Machine Learning for Human Biometrics

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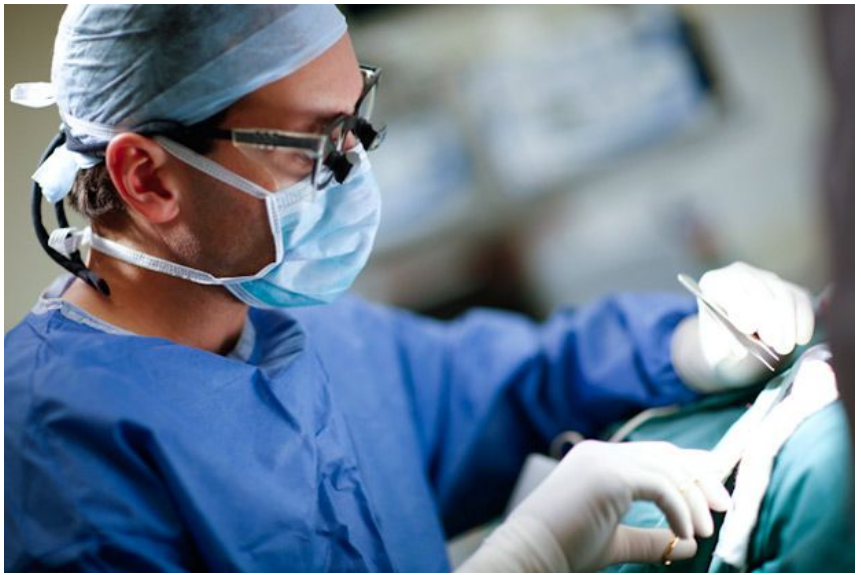
Client: JR Spidell

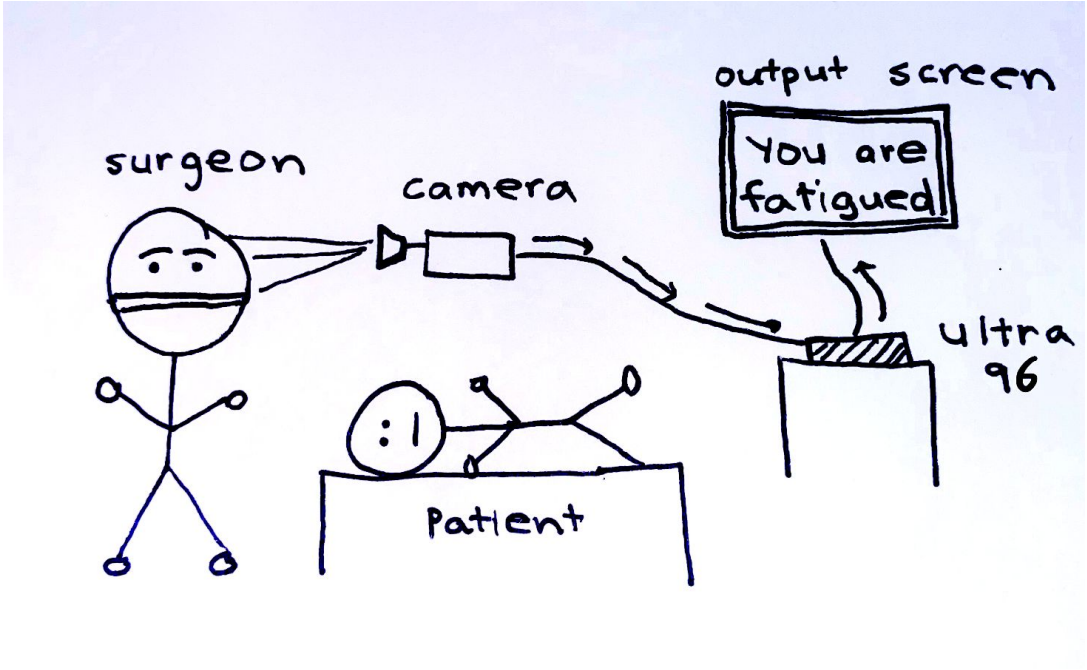
Project Plan

Problem Statement

- Surgeons can sometimes be too focused and not aware of their physical condition
- Humans are not perfect, and they tend to make mistakes
- Surgeons can be under high pressure during surgery



Conceptual Sketch



Requirements

- Analysis shall be performed in real-time in less than 1 second.
- An appropriate prompt shall be straightforward and clear and provided to the user to e.g., take a break.
- The pupil detection algorithm shall process grey scale images, process images at a rate greater than 60 fps, and achieve an accuracy of 96%.

