Practical Deep ANN implementations on embedded devices
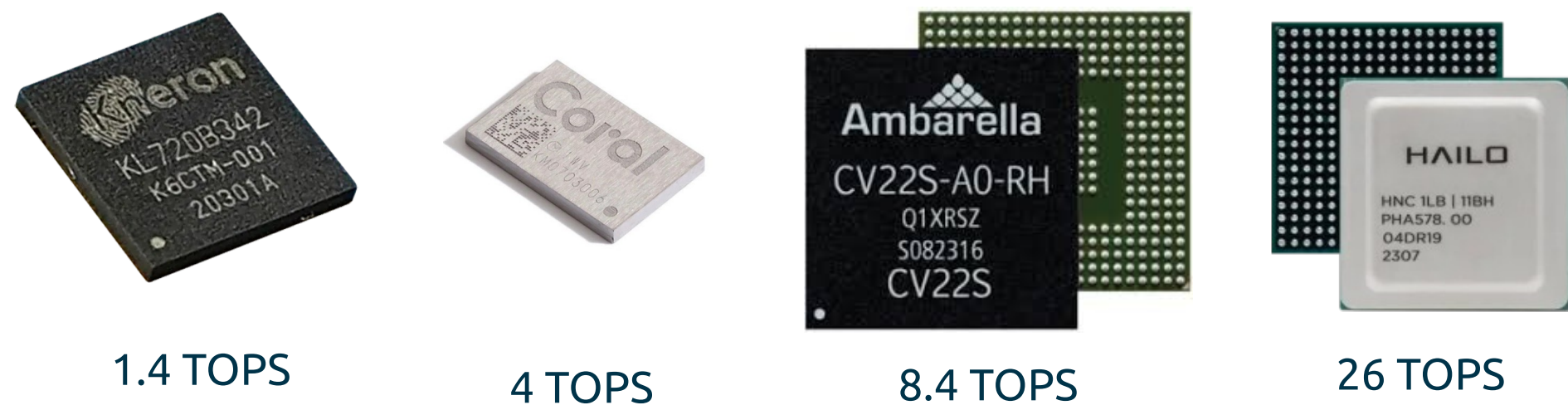
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1. Motivation

More NPUs are emerging for embedded devices:

1.4 TOPS   4 TOPS   8.4 TOPS   26 TOPS

- some solutions are SoC (ARM + NPU)
- some solutions have direct sensor access (camera)
- energy efficiency is outstanding

It is possible to create an IoT sensor
that independently performs complex "on-edge" data analysis
and produces highly processed information for the user
- solving problems that were previously impossible to solve.

