Joint ICTP-IAEA School on FPGA-based SoC and its application to nuclear and scientific Instrumentation Workshop

Computer Vision with SoC

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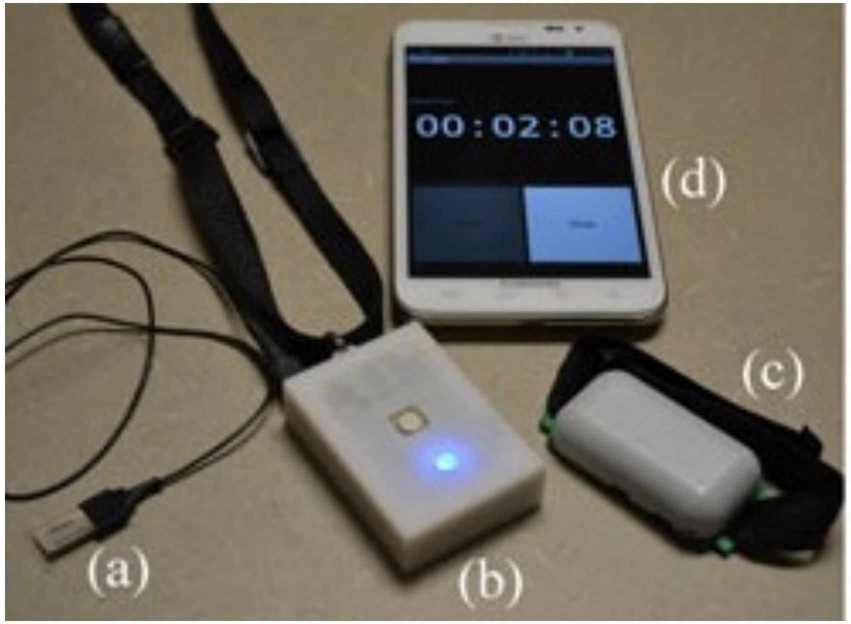
Outline

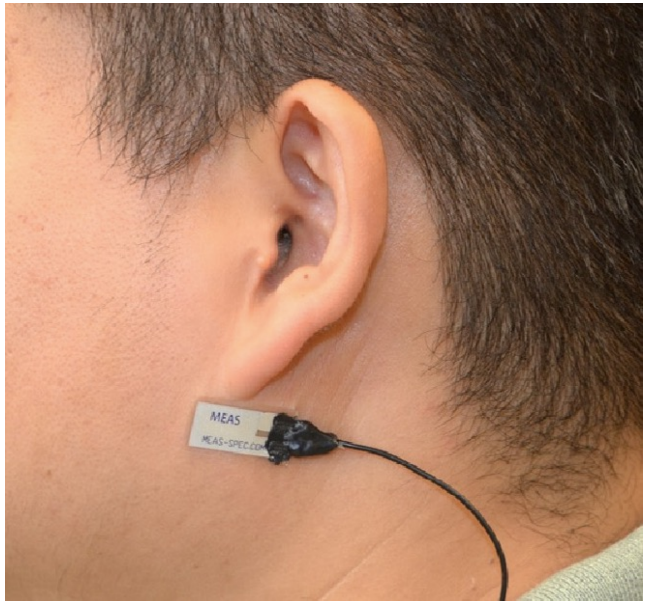
- Image acquisition with FPGA/MCU
- Image recognition on mobile phone
- Vision processing on FPGA/SoC with Matlab
- Computer vision for Advance Driver Assistance System (ADAS)

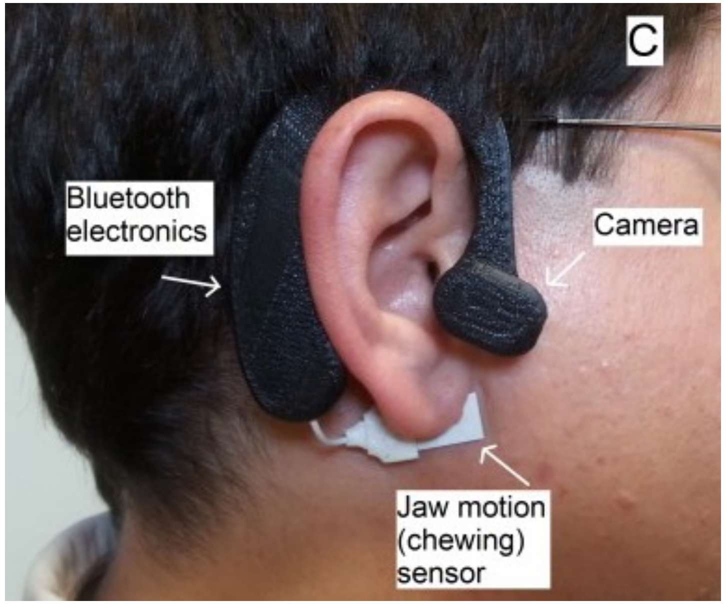
Image acquisition using FPGA

- Automatic Ingestion Monitoring System
  - Chewing Detection
  - Food image acquisition
  - Calorie consumption estimation
- Chewing Detection
  - Piezoresistive sensor (jaw movement sensor)
  - Chewing signal processing
- Food image acquisition
  - Capture and store image on SD Card for post-analysis
- Calorie consumption estimation
  - Images sent to nutritionist for calorie validation

