Case Study on Interior Monitoring featuring Time-of-Flight 3D Imaging for Resource-Constrained Mixed-Critical Systems

Norbert Druml

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Agenda

1 Introduction & Motivation

2 Case Study: Interior Monitoring

3 Outlook and Conclusion

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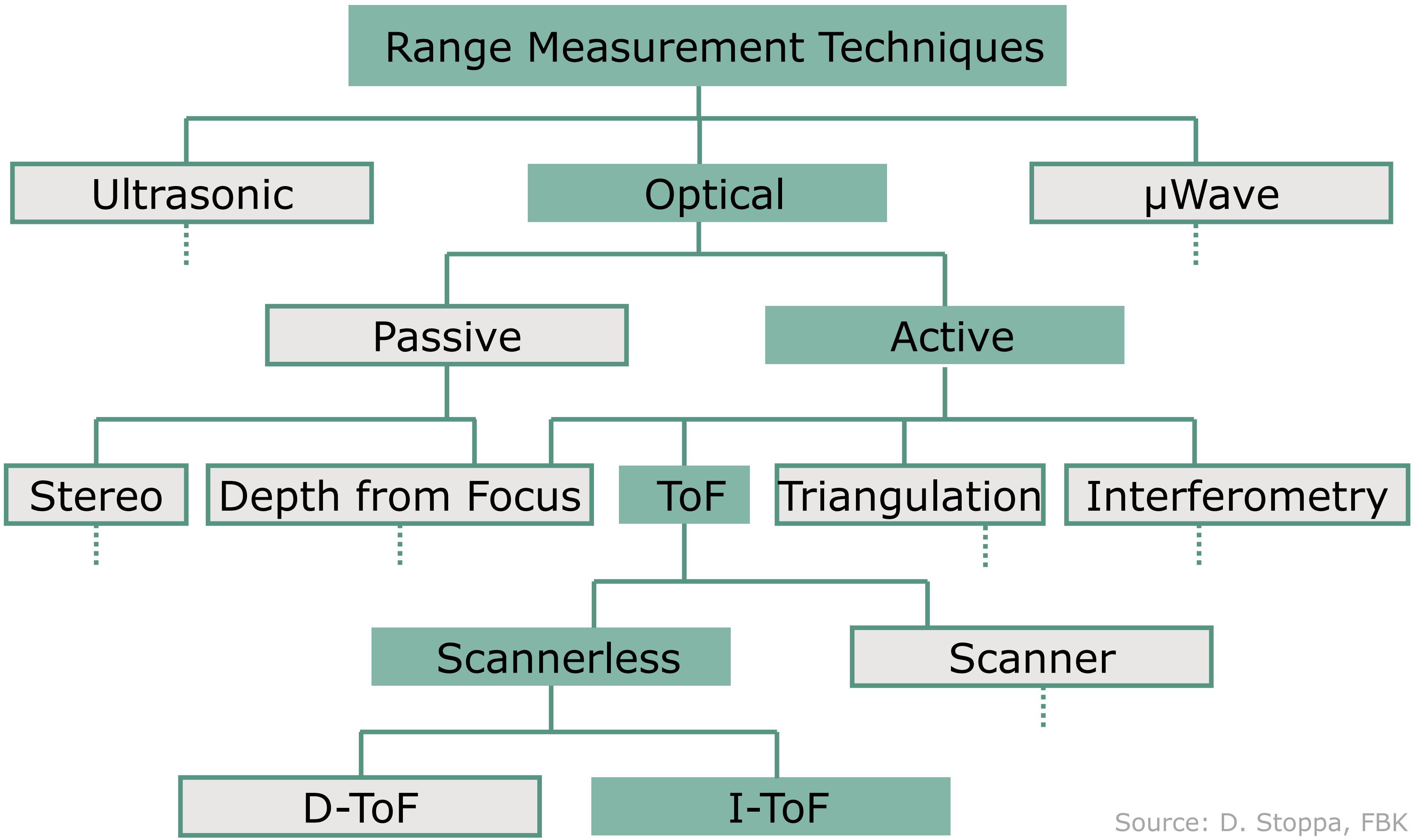
Introduction, 3D Taxonomy

