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Qualcomm

Object Detection @ 1mW

Enabling *Always-On Computer Vision* at the Edge

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Outline

1. Background
2. Use Cases
3. Our Approach
4. Product
5. Future

Goal

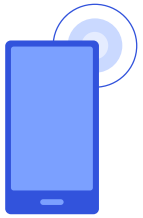
Ultra-low power always-on computer vision

- Ultra-low power for always-on: **System power** less than 1mA on standard lithium cell
- Low latency with typical frame rate of 1-30 fps
- Computer Vision: Insight and information from sensor

Historically

- Image sensor takes 10mW to Ws
- Image processing takes 100mW to Ws

Vision will enhance many use cases across numerous verticals

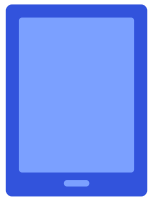


Smartphone

- Face-based auto-wake and auto-sleep
- Always-on trigger for other use cases
- Always-on trigger for iris authentication (removes multiple steps and user initiation)

Smart watch

- Face-based auto-wake and auto-sleep
- Always-on gestures

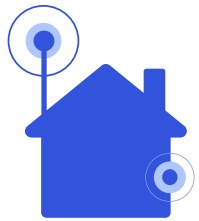


Tablets

- Simple gaze tracking for advertising attribution
- Improved landscape/portrait screen orientation

Virtual reality

- Low power gaze tracking (foveated rendering)
- Low power visual odometry for 6 DoF



‘Intelligent’ occupancy trigger

- Distinguish humans from other objects
- Add data layer to trigger: How many? Where?
- Trigger on particular events or objects

