People/Car Classification using an Ultra-Low-Power Smart Vision Sensor

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FONDAZIONE BRUNO KESSLER

E3DA ENERGY EFFICIENT EMBEDDED DIGITAL ARCHITECTURES

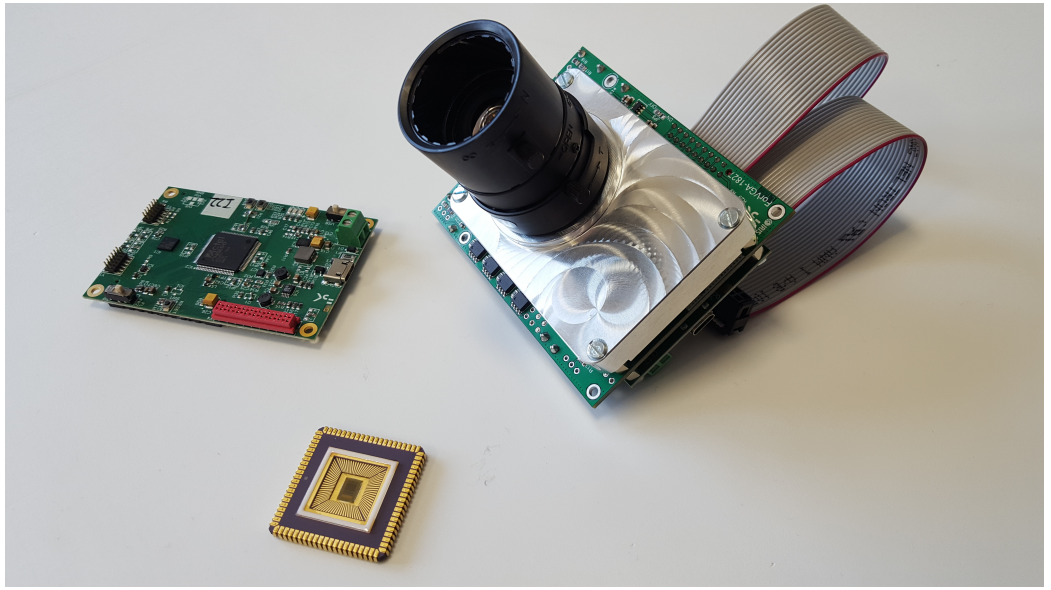
IRIS INTEGRATED RADIATION AND IMAGE SENSORS

- Redundant information leads to:
  - Less computationally-efficient signal processing
  - More data to be transferred

How can redundancy be reduced?

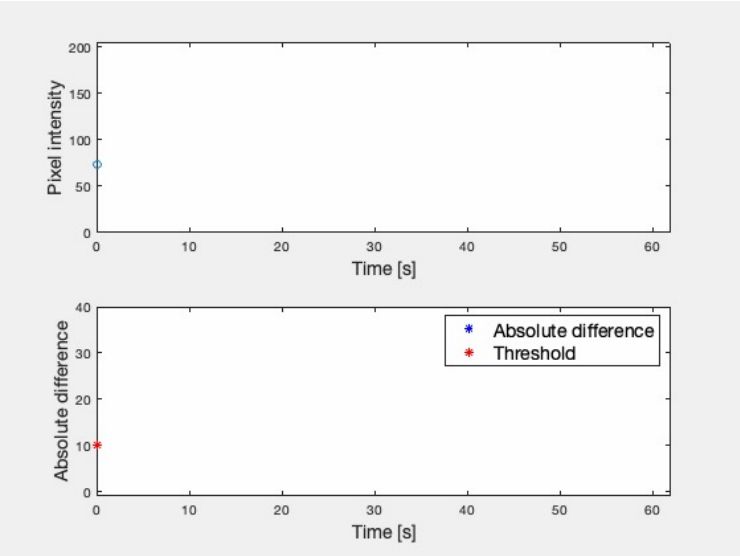
Smart Vision Sensors

- Use motion detection algorithms to reduce image size by showing only moving objects
- Enable event driven computation
- Power consumption:
  - Idle: 344 µW
  - Active: 1350 µW
- Frame rate: 8 fps
- Resolution: 160x120