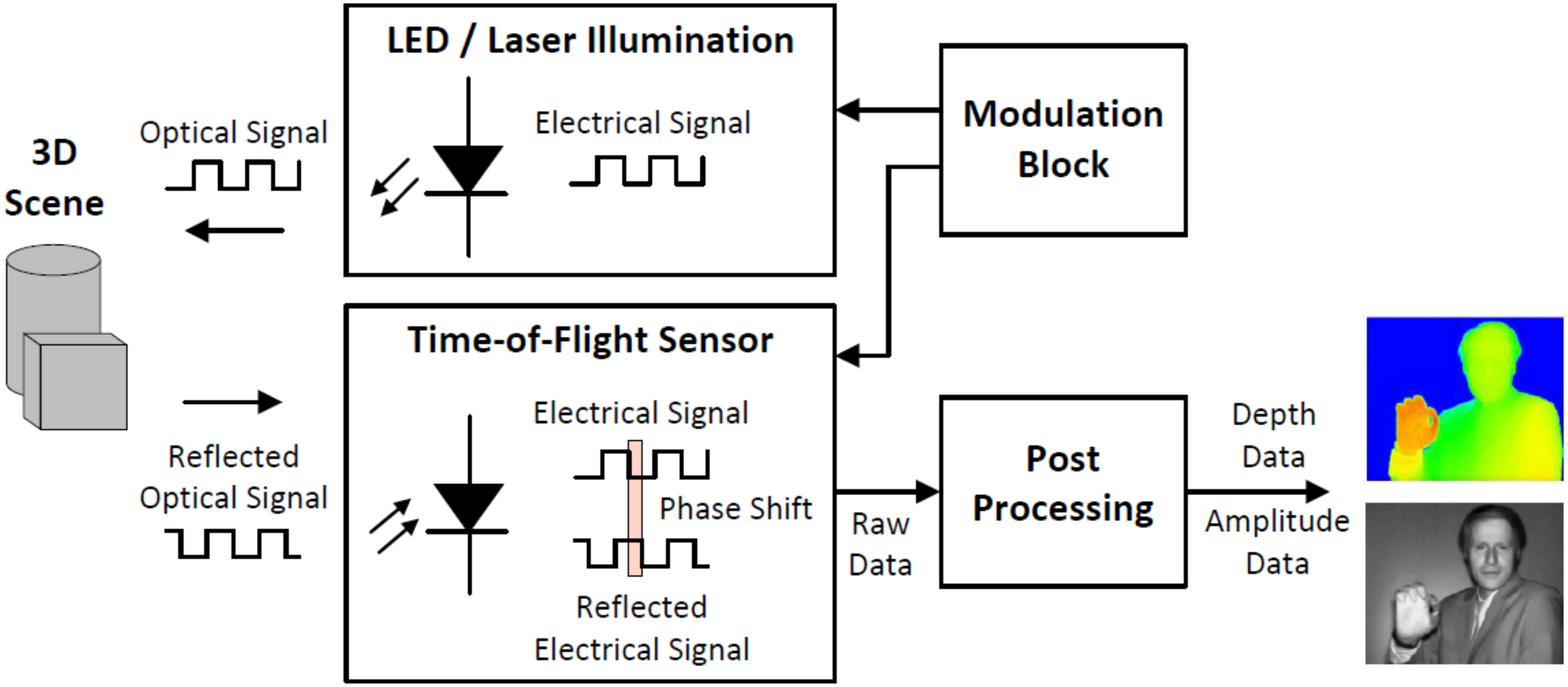


Source: D. Stoppa, FBK

Introduction, Time-of-Flight 3D Imaging

› Time-of-Flight depth sensing working princip

  – Delivers also a robust infrared image



Introduction, Time-of-Flight 3D Imaging

One Sensor – Many Applications

- Consumer
  - 3D Scanning
  - Virtual Reality

- Consumer
  - Touchless gesture control
  - Gaming

- **Automotive Interior**
  - Gesture Control
  - **Driver awareness monitoring**

