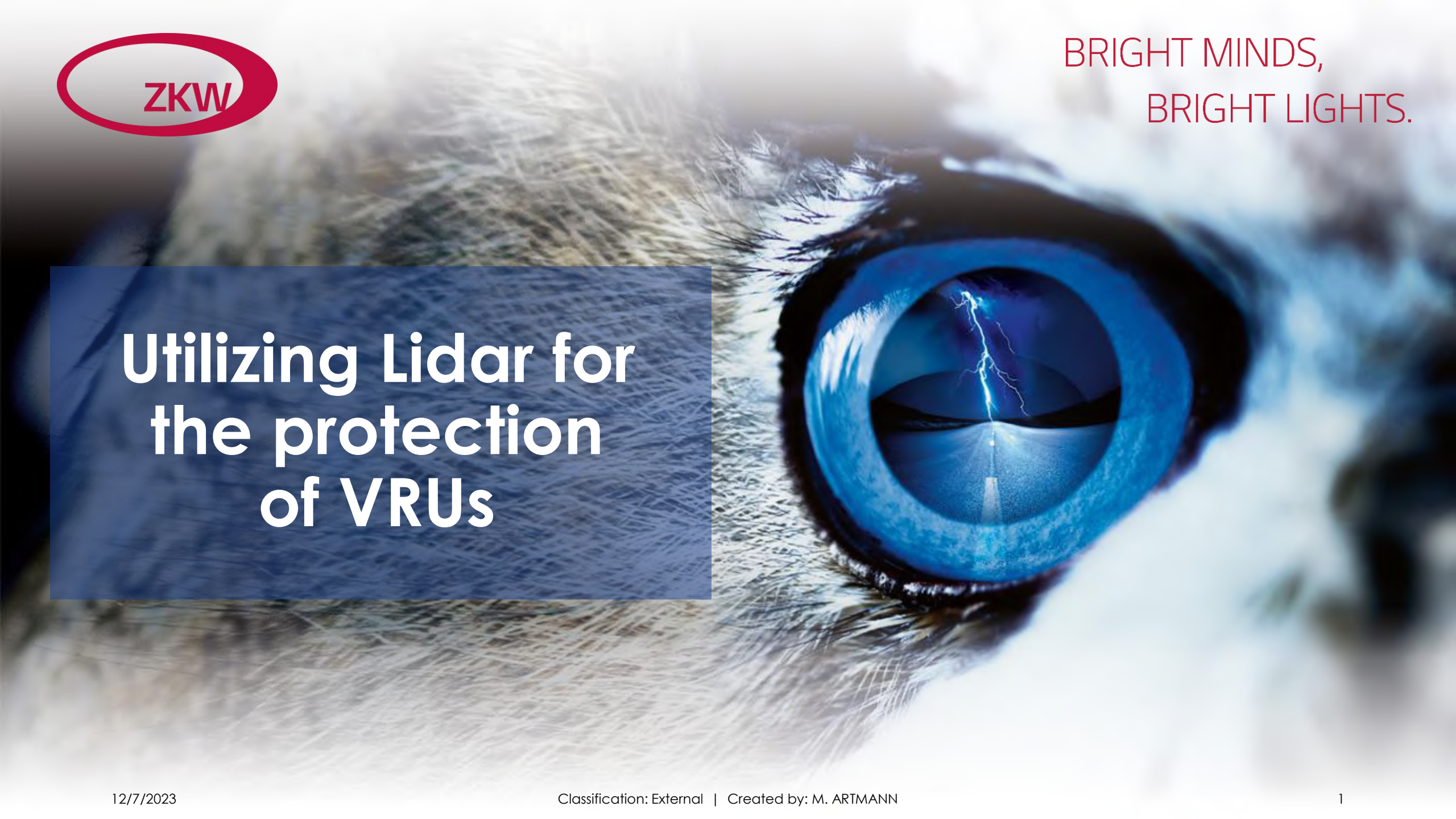
ZKW

BRIGHT MINDS,
BRIGHT LIGHTS.

Utilizing Lidar for the protection of VRUs



SmartProtect

- FFG: The Austrian Research Promotion Agency (FFG) is the national funding agency for industrial research and development in Austria

FFG Promoting Innovation.