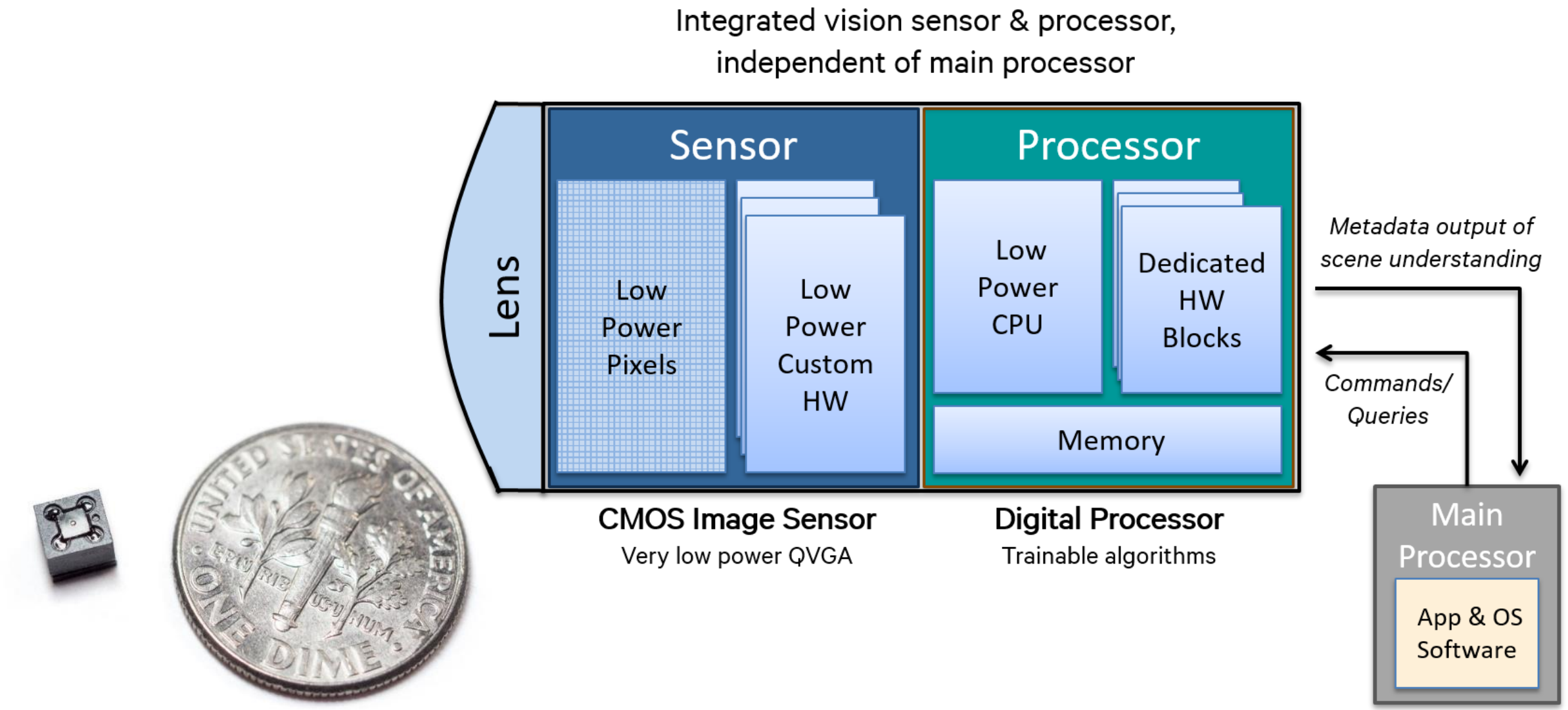
‘Intelligent’ interactivity trigger

- Face detection as a trigger for interactivity
- Smart appliance can react when a user approaches to engage it

Standalone intelligent data sensor

- Heat maps of how a space is occupied
- Privacy advantages – data only, no images captured