- Automotive Exterior
  - Surround view
  - Parking aid

- Industrial
  - Surveillance
  - Factory automation

Camera design optimized for different use-cases

Introduction, Time-of-Flight 3D Imaging

2016 @ Hannover Messe

Motivation – Interior Monitoring

- Why interior / driver monitoring at all?
  - Company Healthyroad implemented a driver monitoring system for professional truck drivers
  - 88,810 km monitored (approx. 2 times the equator)
    - 9,439 km of fatigue
    - 1,470 km of distraction
    - **390 km of sleepiness!!**

- Why Time-of-Flight 3D imaging?
  - Provides robust infrared image during day and night
    - Makes computer vision algorithms easier
  - Provides 3D image for, e.g., head pose tracking

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Interior Monitoring

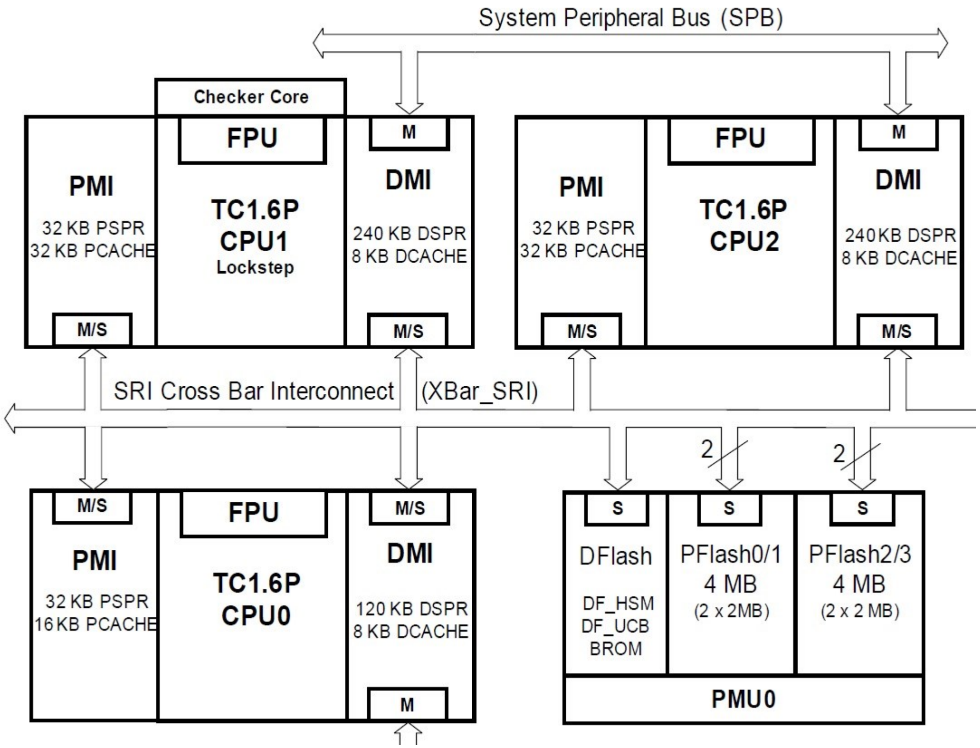
- Requirements
  - Seat occupant / human detection use-case
  - Use Infineon’s AURIX automotive micro controller
  - Perform use-case isolated on one core in order to enable a mixed critical system design

- Major question: **How to implement human detection in a very resource constrained environment**

