EyeCoD: Eye Tracking System Acceleration via FlatCam-based Algorithm & Accelerator Co-Design

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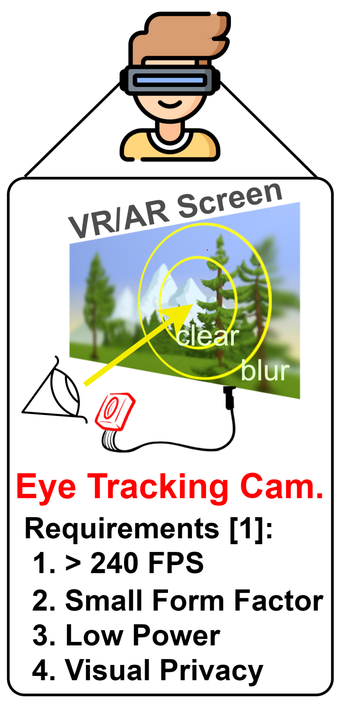
BCAKGROUND AND MOTIVATION

- Eye tracking is an essential human-machine interface modality in AR/VR [1]
  - Challenges for eye tracking [1]
    - >240 FPS
    - Small form factor
    - Power consumption in mW
    - Visual privacy
  - Existing works [2,3]
    - ☹ One order of magnitude slower
    - ☹ Large form factor and low visual privacy due to the adopted lens-based cameras

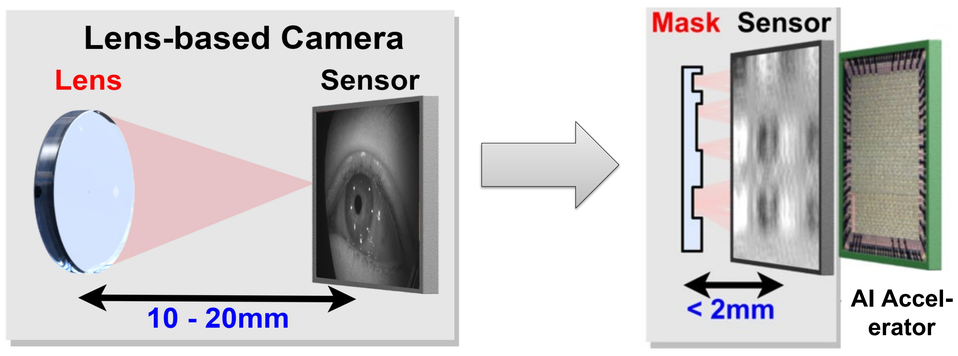


[1] C. Liu, et. al., IDEM'21
[2] Y. Feng, et. al., IEEE VR'22
[3] K Bong, et. al., VLSI'15

UNEXPLORED OPPORTUNITIES

- Can we build a lensless eye tracking system?
  - A Lensless camera, e.g., FlatCam [4]
    - ☺ Small form factor, i.e., 5× ~ 10× thinner
  - A dedicated AI accelerator featuring algorithm and accelerator co-design
    - ☺ >240 FPS
    - ☺ mW power consumption

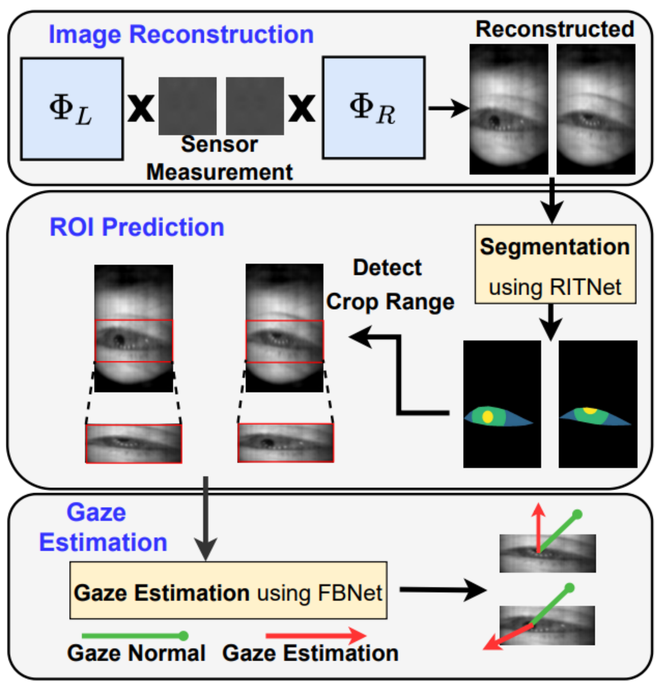
[4] S. Asif, et. al., IEEE TCI'22



EYECOD ALGORITHM

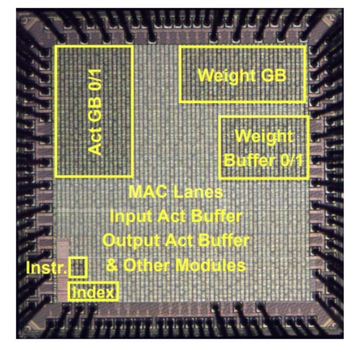
- Predict-then-focus pipeline
  - Stage 1
    - Image Reconstruction
    - Privacy
  - Stage 2
    - ROI Prediction
    - Once per 50 frames
  - Stage 3
    - Gaze Estimation
    - Every frame

