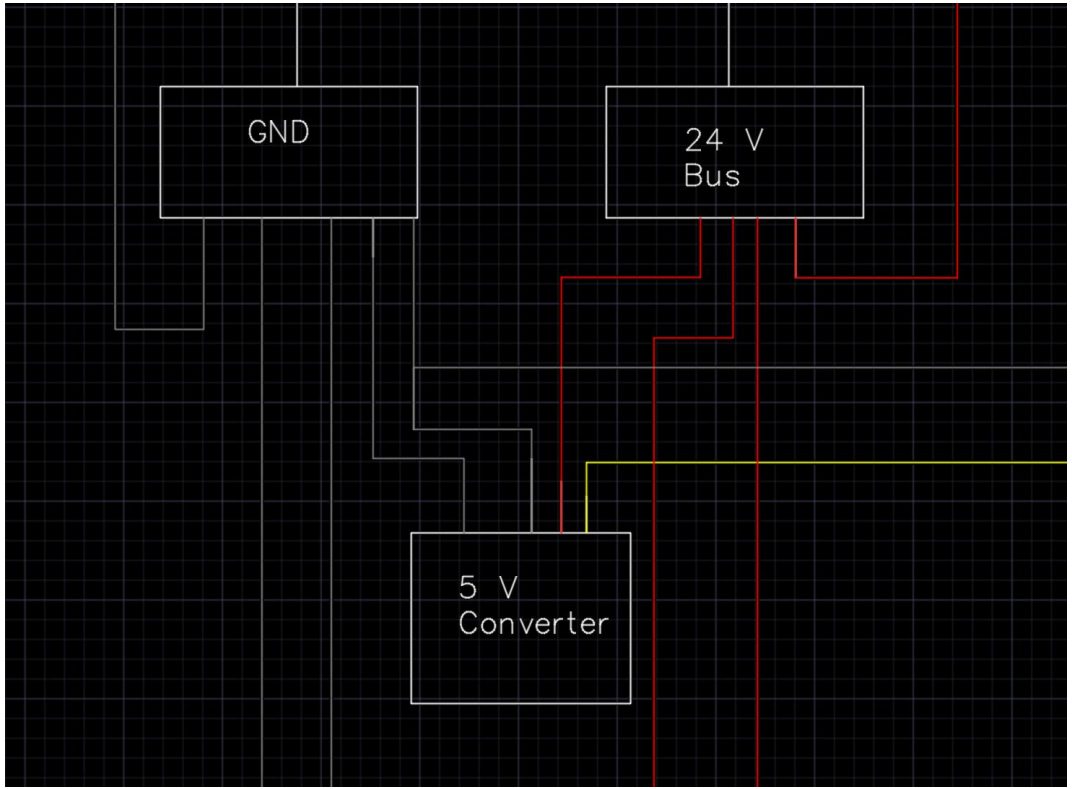
BLDC Primary Spin Motor



2nd and 3rd Degree Stepper Motors



24 V Bus Supply and 5 V Converter

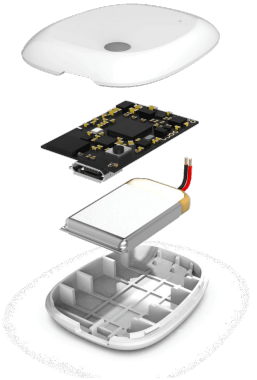


Questions?

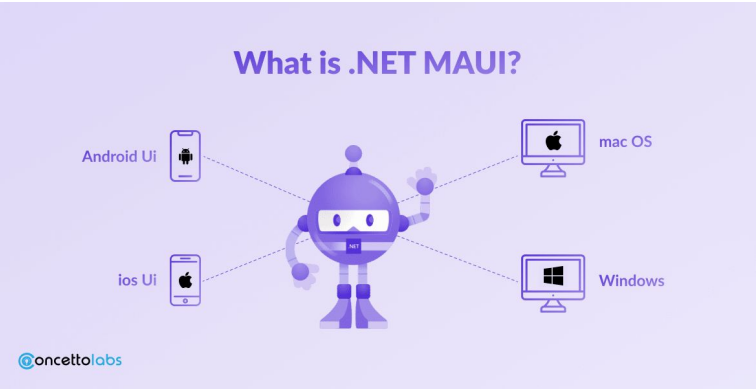
Tools & Tech

Mobile App - Development Technologies

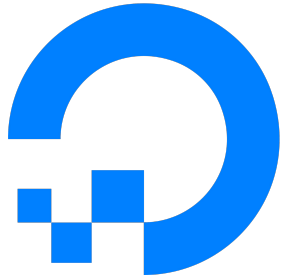
- .NET Maui
- MetaMotionS
- Bluetooth Low Power (BLE)



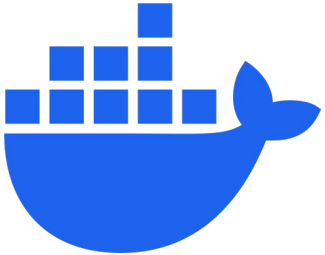
Bluetooth™
Low Energy



Cloud - Development Technologies

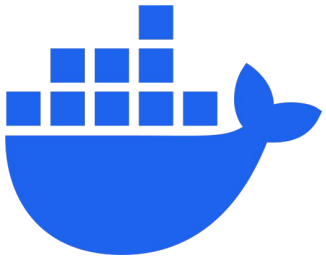


- Postman
- Microsoft EF (Entity Framework) Core
- Liquibase
- Digital Ocean
- Docker
- Swagger Documentation



Ciclopes - Development Technologies

- Python
- PyTorch
- Docker
- IsaacSim
- NumPy
- OpenCV2
- Matplotlib

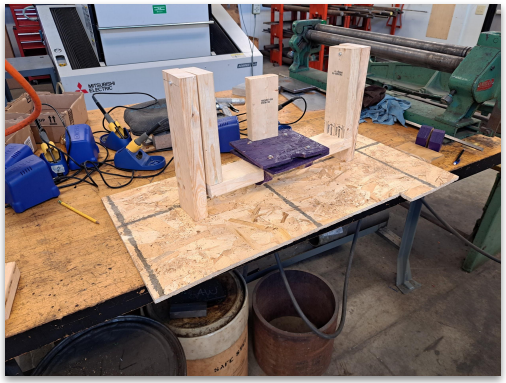


Watch - Development Technologies

- Flutter
- Dart
- Kotlin
- Visual Studio Code
- Bluetooth Low Energy (BLE)
- Android/IOS Launcher (Emulator)

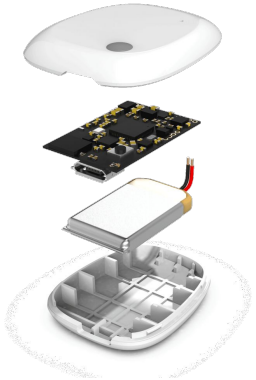
Ball Spinner Mechanical System

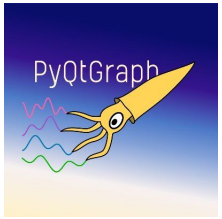
- **SolidWorks**
  - SolidWorks was leveraged heavily throughout the course of this semester to create models of the team's designs as well as to perform FEA testing
- **3D Print Lab**
  - Utilized to rapidly prototype parts for the physical system
- **Machine Shop**
  - The Machine Shop was used extensively to create physical prototypes for the team to visualize and criticise designs.

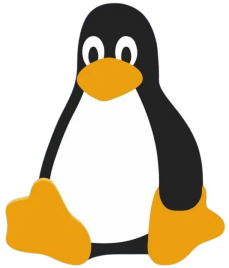


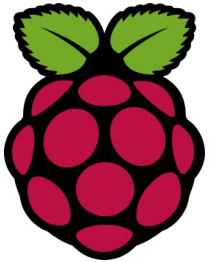
Ball Spinner Controller Technologies

- Linux
- Python
- PyQt6
- PyQtGraph
- Raspberry Pi
- MetaMotionS



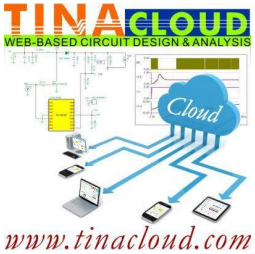






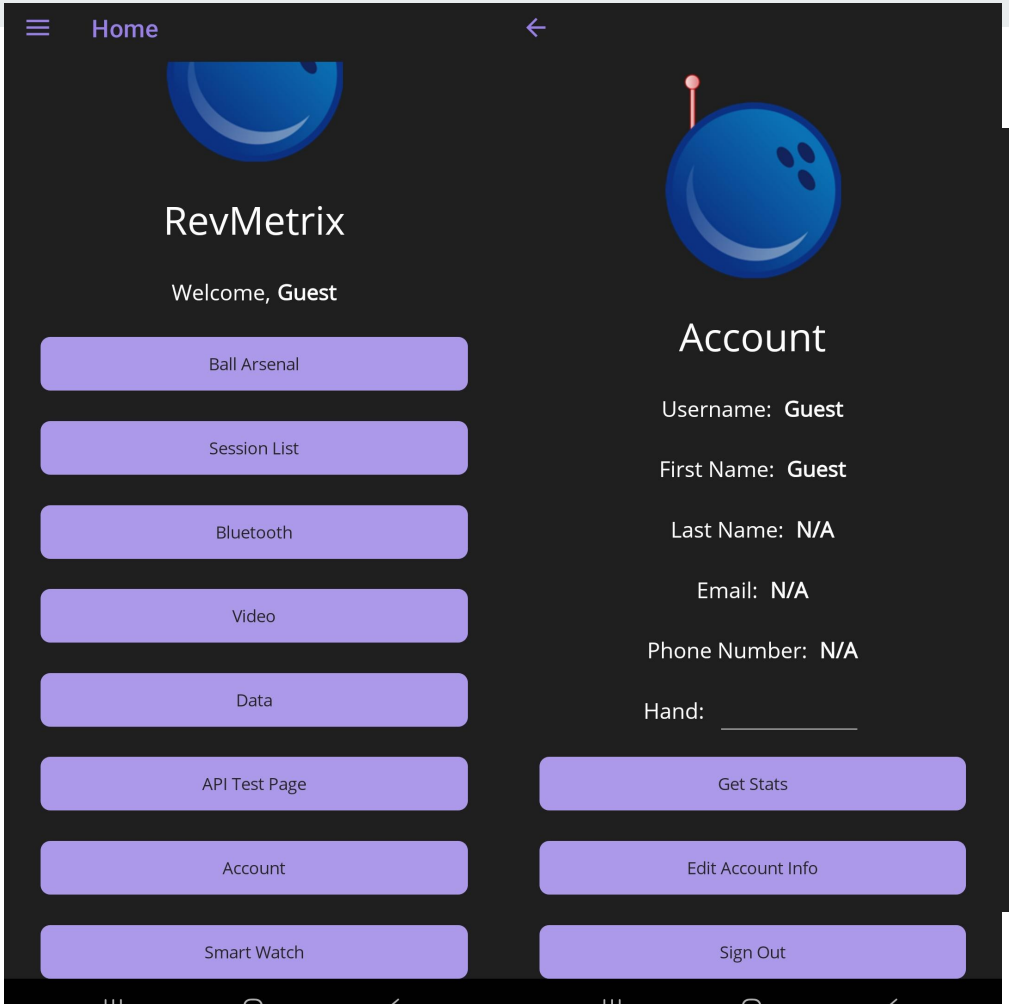
Ball Spinner Controller Technologies Continued

- LGPIO
- Pyvesc
- AutoCAD
- TINACloud
- OnShape
- KiCad

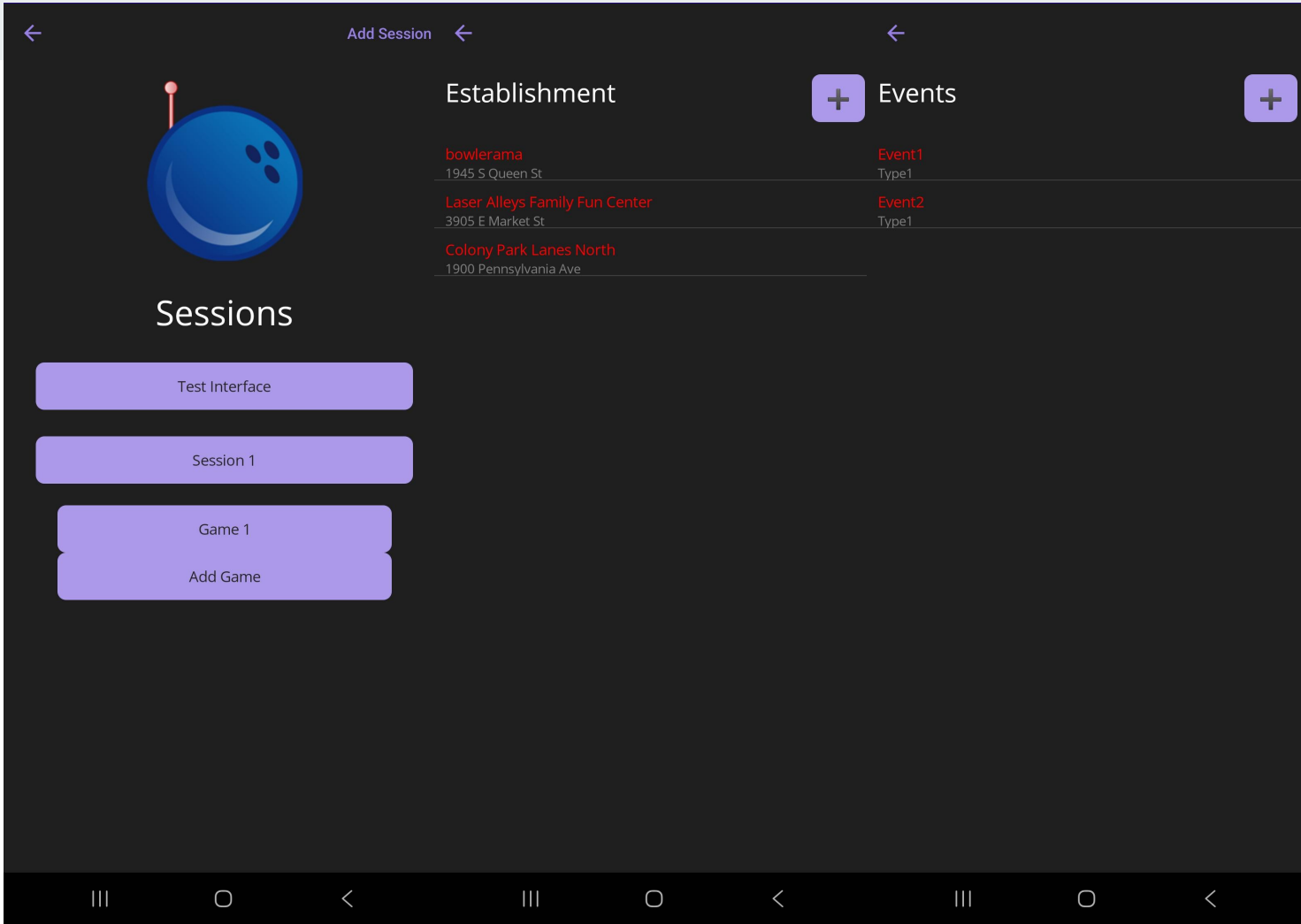


Implementation

Basic Pages

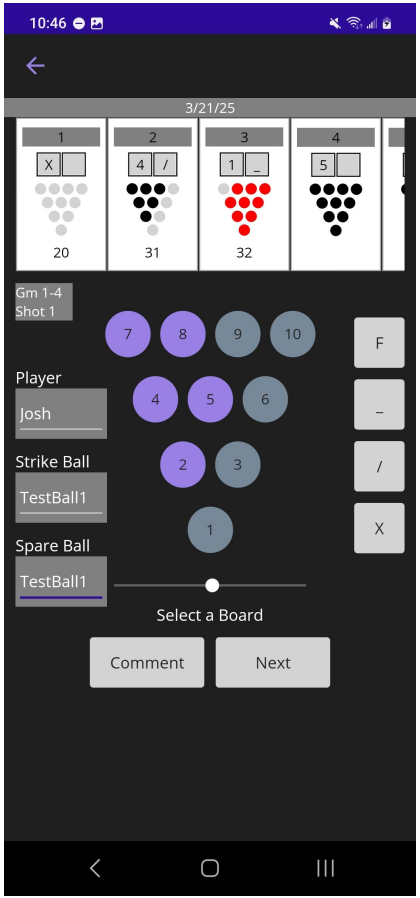

Home
RevMetrix
Welcome, Guest
Ball Arsenal
Session List
Bluetooth
Video
Data
API Test Page
Account
Smart Watch
Account
Username: Guest
First Name: Guest
Last Name: N/A
Email: N/A
Phone Number: N/A
Hand:
Get Stats
Edit Account Info
Sign Out
Ball Arsenal
Search
Filter
TestBall1
12
13
spin