Our always-on vision research and innovation



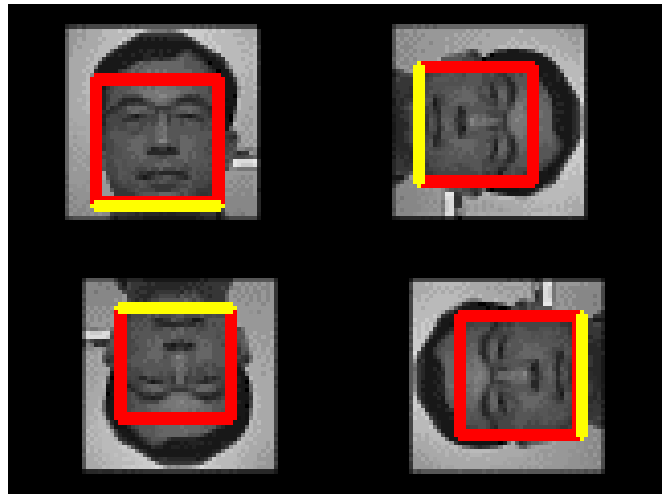
Supports various human detection cases

Half body

Full body

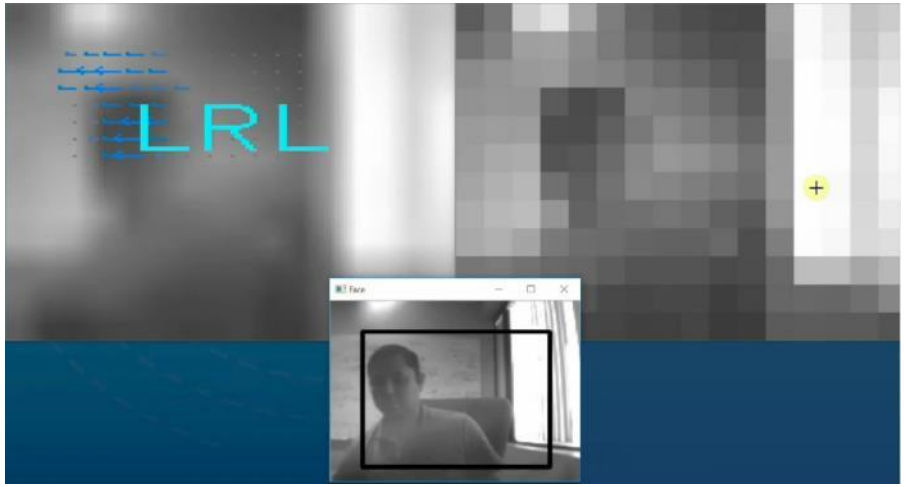
3/4 body

Change Detection

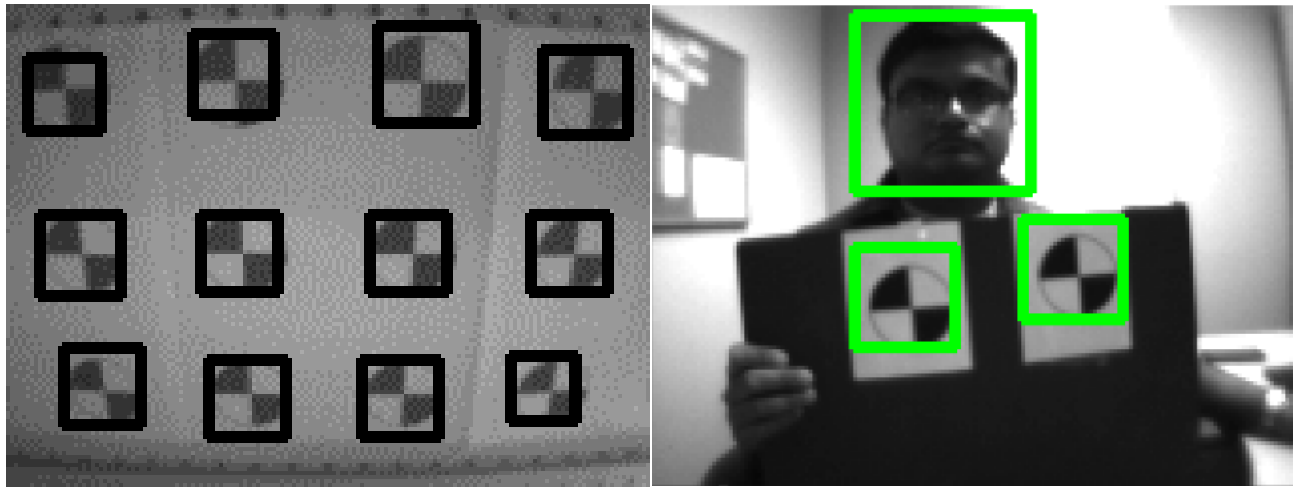


Multiple orientation

Support visual detection across a broad set of use cases



Simple Gesture (e.g. Left-Right-Left)

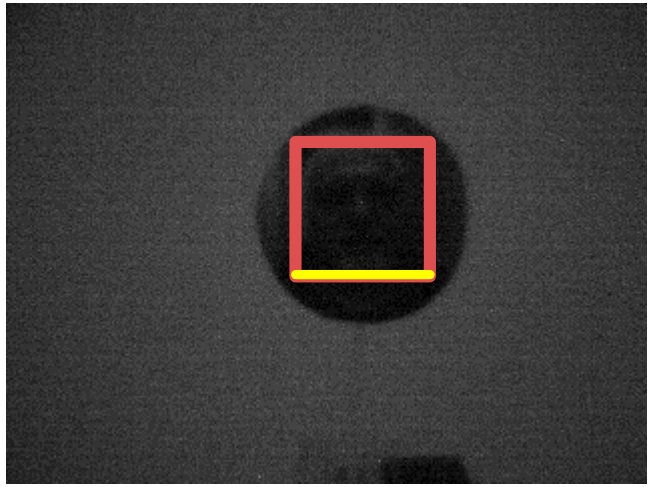


2-D Marker Or Logo, 3D Rigid Body (Toys)

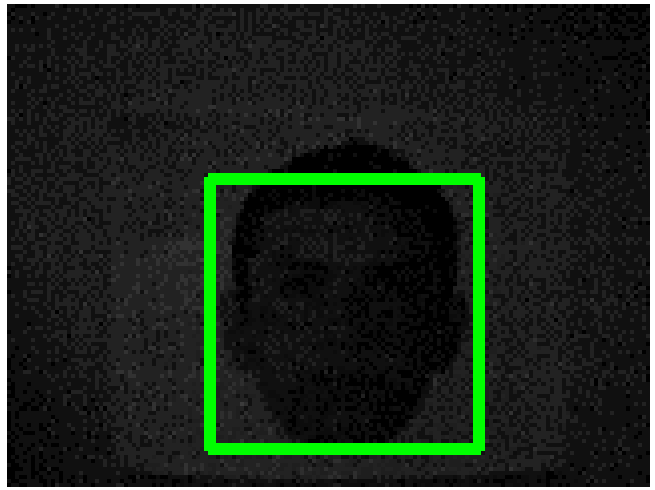
Analytic use case:
(1) Shelf Status
(2) Customer Engagement