Automatic Ingestion Monitoring – University of Alabama







Source: Edward Sazonov, University of Alabama

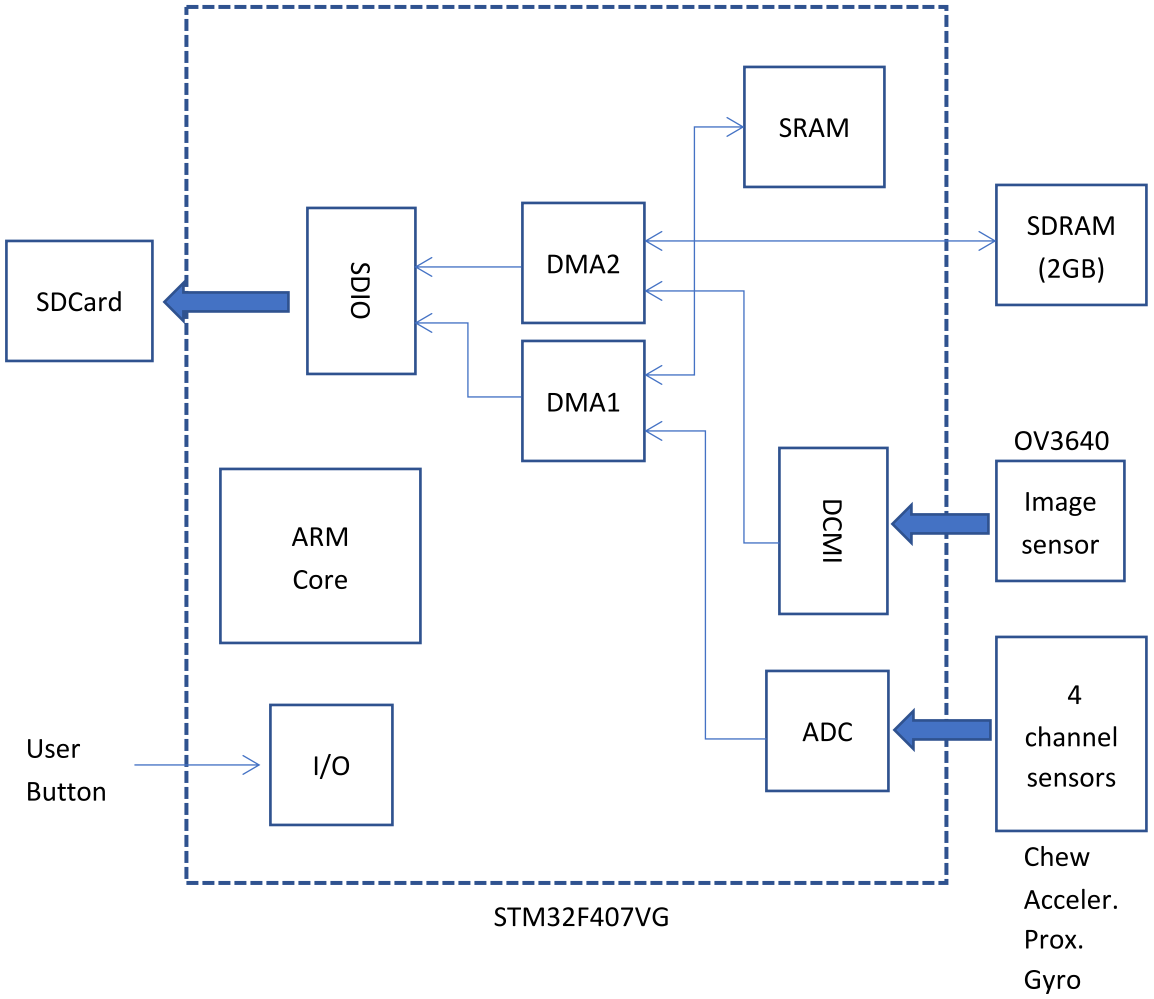
Food Image Acquisition

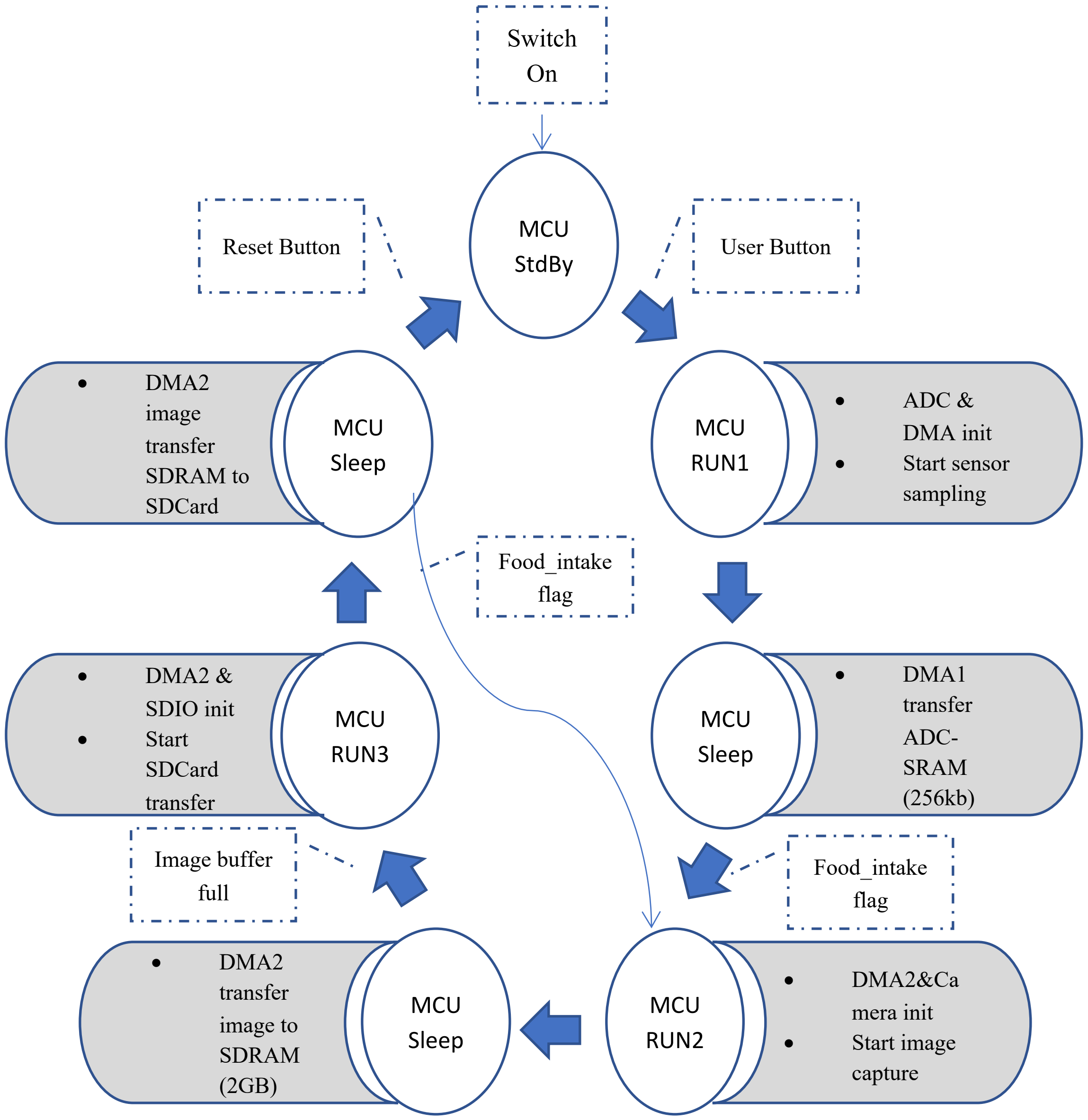
- Image sensor to be attached in a wearable device
- System to continuously capture image at some interval (buffering images)
- Images to be stored in the SD Card once food intake is detected
- System should be small and low power

Platform selection based on benchmarking

- Comparison was made with several different platforms
  - High performance ARM MCU with image acquisition capability
  - Low performance ARM MCU
  - ARM + FPGA
- Low power mode (Sleep, Standby etc) being used for power optimization
  - ARM MCU has a variety of low power operations
- Each peripherals being measured for power consumption

MCU State Diagram





Current consumption benchmarking

STM32F407 (Cortex M4)

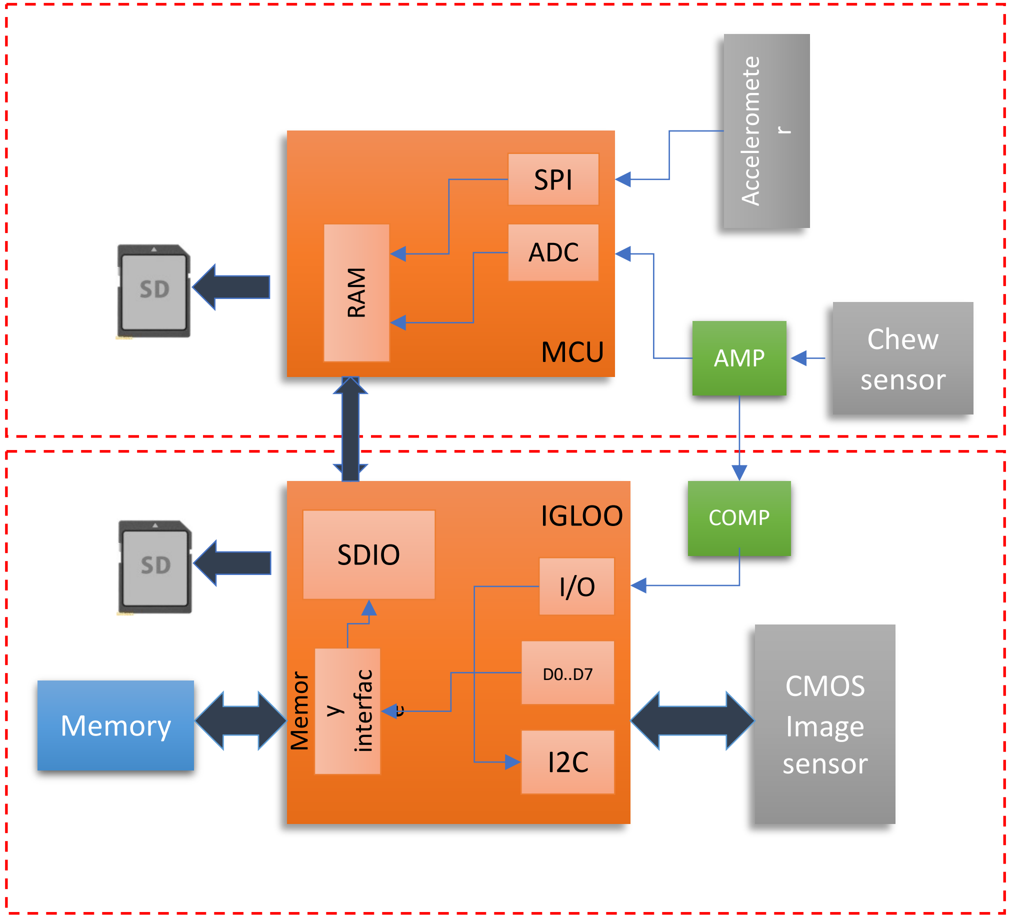
STM32F407 (Running at 168MHz)

Operation	Current Consumption		
	Standby	Run mode	Sleep
MCU Only (all periph off) Measured	3uA	40mA	17mA
MCU + DCMI - Measured	3uA	41mA	18mA
MCU + SDIO - Measured	3uA	41mA	18mA
MCU + SDCard (write) - Measured	N/A	42mA	N/A
MCU(DCMI,SDIO) + CameraOV9650 + SDCard - Measured	0.54mA (No capture)	70mA	22mA (No capture)
MCU + ADC+DMA (No camera, No SDCard) - Measured	3uA	45mA	28mA
Camera OV9650 (Datasheet)	16uA	27mA	N/A

STM32L053 (Cortex M0)

Operation	Current Consumption		
	Run Mode (Clk: 32MHz)	LP Run Mode (Clk: 32KHz)	LP Sleep (Clk: 32KHz)
MCU Only (all periph OFF) - Datasheet	7mA (218uA/MHz)	22uA	4.7uA
MCU Only (all periph OFF) - Measured	N/A	20.8uA	3.7uA
MCU Only (all periph ON) - Datasheet	9mA (280uA/MHz)	28uA	6uA
MCU + ADC - Datasheet	446uA (Clk: 2MHz)	22.2uA	4.8uA
MCU + ADC - Measured	500uA (Clk: 2MHz)	N/A	N/A
MCU + DMA - Datasheet	7.3mA	22.3uA	4.9uA
MCU + USART - Datasheet	7.4mA	22.4uA	5uA