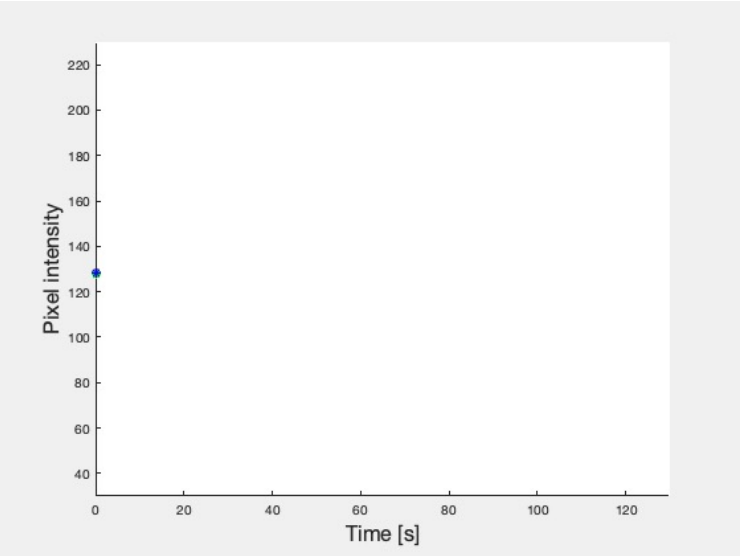
Motion detection

- Not efficient in temporal thresholding
- Not robust to periodic changes



State of the art

- Efficient in temporal thresholding
- Robust to periodic changes



Our approach

Simulation of output

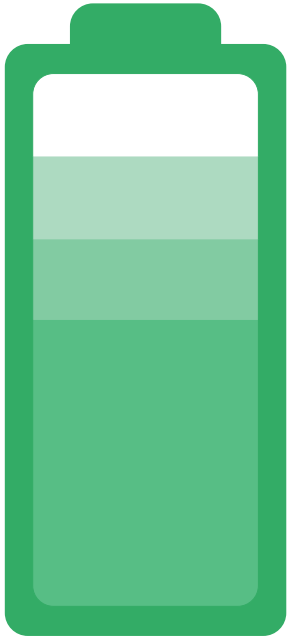
Frame difference  Double threshold

How can we use data from this sensor?

