PROJECT ELM

Detailed Design

sdmay25-01 “ProJect ELM”

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PROBLEM STATEMENT

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- People with **mobility** and **cognitive impairments** face many challenges including maintaining **independence** and **safety**.
- Lack of advanced wheelchair technologies, leaving **gaps in autonomy**, communication, etc.

OUR CLIENT

- Formerly volunteered to help with individuals with cerebral palsy and is motivated to help them further.
- Wants to develop assistive wheelchair tech with features including mobility assistance and real-time seizure detection.

OUR TEAM

- Create a subsystem that detects, locates, and presents info on a user's eye in a camera.

OBJECTIVE

Develop a fast and accurate pupil detection subsystem using machine learning algorithms on an FPGA to support our client's vision of advanced assistive technologies.

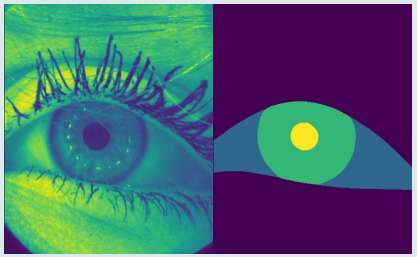
PROJECT OVERVIEW

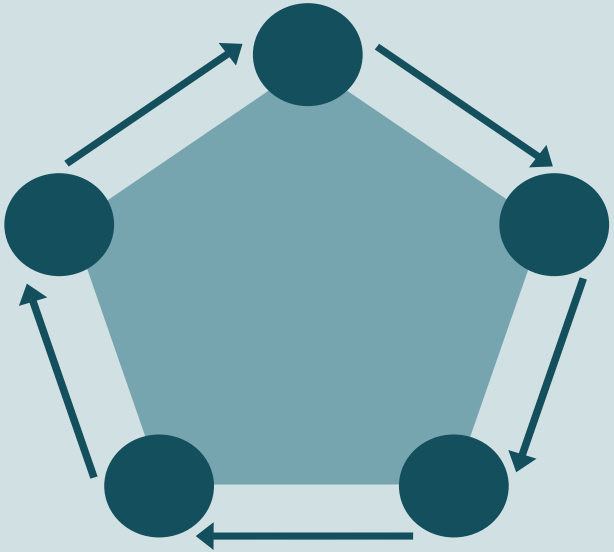
SYSTEMS

- Camera
- Eye location algorithm
- Semantic segmentation ML model
- Ultra96 v2 FPGA
- Display

REQUIREMENTS

- Real-time
- Accurate and performant to [NDA] fps
- Display model outputs and debugging information