Image acquisition – MCU + FPGA



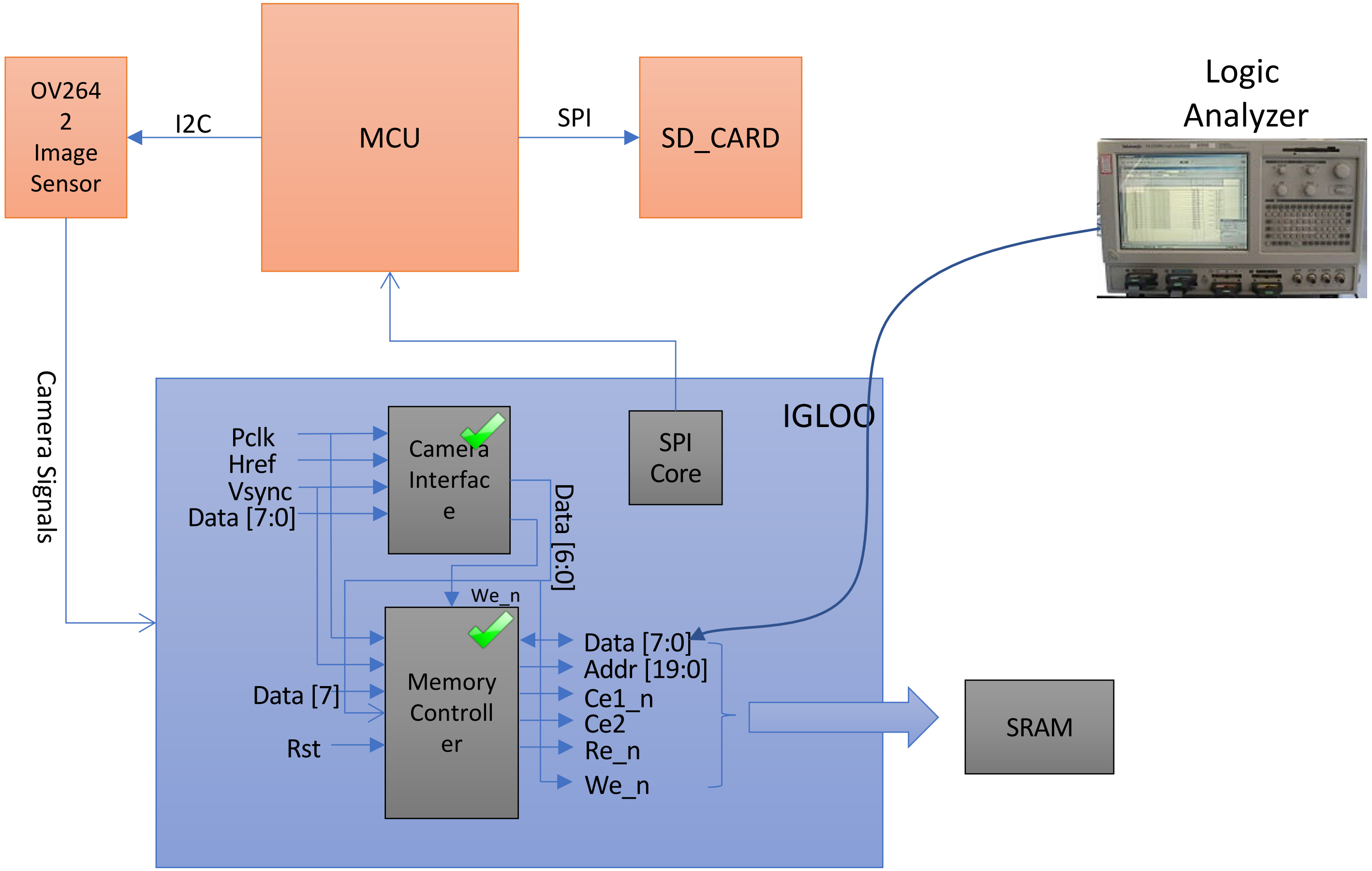
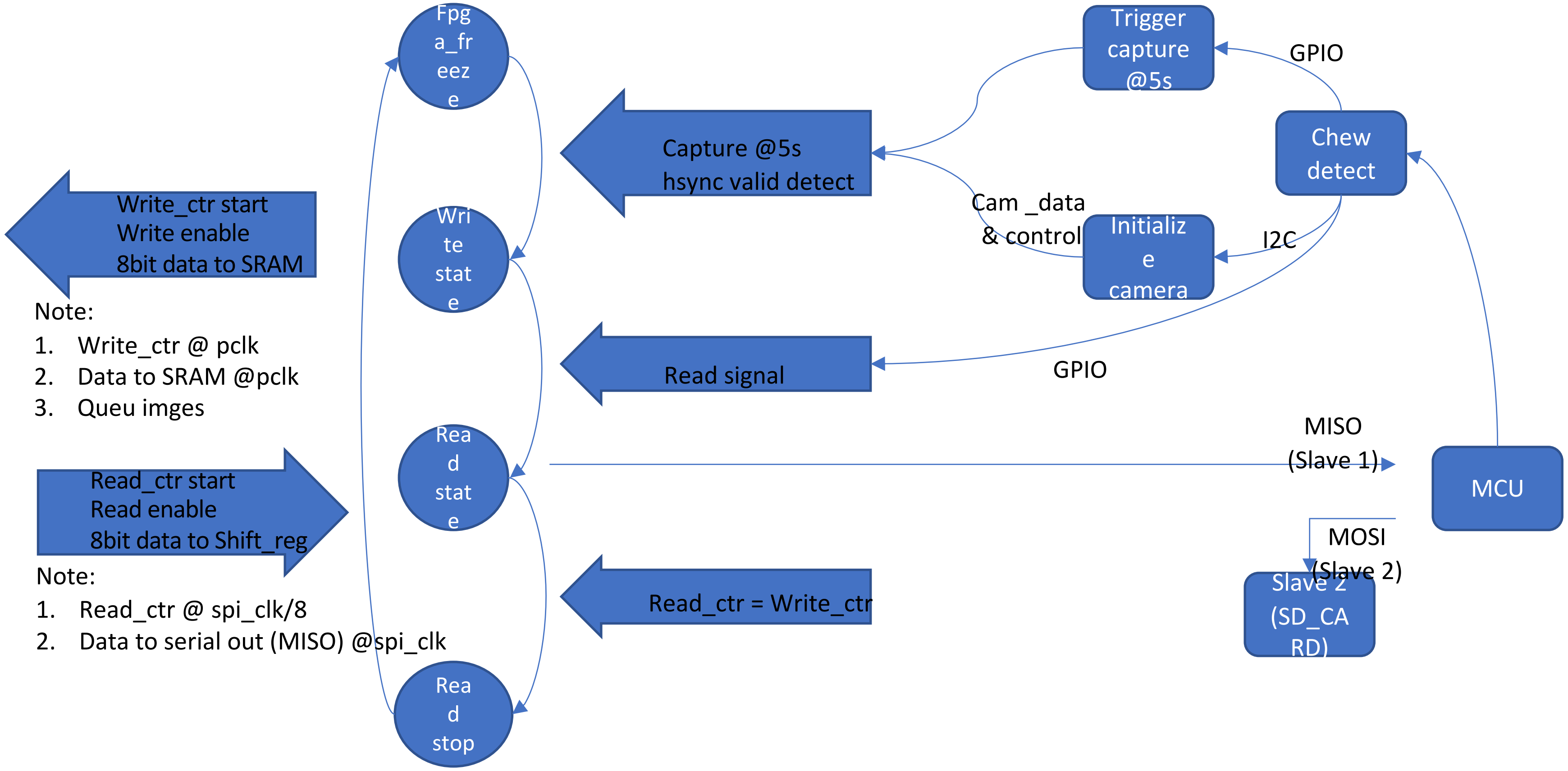
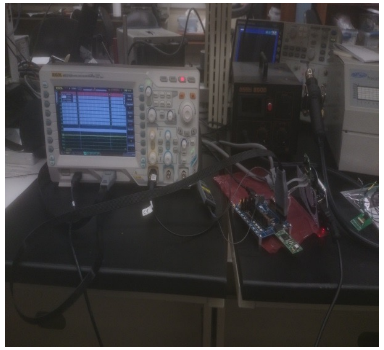


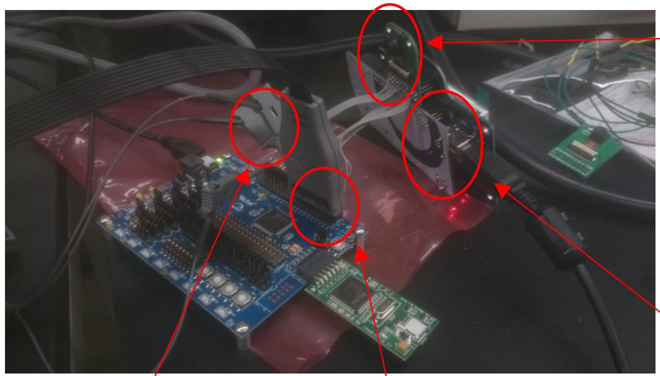
Image acquisition approach



- FPGA in freeze mode
- Wakeup at every 5s by MCU because using single shot mode.
- Image is written to the SRAM at every 5s as a queue of images.
- During writing to SRAM, fpga may only active about 1ms out of 5s.
- Image (from SRAM) is only transferred to the SDCARD only when initiated by MCU. It can be done outside of the food intake episode.
- FPGA will be active again during writing to SDCARD for about 2s.