Target and goal of the work

Smart cities scenario

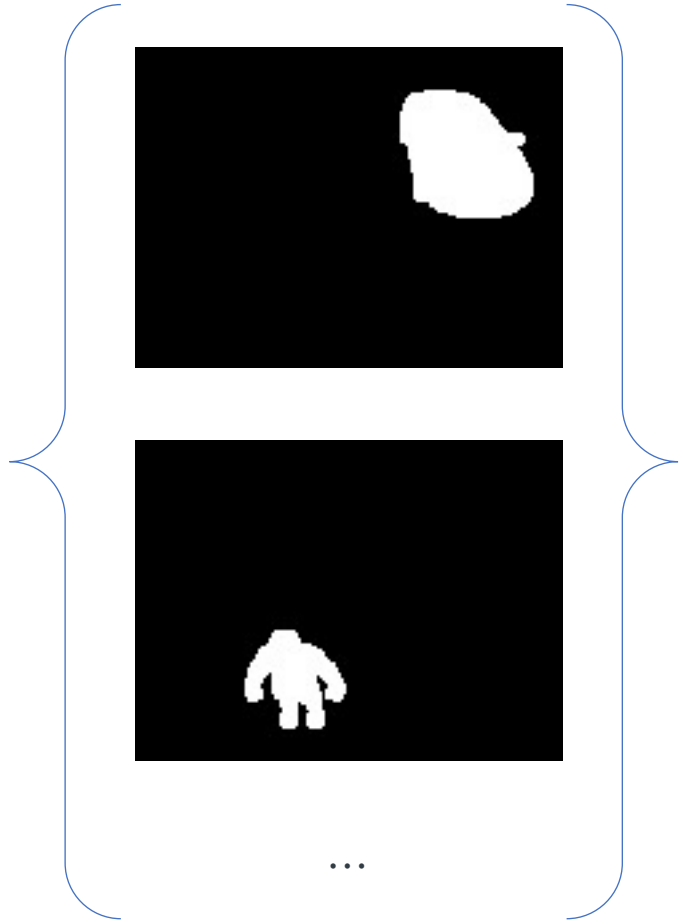
P/C Classifier



Low power

Dataset creation

$$P = \begin{bmatrix} \frac{\cot\frac{fovy}{2}}{aspect} & 0 & 0 & 0 \\ 0 & \cot\frac{fovy}{2} & 0 & 0 \\ 0 & 0 & \frac{n+f}{n-f} & \frac{2*n*f}{n-f} \\ 0 & 0 & -1 & 0 \end{bmatrix}$$