2. Problem
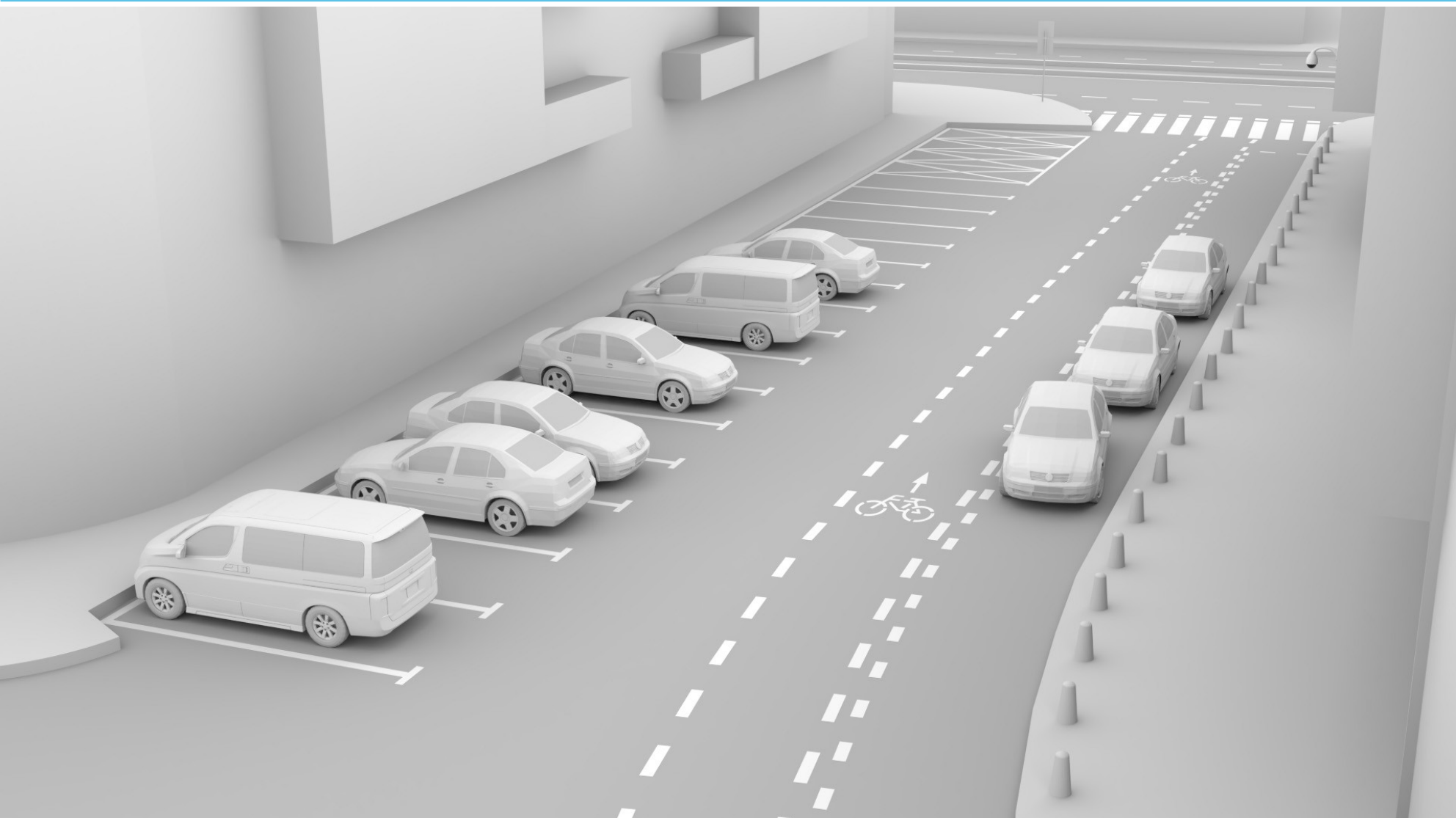
Within Intelligent Transportation System, → a "Universal Vehicle Detector" is needed that meets various requirements depending on the application scenario:

- **Traffic Measurement Stations (automatic)**
  - vehicle detection (>97%)
  - vehicle classification 8+1 (A2)
  - vehicle speed measurement (3%)
  - traffic lane assignment

- **Temporary Traffic Measurements (manual)**
  - extended vehicle classification (up to 13 classes)
  - number of axles
  - vehicle cargo type: tanker, auto-transporter, etc.
  - no intrusion into the road/pavement surface

- **Traffic Management (automatic, real-time)**
  - vehicle speed measurement (3%)
  - vehicle driving direction determination
  - distance between vehicles estimation
  - detection of traffic congestion (per lane)
  - detection of suspicious objects on the road

- **Traffic Safety (automatic)**
  - vehicle identification (ANPR, MMR)
  - dangerous goods identification (ADR, GHS)
  - country recognition / subdivision

- **SmartCity (automatic)**
  - vehicle travel time measurement TTM (based on ANPR)
  - vehicle traffic flow estimation: origin–destination matrix
  - level-of-service LOS real time calculation
 - stop & go traffic problem (heavy congestion)

- **Is there a sensor that meets all requirements?**
  - ✘ inductive loops
  - ✘ pressure sensors
  - ✘ radar
  - ✘ lidar 2D / 3D
  - ✘ ANPR camera
  - ✘ traffic camera
  - ✘ magnetic sensor