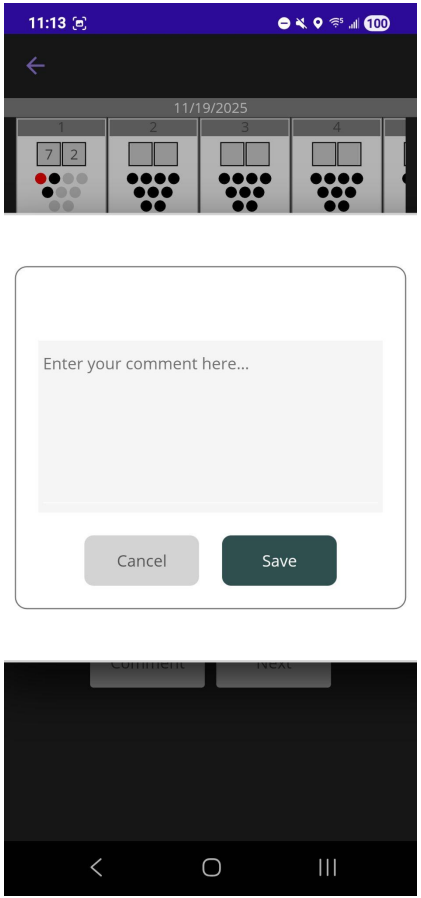
Basic Pages


Add Session
Establishment
bowlerama
1945 S Queen St
Laser Alleys Family Fun Center
3905 E Market St
Colony Park Lanes North
1900 Pennsylvania Ave
Events
Event1
Type1
Event2
Type1
Sessions
Test Interface
Session 1
Game 1
Add Game

Mobile - Shot page

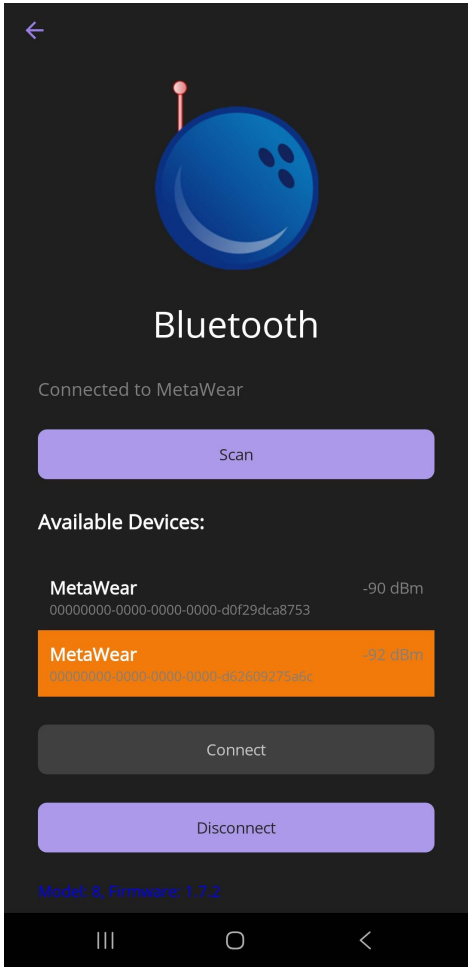
- Frame viewer (Slider)
- Pin input (Pins left standing)
- Ball used per shot
- Comments per shot
- Edit frames/shots

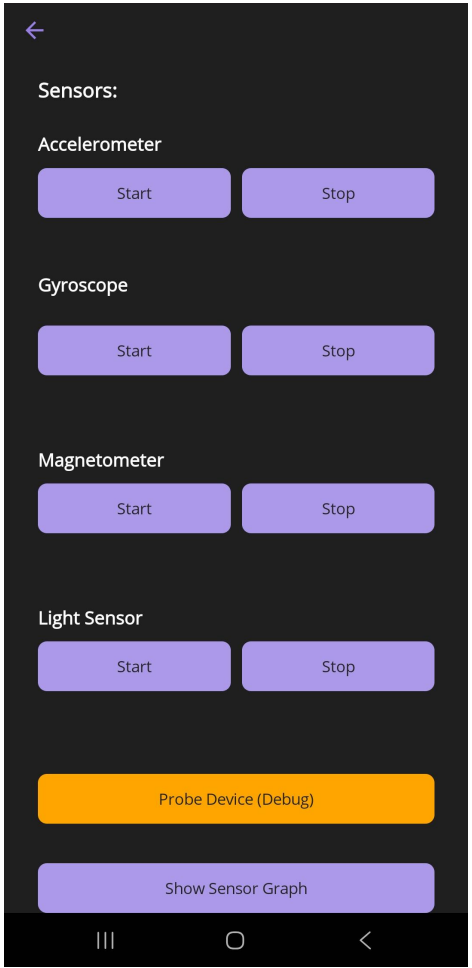




Bluetooth Page

- Connects to the MetaMotionS Module
- Ability to see data for Accelerometer, Gyroscope, Magnetometer, and Light Sensor.





Sensors:

Accelerometer

Start | Stop

Accel: X=-0.01, Y=0.01, Z=2.06

Gyroscope

Start | Stop

Gyro: X=0.00, Y=0.31, Z=0.06

Magnetometer

Start | Stop

Mag: X=-59.50µT, Y=-43.62µT, Z=-7.69µT

Light Sensor

Start | Stop

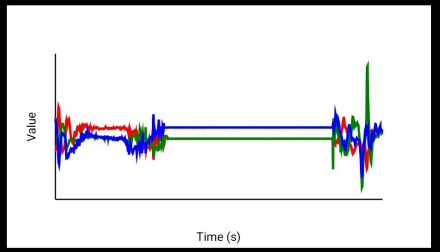
Light: Visible=1774

Probe Device (Debug)

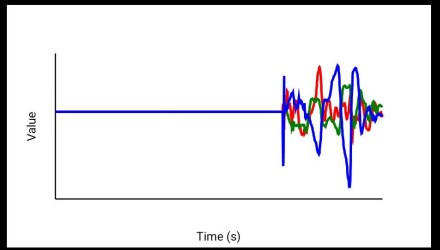
Sensor Data Graph

Sensor Data Graphs

Accelerometer (X, Y, Z in G)



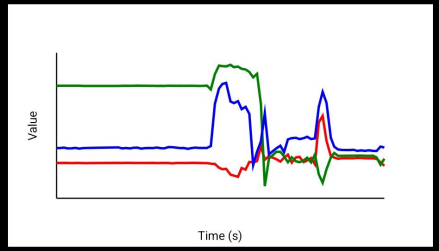
Gyroscope (X, Y, Z in deg/s)



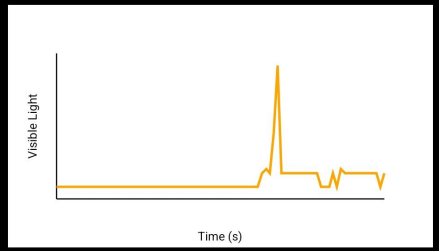
Magnetometer (X, Y, Z in µT)

Sensor Data Graph

Magnetometer (X, Y, Z in µT)

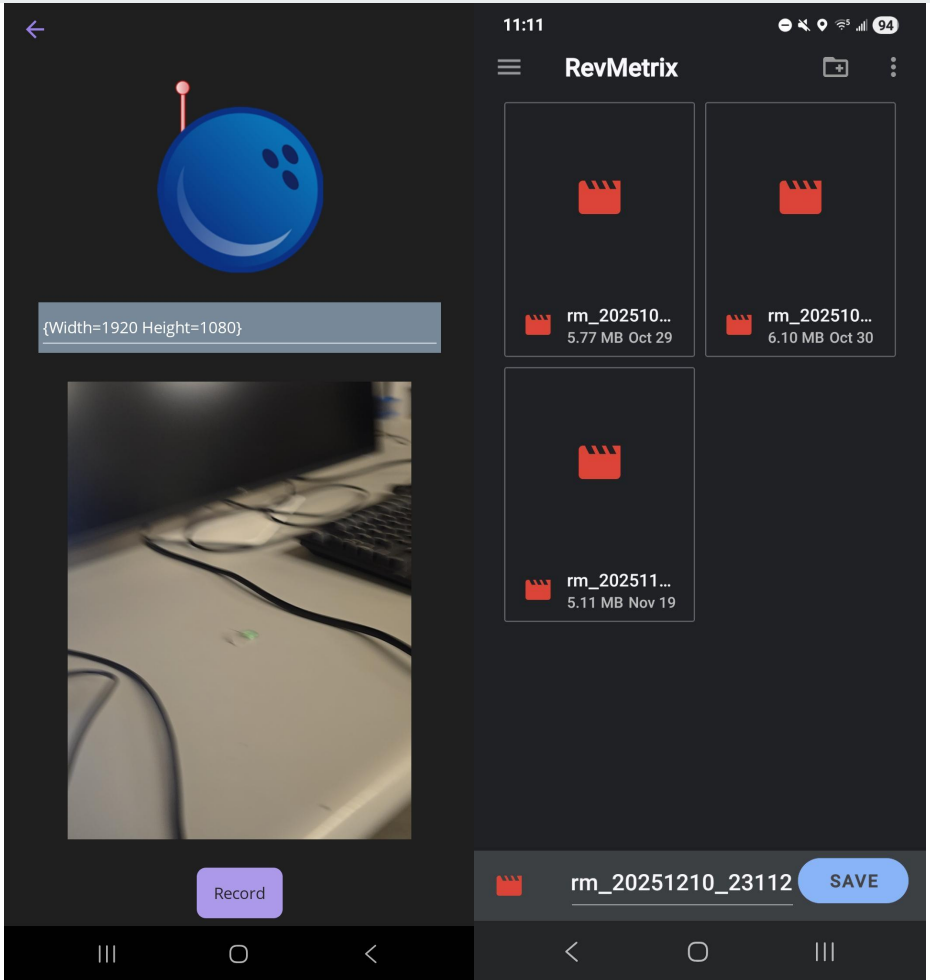


Light Sensor (Visible)



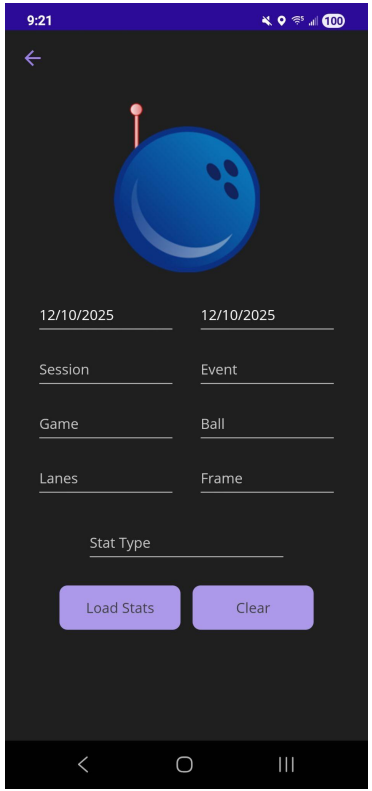
Mobile - Video Page

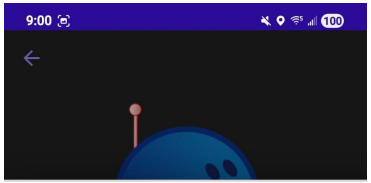
- Resolution selection
- Record and save video
  - Choose save location
  - Choose save name

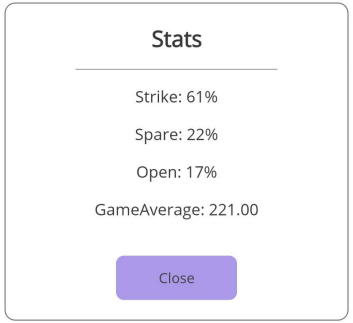


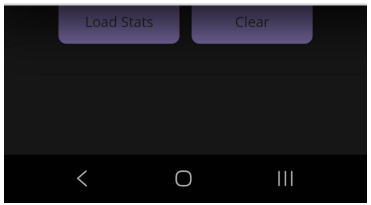
Mobile - Stats Page

- Custom Query Engine
  - Date Range
  - Session
  - Event
  - Game
  - Ball
  - Lanes
  - Frame
  - Type