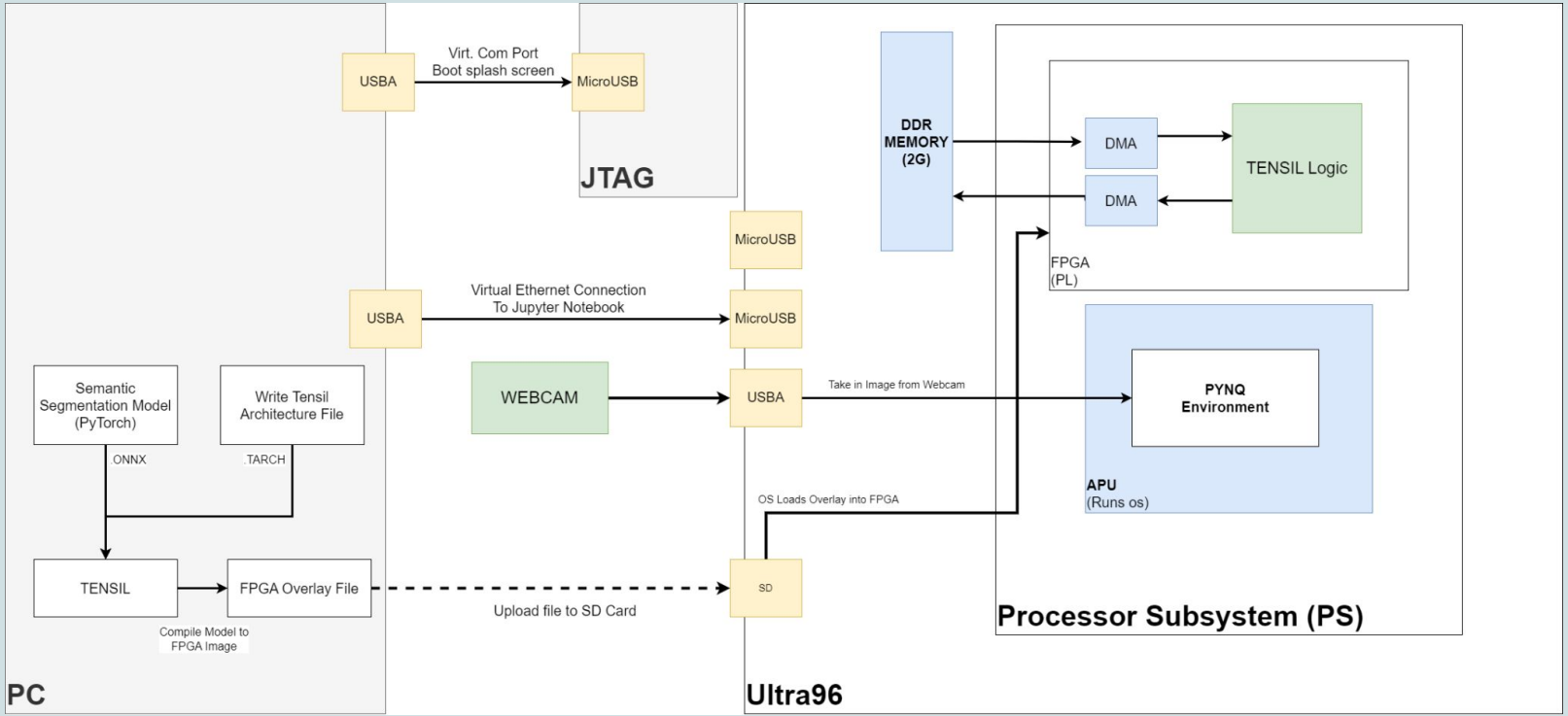


DESIGN & VISUALS

SYSTEM FLOW DIAGRAM

This represents the flow of data (an image/frame) will go through in our system.

SYSTEM BLOCK DIAGRAM



SYSTEM BLOCK DIAGRAM MAJOR COMPONENTS

ULTRA 96

- PYNQ OS
- I/O ports
- Tensil-AI compiles and runs Semantic Segmentation on Processor

THE MODEL

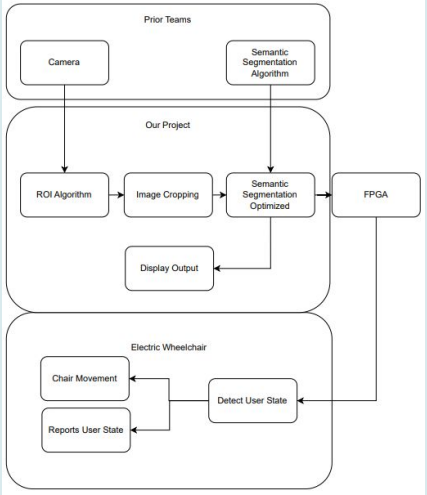
- Trained Model asynchronously passed to Tensil-AI through SD card
- Tensil-AI creates custom FPGA logic
- The Model runs on 4 CPU cores

I/O Devices

- Webcam connection via USB
- Ethernet connection via micro-USB
- JTAG connection boots OS

FUNCTIONALITY

REAL WORLD USE & RESPONSE



Wheelchair Users...

Turn their Head:

ROI Algorithm detects this and tells the system to do nothing

Move their Head:

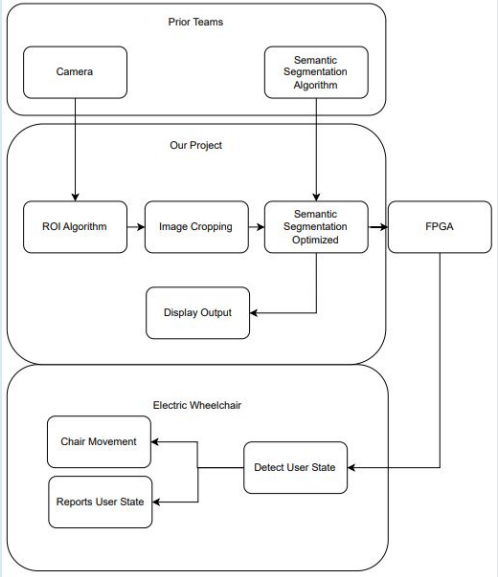
ROI Algorithm detects new eye location, the board reduces the image size and passes it to the Semantic Segmentation Algorithm to find the pupil

Experience Stress or Cognitive Overload:

System detects stress or overload and stops user control

FUNCTIONALITY

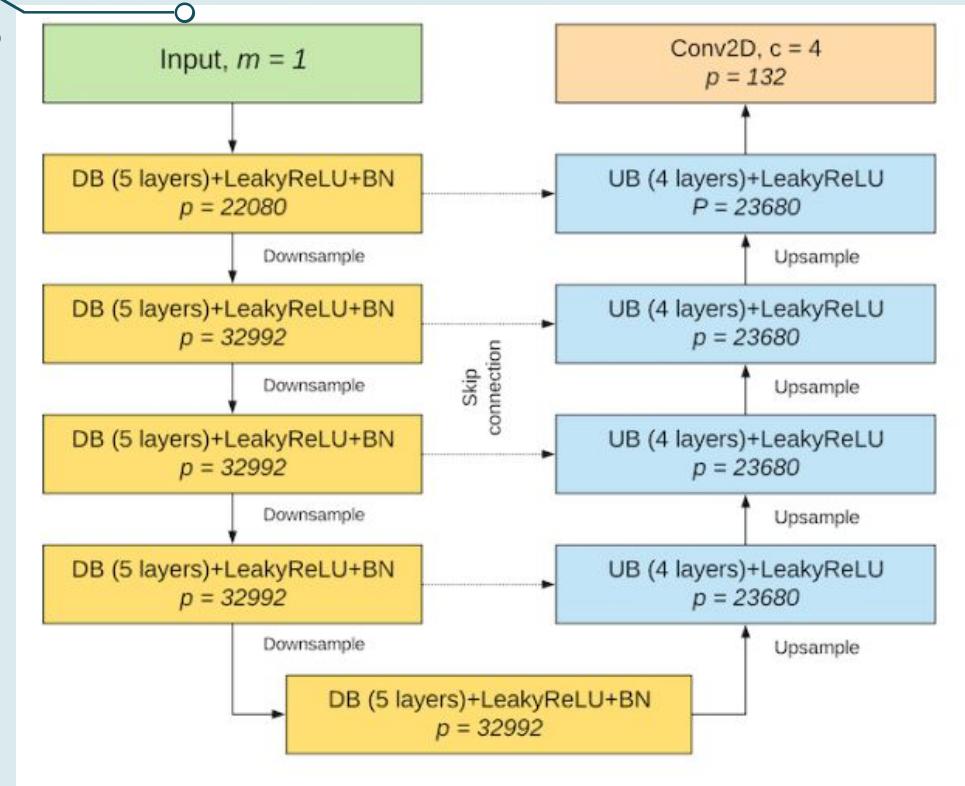
REAL WORLD USE & RESPONSE



Next Sr Design Team SdDec25...
Add Onto This Project:
Seamlessly integrate with new parts

Use Output to get Data for Processing:
Output reliable data with low latency

MACHINE LEARNING MODEL LAYERS



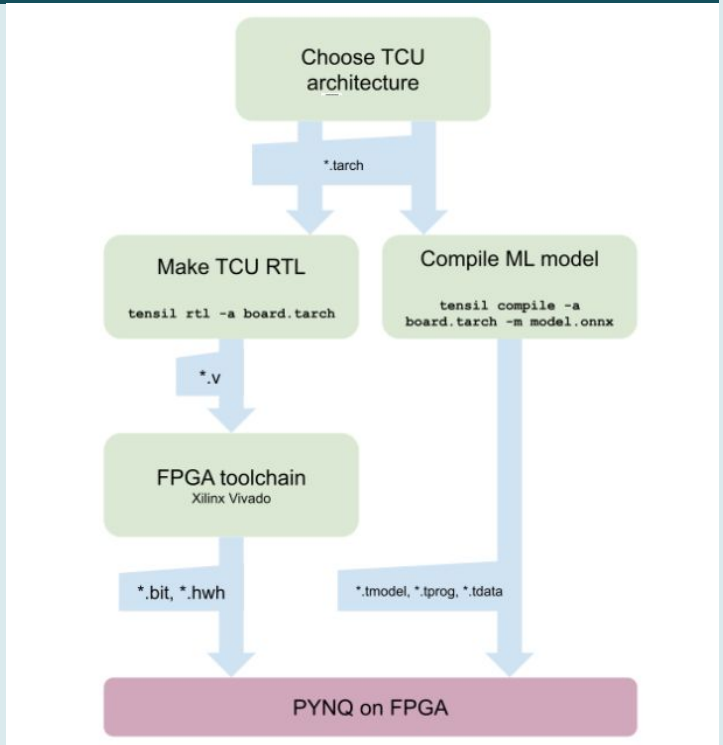
U-NET ARCHITECTURE

- Down Blocks (yellow)
  - Increase channels
  - Decrease resolution
  - Contextualize
- Up Blocks (blue)
  - Decrease channels
  - Increase Resolution
  - Utilize Skip connections for spatial and contextual information

TENSIL

Functionality

- Imagine you “zoom into” the “TENSIL” block on the bottom left corner of the System Diagram. This figure depicts the details.
- Tensil is a tool to:
  - Get the ML model able to be on FPGA Dev board
  - Intake .tarch and .onyx files
  - Outputs all needed files for model to communicate with Ultra96 (Dev board) hardware



AREAS OF CONCERN & DEVELOPMENT

ENVIRONMENT SETUP

- This is a known struggle for previous teams
- There are a lot of different parts coming together on the Ultra96 Dev board
- We expect problems here

Unknows

- With any project, there are unknowns.
- Unknowns in this project can be massive hurdles for our team to get over.

FPS CAPACITY

- Camera must get [NDA] FPS for our system to achieve it.
- Optimizations to ML model may improve but not reach

CONCLUSION

As a result

of our given problem and design diagrams

We will

Increase the performance of an existing FPGA system

To achieve

Throughput high enough to make real-time decisions.

Linking to Our Client's Problem

This increase in data throughput will supplement our client's system, unlocking the ability to predict when end-users might have health-affecting events such as a seizure.

Thanks!

Any questions?