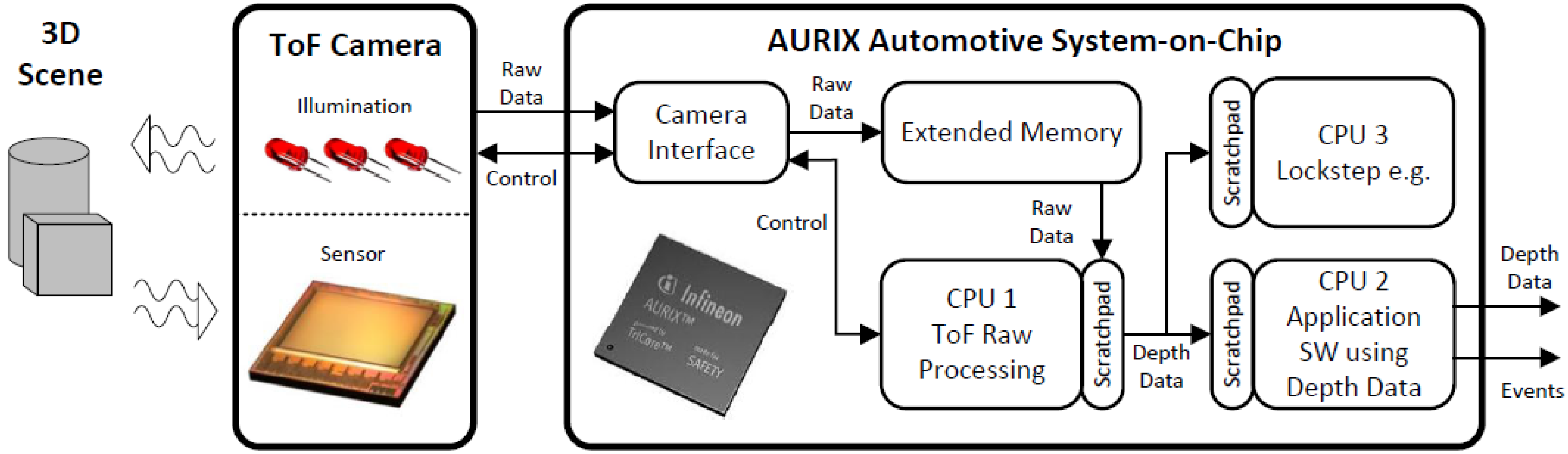
- Approach: Cleverly exploit the ToF 3D information!

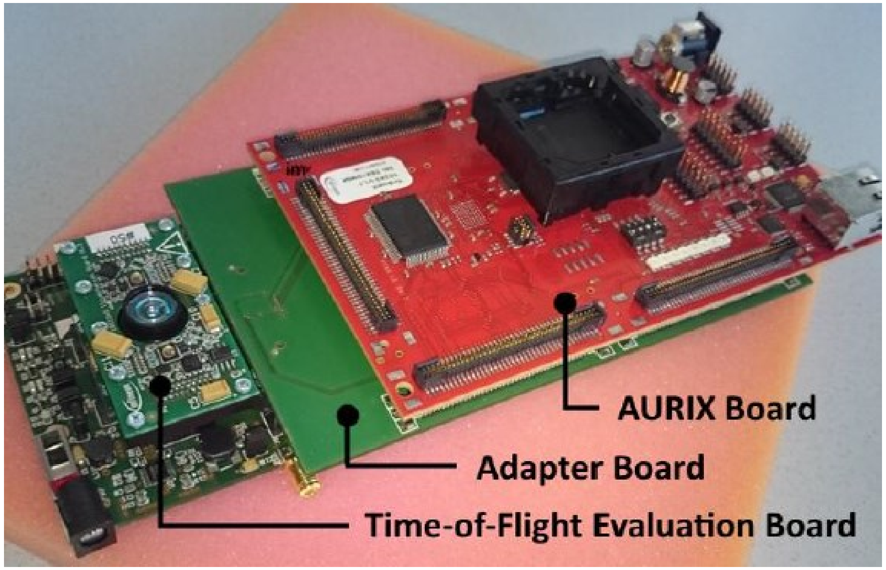
Interior Monitoring

- AURIX TC299 target platform
  - Compliant to ISO 26262, ISO 25119, IEC 61501
  - 32-Bit SoC, 300 MHz, 2728 kBytes SRAM
    - 2048 kBytes global mem
    - up to 240 kByte scratchpad for each CPU
  - Integrates three independent Tri-Cores
  - Each Tri-Core represents a unified RISC/MCU/DSP processor