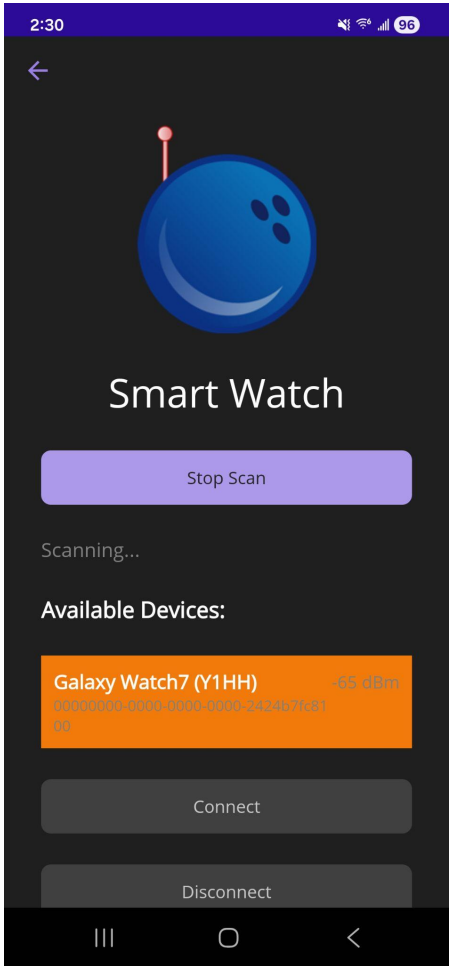


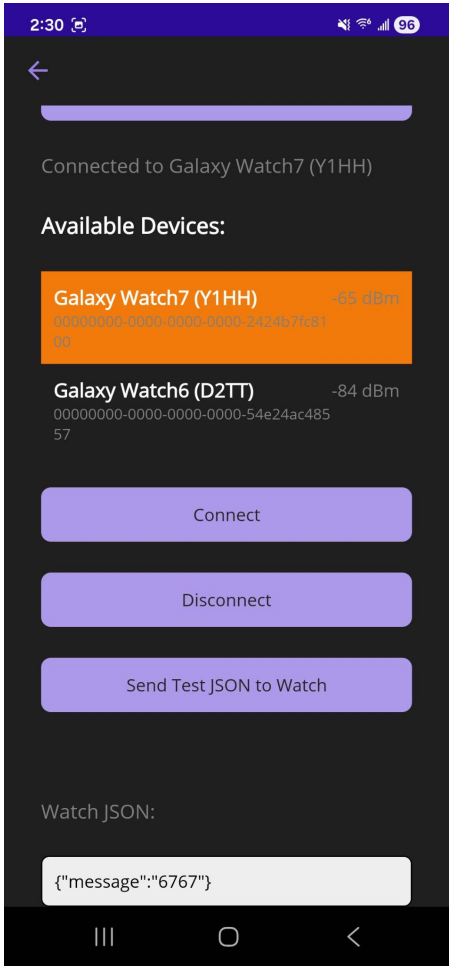




Mobile - Watch Page

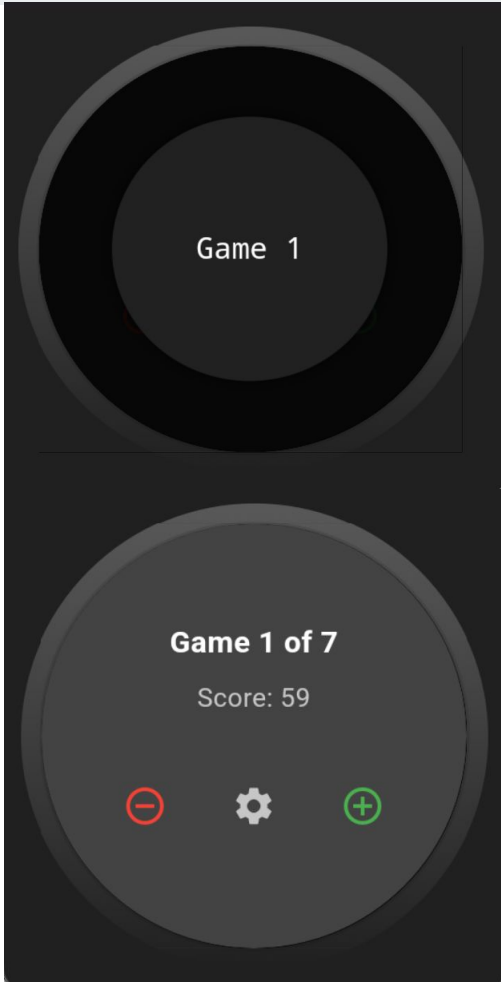
- Scan for available Galaxy Watches
- Connect/Disconnect
- Send/Receive test JSONs





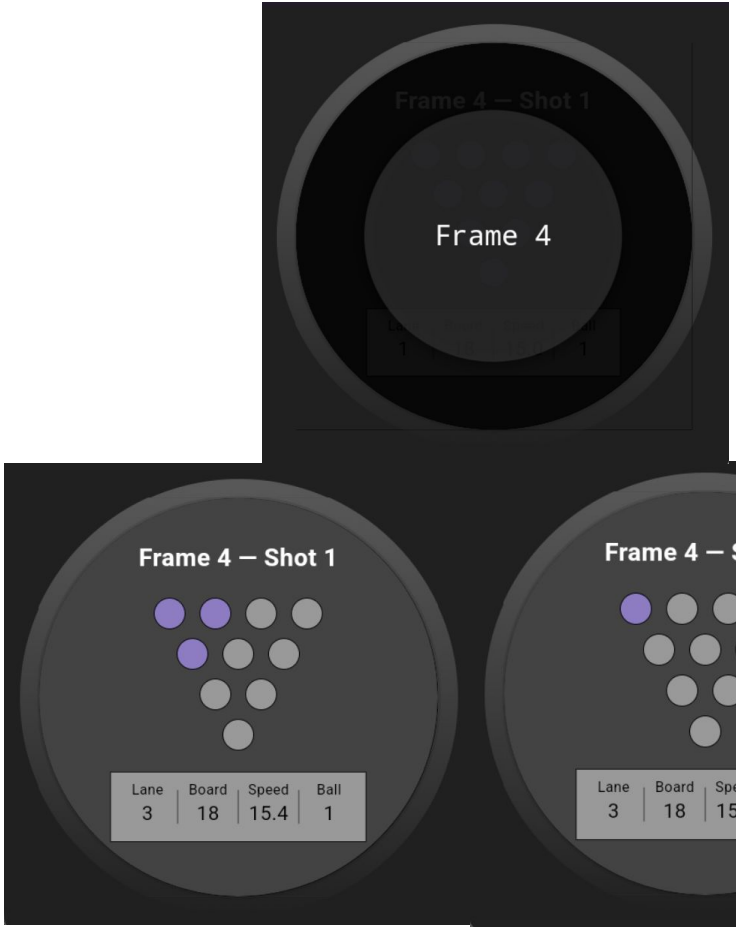
Watch - Game Page

- Game selection overlay (Pop-out Carousel)
- Add and subtract games
- View score
- Access settings



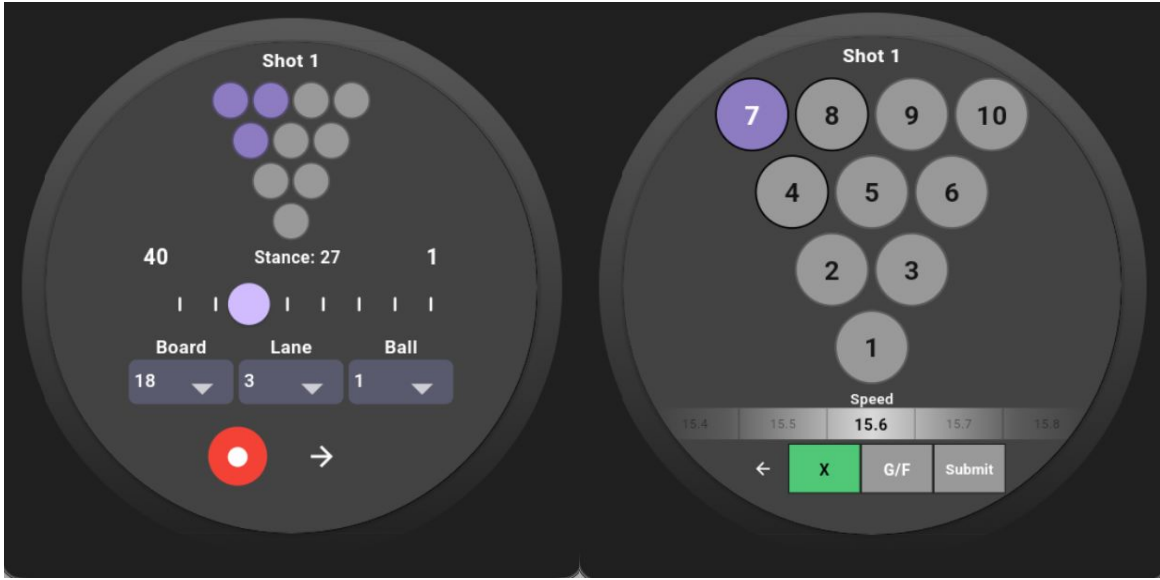
Watch - Frame Page

- Frame selection overlay (Pop-out Carousel)
- View frame data
- Shots overview (Horizontal Swipe)
- Access Shot Input



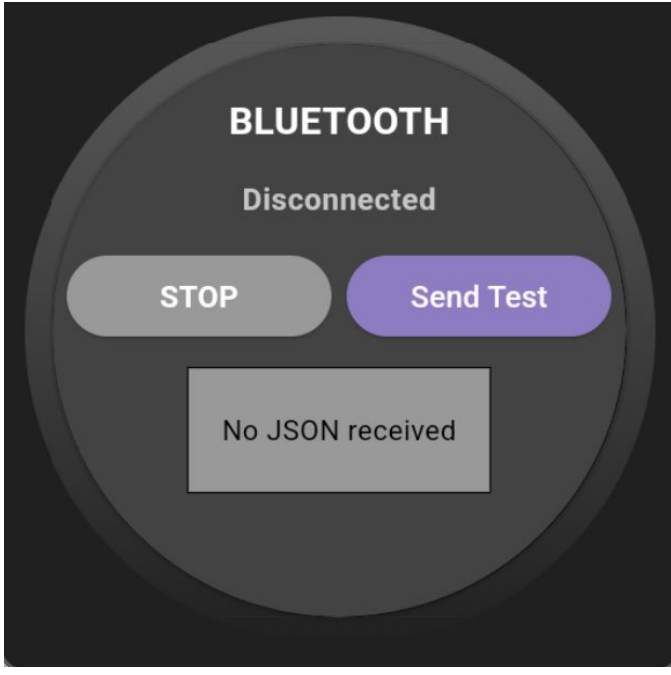
Watch - Shot Page

- Pre-Shot
  - Mini view of last pin state
  - Stance slider
  - Board/Lane/Ball
  - Video Record button
- Post-Shot
  - Pin input (Pins left standing)
  - Ball speed slider
  - Strike/Spare
  - Gutter/Foul
  - Submit shot



Watch - Bluetooth Page

- Disconnect/Connect status
- Device address
- Start/Stop advertising
- Send test packet to phone
- Received JSON section



Watch - BLE packet creation

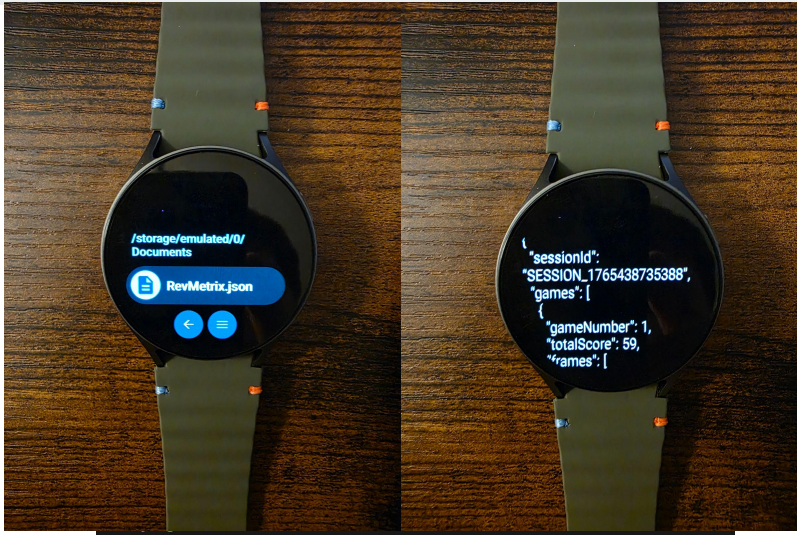
- BLE packet model
- Load prebuilt “session” for testing
- Send “session” over BLE

```
I/flutter (15383): [BLE Test] Creating session...
I/flutter (15383): [BLE Test] Session created:
I/flutter (15383):    Session ID: MINIMAL_TEST_1765438578391
I/flutter (15383):    Games: 1
I/flutter (15383):    Balls: [1, 2, 3]
I/flutter (15383): [BLE Test] Converting to JSON...
I/flutter (15383): [BLE Test] JSON created, calling sendJsonInChunks...
I/flutter (15383): BLEManager.sendJsonInChunks: Sending 828 bytes in chunks
I/flutter (15383): BLEManager.sendRawBLEPacket -> sent 20 bytes
I/flutter (15383): BLEManager: Sent chunk 1/42 (20 bytes)
I/flutter (15383): BLEManager.sendRawBLEPacket -> sent 20 bytes
I/flutter (15383): BLEManager: Sent chunk 2/42 (20 bytes)
I/flutter (15383): BLEManager.sendRawBLEPacket -> sent 20 bytes
I/flutter (15383): BLEManager: Sent chunk 3/42 (20 bytes)
I/flutter (15383): BLEManager.sendRawBLEPacket -> sent 20 bytes
I/flutter (15383): BLEManager: Sent chunk 4/42 (20 bytes)
I/flutter (15383): BLEManager.sendRawBLEPacket -> sent 20 bytes
I/flutter (15383): BLEManager: Sent chunk 5/42 (20 bytes)
I/flutter (15383): BLEManager.sendRawBLEPacket -> sent 20 bytes
I/flutter (15383): BLEManager: Sent chunk 6/42 (20 bytes)
I/flutter (15383): BLEManager.sendRawBLEPacket -> sent 20 bytes
I/flutter (15383): BLEManager: Sent chunk 7/42 (20 bytes)
I/flutter (15383): BLEManager.sendRawBLEPacket -> sent 20 bytes
I/flutter (15383): BLEManager: Sent chunk 8/42 (20 bytes)
I/flutter (15383): BLEManager.sendRawBLEPacket -> sent 20 bytes
I/flutter (15383): BLEManager: Sent chunk 9/42 (20 bytes)
I/flutter (15383): BLEManager.sendRawBLEPacket -> sent 20 bytes
I/flutter (15383): BLEManager: Sent chunk 10/42 (20 bytes)
I/flutter (15383): BLEManager.sendRawBLEPacket -> sent 20 bytes
```

```
2025-12-11 02:31:53.736 18802-19497 app_process64      com.companyname.cellular      D  PHONE BLE RECEIVED → {"sessionId":"MINIMA
2025-12-11 02:31:53.811 18802-19497 app_process64      com.companyname.cellular      D  PHONE BLE RECEIVED → L_TEST_1765438318299
2025-12-11 02:31:53.901 18802-19497 app_process64      com.companyname.cellular      D  PHONE BLE RECEIVED → ","startTime":"2025-
2025-12-11 02:31:53.928 18802-19497 app_process64      com.companyname.cellular      D  PHONE BLE RECEIVED → 12-11T02:31:58.29965
2025-12-11 02:31:53.990 18802-19497 app_process64      com.companyname.cellular      D  PHONE BLE RECEIVED → 9","endTime":null,"i
2025-12-11 02:31:54.050 18802-19497 app_process64      com.companyname.cellular      D  PHONE BLE RECEIVED → sComplete":false,"nu
2025-12-11 02:31:54.110 18802-19497 app_process64      com.companyname.cellular      D  PHONE BLE RECEIVED → mOfGames":1,"balls":
2025-12-11 02:31:54.171 18802-19497 app_process64      com.companyname.cellular      D  PHONE BLE RECEIVED → ["1","2","3"],"games
2025-12-11 02:31:54.227 18802-19497 app_process64      com.companyname.cellular      D  PHONE BLE RECEIVED → ":[{"gameNumber":1,"
2025-12-11 02:31:54.295 18802-19497 app_process64      com.companyname.cellular      D  PHONE BLE RECEIVED → score":0,"startingLa
2025-12-11 02:31:54.353 18802-19497 app_process64      com.companyname.cellular      D  PHONE BLE RECEIVED → ne":1,"lanes":[1],"f
2025-12-11 02:31:54.413 18802-19497 app_process64      com.companyname.cellular      D  PHONE BLE RECEIVED → rames":[{"frameNumbe
2025-12-11 02:31:54.471 18802-19497 app_process64      com.companyname.cellular      D  PHONE BLE RECEIVED → r":1,"lane":1,"shots
2025-12-11 02:31:54.528 18802-19497 app_process64      com.companyname.cellular      D  PHONE BLE RECEIVED → ":[{"shotNumber":1,"
2025-12-11 02:31:54.588 18802-19497 app_process64      com.companyname.cellular      D  PHONE BLE RECEIVED → ball":1,"count":10,"
2025-12-11 02:31:54.653 18802-19497 app_process64      com.companyname.cellular      D  PHONE BLE RECEIVED → leaveType":0,"positi
2025-12-11 02:31:54.710 18802-19497 app_process64      com.companyname.cellular      D  PHONE BLE RECEIVED → on":"pocket","timest
2025-12-11 02:31:54.767 18802-19497 app_process64      com.companyname.cellular      D  PHONE BLE RECEIVED → amp":"2025-12-11T02:
2025-12-11 02:31:54.860 18802-19497 app_process64      com.companyname.cellular      D  PHONE BLE RECEIVED → 31:58.299709","speed
2025-12-11 02:31:54.919 18802-19497 app_process64      com.companyname.cellular      D  PHONE BLE RECEIVED → ":15.0,"hitBoard":18
2025-12-11 02:31:54.981 18802-19497 app_process64      com.companyname.cellular      D  PHONE BLE RECEIVED → }]},{"frameNumber":2
2025-12-11 02:31:55.039 18802-19497 app_process64      com.companyname.cellular      D  PHONE BLE RECEIVED → ,"lane":1,"shots":[]
2025-12-11 02:31:55.131 18802-19497 app_process64      com.companyname.cellular      D  PHONE BLE RECEIVED → },{"frameNumber":3,"
2025-12-11 02:31:55.188 18802-19497 app_process64      com.companyname.cellular      D  PHONE BLE RECEIVED → lane":1,"shots":[]},
2025-12-11 02:31:55.279 18802-19497 app_process64      com.companyname.cellular      D  PHONE BLE RECEIVED → {"frameNumber":4,"la
2025-12-11 02:31:55.341 18802-19497 app_process64      com.companyname.cellular      D  PHONE BLE RECEIVED → ne":1,"shots":[]},{"
2025-12-11 02:31:55.428 18802-19497 app_process64      com.companyname.cellular      D  PHONE BLE RECEIVED → frameNumber":5,"lane
2025-12-11 02:31:55.520 18802-19497 app_process64      com.companyname.cellular      D  PHONE BLE RECEIVED → ":1,"shots":[]},{"fr
2025-12-11 02:31:55.578 18802-19497 app_process64      com.companyname.cellular      D  PHONE BLE RECEIVED → ameNumber":6,"lane":
2025-12-11 02:31:55.672 18802-19497 app_process64      com.companyname.cellular      D  PHONE BLE RECEIVED → 1,"shots":[]},{"fram
2025-12-11 02:31:55.761 18802-19497 app_process64      com.companyname.cellular      D  PHONE BLE RECEIVED → eNumber":7,"lane":1,
2025-12-11 02:31:55.819 18802-19497 app_process64      com.companyname.cellular      D  PHONE BLE RECEIVED → "shots":[]},{"frameN
2025-12-11 02:31:55.914 18802-19497 app_process64      com.companyname.cellular      D  PHONE BLE RECEIVED → umber":8,"lane":1,"s
2025-12-11 02:31:56.005 18802-19497 app_process64      com.companyname.cellular      D  PHONE BLE RECEIVED → hots":[]},{"frameNum
2025-12-11 02:31:56.057 18802-19497 app_process64      com.companyname.cellular      D  PHONE BLE RECEIVED → ber":9,"lane":1,"sho
2025-12-11 02:31:56.147 18802-19497 app_process64      com.companyname.cellular      D  PHONE BLE RECEIVED → ts":[]},{"frameNumbe
2025-12-11 02:31:56.243 18802-19497 app_process64      com.companyname.cellular      D  PHONE BLE RECEIVED → r":10,"lane":1,"shot
2025-12-11 02:31:56.296 18802-19497 app_process64      com.companyname.cellular      D  PHONE BLE RECEIVED → s":[]},{"frameNumber
```