Federal Ministry
Republic of Austria
Climate Action, Environment,
Energy, Mobility,
Innovation and Technology

- Started 2020, ended 06/2023

- Consortium:

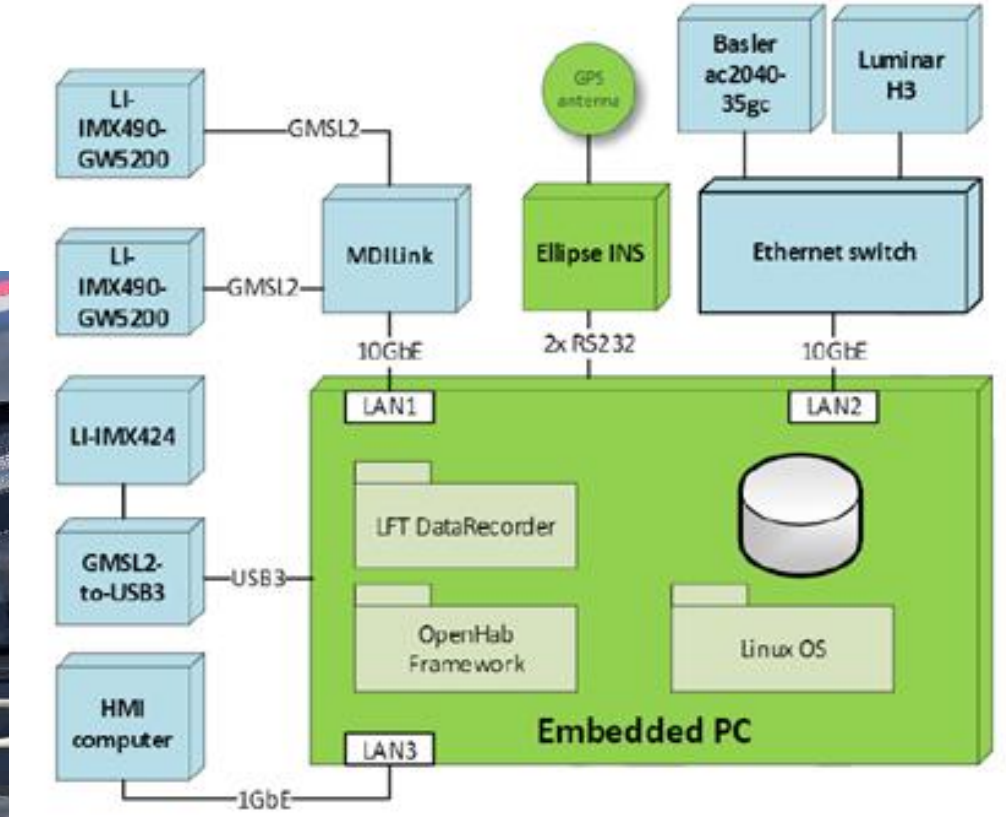
TU WIEN TECHNISCHE UNIVERSITÄT WIEN Vienna University of Technology