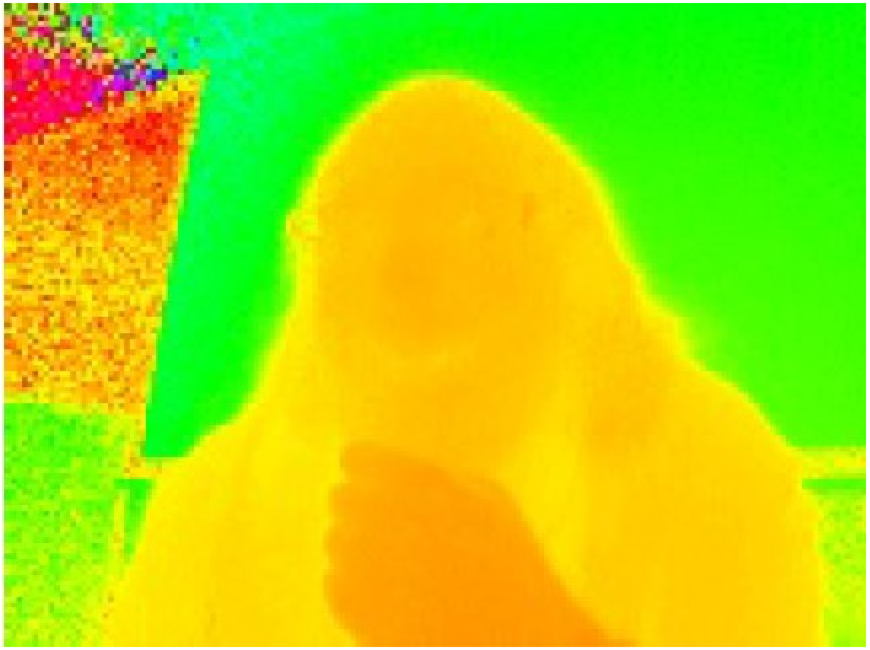
Interior Monitoring





Interior Monitoring

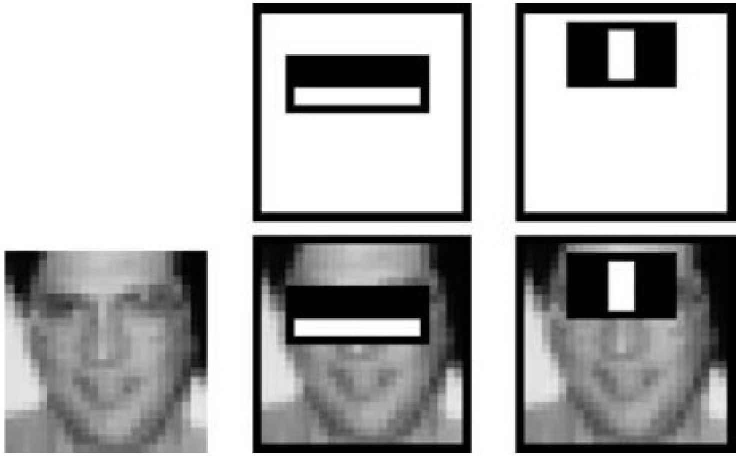
- Step 1: Background removal
  - Reduce the search space for the human detection algorithm
  - Use, e.g., Otsu or simple arithmetic mean to remove background



Interior Monitoring

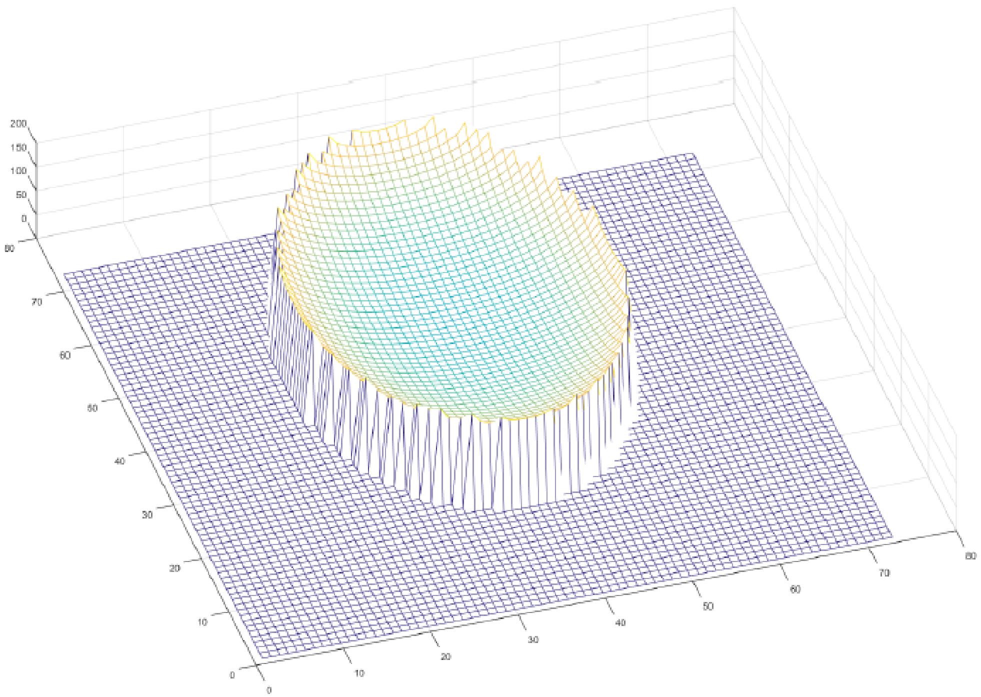
- Step 2: Foreground area checking
  - Check whether the foreground area can contain a head
  - If area is too small -> end calculation with negative result

