Senior Design Project SDDEC25–01

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Problem & Approach

The Problem:
Wheelchair users with conditions like cerebral palsy or epilepsy face sudden medical episodes with limited ability to respond. Current solutions are reactive, not proactive.

Our Approach:
VisionAssist is a *prototype system* designed to explore real-time eye tracking on embedded hardware. It *aims to* enable future medical monitoring capabilities through:

- **Real-time eye tracking:** 60 FPS semantic segmentation on AMD Kria KV260
- **Privacy-first:** All processing on-device, no cloud
- **Embedded AI:** Optimized U-Net model for edge deployment

Research Scope:
This senior design project focuses on *engineering challenges* of real-time embedded AI, not clinical validation. Future work requires IRB-approved user studies.

System Architecture

End-to-End Processing Pipeline:

[System Architecture Diagram]

Camera Input → Preprocessing → U-Net (DPU) → Feature Extraction → Eye Tracking Output

8.3ms per frame | 60 FPS throughput | Pipelined DPU scheduling

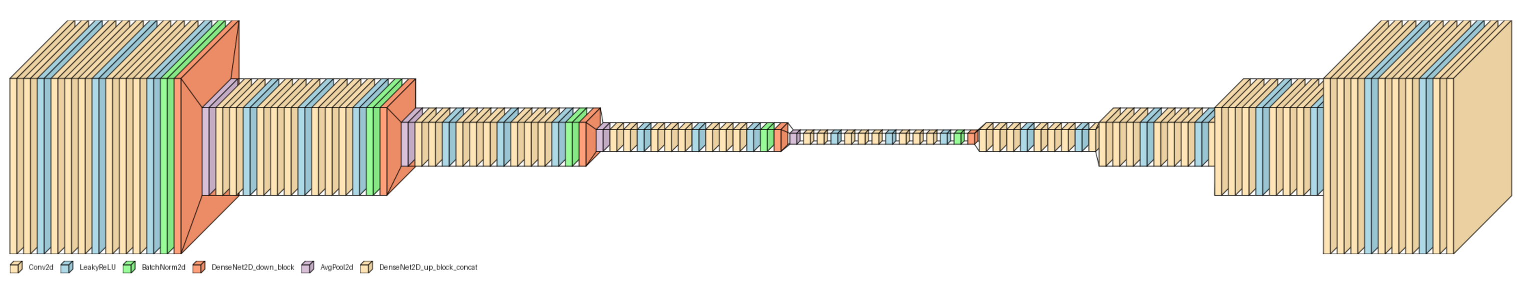
Processing Steps:

1. Image capture & preprocessing (gamma, CLAHE)
2. U-Net segmentation on DPU accelerator
3. Pupil detection & blink classification
4. Real-time feature tracking

Hardware & AI Model

Hardware Platform:
AMD Kria KV260 with Quad-core ARM Cortex-A53 + DPU accelerator

AI Model: U-Net Semantic Segmentation



Encoder-decoder with skip connections for fine-grained pupil detection. Model compressed and quantized for DPU acceleration.