Watch - Write to local storage

- Main session object converted to JSON
- Session JSON printed to console
- Session JSON written locally in Documents

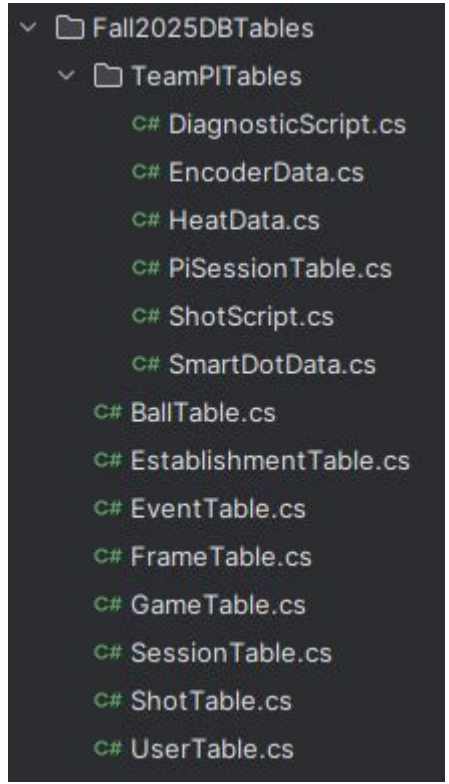



```
I/flutter ( 3004): {
I/flutter ( 3004):   "sessionId": "SESSION_1765437667778",
I/flutter ( 3004):   "games": [
I/flutter ( 3004):     {
I/flutter ( 3004):       "gameNumber": 1,
I/flutter ( 3004):       "totalScore": 59,
I/flutter ( 3004):       "frames": [
I/flutter ( 3004):         {
I/flutter ( 3004):           "frameNumber": 1,
I/flutter ( 3004):           "lane": 1,
I/flutter ( 3004):           "shots": [
I/flutter ( 3004):             {
I/flutter ( 3004):               "shotNumber": 1,
I/flutter ( 3004):               "ball": 1,
I/flutter ( 3004):               "count": 10,
I/flutter ( 3004):               "leaveType": 0,
I/flutter ( 3004):               "position": "Strike",
I/flutter ( 3004):               "timestamp": "2025-12-11T02:19:08.539800",
I/flutter ( 3004):               "speed": 15.6,
I/flutter ( 3004):               "hitBoard": 13
I/flutter ( 3004):             }
I/flutter ( 3004):           ]
I/flutter ( 3004):         },
```

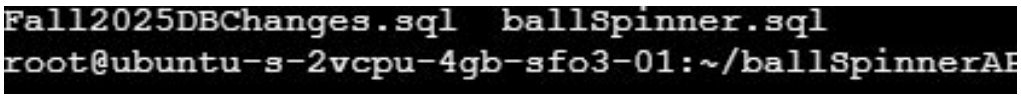
Cloud - Migration Tools

- Safe SQL code generation
- Tables are organized into C# classes
- Lower likelihood of corrupting DB with SQL changes

C# files containing table information



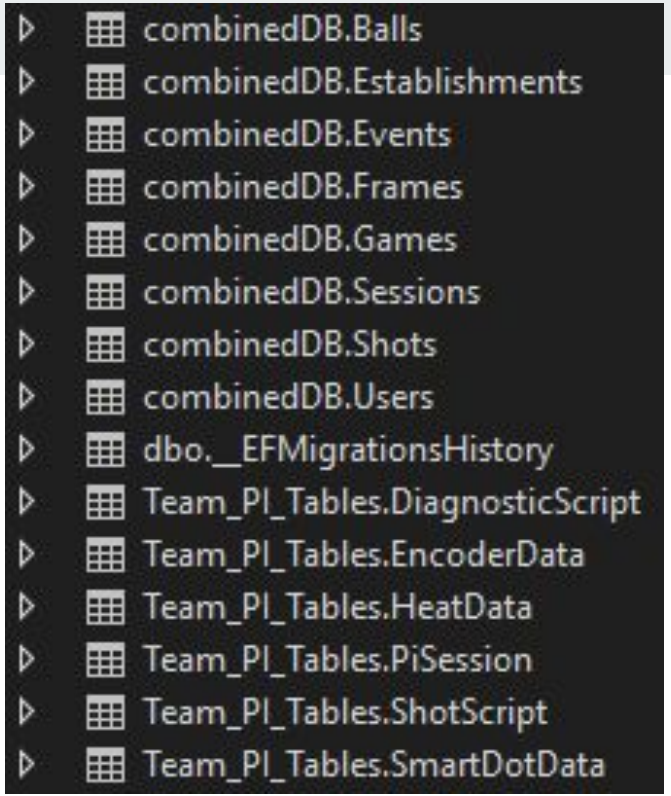
Generated script file in Droplet



Cloud - Database

- Added 15 new tables under 2 new schemas
- Migration History to track DB updates
-

Screenshot from Visual Studio Server Explorer



	MigrationId
1	20251021160455_AddTables
2	20251029015335_UsersEstabGamesSeshShots
3	20251104170247_AddPiTables
4	20251116200753_AddedPiTables
5	20251117231619_AddDataSelectorToSmartDotTable
6	20251204020317_AddedReplayIterationColumnToEncoderSmartDotHeat
7	20251204023329_DataSelector
8	20251204023631_ReplayIteration
9	20251204024742_AddedReplayIteration

Screenshot of migration history from this semester (stored in DB)

Cloud - API

- Added 30 new API endpoints
- Create/Edit endpoints for both the Cellular and Pi Teams

GET	/api/gets/GetAppUsers
GET	/api/gets/GetAppShots
GET	/api/gets/GetAppSessions
GET	/api/gets/GetAppGames
GET	/api/gets/GetAppEstablishments

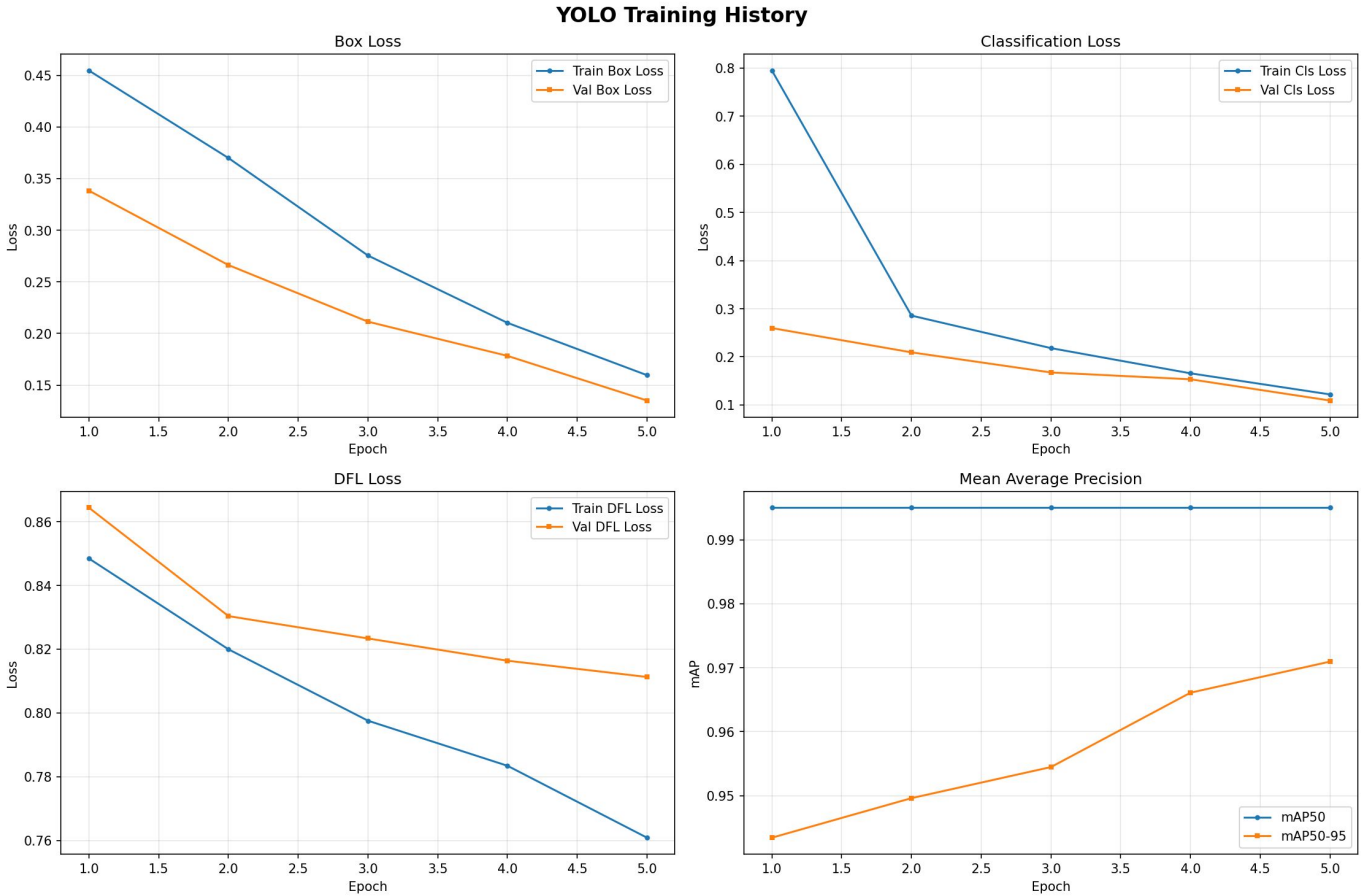
GET	/api/gets/GetBallsByUsername
GET	/api/gets/GetEventsByUsername
GET	/api/gets/GetFramesByGameId
GET	/api/gets/GetShotsByUsername
POST	/api/posts/PostBalls
POST	/api/posts/PostEvent
POST	/api/posts/PostFrames

GET	/api/gets/GetAllPiDiagnosticScriptBySession
GET	/api/gets/GetAllPiEncoderDataBySession
GET	/api/gets/GetAllPiHeatDataBySession
POST	/api/gets/GetAllPiSessions
GET	/api/gets/GetAllPiShotsBySession
GET	/api/gets/GetAllPiSmartDotDataBySession