3. Evolution - first step

- **ANPR SmartCamera - Gen 1**
  - vehicle detection
  - vehicle number plate recognition ANPR
  - country recognition
  - vehicle classification (car, lgv, bus, truck)
  - limited performance - no NPU, CPU only
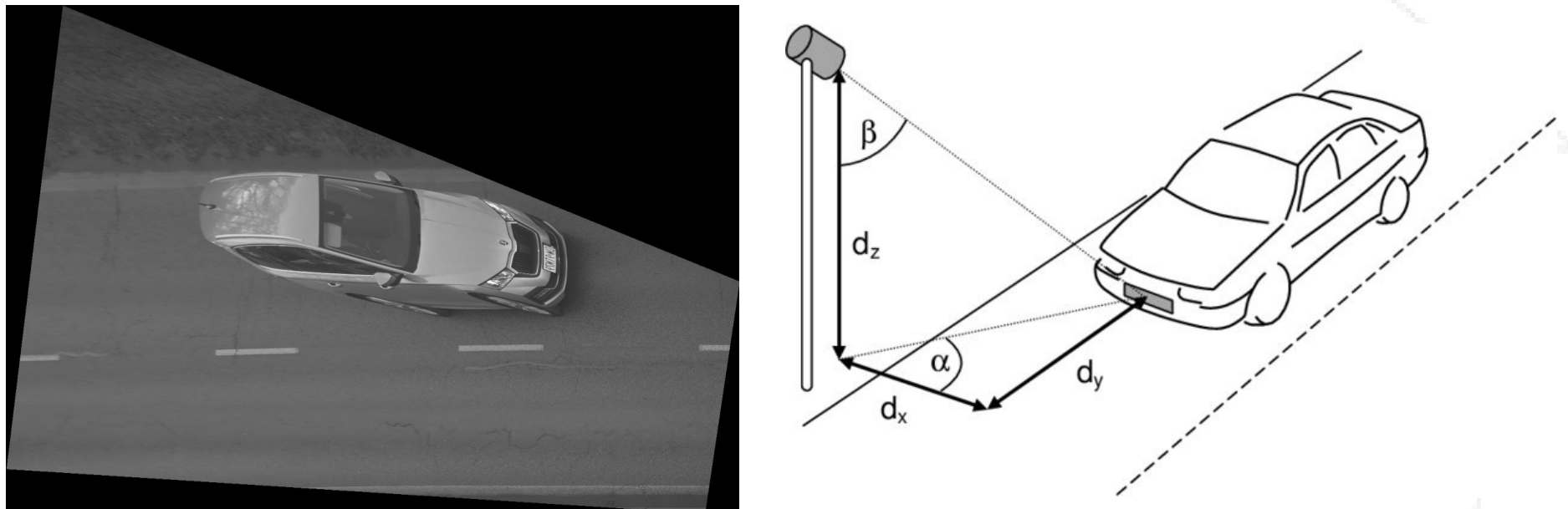 - limited camera FOV

Zdjęcia pojazdu
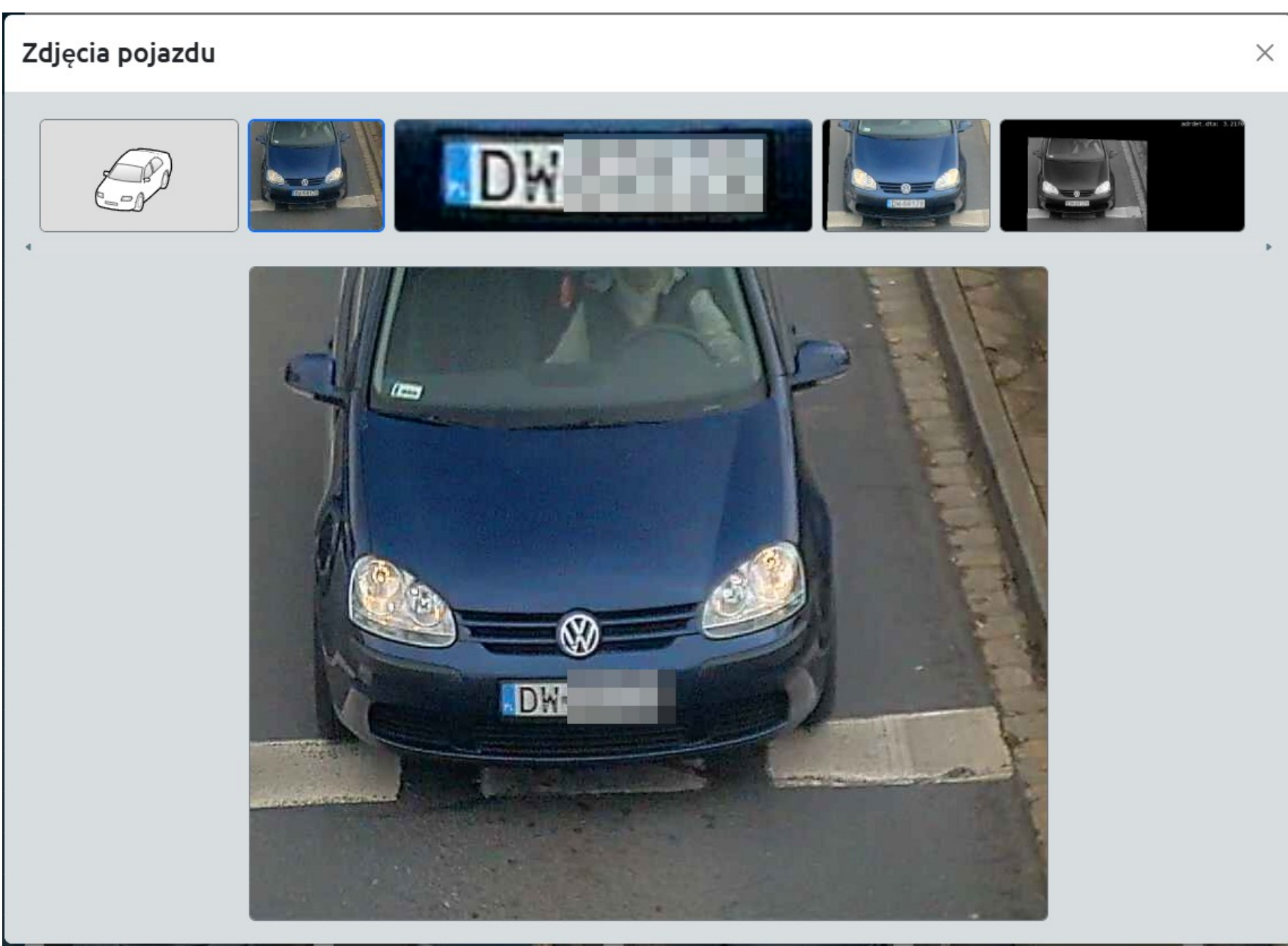
4. Evolution - second step