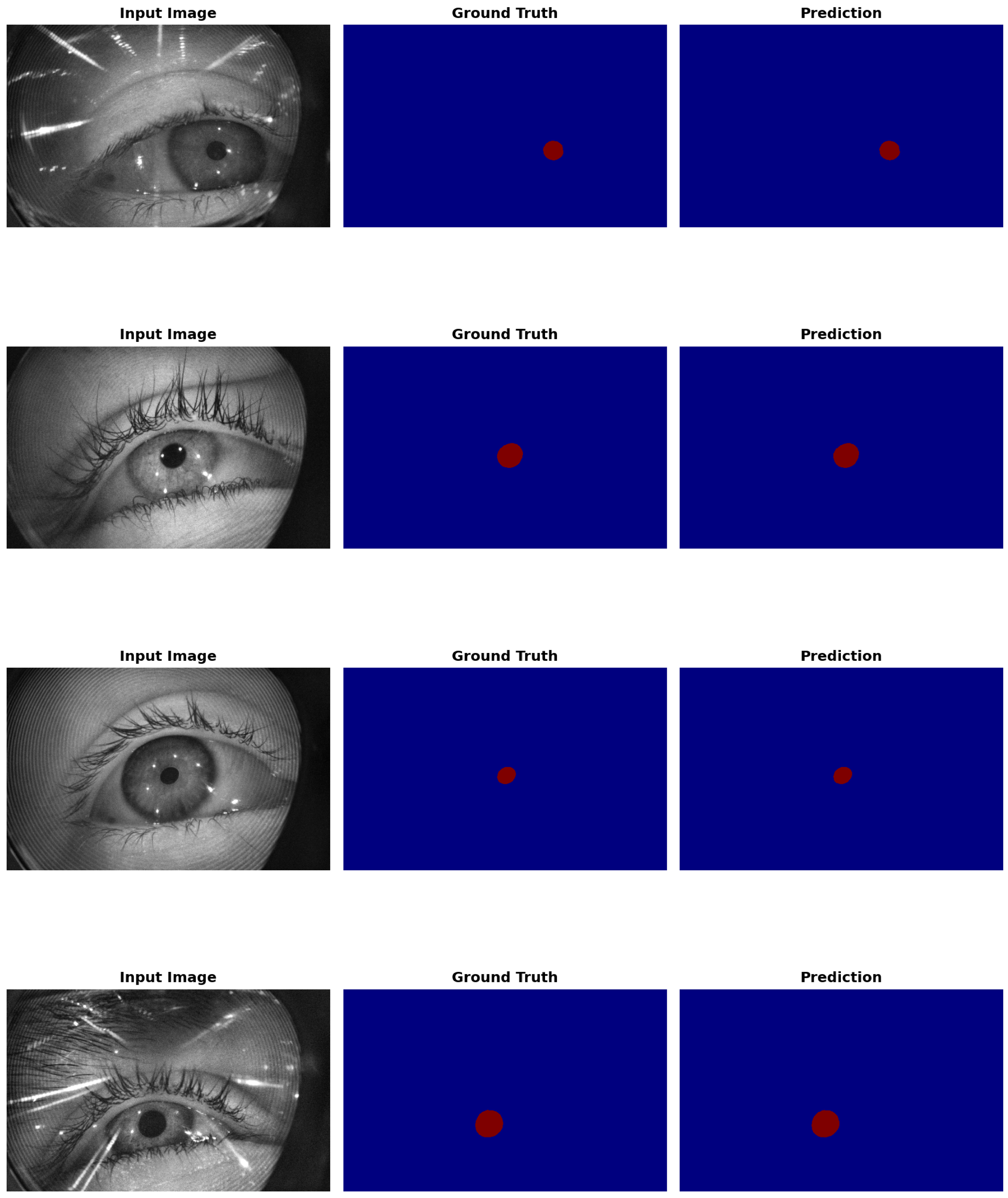
Key Innovation: 5× Throughput via Pipelined Scheduling
Efficient DPU resource sharing across multiple algorithms (segmentation, blink detection, tracking) with fair allocation—no starvation.

Target Performance:

- **Throughput:** 60 FPS (4 frames in <33.2ms)
- **Accuracy:** 98.8% IoU (target: 99.8%)
- **Privacy:** 100% on-device processing

Performance & Validation

Model Predictions:



Visual results showing accurate pupil center detection across varying eye positions and lighting conditions. The model consistently predicts pupil locations (red dots) matching ground truth annotations.

What This Means:

- **60 FPS:** Enables smooth, responsive eye movement tracking
- **98.8% IoU:** Accurate pupil detection across lighting conditions
- **24+ hours:** Reliable for all-day wheelchair use
- **On-device:** No network dependency, preserves privacy

System Validation:

- **Lighting robustness:** >98% accuracy in varied conditions
- **Scheduling fairness:** Zero missed deadlines under load
- **IEEE compliance:** Testing per IEEE 3129–2023 & IEEE 2802–2022

Impact & Next Steps

Key Achievement:
5× throughput improvement through pipelined DPU scheduling—proves intelligent resource allocation outperforms hardware upgrades.

Safety & Ethics:

- **Fail-safe design:** System defaults to safe state on failure
- **User autonomy:** Monitoring does not override user control
- **Privacy-first:** Zero external data transmission
- **Accessibility:** Designed for diverse user needs

Next Steps:

- **IRB-approved user studies** with wheelchair users
- **Medical device certification** pathway
- **Integration with caregiver alert systems**
- **Refinement:** Target 99.8% IoU accuracy

Impact:
This project demonstrates that *edge AI can enable privacy-preserving assistive technologies* without requiring cloud infrastructure or expensive hardware—making advanced monitoring more accessible to individuals with disabilities.