Ultra-low Power Always-On Computer Vision

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Qualcomm Artificial Intelligence Research is an initiative of Qualcomm Technologies, Inc.

Outline

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

Goal

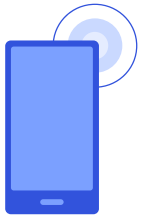
Ultra-low power always-on computer vision

- 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

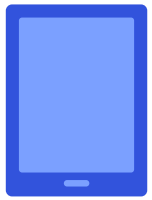


Smartphone

- 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

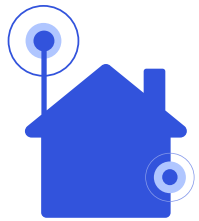


Tablets

- 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

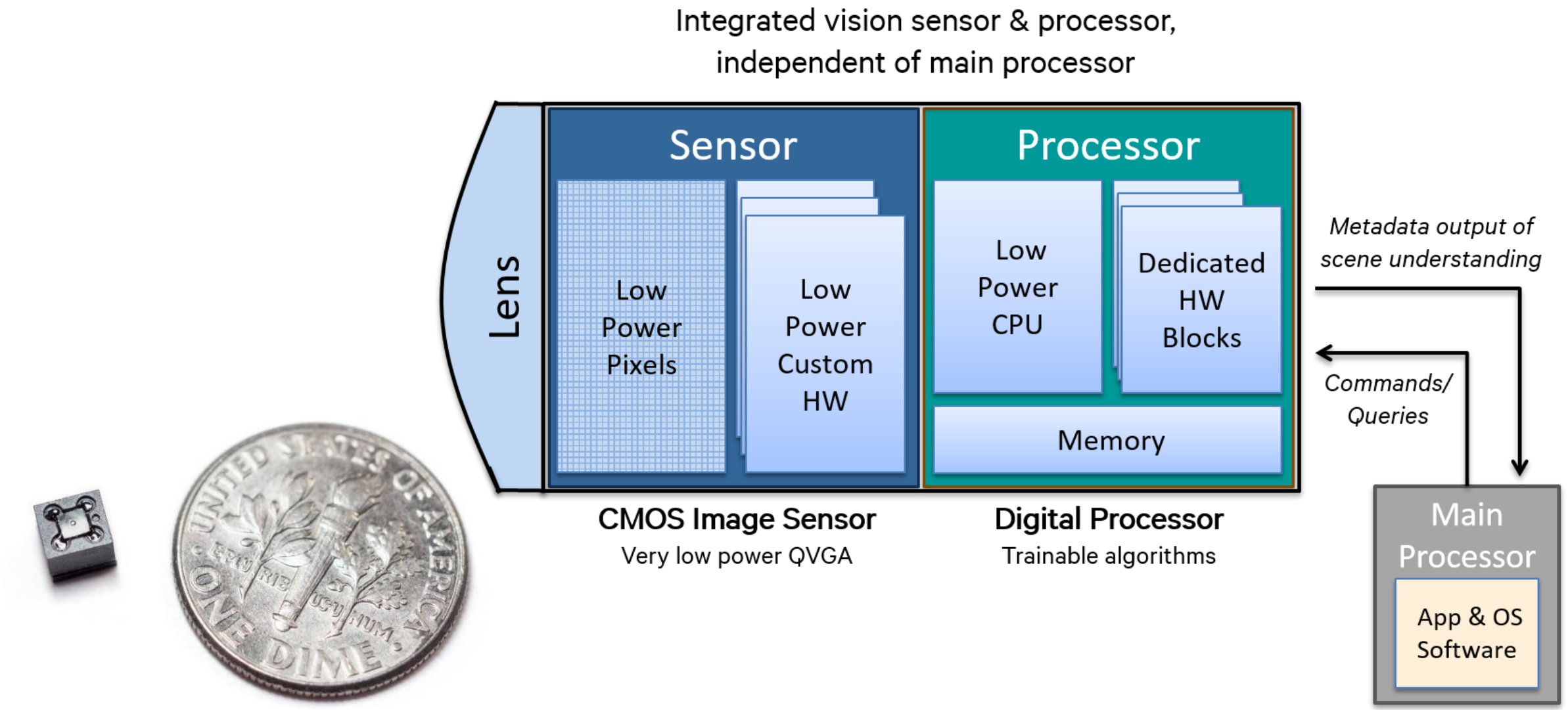
‘Intelligent’ interactivity trigger

- 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



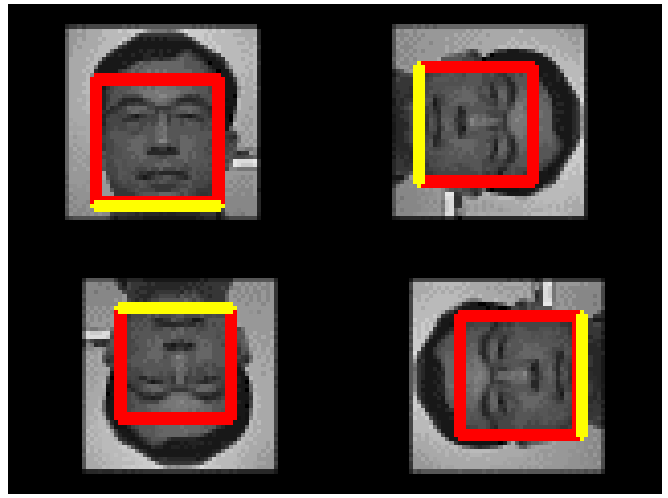
Supports various human detection cases

Half body

Full body

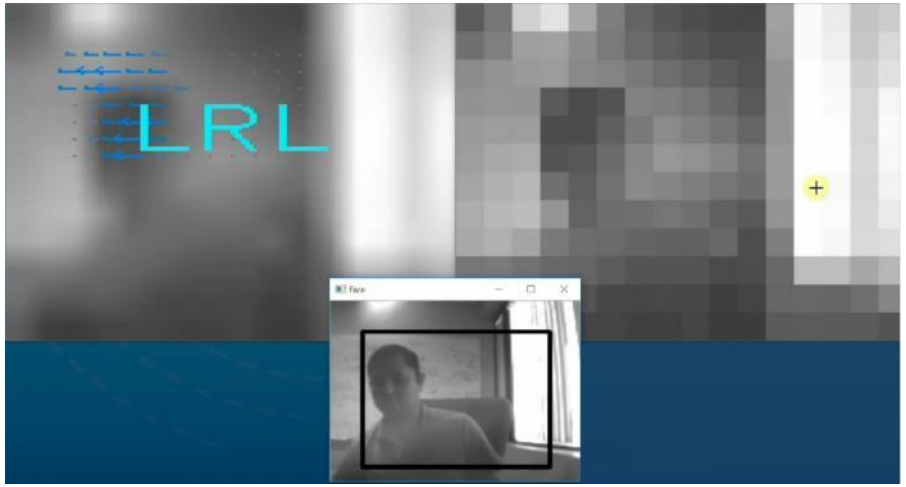
3/4 body

Change Detection

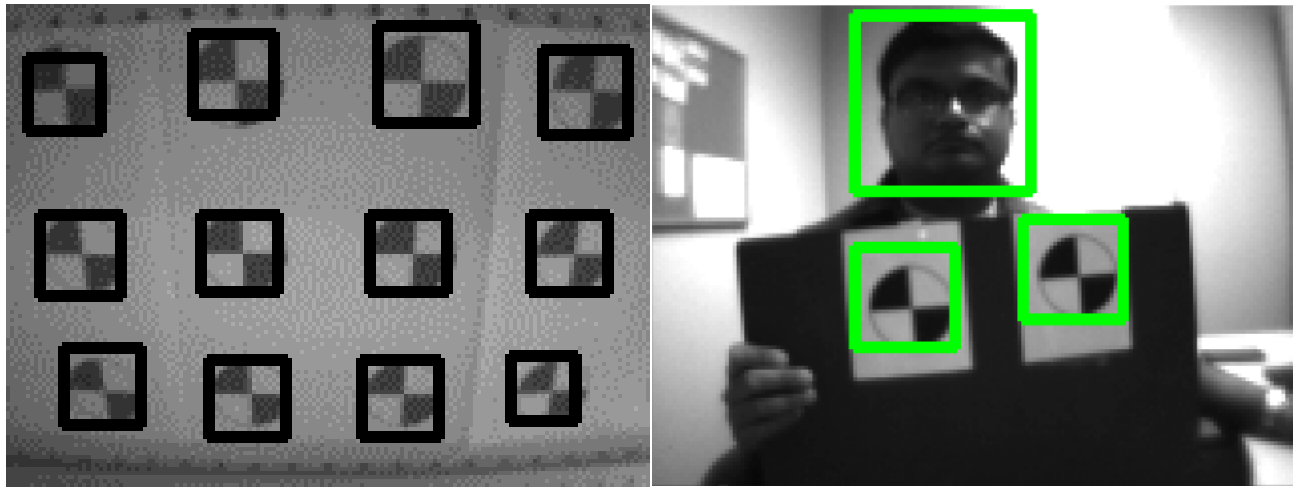


Multiple orientation

Support visual detection across a broad set of use cases



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

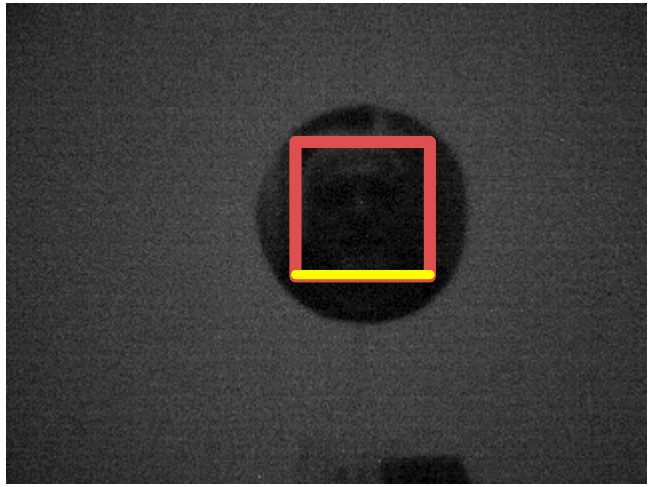


2-D Marker Or Logo, 3D Rigid Body (Toys)

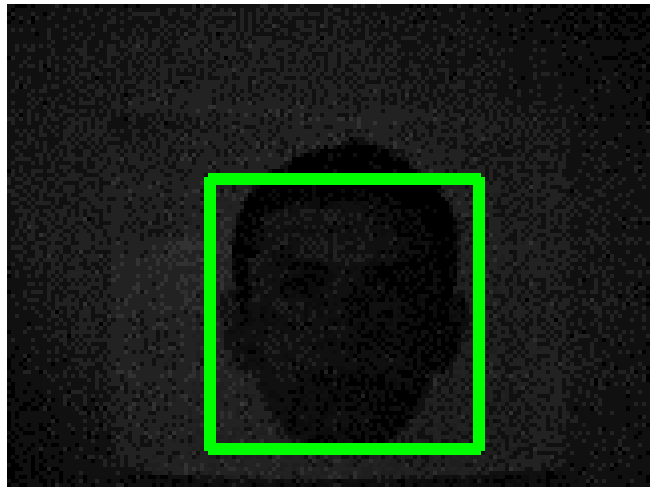
Analytic use case:
(1) Shelf Status
(2) Customer Engagement

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

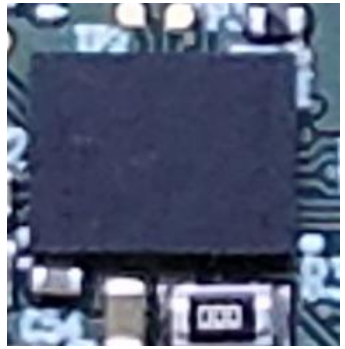
Our System Approach for Always-on Computer Vision

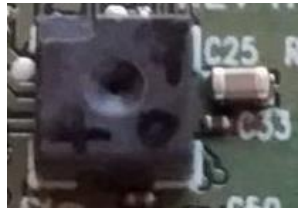
- Favor algorithms with adaptive compute
  - Only perform computer vision when image/area has changed
  - Run light weight algorithms first
  - Favor algorithms/models with content adaptive capabilities
  - Stop when there is enough information:
    many application only needs to know the presence of 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