- **ANPR SmartCamera - Gen 2**
  - Ambarella CV22s chip (SoC + NPU)
  - crucial algorithms run on the NPU
  - extended camera FOV
  - full frame processing 1920x1080
  - <40ms per frame / every frame generates all data
  - vehicle number plate tracking

- **3D Camera Auto-calibration**

  - vehicle speed measurement
  - vehicle driving direction estimation
  - extedned Make-and-Model recognition
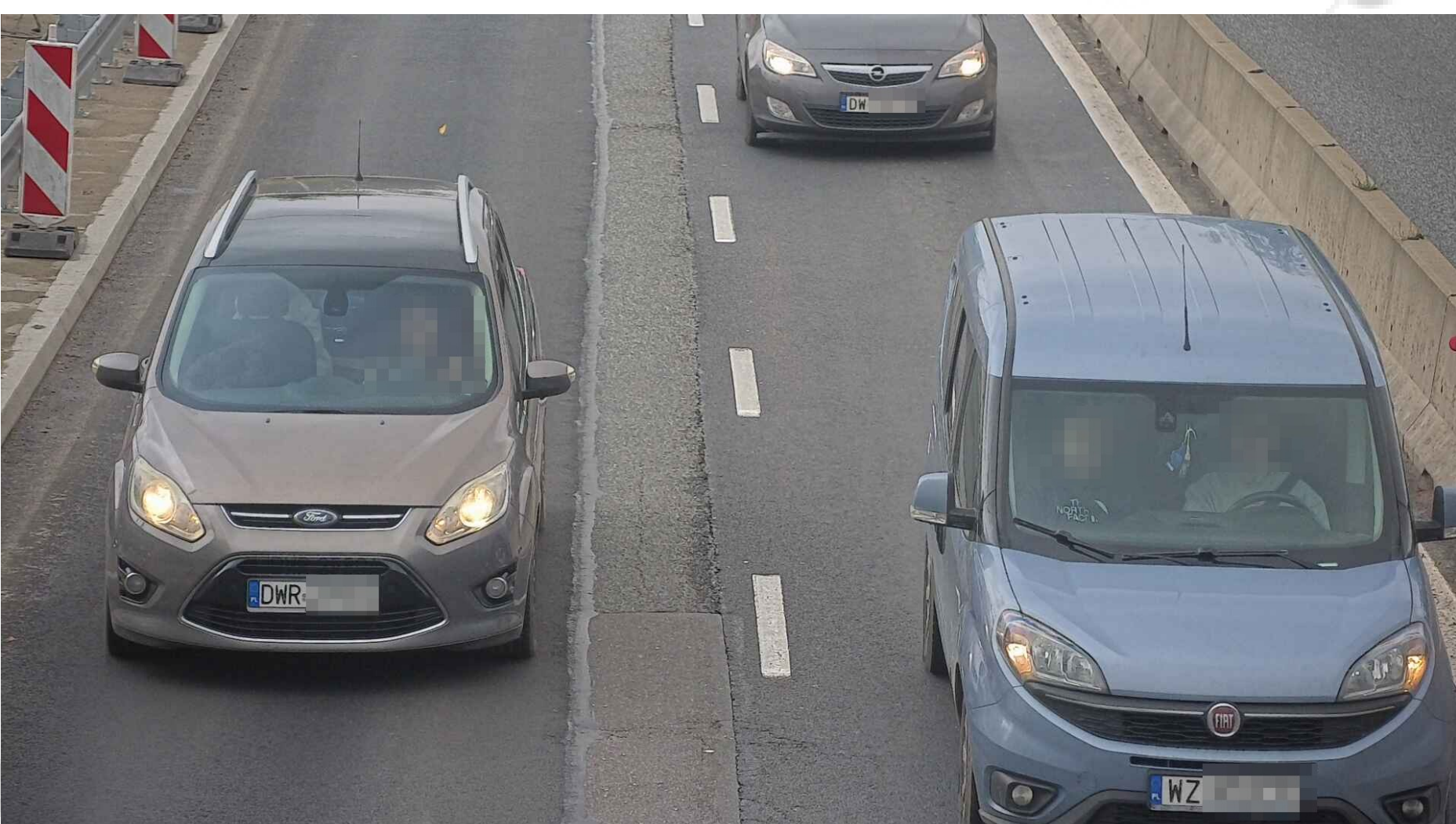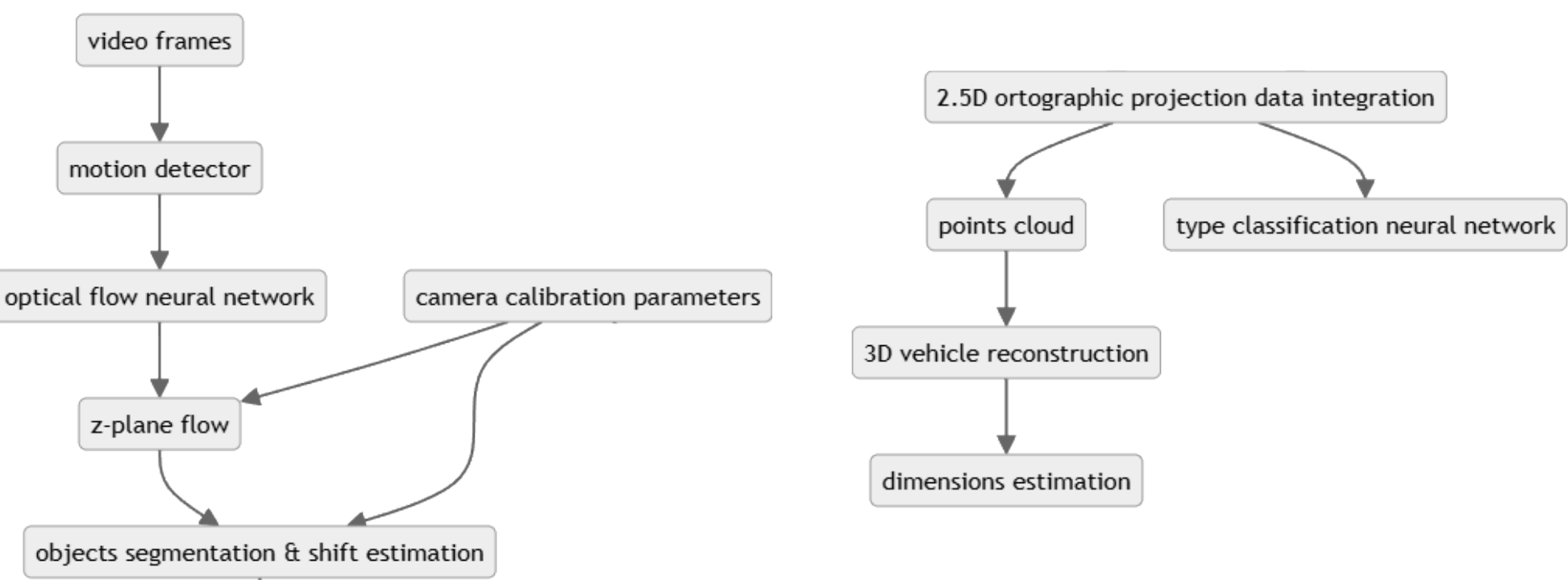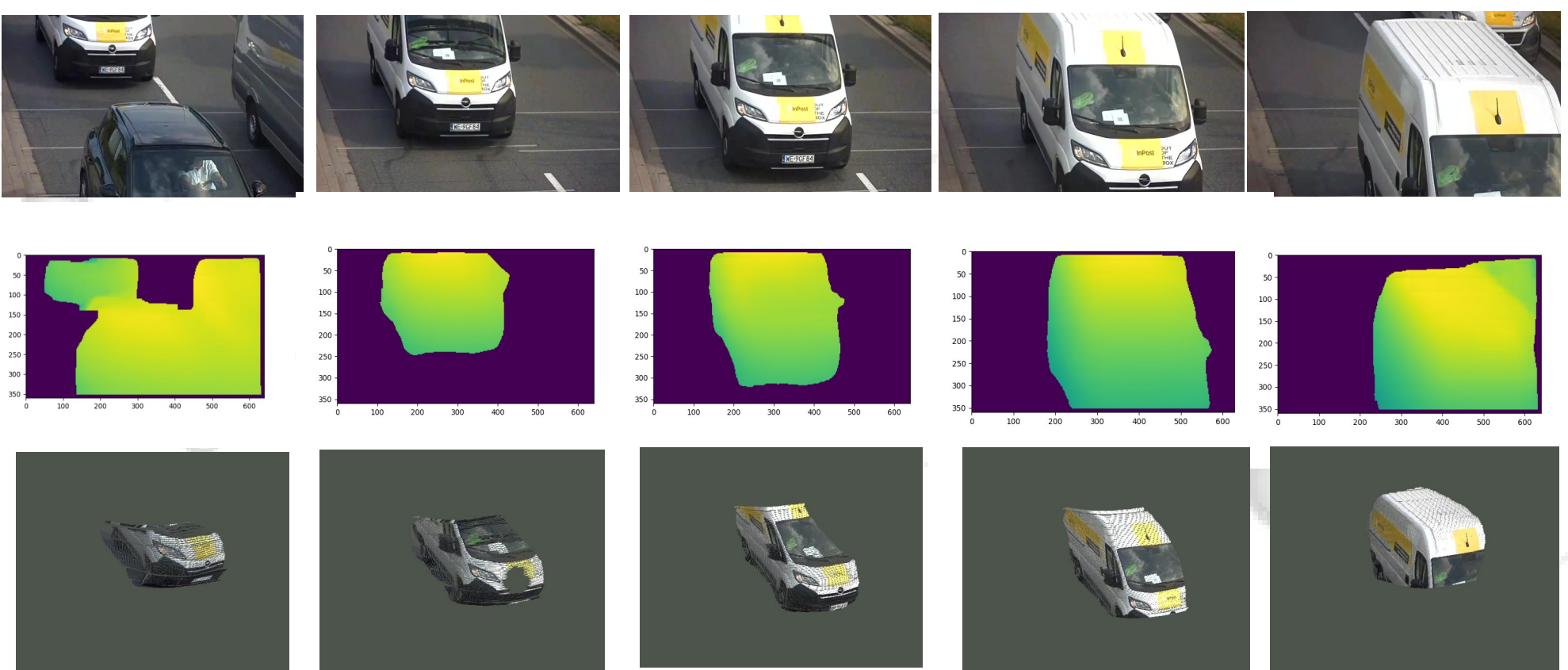

5. Evolution - final step

- **ANPR SmartCamera - Gen 3**
  - CPU - Intel Atom
  - NPU - Hailo-8
  - global shutter SONY Preguis
  - full frame processing 3MP-5mP
  - IR strobe illumination
  - structure-from-motion for 3D vehicle shape estimation

- **3D Structure from Motion**

- **DNN for on-edge optical flow computation**
  - input → sequence of 5 frames RGB 640×384 px
  - output → optical-flow avg (dx, dy)
  - architecture → feed-forward hourglass, pseudo-attention
  - size → 360.000 parameters, ~50 fps on Hailo-8

- **Result (on-edge, real-time)**

VLOOP l: 6.90 w: 1.92 h: 2.44
WIM l: 6.90 w: 1.96 h: 2.50