EMOTION3D

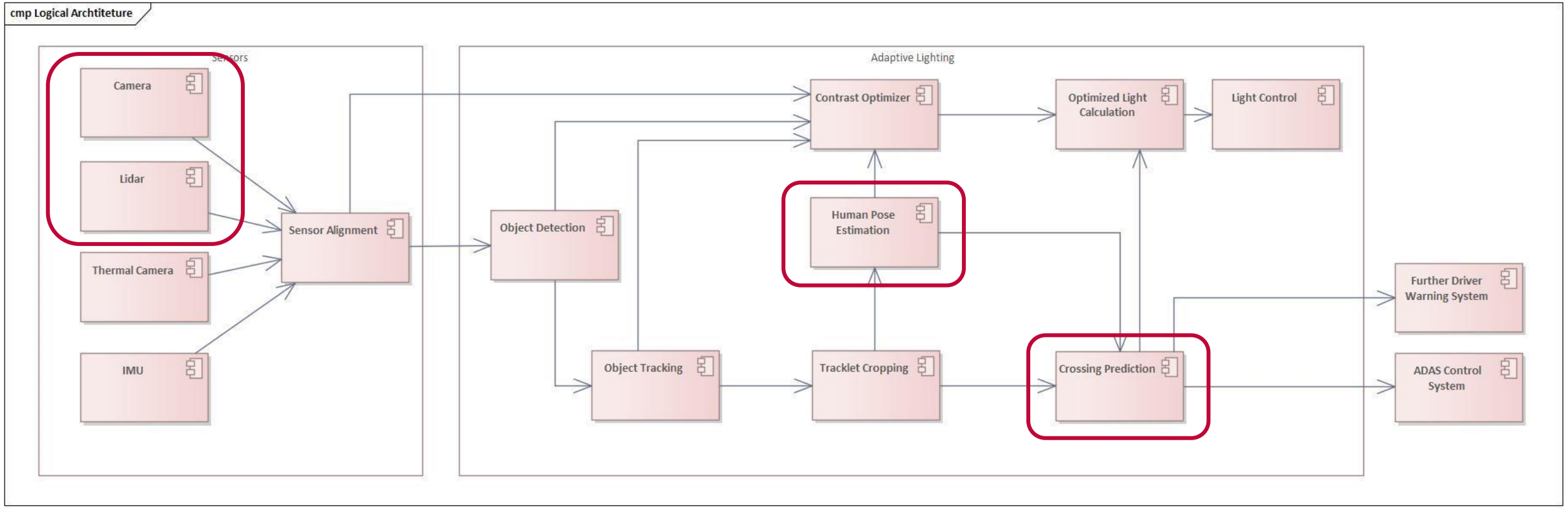
ZKW

- GOAL: Development of a robust sensor system that is capable to predict the behavior of VRUs

Sensor setup



System overview



VRU detection

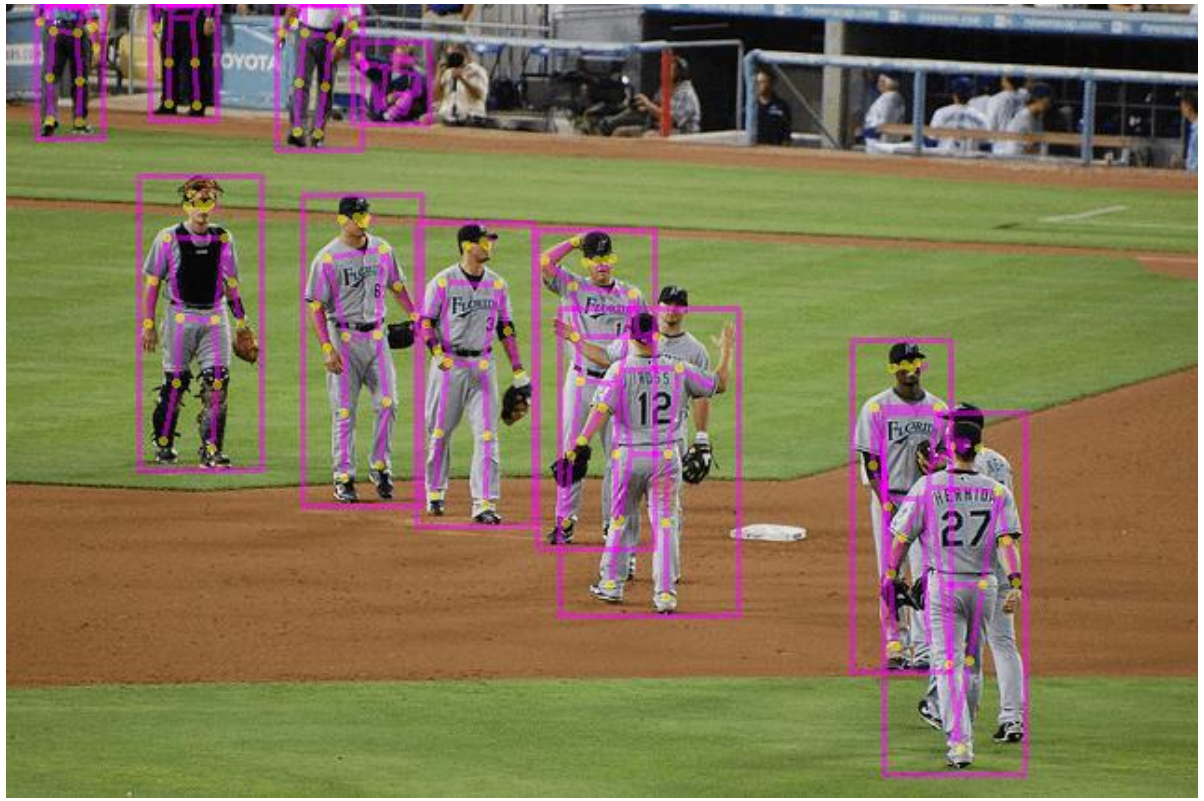
- Detect VRUs
- Predict the intention and possible crossing
- Approach:
  - Fusion of camera and LiDAR data
  - Extract pose and localization
  - Transfer information to intention prediction algorithm