Experimental setup





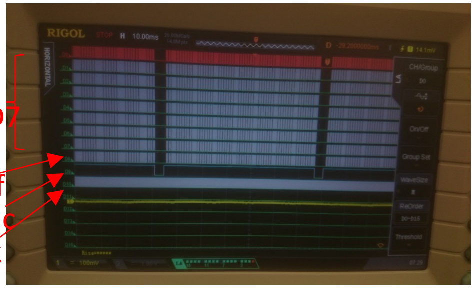
OV2640

Arduino

Camera control signal:

- Pclk
- Href
- Vsy
  nc

FPGA_DataOut D[7:0]

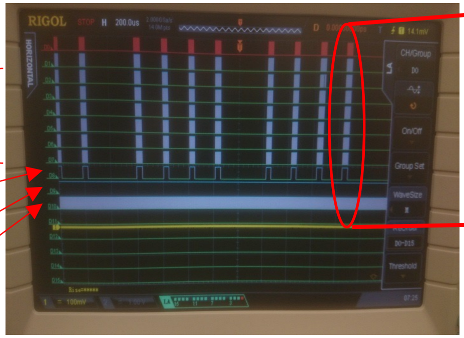


D0-D7

Href

Vsync

Pclk

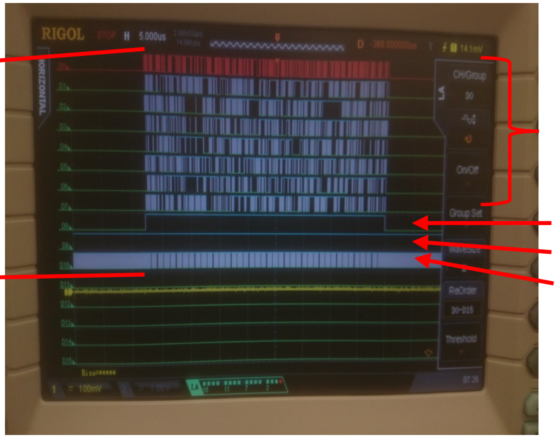


D0-D7

Href

Vsync

Pclk

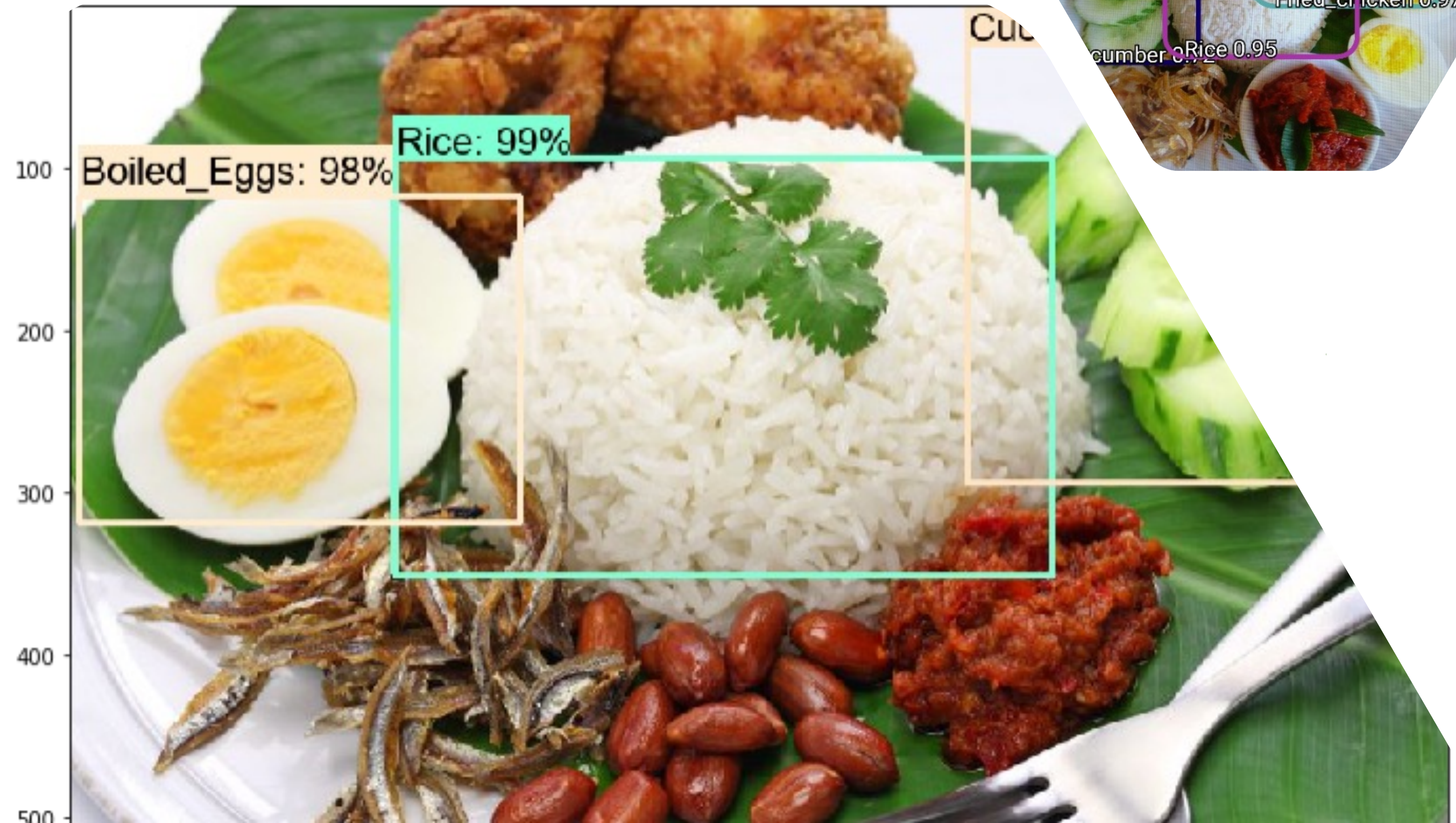


D0-D7

Href

Vsync

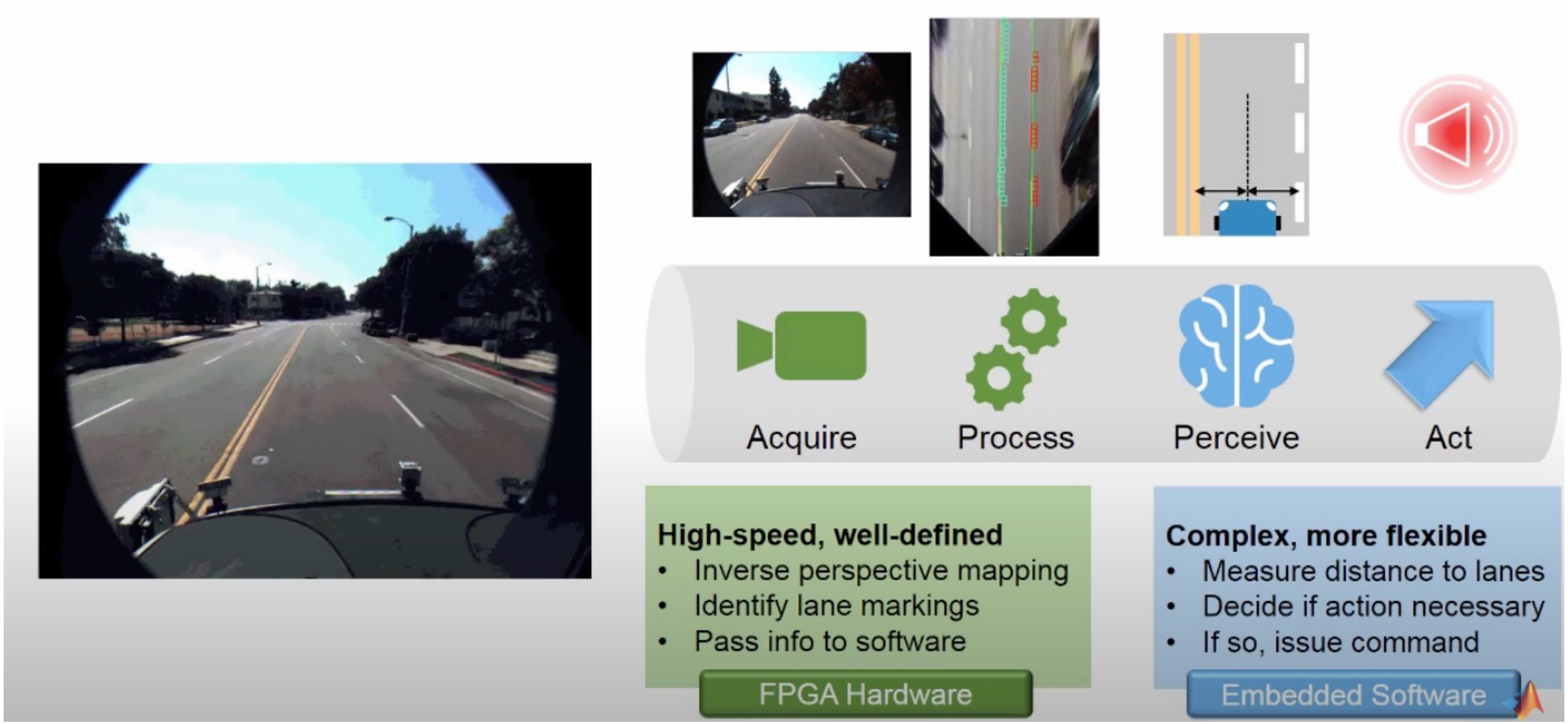
Pclk



Automatic food intake system – new prototype

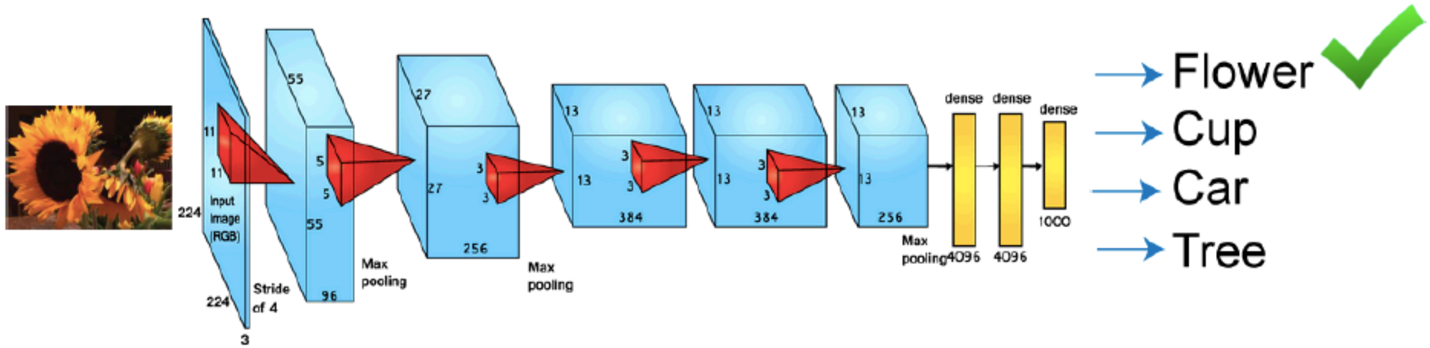
- Contactless chewing detection
- Automatic food volume and calorie estimation
- Automatic food recognition (deep learning)

Vision processing on FPGA/Soc with Matlab



Source: Mathworks®