POST	/api/posts/PostPiDiagnosticScripts
POST	/api/posts/PostPiEncoderData
POST	/api/posts/PostPiHeatData
POST	/api/posts/PostPiSessions
POST	/api/posts/PostPiShot
POST	/api/posts/PostPiSmartDotData

Ciclopes - Training/Evaluation of Segmentation

- Supervised Fine Tuning of YOLOv11s-seg on synthetic data
- Slightly overfit

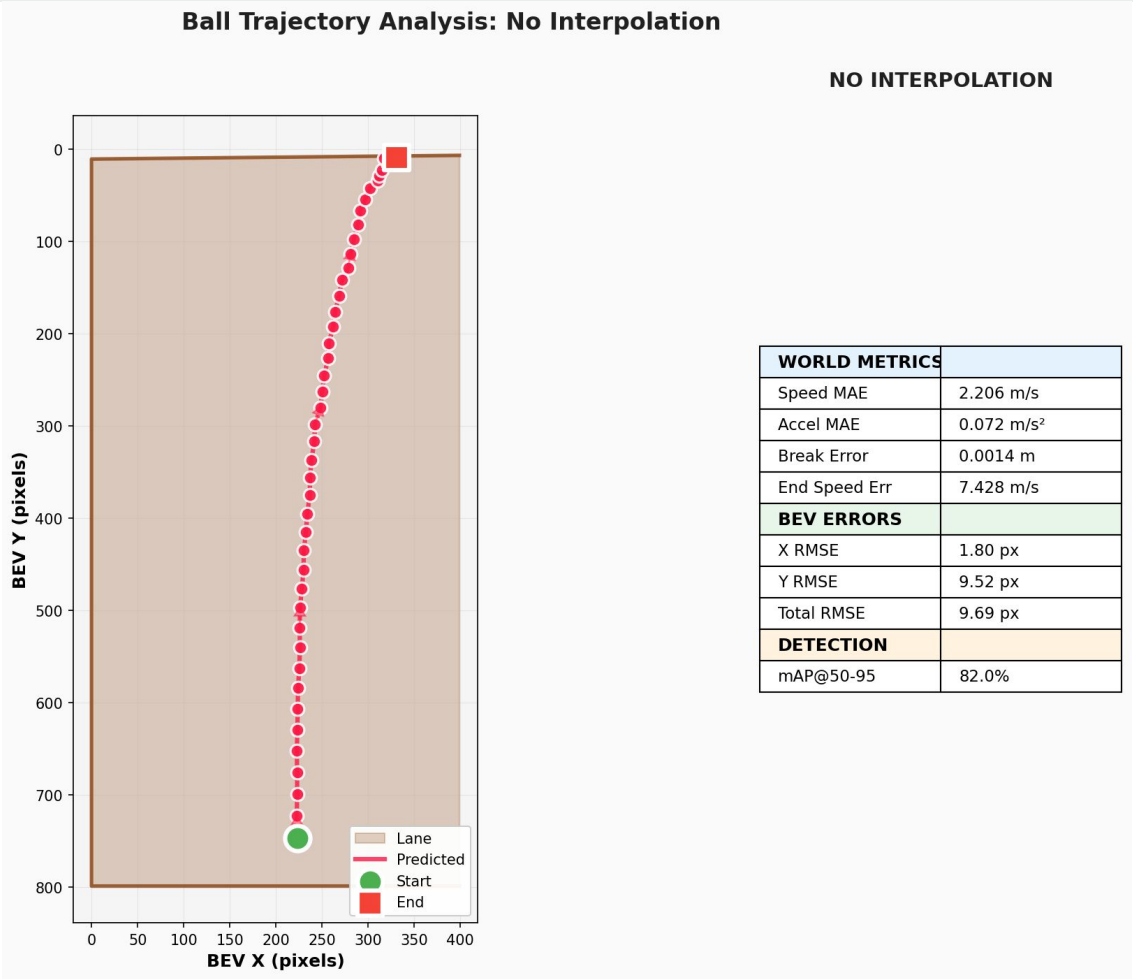


Ciclopes - Evaluation of End to End Processing - None

- BEV unit x RMSE of 1.8px ~ 4 mm
- BEV unit y RMSE of 9.52 px ~2.1 cm

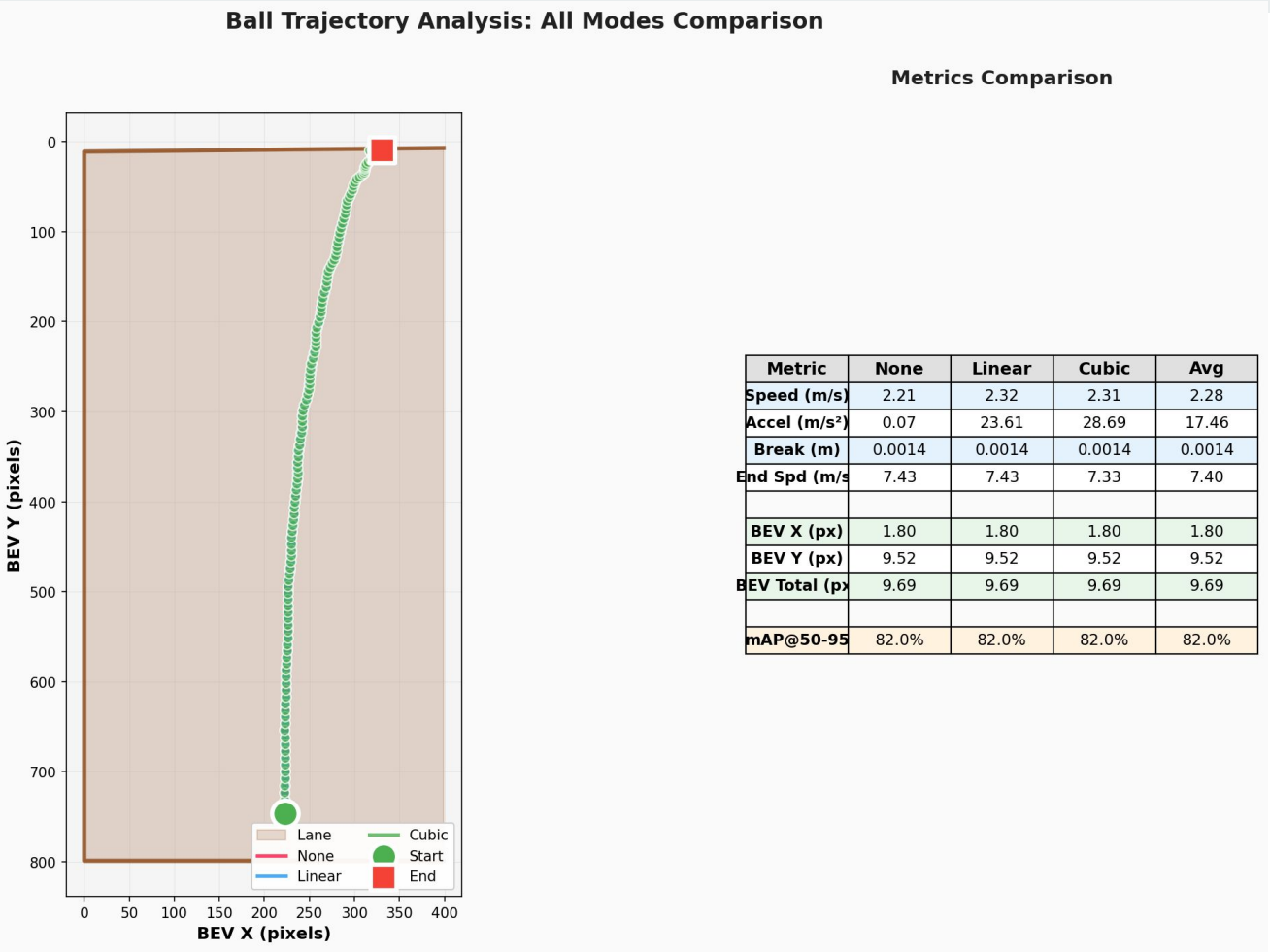
Total RMSE of 9.69px ~2.2 cm

Factors in distortion of increasingly non linear mapping of homography down the lane



WORLD METRICS	
Speed MAE	2.206 m/s
Accel MAE	0.072 m/s²
Break Error	0.0014 m
End Speed Err	7.428 m/s
BEV ERRORS	
X RMSE	1.80 px
Y RMSE	9.52 px
Total RMSE	9.69 px
DETECTION	
mAP@50-95	82.0%

Ciclopes - Evaluation of End to End Processing - All



Metrics Comparison

Metric	None	Linear	Cubic	Avg
Speed (m/s)	2.21	2.32	2.31	2.28
Accel (m/s²)	0.07	23.61	28.69	17.46
Break (m)	0.0014	0.0014	0.0014	0.0014
End Spd (m/s	7.43	7.43	7.33	7.40
BEV X (px)	1.80	1.80	1.80	1.80
BEV Y (px)	9.52	9.52	9.52	9.52
BEV Total (px	9.69	9.69	9.69	9.69
mAP@50-95	82.0%	82.0%	82.0%	82.0%

Ciclopes - SAM3 Test - “lane” Prompted Segmentation

- Using SAM3 Segment Anything
- Prompt “lane”

- Brittle with reflections and lighting

Ciclopes - Takeaways from Experimentation

- Robustness to lane gloss and specular reflections is a requirement
- Postprocessing is the most important part of the stack
- Large general models still do not outperform smaller “narrow domain” models
- Interpolation is brittle with low frames per second and few data points
- Calculating a standard linear map for homography will introduce distortion the farther away the ball is

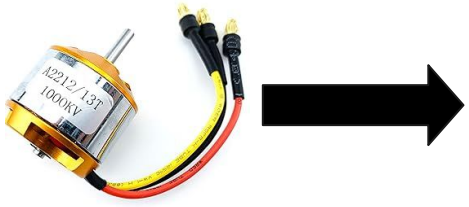
Ball Spinner Controller - BSC Class

- Core singleton class for communicating between pages
- It holds all of the most important objects
  - CloudAPI
  - Session
  - Data Controller
  - Motors

Ball Spinner Motors and Drives

- Primary axis - Sensored BLDC motor +Flipsky VESC controller
  - High RPM capabilities
  - Hall Sensors provide reliable startup and consistent acceleration
  - VESC provides current limiting, temperature monitoring and fault detection
- Second and third axis - Nema 17 stepper motor + DM542 driver
  - Precise angle control
  - High holding torque for tilt and rotation
  - Reliable industrial grade step driver

NEMA 17 stepper motor

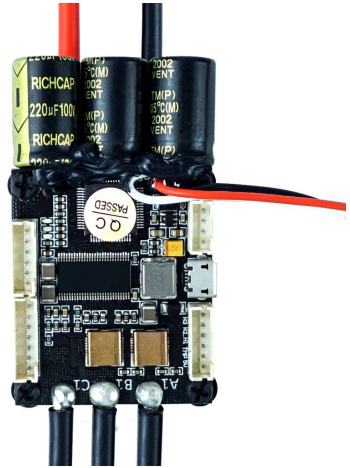


A2212/13T 1000KV outrunner motor

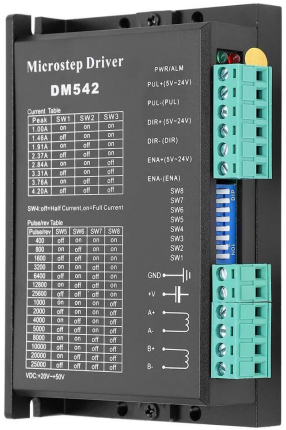
E3665 2500KV inrunner motor

Ball Spinner Controller Continued...

- Primary axis motor configuration
  - Completed Hall sensor detection and motor characterization in VESC tool
  - Pi sends commands over USB to the ESC
  - Controlled via PWM (Pulse Width Modulation)
- Second & third axis stepper motor configuration
  - Microstepping and current dip switches configured to 1.46A an
  - Pi generates controlled STEP/DIR pulses with an adjustable frequency
  - Created angle based control routines



Flipsky VESC 4.20

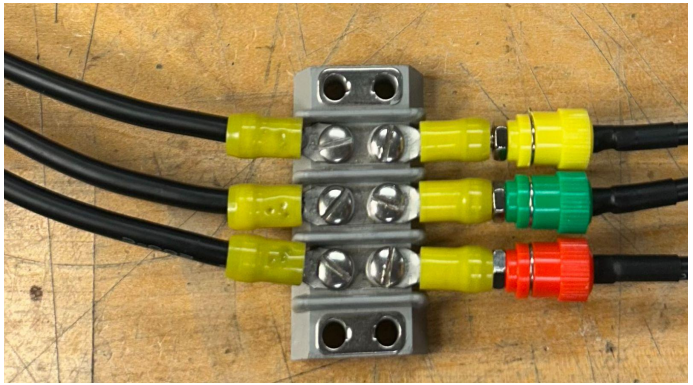


DM542 Microstep Driver

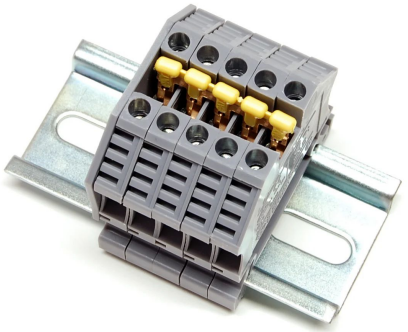
Ball Spinner Power System and Safety

- 24 V Distribution Power Rail
  - Supports both motor drivers with adequate voltage overhead
  - Lower current
  - Reduced wire heating
- 5 V Power Rail
  - 24 V to 5 V Buck Converter
  - Isolation from motor noise
- Motor switches
- Status indicators
- Wiring and modularity