- Step 3: 3D Haar-like filtering
  - Implement an adapted Viola-Jones algorithm using 3D data
    - E.g., there is likely no object left and right of the head



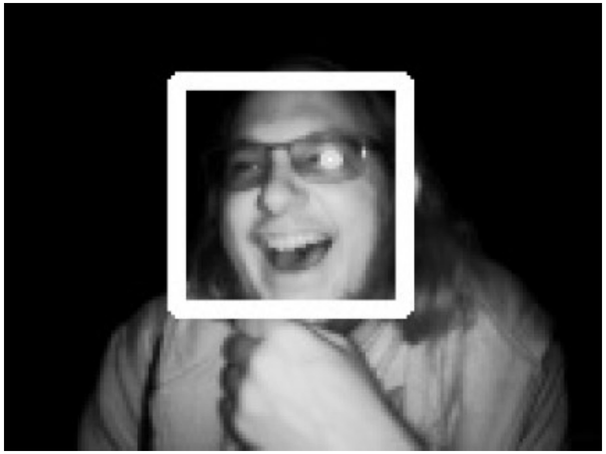
Interior Monitoring

- Step 4: 3D template matching
  - Check whether the 3D region of interest matches a somehow a 3D ellipsoid



Interior Monitoring

- Final Step: Simplified Viola-Jones
  - Use a reduced cascade of classifiers to detect a face in the ROI of the amplitude image