Successful detection in challenging light scenarios

- Detection scenario at distance and low light is challenging
- Model and algorithm must be resilient to these scenarios
- Sensor also sensitive to 850 nm IR



Face at low light (0.1 lux)



Face detection low light indoor at 768us

Full Body 20 ft 3 lux

Full Body in direct sunlight

What needs to be done for Always-on Computer Vision

Our Approach	Traditional Approach
Image itself is secondary to information	Image quality paramount
Monochrome works in most cases. ≤ 8-bit sufficient	Color & wide bit-depth preferred
Focus can be good enough in most cases	Focus, autofocus, Bokeh important
Adequate pixel count for applicable distance	Higher pixel count
System power optimized including sensor	Sensor & algorithm/model often split
Images shot in challenging lighting	Camera & subject posed for best image
Inference is heavily weighted	Balance between training & inference time
Algorithms redesigned with memory & power in mind	Built upon available technologies
Metrics may be event-based	Typical metric is frame-based

Count your pennies, every savings in power adds up

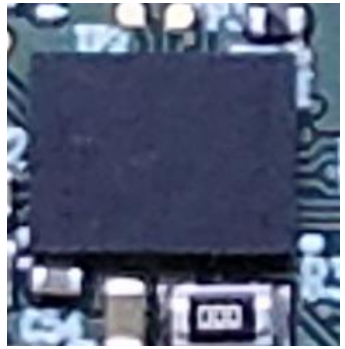
Our System Approach for Always-on Computer Vision

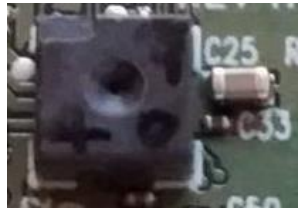
- Favor algorithms with adaptive compute
  - Only perform computer vision when image/area has changed
  - Run light weight algorithms first
  - Favor algorithms/models with content adaptive capabilities
  - Stop when there is enough information:
    many application only needs to know the presence of 1 object vs. all objects
- Simplify
  - Often easier to run models at different scales than resizing images
  - Optimize brightness to favor detection
- Optimize the entire system end-to-end
  - Use low power sensor
  - Optimize IO
  - Move algorithms to HW when possible
  - Keep memory close to compute engine