Vision processing on FPGA



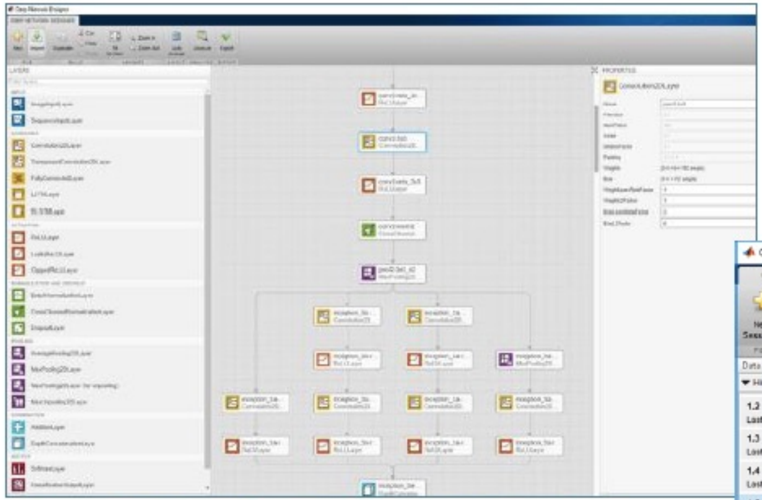
	input	conv 1	conv 2	conv 3	conv 4	conv 5	fc6	fc7	fc8	Total	
Parameters (Bytes)	n/a	140K	1.2M	3.5M	5.2M	1.8M	148M	64M	16M	**230 M**	Off-chip RAM
Activations (Bytes)	588K	1.1M	728K	252K	252K	168K	16K	16K	4K	**3.1 M**	Block RAM
FLOPs	n/a	105M	223M	149M	112M	74M	37M	16M	4M	**720 M**	DSP Slices

Source: Mathworks®

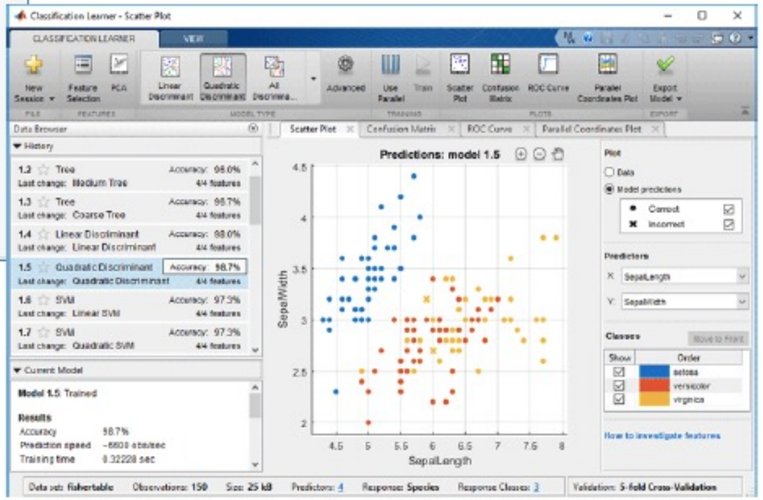
Vision processing on FPGA

AI Modeling

- Model design and tuning
- Hardware accelerated training
- Interoperability



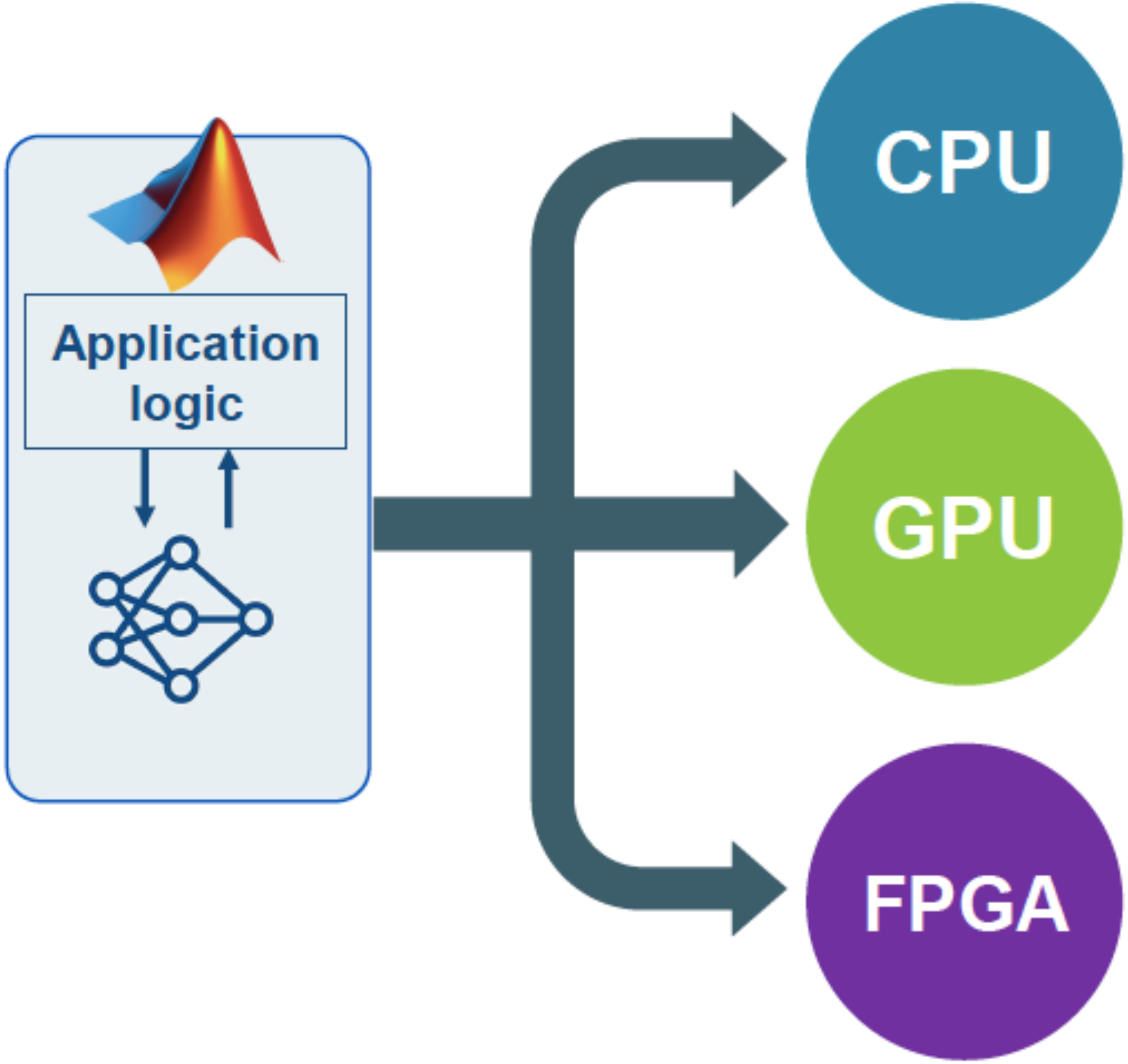
Deep Network Designer app to build, visualize, and edit deep learning networks