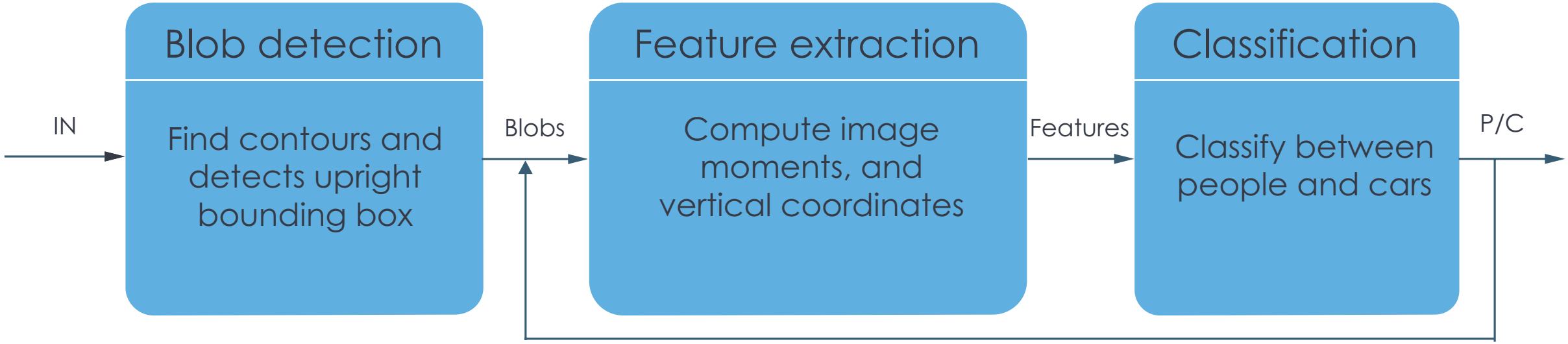


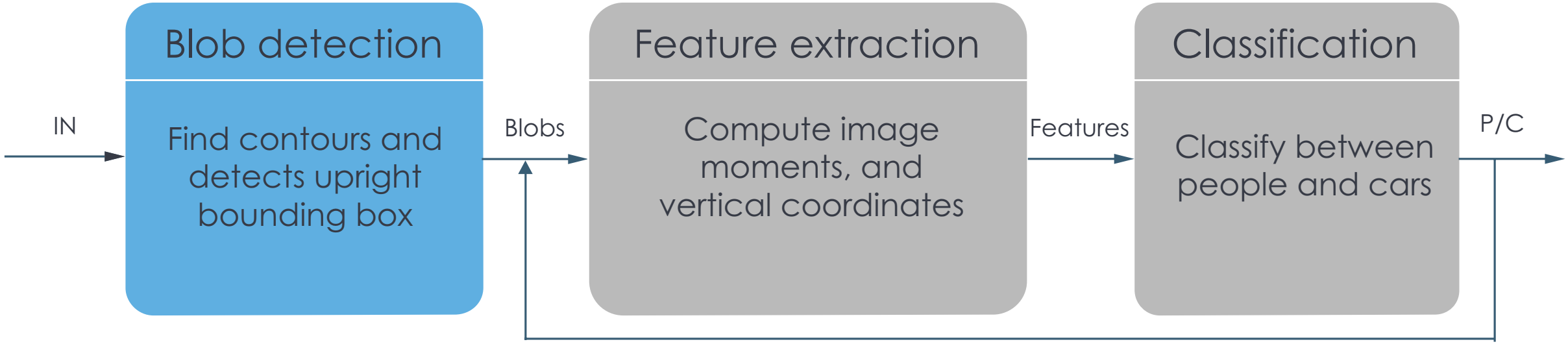
3D models

Perspective projection

Artificial dataset

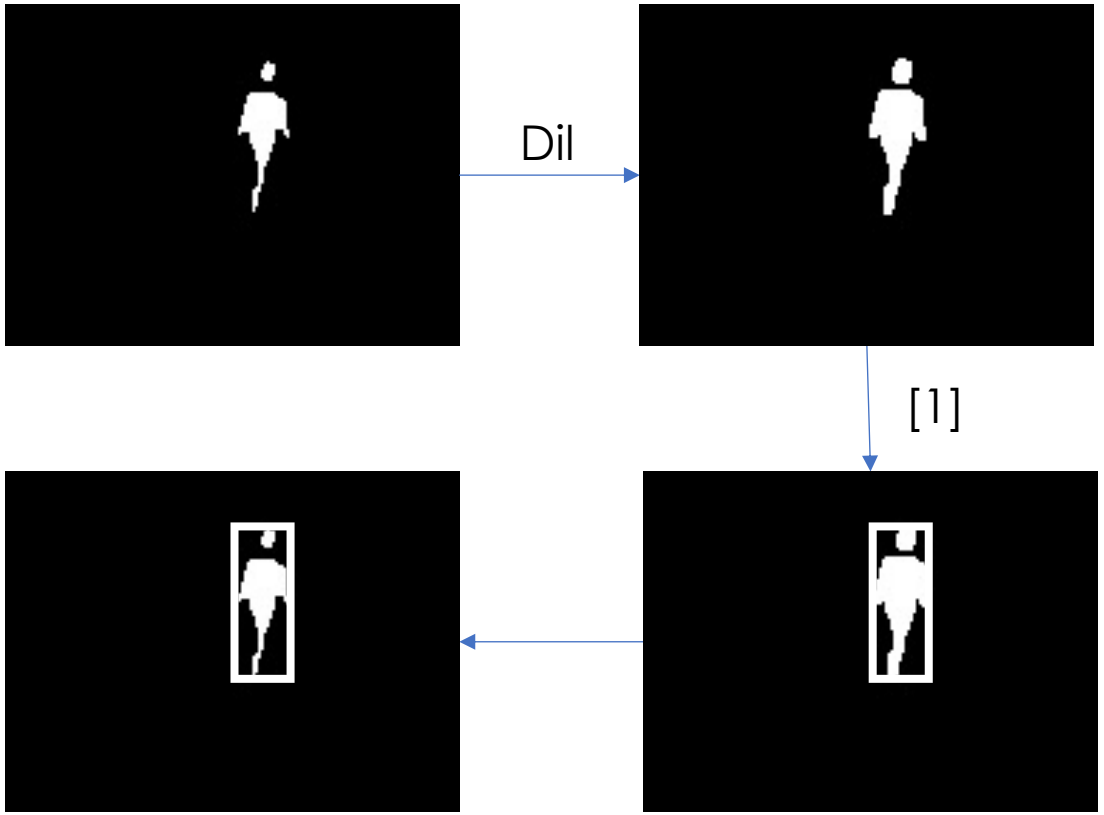
Algorithm outline



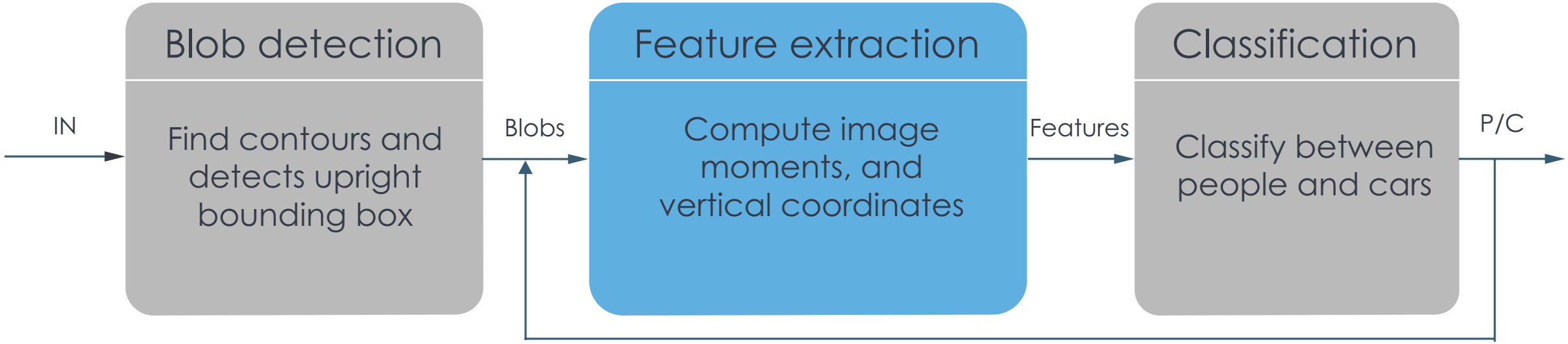

IN
Blob detection
Find contours and detects upright bounding box
Blobs
Feature extraction
Compute image moments, and vertical coordinates
Features
Classification
Classify between people and cars
P/C

Blob detection

- Border following algorithm [1]
- Get a series of contour's pixels



[1] Suzuki, et al. *Topological Structural Analysis of Digitized Binary Images by Border Following*. CVGIP 30 1, pp 32-46 (1985)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Feature extraction

- Chosen after an analysis on objects' geometry:
  - Area of the blob
  - Variances on the two axis
  - Minumum vertical coordinate