Requirements

- The database shall accept a stream of data from eye-movement classification algorithm and provide data visualizations.

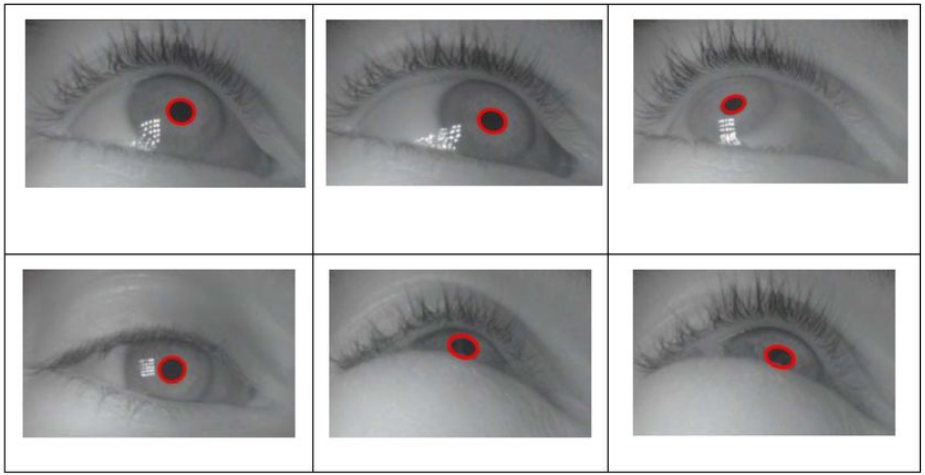
- Our project shall not violate any laws.

Constraints/Considerations

- Lighting condition of the surgery room
- Glares on the pupil from wearing glasses or lights
- Surgeons might ignore the prompt from the device

Market Survey

- Our project combines:
  - Convolutional Neural Network (CNN)
  - Robust Eye Movement Detection for Natural Viewing (REMoDNaV)
  - InfluxDB
  - Ultra96
  - ArduCam Camera Module



Tracking movement of the pupil

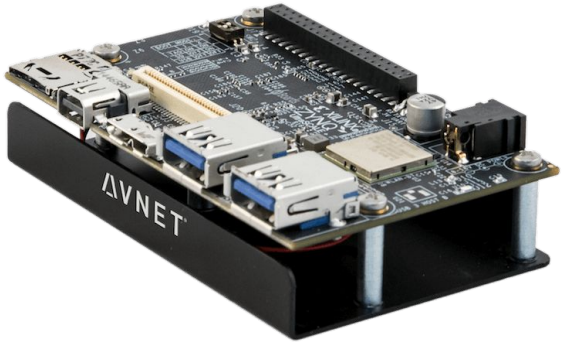
Potential Risks & Mitigation

- InfluxDB crashing: backup database to increase redundancy
- Pupil detection algorithm crashing
- Inaccuracy of the pupil detection algorithm
- Ultra96 overheating: attach a cooling system
- Data breach: encrypt our data

Resource Estimate

- ArduCam for Raspberry Pi NOIR OV5647 Camera Module: MSRP $27.99.
- Ultra96-V2: MSRP $299.00.
- Total: $326.99