P1-150-24 Power Supply



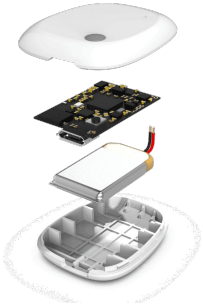
BLDC motor harness

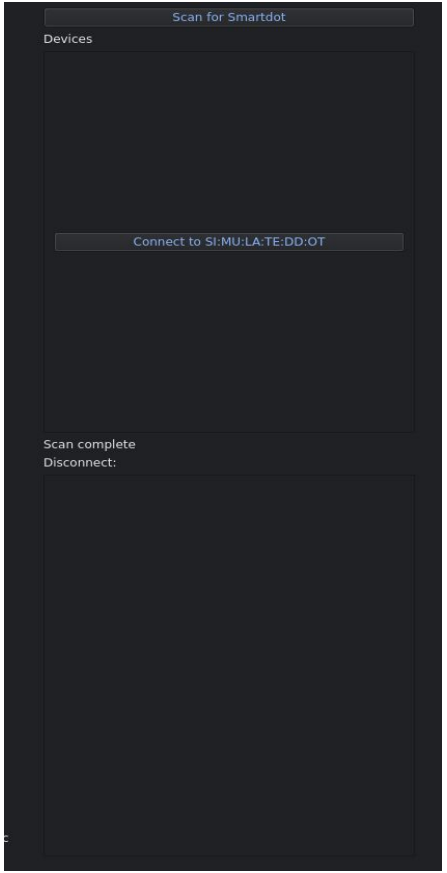


Industrial din rail term block

Ball Spinner Controller - SmartDot

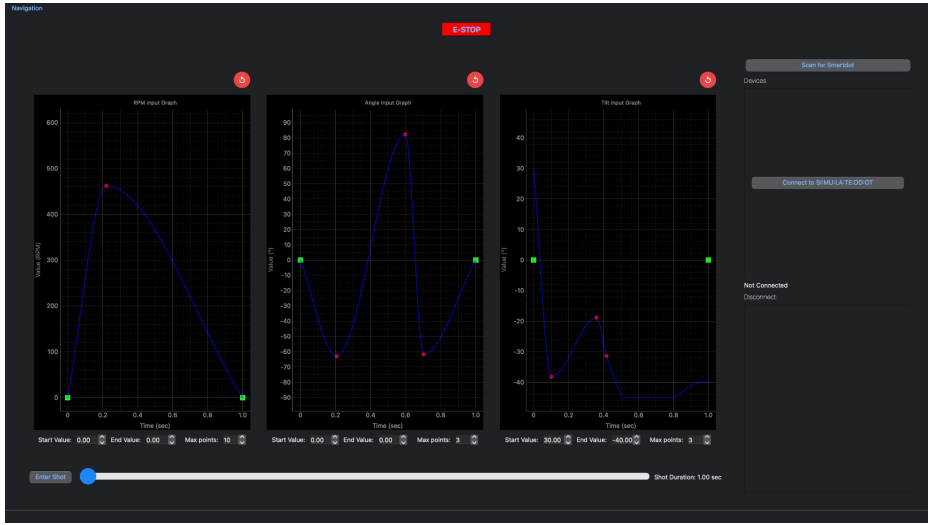
- iSmartDot
  - MetaMotionS
  - Simulated Smart Dot
- MetaWear Implementation
- Scan, Connect, and Disconnect
- Smart Dot Connection Manager





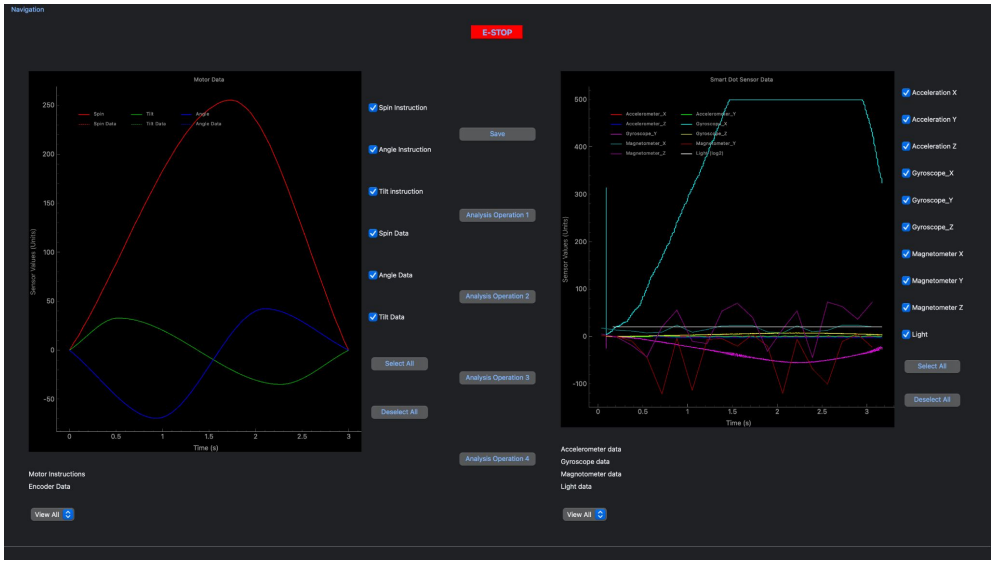
Ball Spinner Controller - Shot Mode

- 3 input graphs allow user to make shot instructions
- Slider lets user select length of shot



Ball Spinner Controller - Analysis Mode

- Smart dot and motor data are loaded in from the Data Controller
- Data is passed into the SmartDot graph and Motor Graph



Ball Spinner Controller - Diagnostic Mode

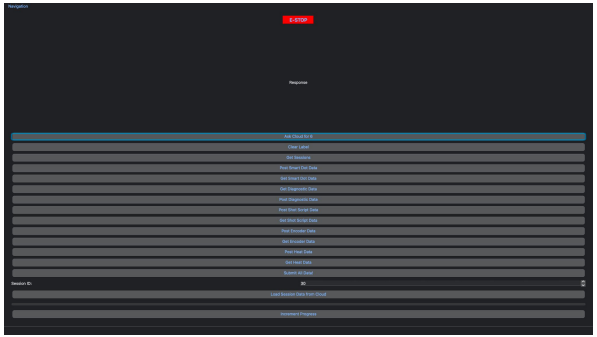
- Individual motor control- 3 dials
- Real-time graphical feedback
- SmartDot connectivity for quick data collection

Ball Spinner Controller - Models

- Session
- Data Controller
- Diagnostic Script Data
- Shot Mode Data
- Smart Dot Data
- Encoder Data
- Heat Data

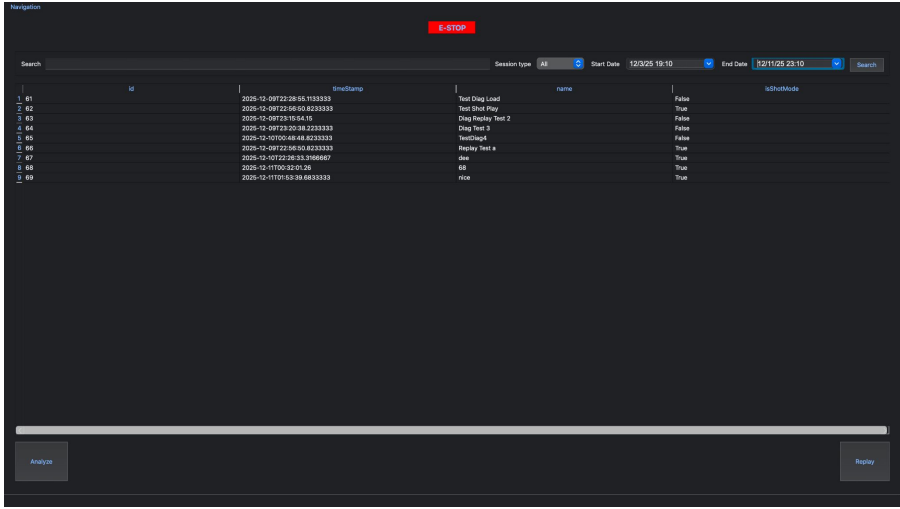
Ball Spinner Controller - CloudAPI

- APIUtils
- HTTPS
- Object Serialization



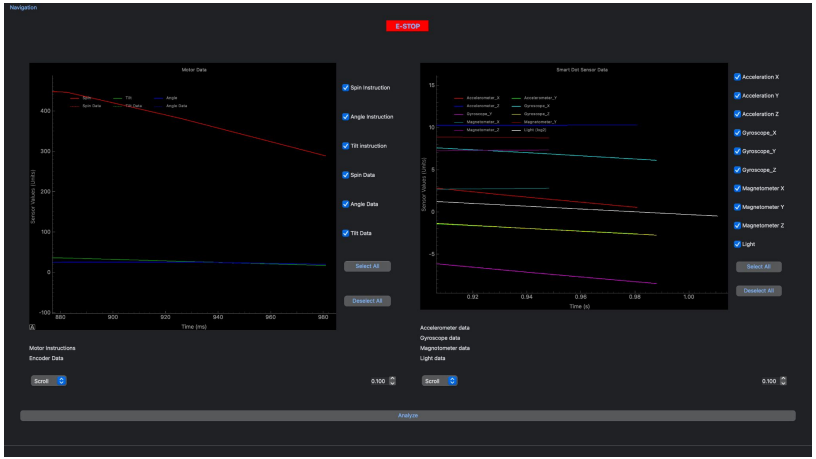
Ball Spinner Controller - Data View Page

- Data is loaded from cloud into table
- User can filter data by date
  - User can further refine data by searching across fields
  - User can also filter for session type
- User can either replay or analyse previous shot



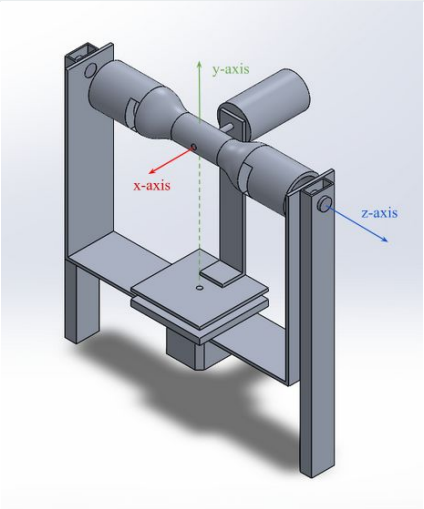
Ball Spinner Controller - Replay Mode

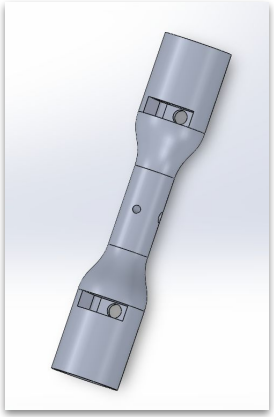
- Shot data us unpacked from data controller
- Every 50ms* a thread is spawned from the pool
- Thread instructs motor and returns when it returned
- When it returned is put into the graph.



Ball Spinner Mechanical System

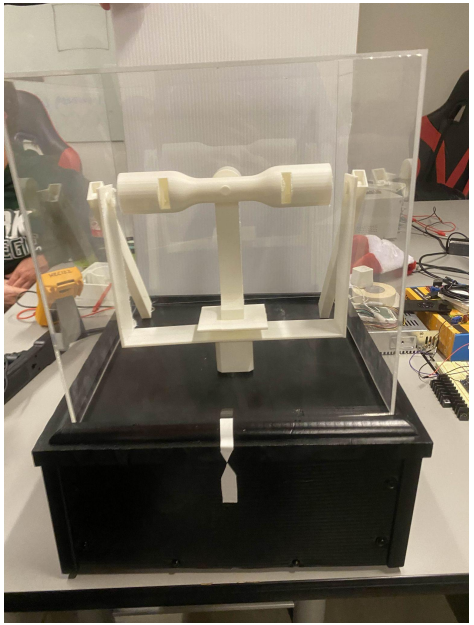
- **Wooden prototype as an early representation of the system**
- **Model developed based on feedback**
  - Aluminum selected as material
  - Smaller and lighter to reduce required torque and power consumption
- **SmartDot holder**
  - Design changed as the system size changed
  - 3D printed to use in a test setup for X-axis





Ball Spinner Mechanical System

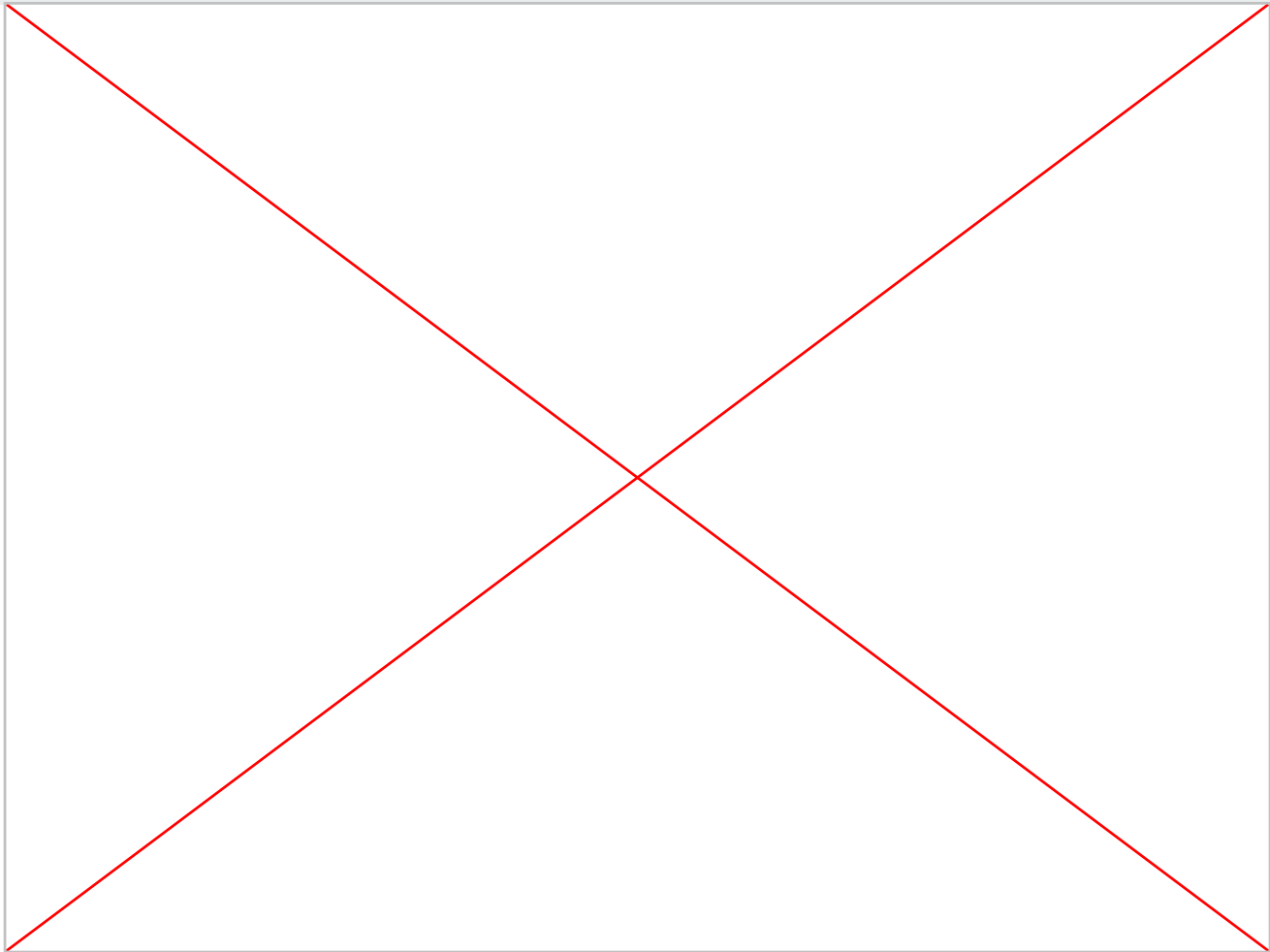
- **BSC Enclosure and Platform**
  - Houses motor control equipment and other future Team Pi components
  - Made of modifiable and easy to replace paneling for quick and hassle free alterations
  - Holds acrylic safety casing stable for safe viewing and ease of transport
  - Holds considerable weight, making such a consideration a non-factor in future decisions.