ROI: Region of Interests



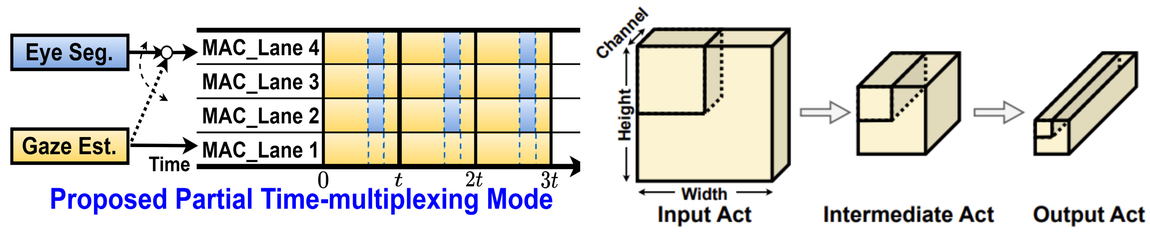
EYECOD ACCELERATOR

- EyeCoD accelerator features:
  - Partial time-multiplexing mode
    - Workload orchestration
  - Intra-channel reuse
    - Depth-wise convolutional layers
  - Inter-layer activation partition
    - Save 36% activation memory
    - Save 50% ~ 60% activation bandwidth



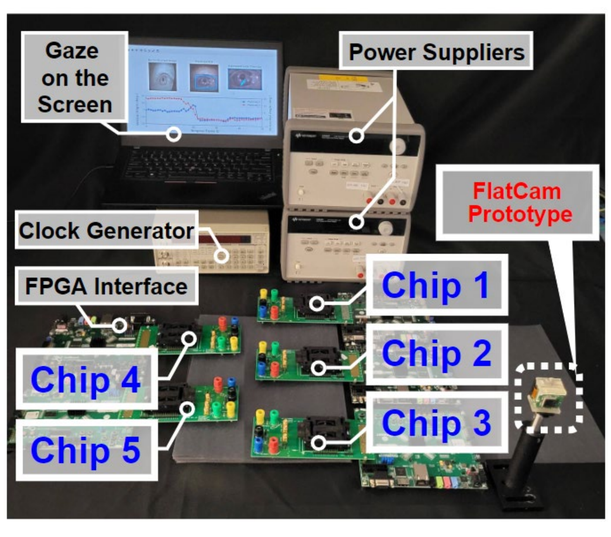
Chip Die Photo [5]

[5] Z. Yang, et. al., VLSI'22



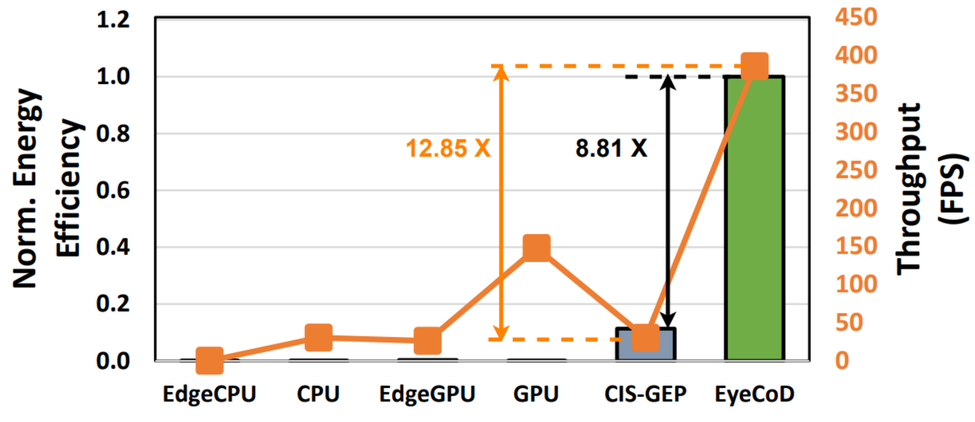
EVALUATION RESULTS

- Evaluation setups
  - Datasets
    - OpenEDS'19 & OpenEDS'20
  - Metrics
    - Gaze estimation accuracy
    - Throughput
    - Energy efficiency
  - Chip configuration
    - Silicon prototype (28nm)



EyeCoD System Overview

Act GB0/GB1	Weight Buffer0/1	Weight GB	Index SRAM	Instr. SRAM
512KB * 2	64KB * 2	512KB	20KB	4KB
MAC Lanes	**MACs/MAC Lane**	**Area**	**Clock frequency**	**Power**
128	8	8 mm^2	370MHz	335mW



- EyeCoD over SOTA eye tracking accelerators
  - 12.8× throughput improvement and 8.1× higher energy efficiency over CIS-GEP, respectively.
- EyeCoD over CPU/GPU platforms
  - 2966×, 12.7×, 14.8×, and 2.61× throughput improvements over EdgeCPU, CPU, EdgeGPU, and GPU

Theme 2, Task 3131.006

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