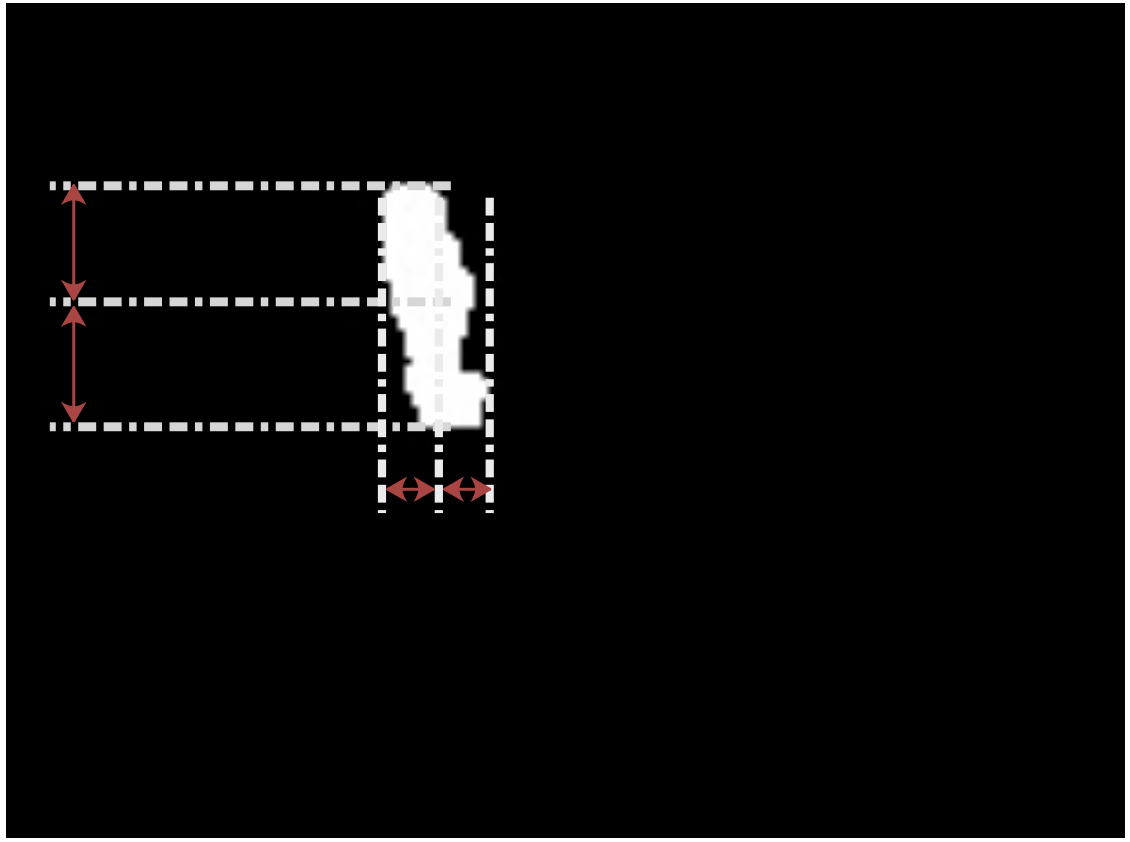
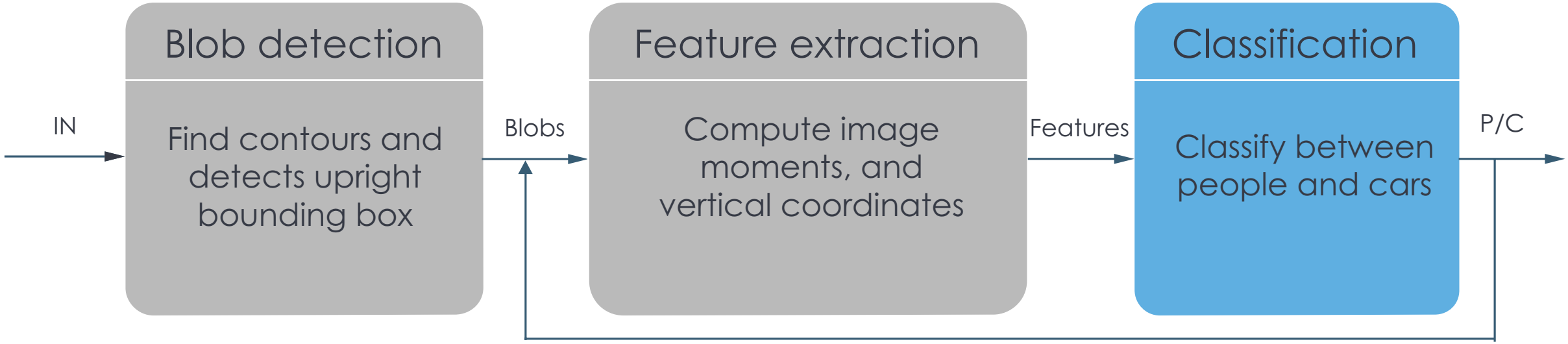