ArduCam Camera Module

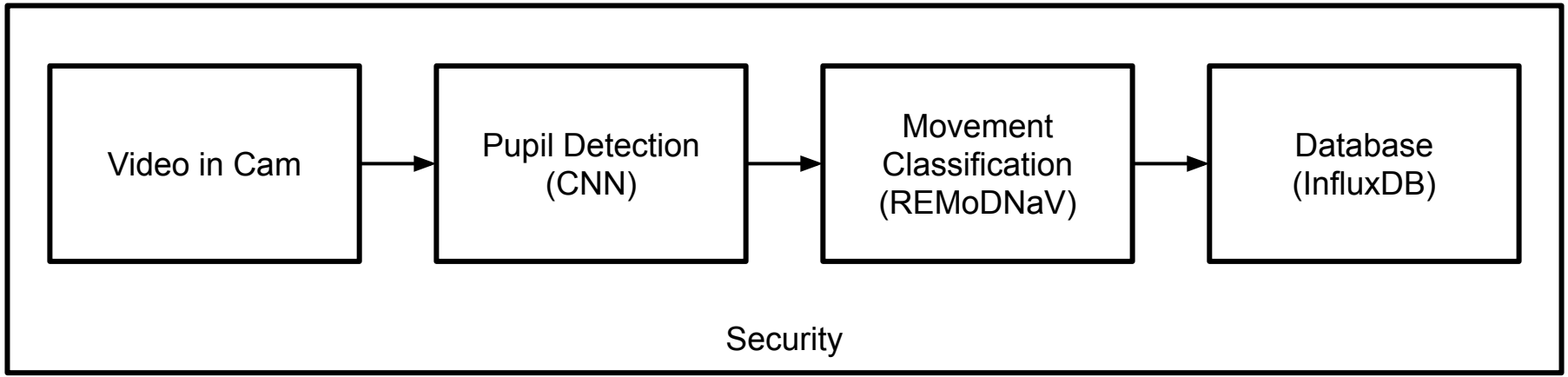


Ultra96-V2

System Design

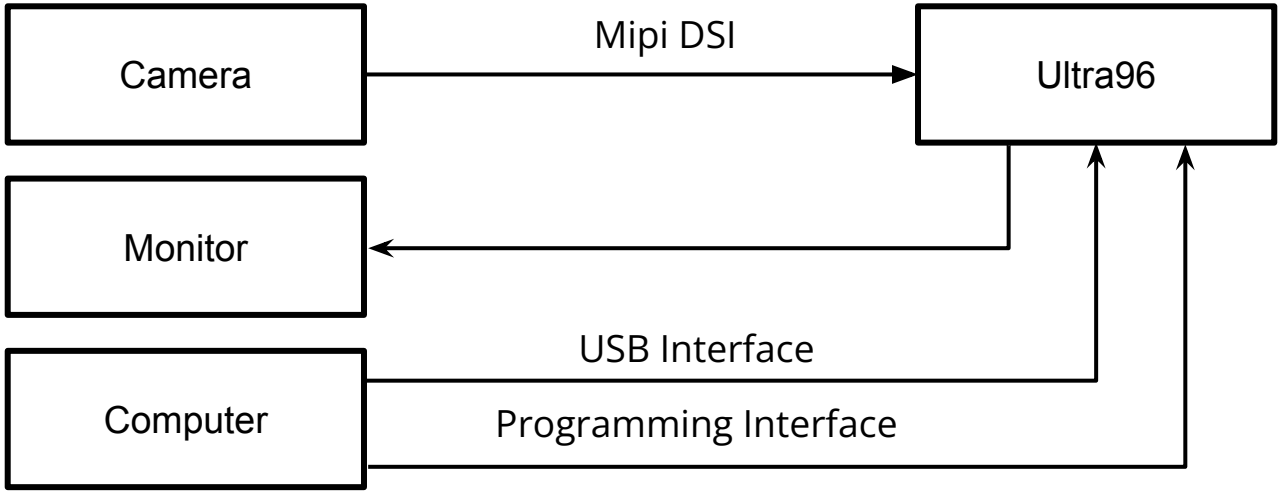
Detailed Design

- Main components:



Detailed Design

- Components Interface with Ultra96 Board:



Functional Decomposition

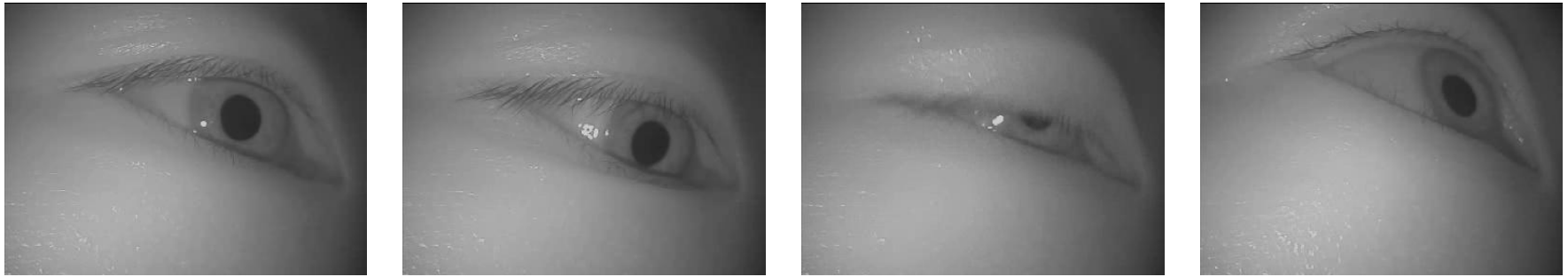
We have decomposed our project into five components:

- Hardware
- Pupil detection algorithm
- Eye-movement classification
- Database
- Security

Functional Decomposition

Hardware:

- A video stream of the user’s eye through the ArduCam camera module which will be input into the Ultra 96 board.