Product: Qualcomm® QCC112 Chipset

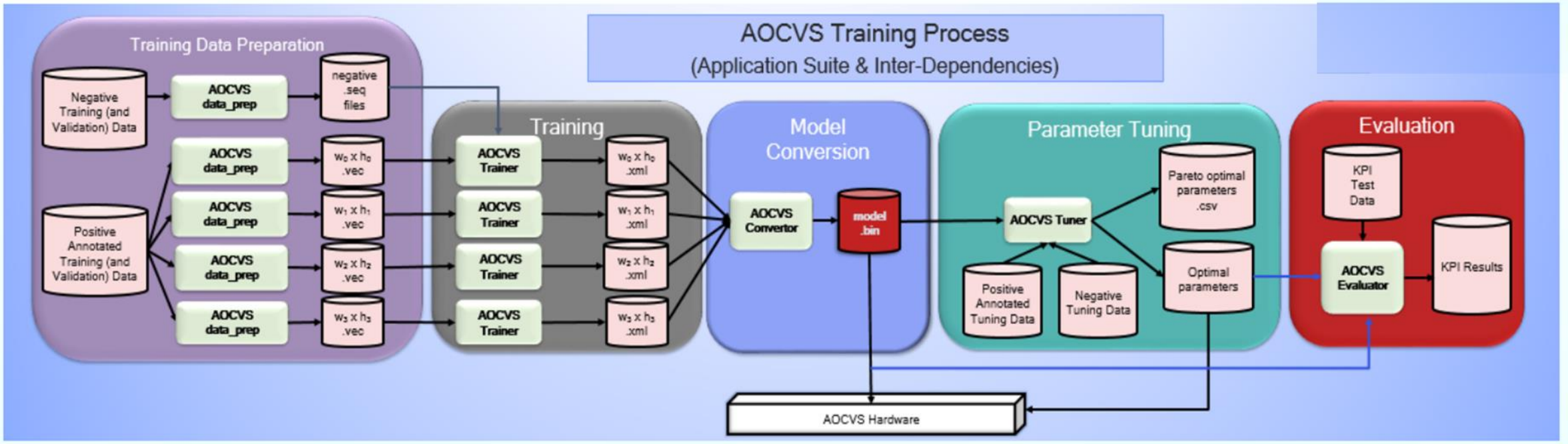
Available commercial product

- Supports many uses at ~1mW, including chip, sensor, and power management
- Features:
  - Ultra-low-power MCU
  - Streaming Array Processor (SuP)
    - Programmable
    - Can be power collapsed
    - Data bursted with DMA into TCM
  - Embedded PMU
  - Vision Accelerator
  - Custom memory
    - 2X lower dynamic power and 3X lower retention power vs. standard memory cell





Training Tool: AOCVS (Always-on Computer Vision System) Portal



AOCVS Data Prepare

DataPrep

This tool helps in augmenting the training dataset for better traning and model accuracy

AOCVS Trainer

Trainer

The tool generates a model by training with the input datasets

AOCVS Bin Converter

Converter

Tool to convert the XML model files to Binary format

AOCVS Tuner

Tuner

Tool to tune the parameters for a given model for better accuracy

AOCVS Evaluator

Evaluator

The tool helps in evaluating an input dataset against a model

Visualization of Results

Show Recent Jobs 25

Select all | Deselect all | Delete Jobs | Stop Jobs

Search:

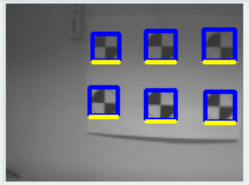
RunID.	Date	Status	Algo	Model(s)	Input Type	Config	Results	Edit
14	2019-09-16 12:50:29.057	Completed	OD	circle_10_13_16_model.bin	File with list of images	Config	Results	Edit
13	2019-09-16 12:49:16.328	Completed	OD	circle_10_13_16_model.bin	File with list of images	Config	Results	Edit
12	2019-09-05 10:29:54.975	Completed	OD	fullbody_model.bin	List of images	Config	Results	Edit
11	2019-09-05 10:29:21.068	Completed	OD	fullbody_model.bin	List of images	Config	Results	Edit
10	2019-09-05 10:28:41.532	Completed	OD	face_model.bin	List of images	Config	Results	Edit
9	2019-09-05 10:27:50.489	Completed	OD	face_model.bin	List of images	Config	Results	Edit
8	2019-09-05 10:20:05.618	Completed	OD	face_model.bin	Video file	Config	Results	Edit
7	2019-09-05 08:55:10.470	Completed	OD	circle_pattern_10_13_16.bin	File with list of images	Config	Results	Edit
6	2019-09-05 08:54:35.959	Completed	OD	circle_pattern_10_13_16.bin	File with list of images	Config	Results	Edit
5	2019-09-05 08:53:05.583	Stopped	OD	circle_pattern_10_13_16.bin	File with list of images	Config	Results	Edit

Showing 1 to 10 of 14 entries 1 row selected

Previous 1 2 Next

Run ID :14 (Running) Evaluator Log Result CSV Output tarball

Show 10 entries Search:

No.	Processed Frame	Details
1		image105_out_14_0.bmp 6 detections LBP Count: 18089 Detect #1 X0 : 58 Y0 : 20 W0 : 19 H0 : 19 Orientation : 0 Score : 11 Detect #2 X1 : 94 Y1 : 18 W1 : 21 H1 : 21 Orientation : 0 Score : 6 Detect #3 X2 : 133 Y2 : 17 W2 : 22 H2 : 22 Orientation : 0 Score : 3 Detect #4 X3 : 56 Y3 : 56 W3 : 20 H3 : 20 Orientation : 0 Score : 9 Detect #5 X4 : 94 Y4 : 58 W4 : 21 H4 : 21 Orientation : 0 Score : 10 Detect #6 X5 : 134 Y5 : 59 W5 : 21 H5 : 21 Orientation : 0 Score : 8
2		image11_out_14_1.bmp