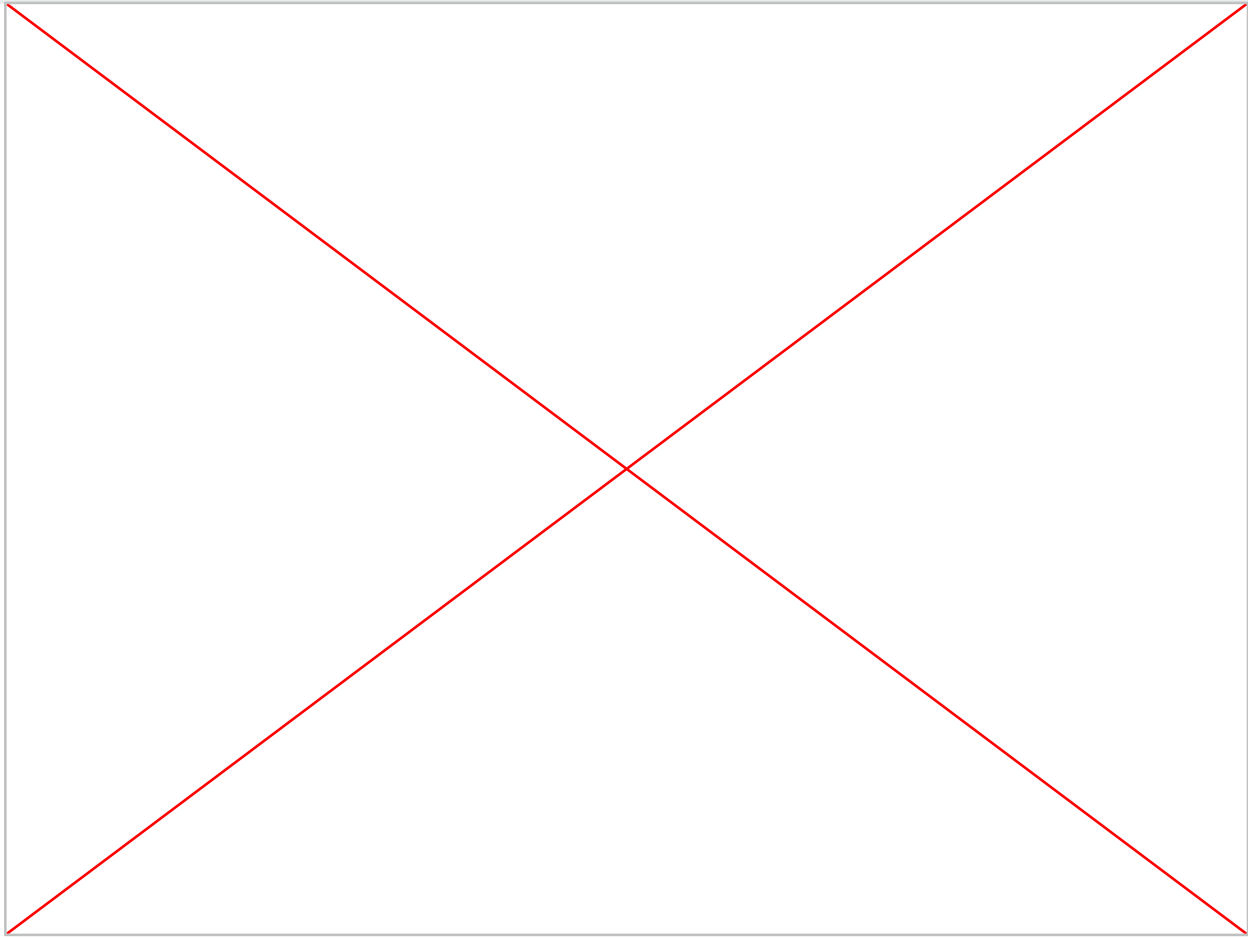
Demonstration

Mobile

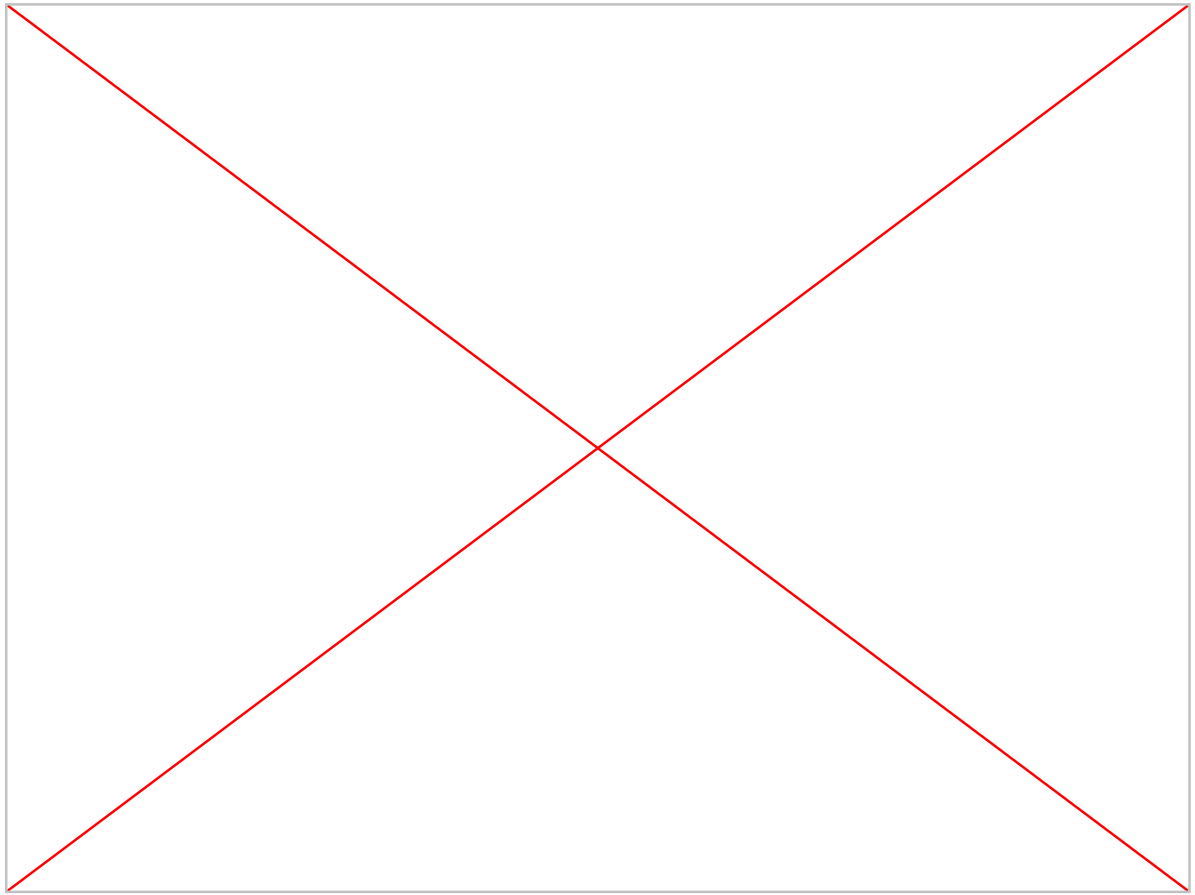
Watch



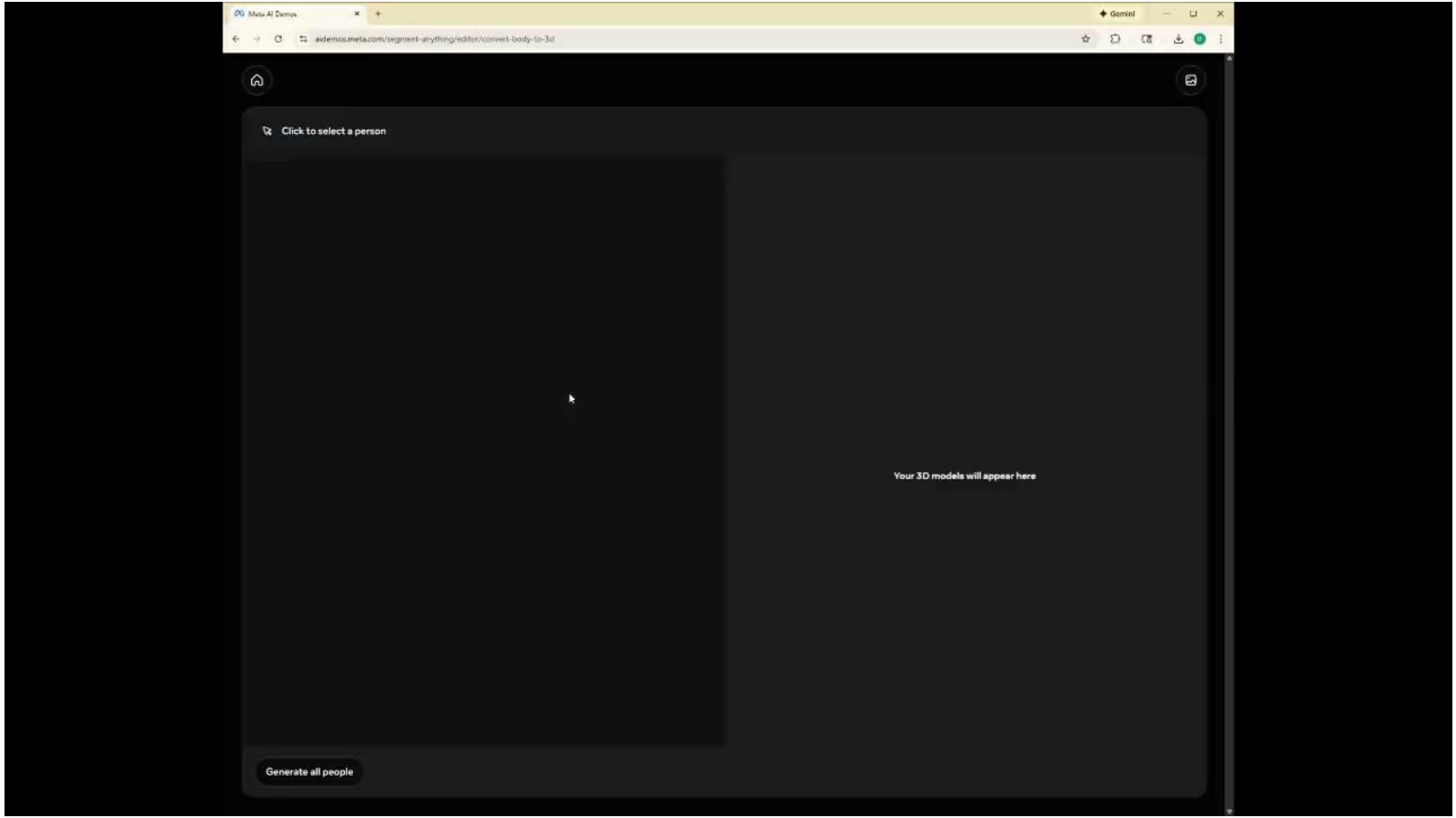
Cloud - Pi and Mobile API



Cloud - Mobile App



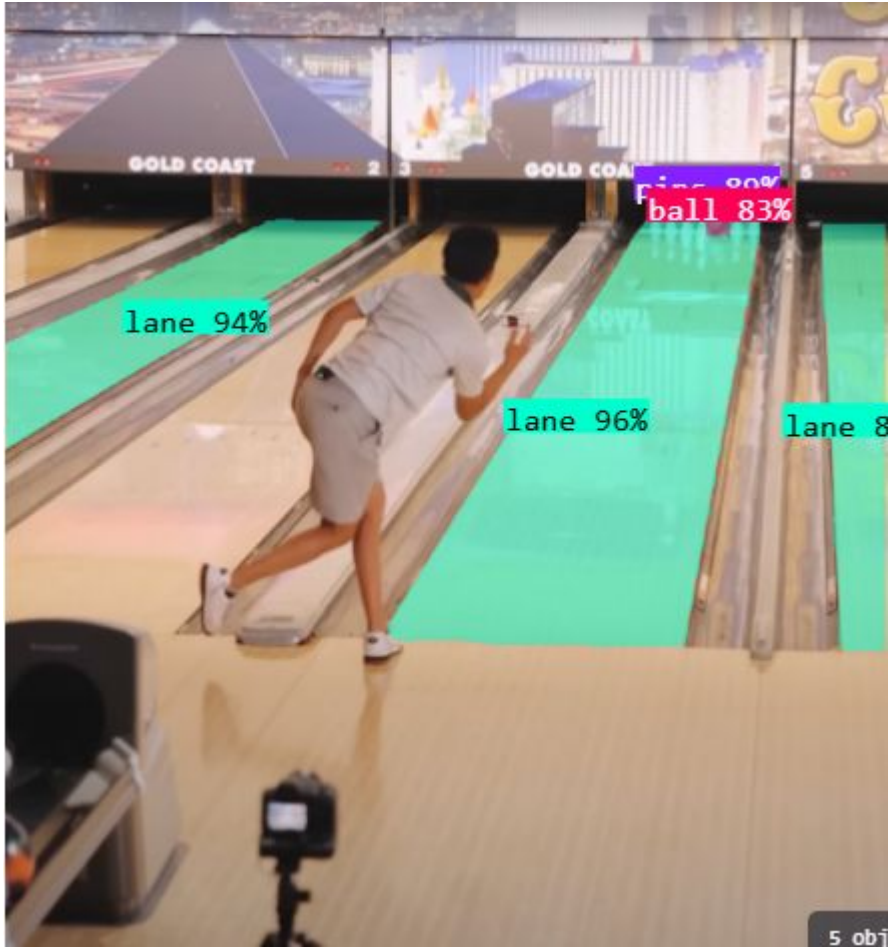
Ciclopes - SAM3D Body Demo



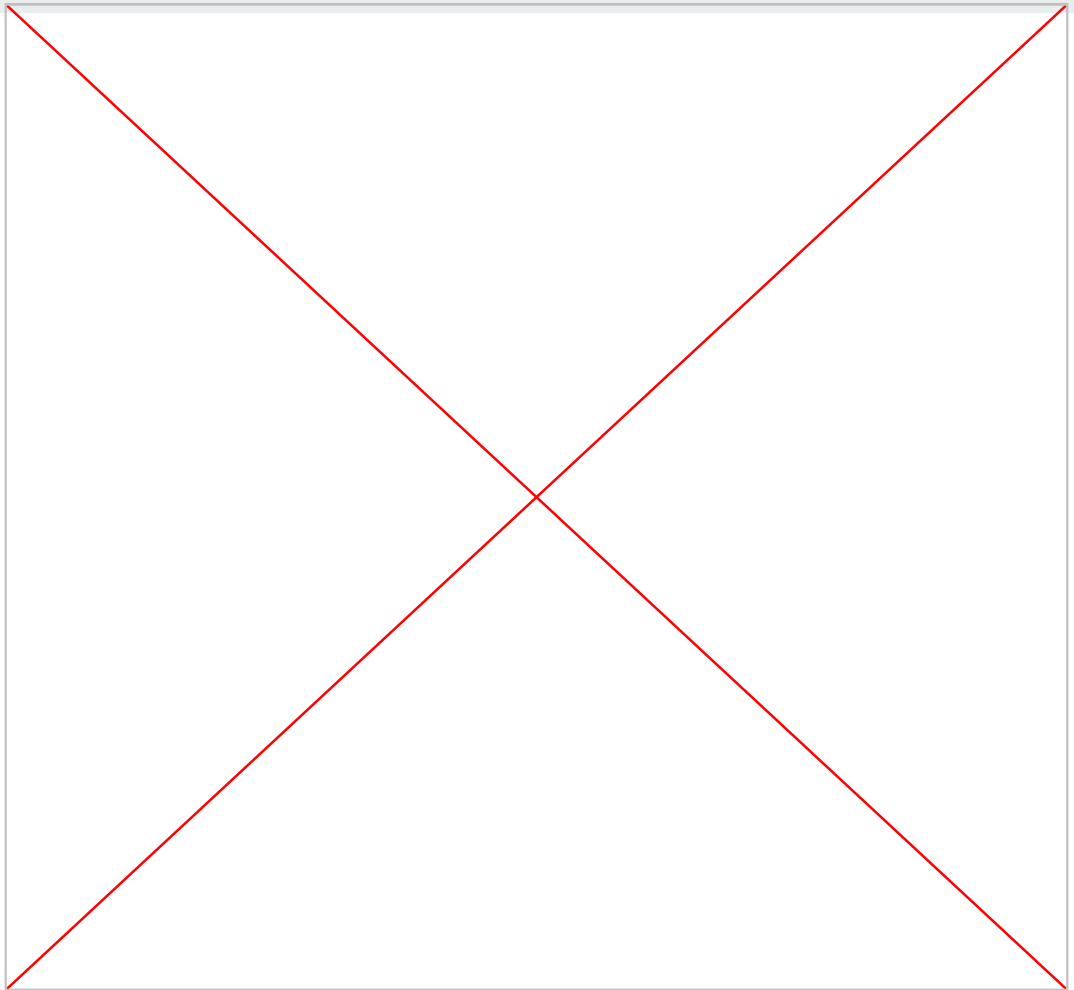
Ciclopes - Real World Working Version

- YOLOv11n-seg fine tuned model from LaneTrax
  - Nano size = Real Time On Device Inference
- Open Dataset
  - ~1800 Labeled Frames
  - Ready for training