Intention prediction principles

- Goals:
  - Develop procedures to analyze and extrapolate the paths of VRUs
  - Develop prediction whether VRU path crosses driving path of ego vehicle (potential hazard)
- Approach
  - Fuse data from different modalities
  - Combine position, size, **pose** and visual representation of VRUs

Pose extraction

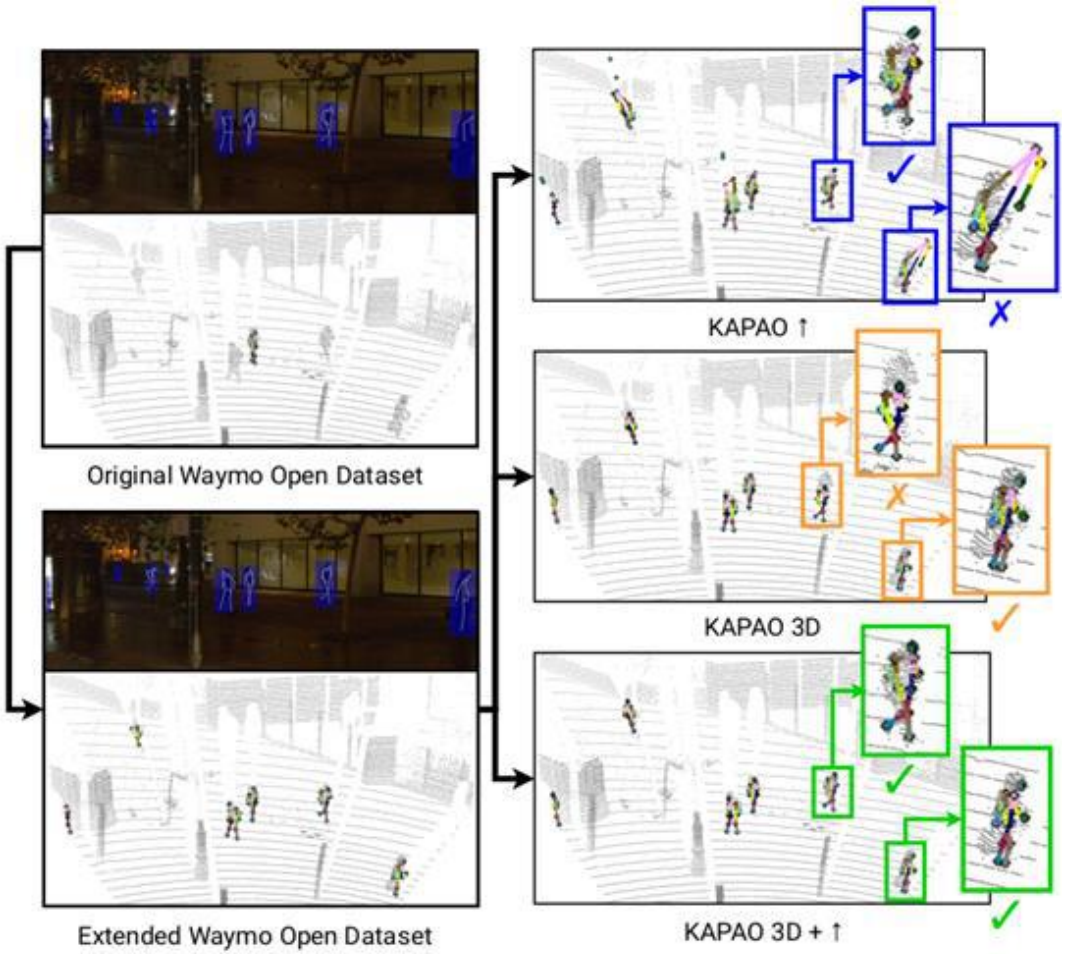
- Basic principle: use a robust 2D pose estimation and extend it to 3D
- Idea: use KAPAO
  - KAPAO = *keypoints and poses as objects*
  - Efficient single-stage multi-person human pose estimation
  - Simultaneous detection of pose objects and keypoint objects, fused to predict human poses