Showing 1 to 10 of 51 entries

Previous 1 2 3 4 5 6 Next

Visualization of Key Performance Metric and Compute Tradeoffs

Show Recent Jobs 25

Select all | Deselect all | Delete Records | Stop Jobs

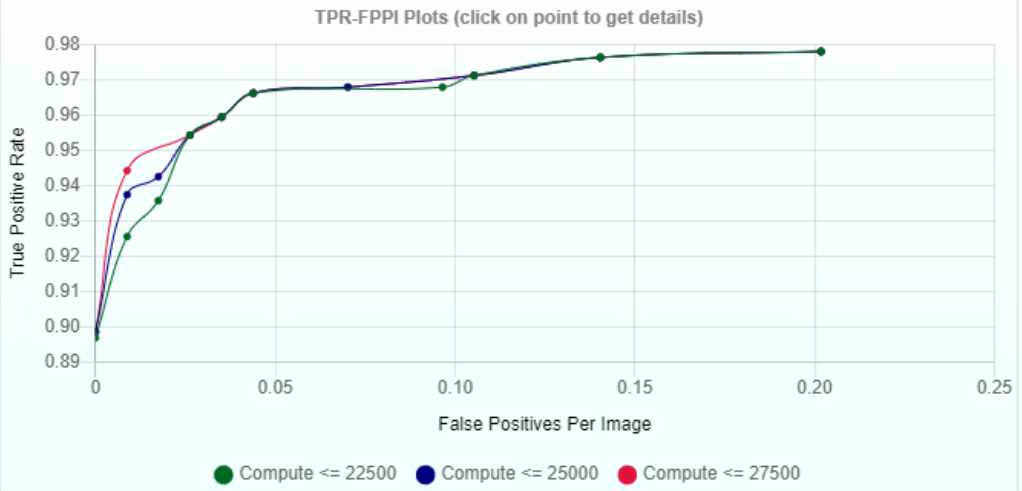
Search:

RunID.	Date	Status	Model	GT File	MaxFPPI	Config		
6	2019-09-16 12:28:12.552	Completed	circle_10_13_16_model.bin	tuning_data.txt	0.05	Config	Results	Edit
5	2019-09-05 10:23:51.799	Completed	circle_pattern_10_13_16.bin	tuning_data.txt	0.05	Config	Results	Edit
4	2019-09-05 06:50:12.091	Completed	circle_pattern_10_13_16.bin	tuning_data.txt	0.05	Config	Results	Edit
3	2019-09-05 06:49:21.500	Completed	circle_pattern_10_13_16.bin	tuning_data.txt	0.05	Config	Results	Edit
2	2019-09-05 06:46:30.806	Stopped	circle_pattern_10_13_16.bin	tuning_data.txt	0.01	Config	Results	Edit
1	2019-09-05 06:33:44.624	Completed	circle_16_20_25.bin	tuning_data.txt	0.01	Config	Results	Edit

Showing 1 to 6 of 6 entries 1 row selected

Previous 1 Next

Run ID :5 (Completed) Tuner Log GT File Output Pareto CSV Output tarball



Tuned Parameter	Optimized Value
Row Strides	3,3,1,1
Column Strides	4,3,2,2
Merge Rect Threshold	3
Dist Rect Threshold	5
Min Object Size	1
Max Object Size	160
Num Stages	8

Tuner Result	Computed Values
True Positive Rate	0.9662
False Positive Per Image	0.0439
Precision	0.9913
F1 Score	0.9786
Compute Complexity	22044
Tuner Run Time	62 seconds.

Evaluate Model Object Detect

Resources

- https://www.qualcomm.com/invention/artificial-intelligence
- Contact us at CVM@qti.qualcomm.com for developing new use cases and hardware evaluation for your products

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