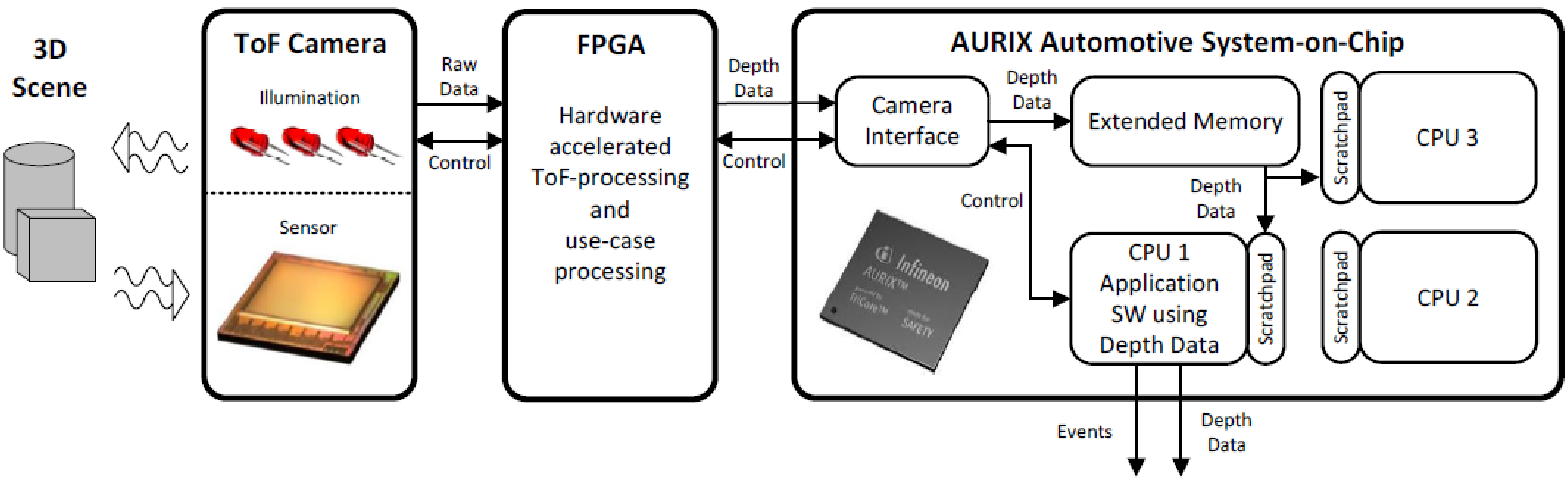


- Results:
  - Total memory consumption: 211 kB
    - Fits into AURIX's local scratchpad memory -> **runs isolated!!**
  - Detection rate: 1-2 FPS (data dependency), >80%
  - False positives <5%

Interior Monitoring

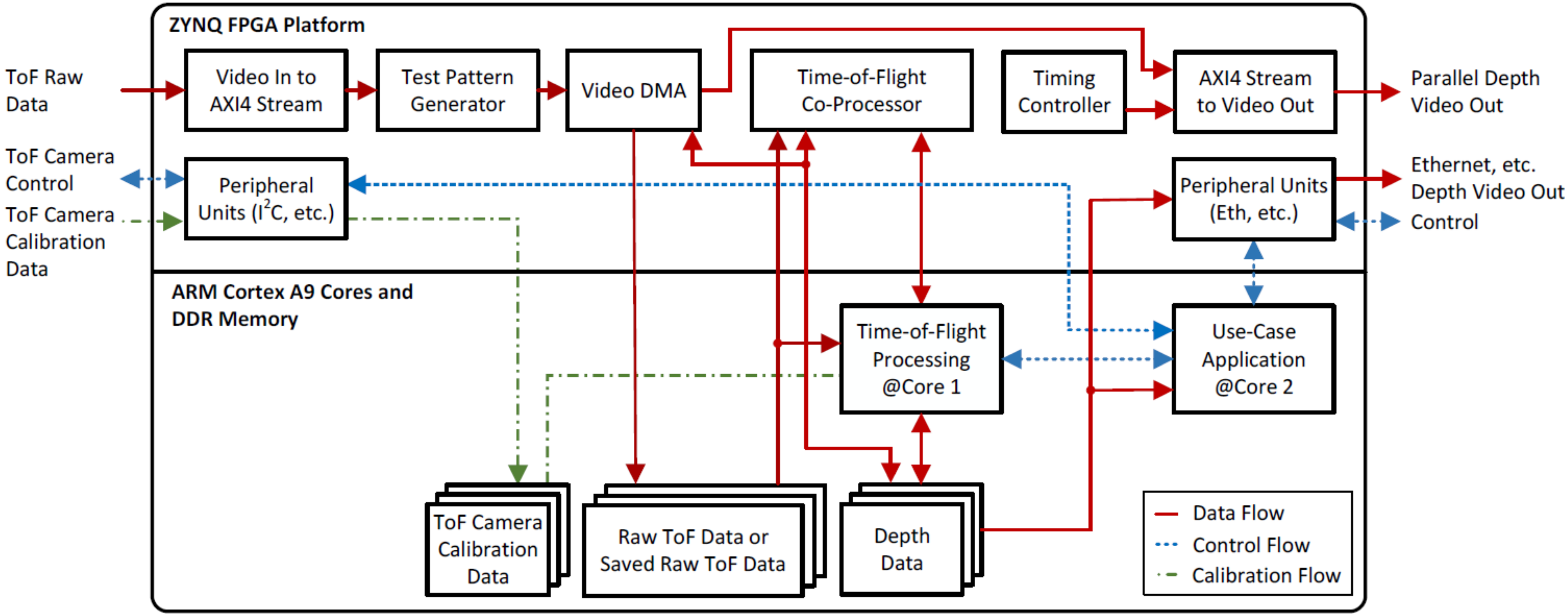
- Comparison with OpenCV?
- Does our approach bring any benefits at all?