Classification Learner app to try different classifiers and find the best fit for your data set

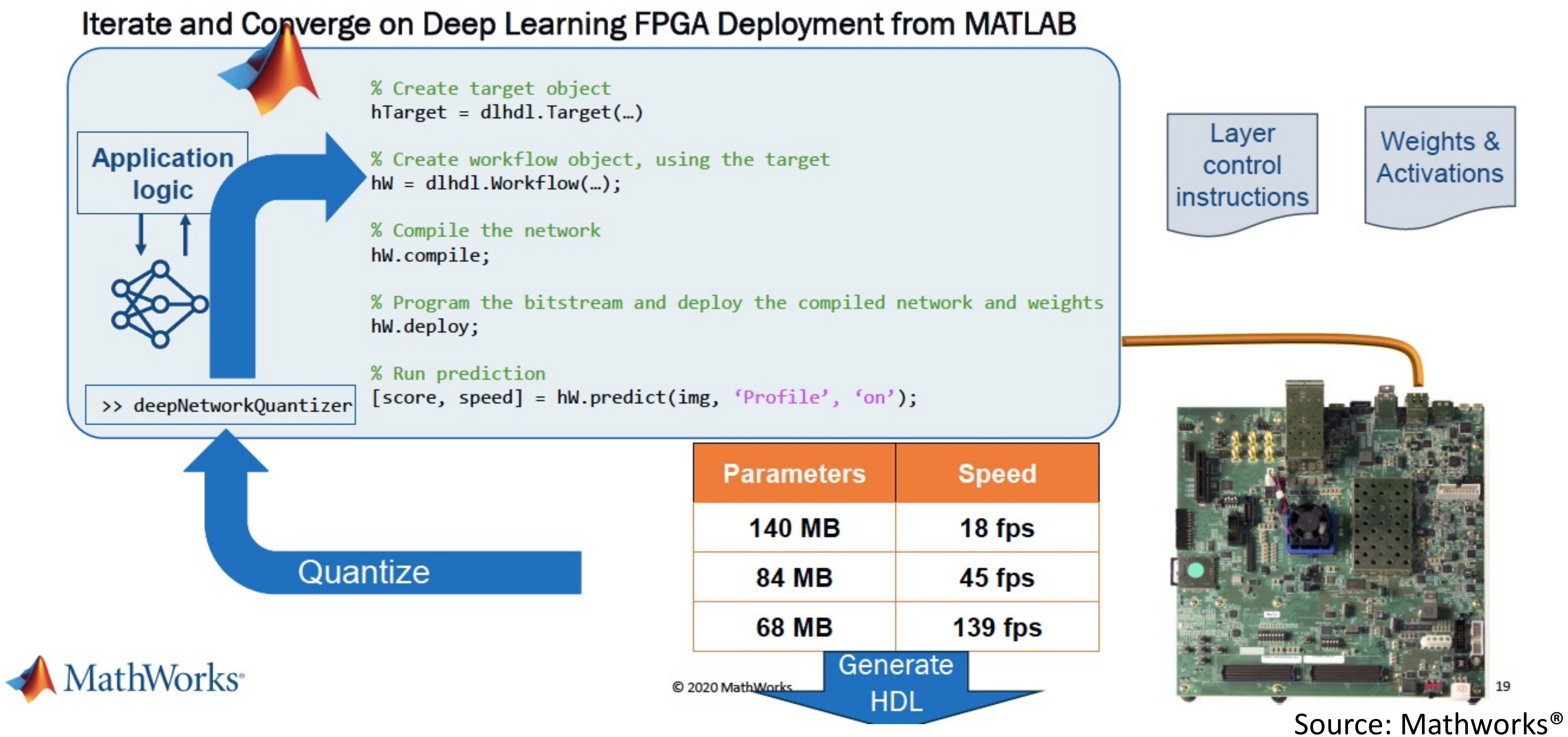
Source: Mathworks®

Vision processing on FPGA



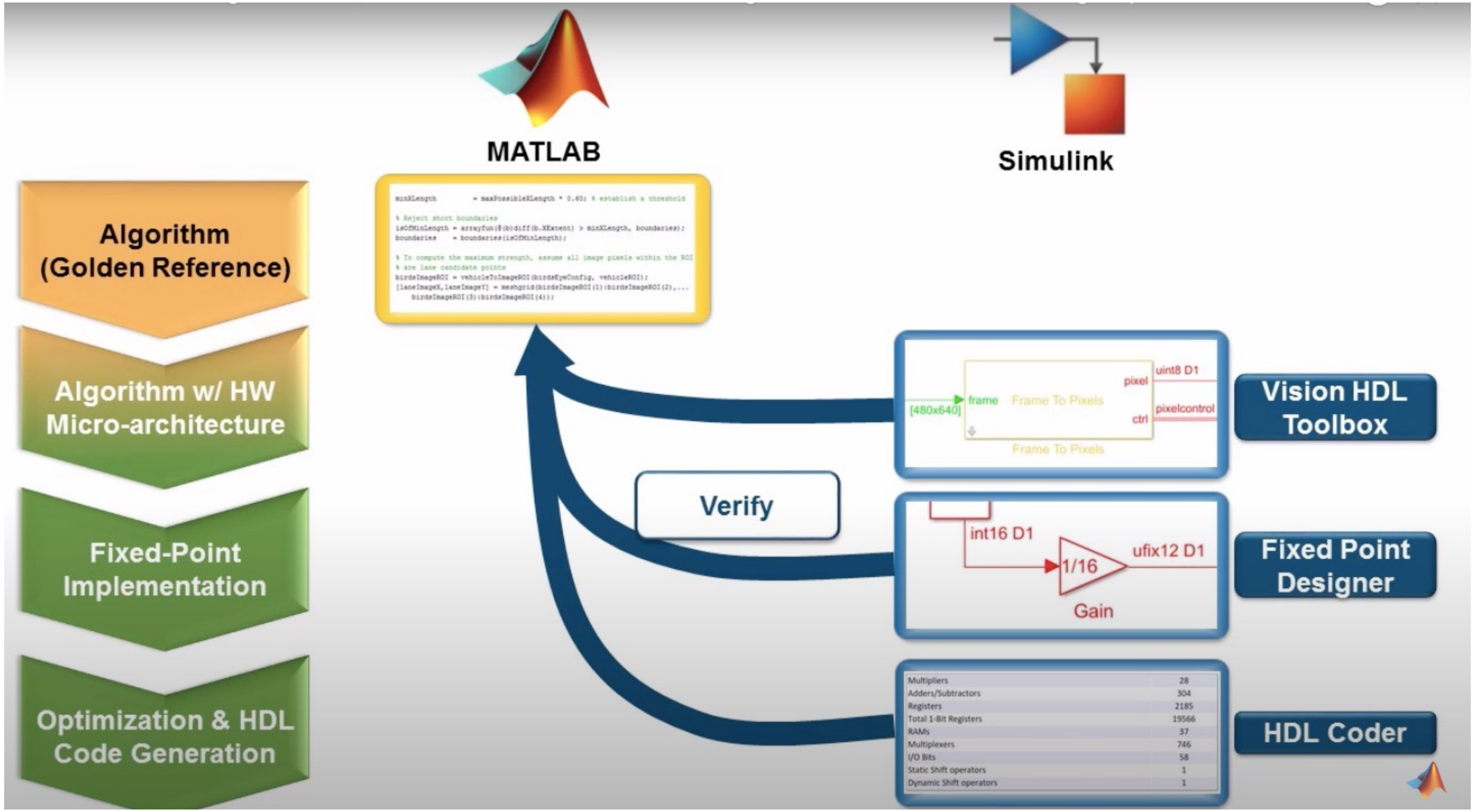
Source: Mathworks®

Vision processing on FPGA