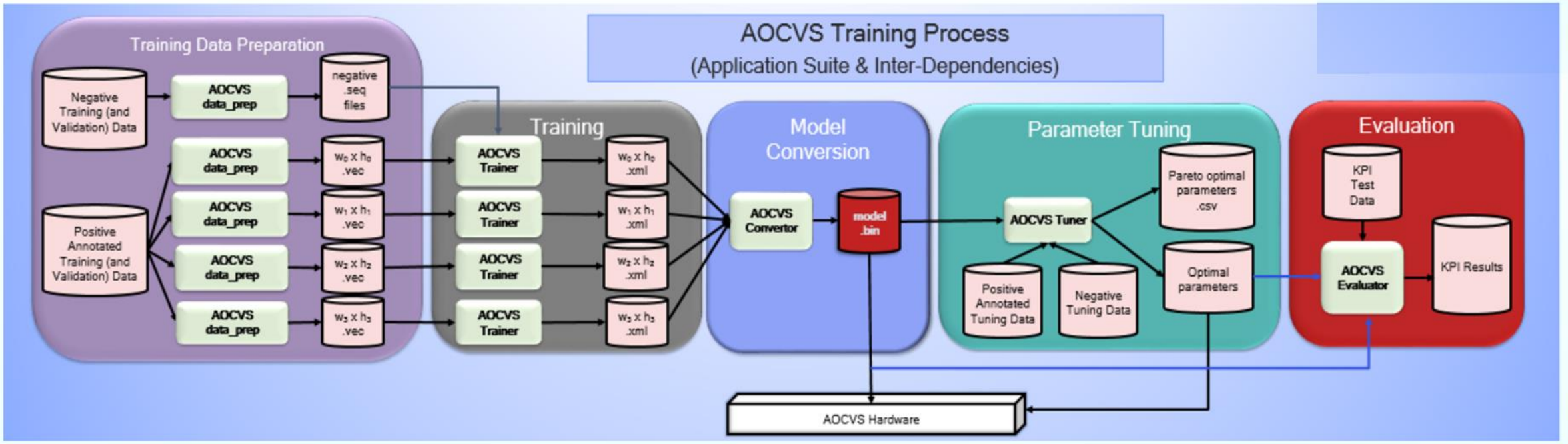
Available commercial product

- 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:

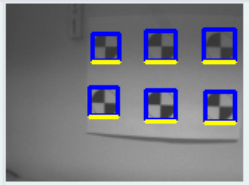
RunID.	Date	Status	Algo	Model(s)	Input Type	Config	Results	Edit
14	2019-09-16 12:50:29.057	Completed	OD	circle_10_13_16_model.bin	File with list of images	Config	Results	Edit
13	2019-09-16 12:49:16.328	Completed	OD	circle_10_13_16_model.bin	File with list of images	Config	Results	Edit
12	2019-09-05 10:29:54.975	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

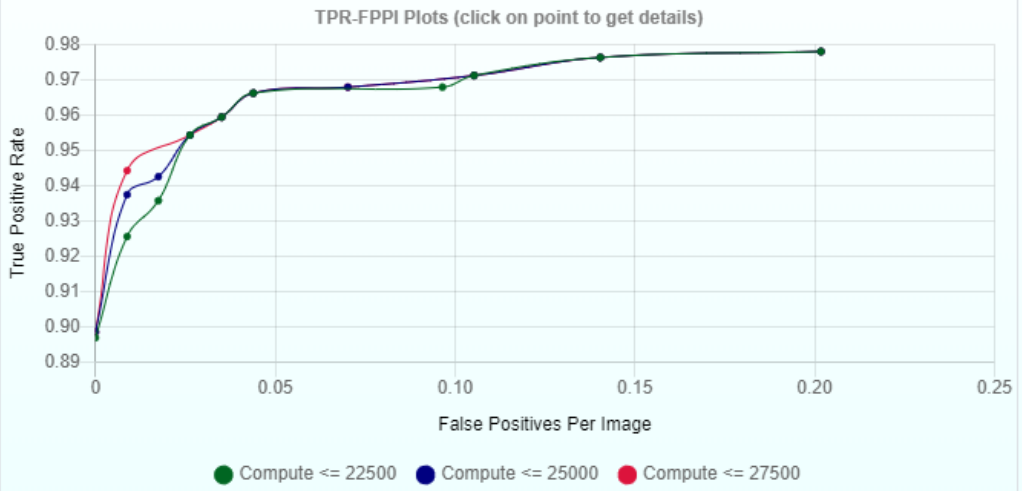
Search:

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

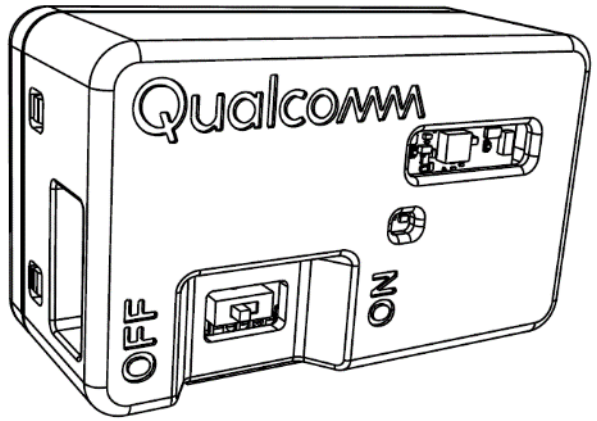
Run ID :5 (Completed) Tuner Log GT File Output Pareto CSV Output tarball



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



>100 FPS Face Detection

Come by after talk and see the demo!!

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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