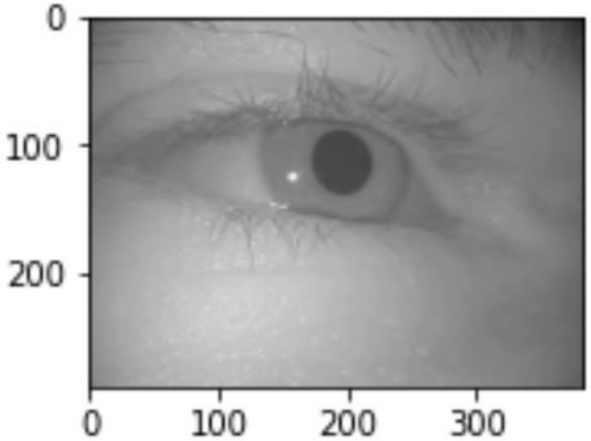
Video stream of eye movement being recorded by a camera

Functional Decomposition

Pupil Detection Algorithm:

- A neural network that outputs the coordinates of a user's pupil on an X-Y plane along with the corresponding timestamp.

	Timestamps	X	Y
0	0.000000	441.887238	345.482391
1	0.034483	443.010193	345.707489
2	0.068966	443.076508	346.186829
3	0.103448	444.135345	346.444672
4	0.137931	444.222656	346.829926
5	0.172414	444.823517	347.008789
6	0.206897	444.993591	346.830627
7	0.241379	444.607727	347.068634



Pupil's movement being tracked on an x-y plane

Functional Decomposition

Eye-movement Classification:

- Takes the pupil's movements and makes classifications on them.
- Will use eye movement classification data to determine if a user is stressed, tired, or under work overload

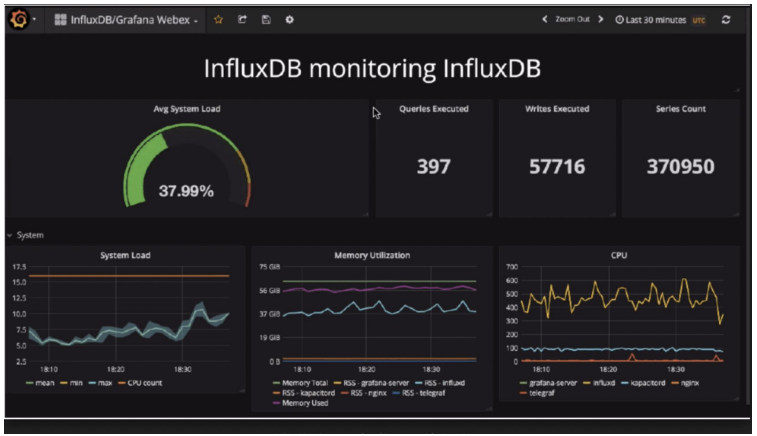
```
eye movement type to number: Error = 1,Blink = 2,Fixation = 3,Saccade = 4,SM = 5

FRAME;Eye Movement Type;
1;3;
2;3;
3;3;
4;3;
5;3;
6;3;
7;3;
8;3;
9;3;
10;3;
```

Output of Classification algorithm. Each frame is followed by an eye movement type

Functional Decomposition

Database:

- A database where the classifications are stored, so they can be used for analysis after the procedure.
- Use visualization software to visualize the data.



Functional Decomposition

Security:

- Multiple layers of security such as encryption and authentication is added to combat cyber attacks and threats.
- When the system isn’t being used by employees, it will be isolated from the network to prevent any attacks.

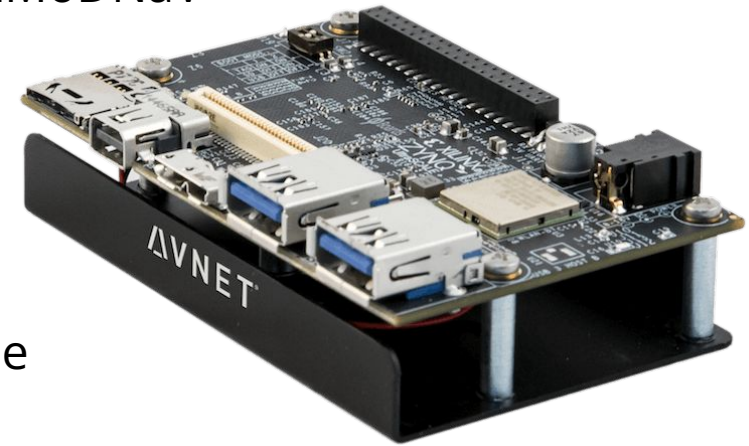
Hardware and Software Used

Software:

- Pupil detection algorithm: CNN
- Eye-movement classification algorithm: REMoDNaV
- Database: InfluxDB