- Tested using open inference on Roboflow



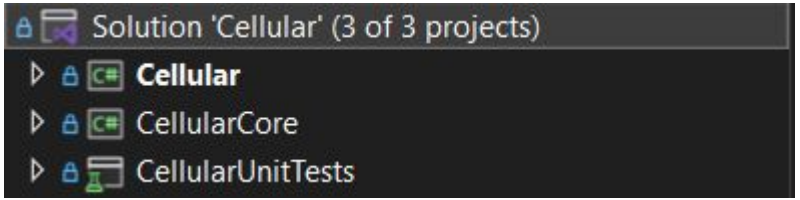
Ball Spinner Demo

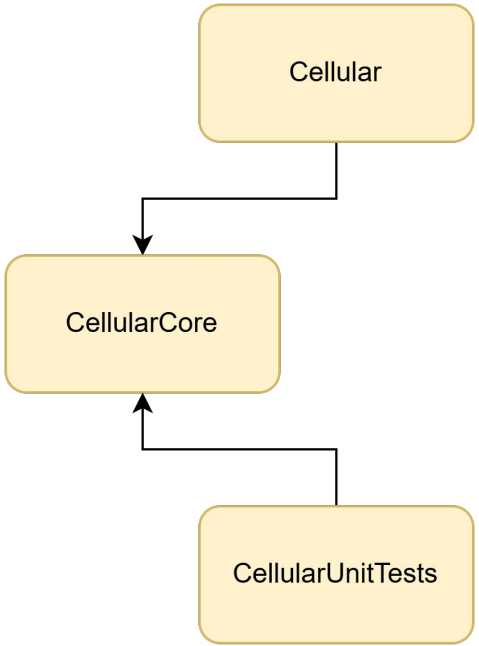


Automated Testing Framework

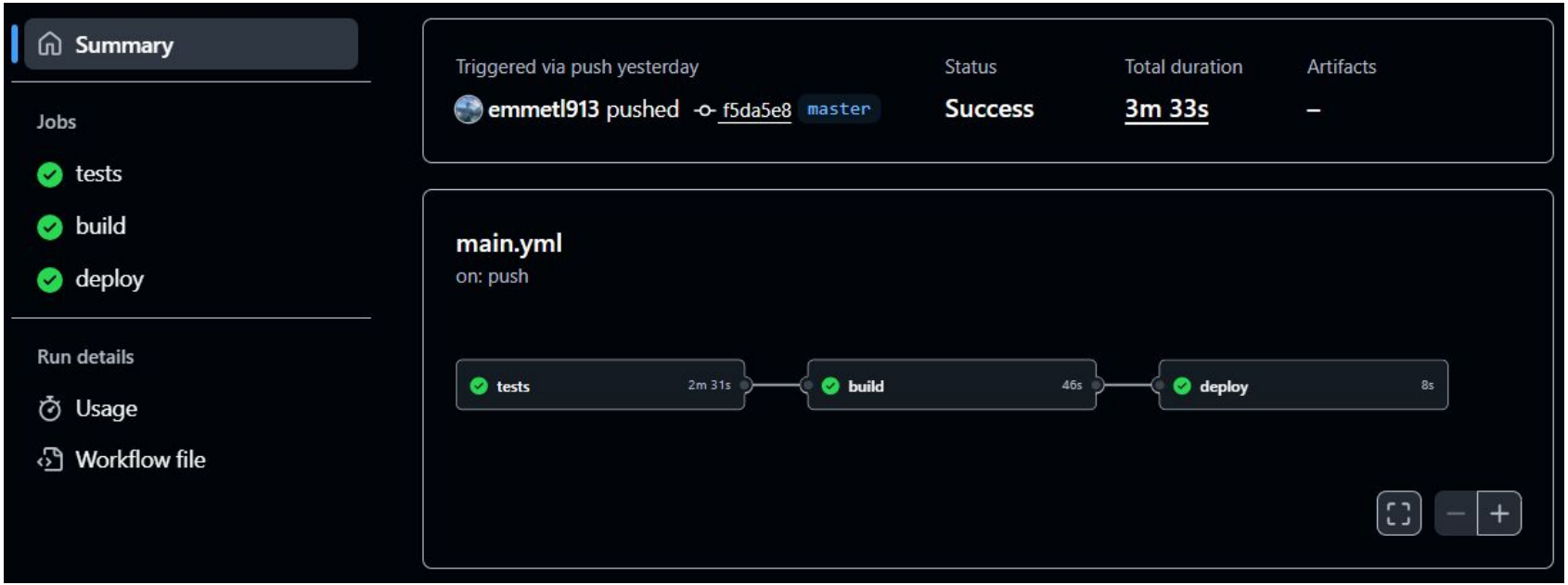
Mobile App

- Cellular
  - Main App Functionality
- CellularCore
  - Contains core methods for Cellular
  - ShotCalculator.cs
  - StatsCalculator.cs
- CellularUnitTests
  - Tests CellularCore methods

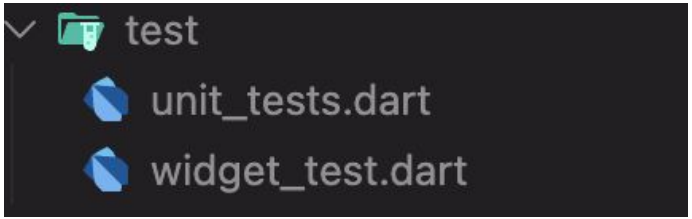




Cloud - CI/CD Pipeline



Watch Tests




```
charlescarroll@DESKTOP-C7TGMLH flutter_prototype % flutter test test/unit_tests.dart
00:03 +31: All tests passed!
```

```
charlescarroll@DESKTOP-C7TGMLH flutter_prototype % flutter test ./test/widget_test.dart
00:01 +3: All tests passed!
```

Future Work

Mobile

- Improved stats page
  - Pocket, Split, Washout %
  - Histograms
  - Graphs/ Charts
- Improve sessions and events
- Improve Custom Query System
- Improve MetaMotionS Connection
- Improve UI and UX
- Implement Full Cloud Features

Watch

- Adjust UI
  - Relative Sizing
  - Swipe Navigation
  - Score Changes
  - Pre/Post Shot Items
- Backend work
  - Parsing incoming data (phone side and watch side)
  - Packaging data
  - Stored data/Local data/bluetooth data: Handshake between
- Create wiki page
  - Getting application on to watch
  - Tutorial of application
- Cross platform integration (stretch goal)
  - Swift files into Flutter framework
- Ciclopes integration (stretch goal)
- Real time synchronization (stretch goal)

Cloud

- API Improvements and Additions
- Automated Testing Improvements
- CI/CD Pipeline Additions
- Seperate database migration application

Ciclopes - Keeping it Real - No Need for Synthetic Data

- Leverage open dataset(s)
  - May need to mix multiple datasets to push performance and generality
- On device inference
  - Model can be exported to ONNX runtime
    - General format for multi platform
  - .NET MAUI does not integrate automatically with platform tensor core APIs
    - Legacy models will not have tensor cores
  - Evaluate tradeoff between development speed, implementation complexity, and resulting change in user value
- Mirroring sim implementation with real world collected/labeled data
  - Does not have ground truth labels/metrics to test post processing like sim
- Good video for evaluation is a requirement
  - It is extremely difficult to find quality videos online

Ciclopes - Improving Accuracy Through Image Cropping

- Implement prediction of future steps down the path to drive image cropping
- Once lane is found, crop to not include any more noise than already exists
- Cropping out other lanes/balls, both in pre and post processing

Ciclopes - SAM3D Pose Rendering

- Give user freedom to do ball/lane segmentation and/or pose detection
- Requires clean UI/UX for swiping and interfacing with renders
- Must be done in cloud
    - Introduces data storage/fetching complexity
- Not all users may be able to utilize fully due to differing experience levels

- Requires backend service setup

Ciclopes - Proposal: LLM Powered Data Analysis

- Small optional feature to allow users to leverage LLM powered data analysis over saved data
  - Some users may be apprehensive about feedback
- Leverages current LLM capabilities to use tools and analyze large amounts of data
- Allows users of all skill/experience levels to get actionable insights from collected data
- Introduces data storage/fetching complexity
- Reasoning models can be expensive
  - For production setup

Ball Spinner Controller - Software

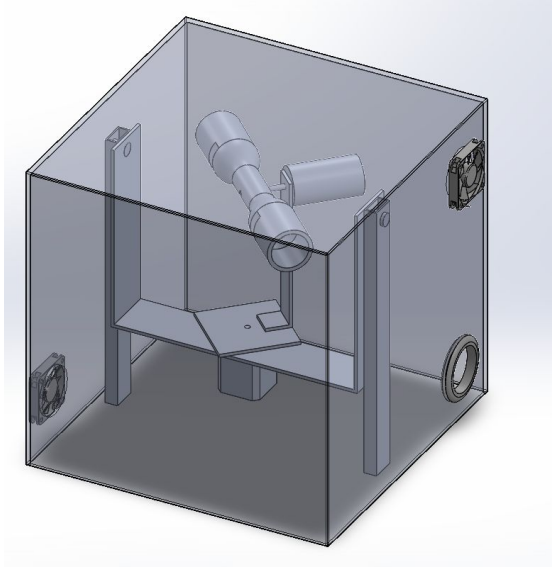
- Smart Dot connection robustness
- Update Smart Dot tables to remove data selector
- Simulation manager for missing hardware
- Self run full system test sequence
- Analysis operations
- Display encoder data
- Reload old shots from Cloud into the Shot Input Page to edit

Ball Spinner Controller - Hardware

- Logic level Shifters- 3.3 V to 5 V
- Resistive Brake
- Indicator Lights
    - Power, motor arming, software faults
- Enhanced Safety features
- Buttons/Switches
- PCB Development
- Communication Expansion UART or CAN BUS

Limit Switches

Ball Spinner Mechanical System



Aluminum Final Prototype & Enclosure

- **Physical and electronic stops to prevent motors from spinning past the maximum required angle**
- **Wire routing from motors to the Ball Spinner Controller**
- **Modifications to acrylic housing**
  - Hole and grommet for exterior wires
  - Vents or fans for motor cooling

Ball Spinner Mechanical System

Enclosure Platform

- **Modifications to side paneling**
  - Holes cut for required port access
  - Space made for fan ventilation of Team Pi's equipment (pi, motor controllers, etc).
- **Installation of Team Pi's Equipment**
  - Placement and wiring to be determined
  - Space and routing options are available

Conclusion

Mobile

- **What we accomplished**
  - Implementation of Basic Cloud Saving
  - Video Page
  - Basic Stats Page
  - Improved shot page
  - Bluetooth Connecting with Watch and MMS
- **What we would change**
  - Bluetooth Connection needs refining
  - Shot page can always be improved
- **What we learned**
  - Add more comments/documentation

Watch

- **What we accomplished**
  - Working prototype
  - Game Page/Frame Page/Shot Page/Bluetooth Page
  - BLE comms with mobile application
  - Packet building/delivery to phone (test)
  - Video recording from watch
  - Local storage
- **What we would change**
  - Focused too much on IOS at beginning
  - Spend more time (more refined)
- **What we learned**
  - Widget building is very picky
  - Implement own feedback

Cloud

- **What we accomplished**
  - Ability to migrate the Database
  - Automatic SQL Script generation
  - Updated Database with new schema (15 new tables, 2 new schemas)
  - Added 30 new API endpoints and database controllers
  - Connected Cloud Application to both the Mobile and BSC Projects
- **What we would change**
  - Implement generic Database Controllers and API Endpoints
  - More flexible use of API endpoints
- **What we learned**
  - More documentation for future developers
  - Better organization of files
  - Abstract out complicated processes

Ciclopes

- **What we accomplished**
  - Verified our end to end process works in sim
  - Defined a plan moving forward to implement a real world
- **What we would change**
  - Introduce a more robust nonlinear mapping for homography to start
    - Caused confusion that something may have been setup wrong but it was just distortion
  - Get a robust test suite much earlier
    - The test suite after implementation drove decision making
- **What we learned**
  - Pixel math is very brittle
    - Distortion of the lens caused mis calibration even in sim

Ball Spinner Controller

- **What we accomplished**
  - Independent control over all 3 motors
  - Simulate a shot on all 3 motors
  - Integrated power distribution
- **What we would change**
  - Separate logic from UI code
  - Perform incremental subsystem testing earlier
- **What we learned**
  - Importance of modular design
  - Good documentation reduces communication issues across team members

Ball Spinner Mechanical System

- **What we accomplished**
  - Determined Torque specs for motors
  - Designed all three degrees of freedom
  - 1st and 2nd degree systems constructed
  - Designed and built enclosure for electrical hardware
- **What we would change**
  - Transition to a more finalized version of the 1st and 2nd degree sooner to allow for testing
  - Add the third degree and mechanical stops
- **What we learned**
  - Communicate with other teams to ensure project progression will be meaningful for the overall project