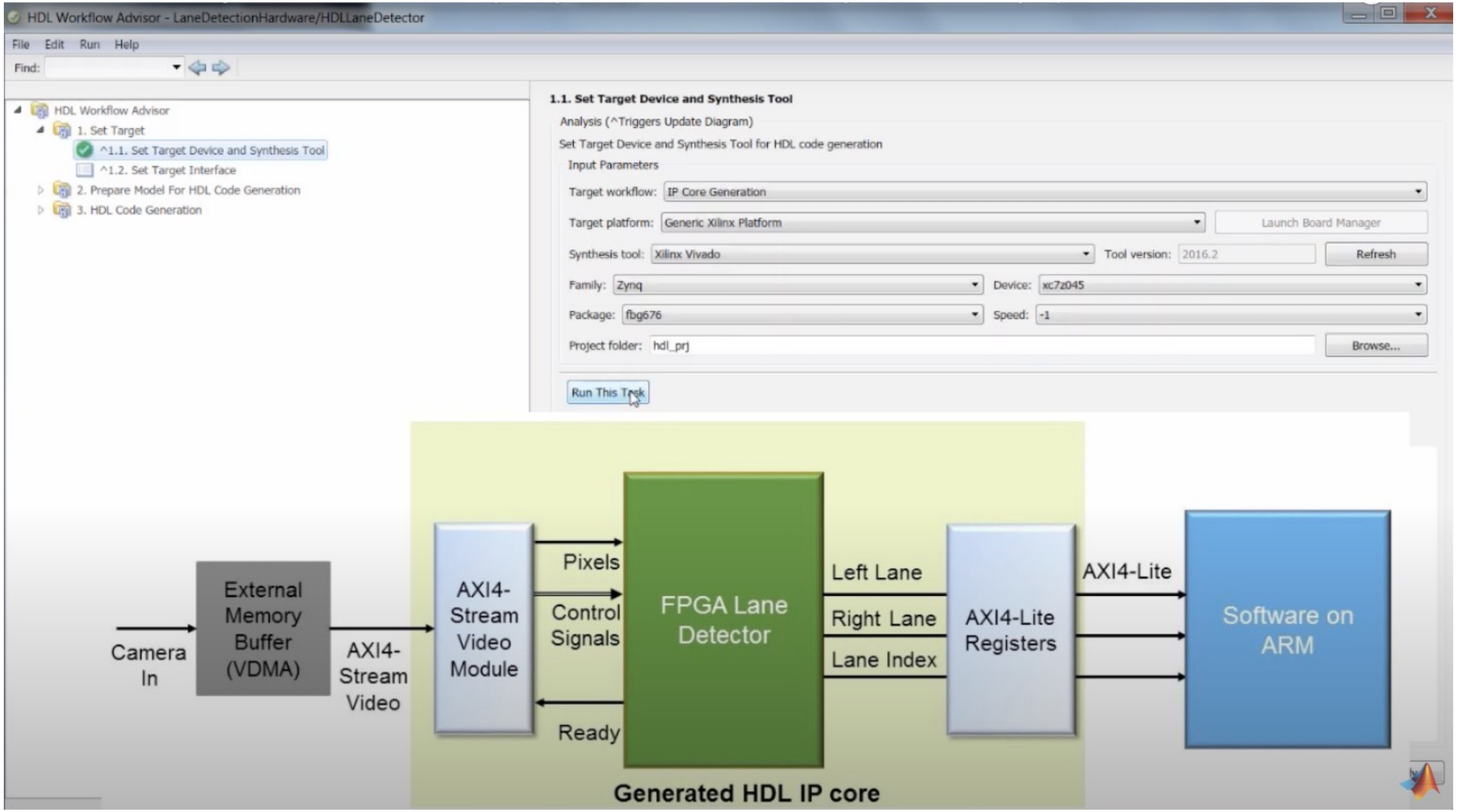
Source: Mathworks®

Vision processing on FPGA



Source: Mathworks®

Vision processing on FPGA

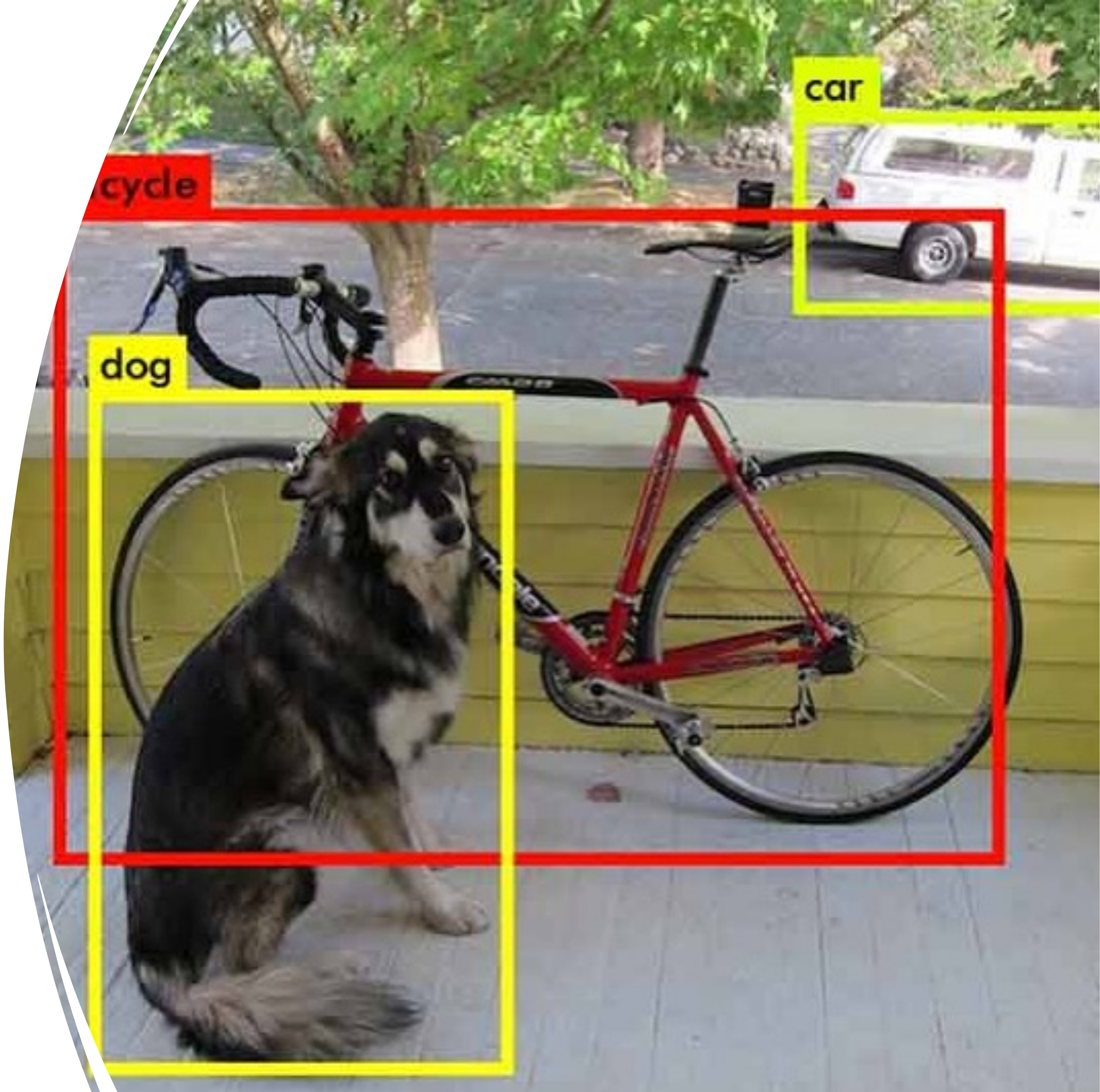


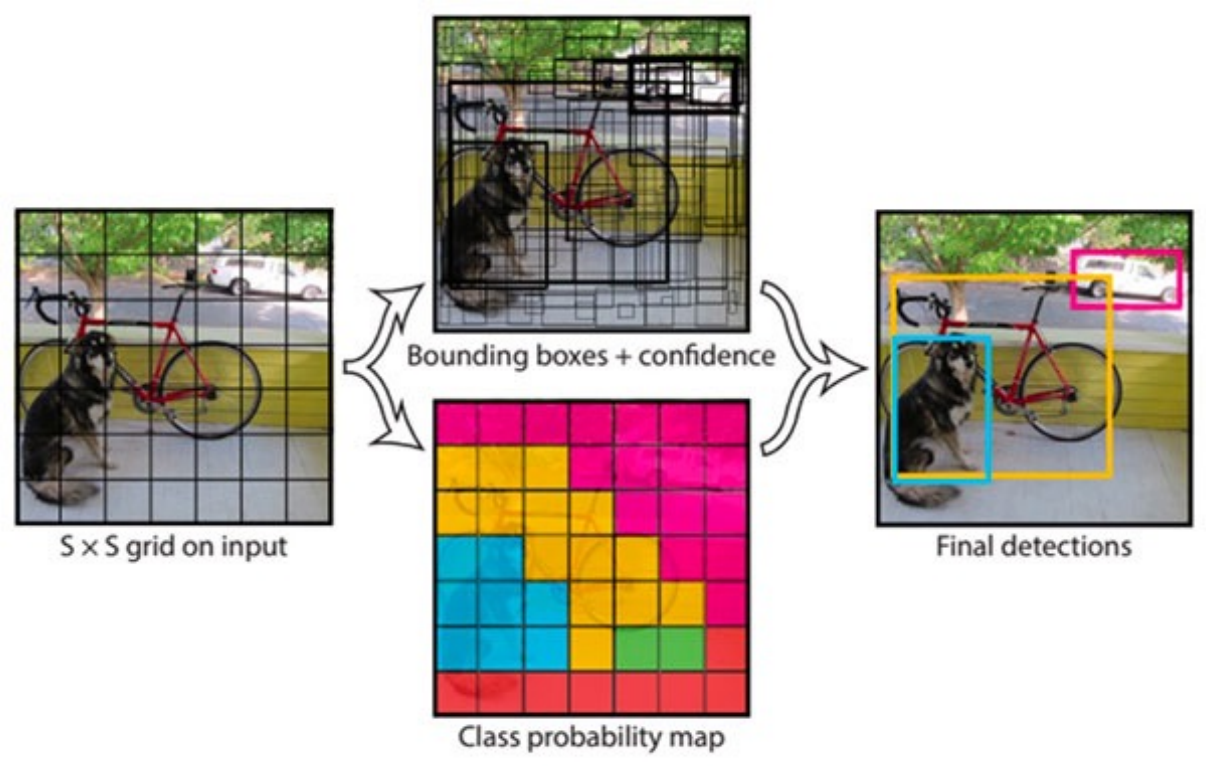
Source: Mathworks®

Computer vision for Advance Driver Assistance System (ADAS)