- 2nd generation system design



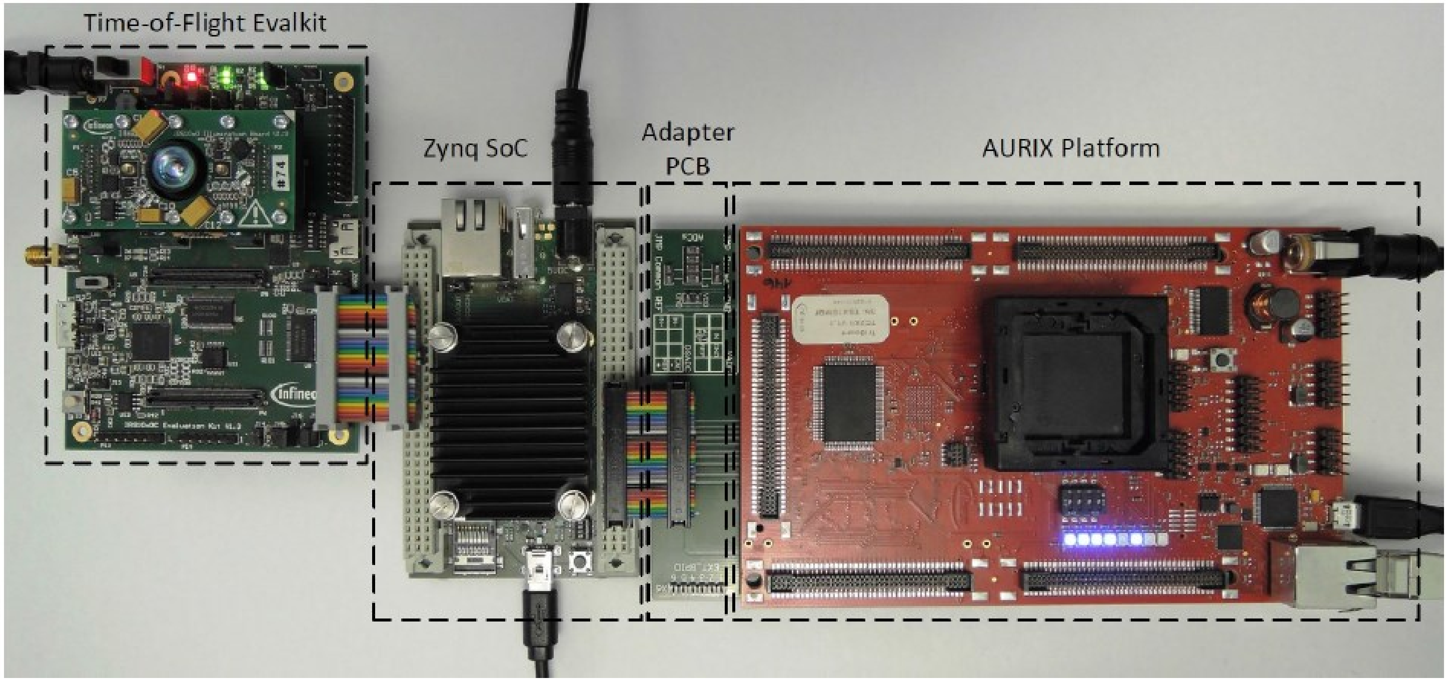
Interior Monitoring

- Xilinx Zynq: asymmetric multi-processing platform
  - Core 1: Time-of-Flight processing
  - Core 2: Linux and interior monitoring use-case application



Interior Monitoring

- Results:
  - OpenCV standard Viola-Jones face detection
  - Without any Time-of-Flight preprocessing: **~507 ms**
  - With Time-of-Flight preprocessing: **~277 ms**



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Outlook and Conclusion

- Implemented two prototypes for interior monitoring
- Enables new use-cases for assisted and automated driving
  - E.g., drowsiness detection, passenger-based payment and car-pooling

- **Time-of-Flight 3D imaging** can drastically **improve computer vision** algorithms

- Outlook
  - Together with Kostal we are developing an automotive-qualified driver monitoring system based on Time-of-Flight 3D imaging

Part of your life. Part of tomorrow.