*Image moments: statiscal property of an image, used to compute area and variances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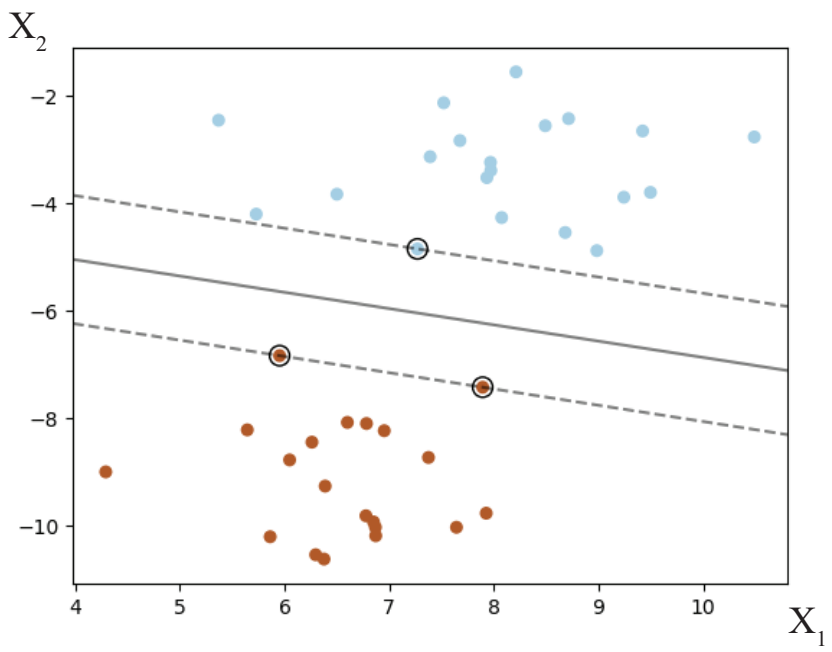
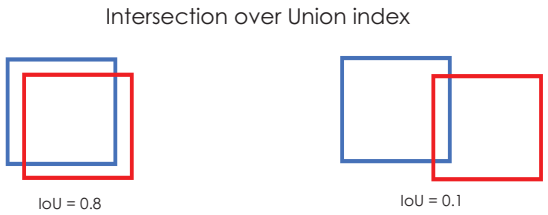
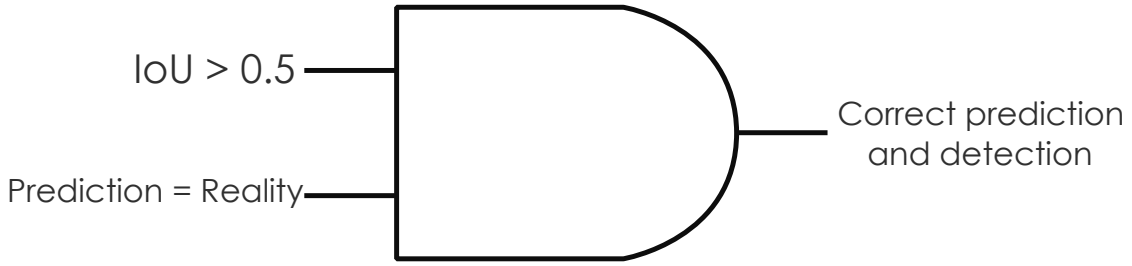
Classification

- Support Vector Machine, a pattern analysis algorithm
- Performs well in experiments for this task
- Suitable computational complexity for our resource-constraint platform
- Trained on the artificial dataset for the classification of real data



Performance analysis





		Actual values	
		Positive	Negative
Predictions	Positive	188	10
	Negative	75	362

Accuracy: ~90%

	Actual value			
	Correct	Incorrect	Total	Error Rate
FORENSOR	239	33	272	0.12
FD	151	121	272	0.44

ER drop: 32%

Power consumption

- **1.9 mW** - Estimated
- Based on the number of operations (additions, multiplications, comparisons) in the code
- Necessary Clock rate, for ARM Cortex-M4 MCU

	Operations/frame
Blob detection	38760
Feature extraction	10500
Classification	8
Total	49268

Conclusion

- Edge computing to extract information from images
- Optimization of acquisition, detection and classification pipeline:
  - Ultra-Low-Power Smart Vision Sensor
  - Detection and classification with an accuracy of ~90%
- Low power consumption: 1.9 mW
- Final goal: tracking objects and scene understanding

Thank you for your attention,
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