Object Detection

- Object detection models are used to determine the object present in the image
- It will draw the bounding boxes around the detected objects
- Classification is used to identify the object’s class inside the bounding box
- Example models are RCNN, Fast-RCNN, YOLO, SSD, etc





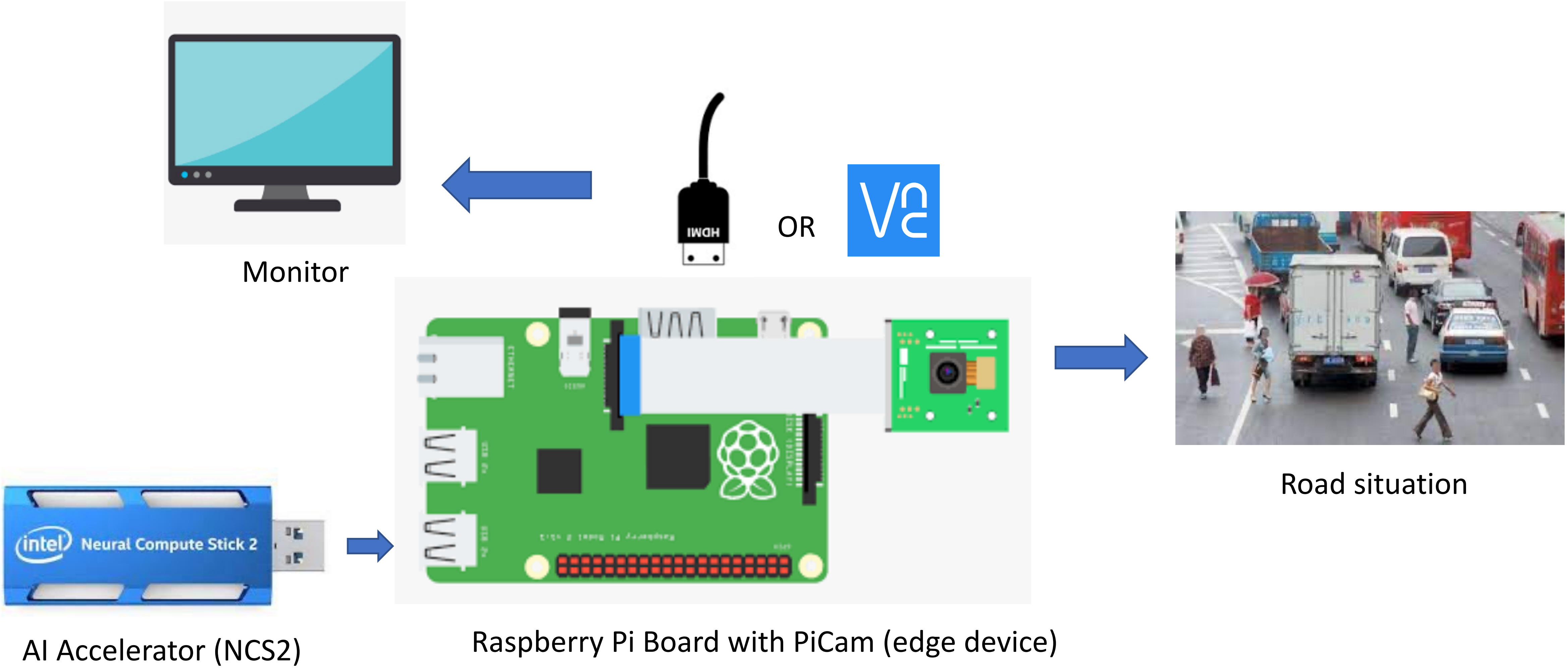
YOLO models (You Only Look Once)

- Splitting the input image into a grid of cells
- Each cell is responsible to predict a bounding box if the centre of an object falls into a grid cell
- Each grid cell predicts bounding boxes, confidence scores for those boxes and conditional class probabilities

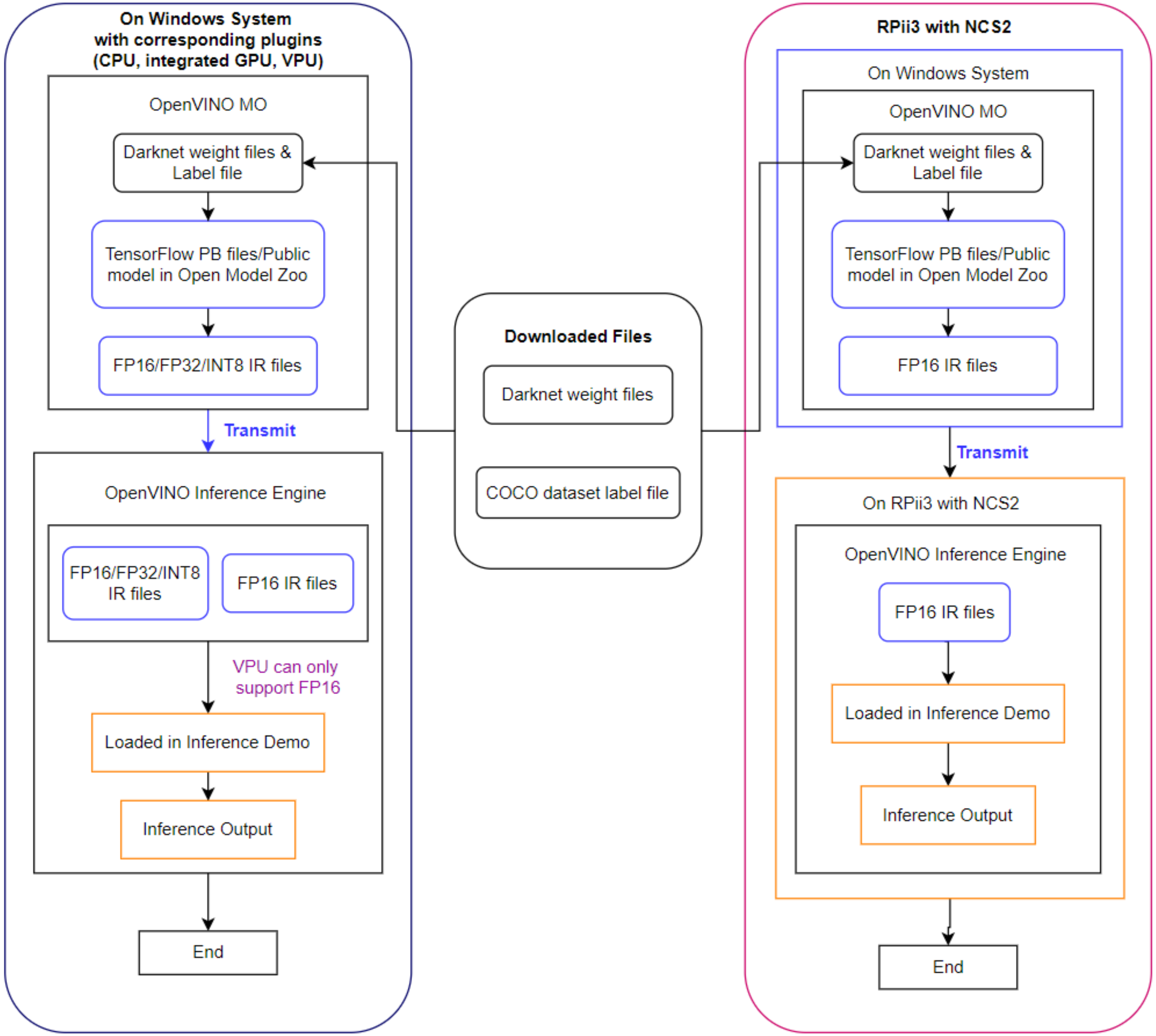
Solution and advantages:

- Simpler network structure
- Faster, even with real-time property; able to process real-time streaming video with lower latency
- Maintaining a proper accuracy range

Hardware Setup



Compilation Workflow




intel
Neural Compute Stick 2

Benchmark Analysis and Inference Performance

Device	Price	FPS
Intel Core i5-9300H CPU	High	27.2
Intel UHD Graphics 630	High	46.6
Dell Laptop (edge) + NCS2	Average	20.7
RPi 3B + NCS2	Low	3.2

Device	Latency (ms)	Confidence Percentage (class car)
Intel Core i5-9300H CPU	36.7	99.4
Intel UHD Graphics 630	21.4	99.6
Dell Laptop (edge) + NCS2	48.3	98.8
RPi 3B + NCS2	289.3	98.2

Thank You

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