Hardware:

- Development Board: Ultra96
- Camera: ArduCam OV5647 Camera Module



Test Plan

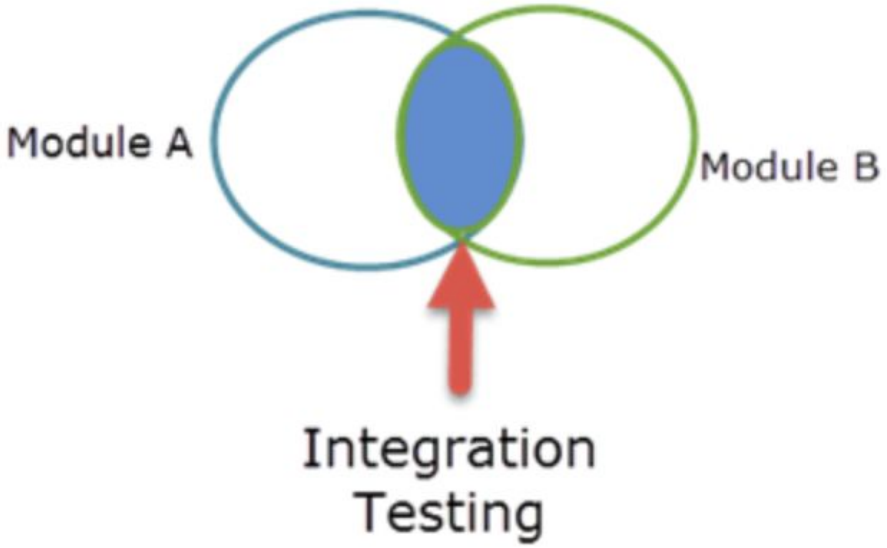
Unit Testing

Test individual units of source code:

- Accuracy of pupil detection algorithm
- Output of eye-movement classification algorithm
- InfluxDB read and write operations

Integration Testing

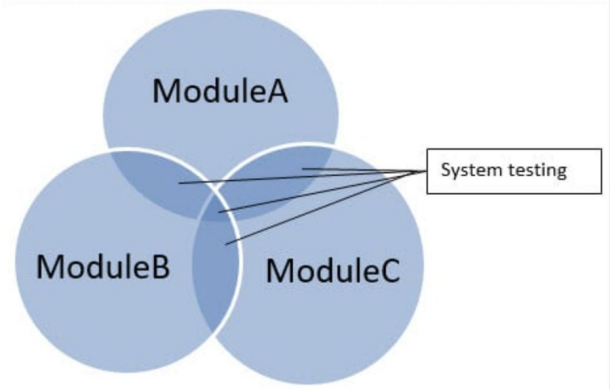
- Combine individual modules and test them as a group
- Example: CNN and InfluxDB



System Testing

Test the complete integrated system and evaluate its compliance with the specified requirements:

- read and write to the database in real time
- detect the location of the pupil accurately
- output its prediction based on the movement of the pupil



Acceptance Testing

- Verify with client that requirements are satisfied
- Validate that our system meets its intended use

Security Testing

- Identify potential risks
- Implement security features
- Penetration test
- Fix any other problems within the new security solution

Current Project Status

Current Project Status

Hardware:

- We have not tried to run our project with Ultra96.
- We should be able to meet the requirement since Ultra96 are build for this kind of application.
- Display image from Ultra96 to a monitor.

Current Project Status

Database:

- Successfully installed InfluxDB on a local machine.
- Able to write and query data.
- Will be looking up on how to integrate the database into an ARM based development board.

Current Project Status

Pupil Detection algorithm:

- Output the prediction of X-Y coordinates of the pupil with their corresponding timestamp.
- Process grey scale images.
- Process frames at a rate of 30 fps.

Current Project Status

Eye Movement Classification Algorithm:

- The algorithm can receive any input file with x-y coordinates of the pupil's location at a timestamp.

- Can output whether a saccade, fixation or smooth pursuit eye movement classification occurred during a certain time period.

Current Project Status

Security:

- Verification methods still work in progress for Ultra96 and security measures/encryptions in place once Ultra96 setup is complete.

- Make sure project does not violate any laws especially the National Biometric Information Privacy Act of 2020.

Plans for Next Semester

- Integrate different part of project together (hardware, machine learning algorithm, database, security).
- Ensure that database is able to ingest and output data as fast as the rate of frames processed by the algorithm.
- Perform testing with volunteers if possible.
- Create survey with a list of questions to help determine the accuracy of our device.
- Optimize our product as needed.

Thank You

Questions?