Source: https://github.com/wmcnally/kapao

Pose extraction

- Three approaches to add 3D information
  - **KAPAO Lift (↑):** add depth information from LiDAR (LiDAR Lift)
  - **KAPAO 3D:** estimate depth directly from images
  - **KAPAO 3D+Lift(↑):** use LiDAR Lift to correct depth estimation from images
- Create 3D dataset to compare performance of each approach
  - Use Waymo open dataset (2D)
  - Extract 3D information and add it to the dataset = extended Waymo open dataset (3D)
- Test each approach against recorded and annotated measurement data
  - Zalazone
  - Digitrans
  - Public road Vienna



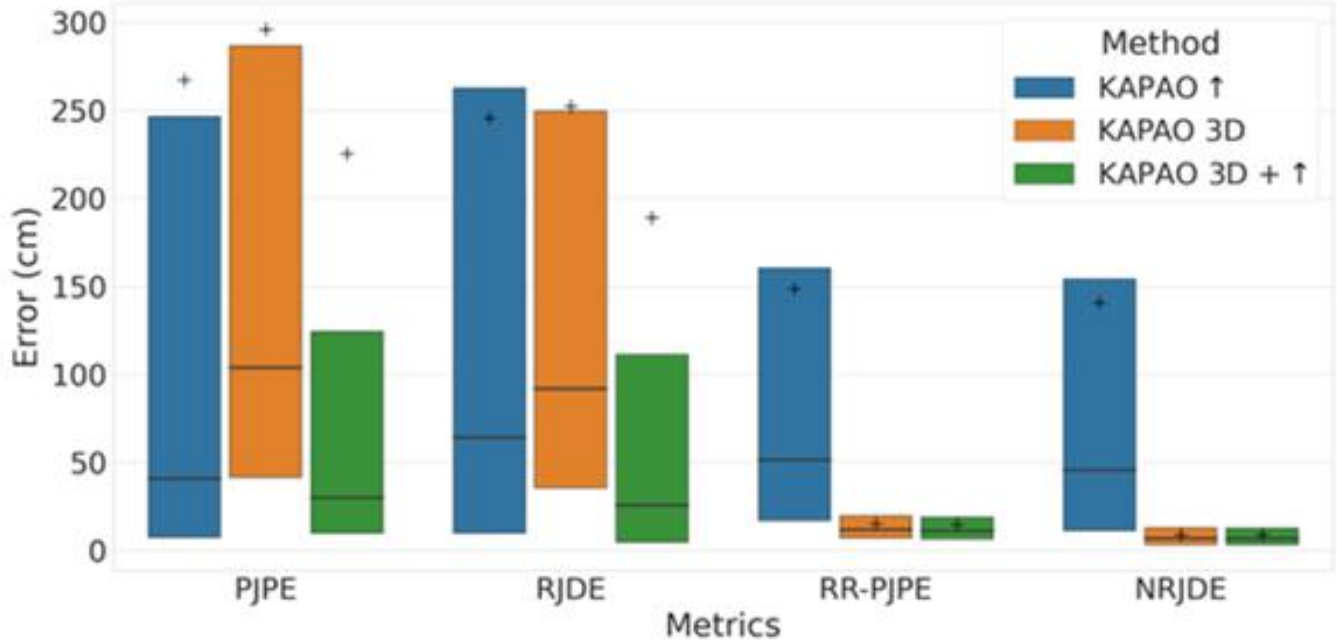
Performance analysis

> Quantitative analysis

- > **Per joint position error**, absolute (PJPE) and relative against root (RR-PJPE)
- > **Joint depth error**, absolute (RJDE) and relative against root (NRJDE)

> Summary

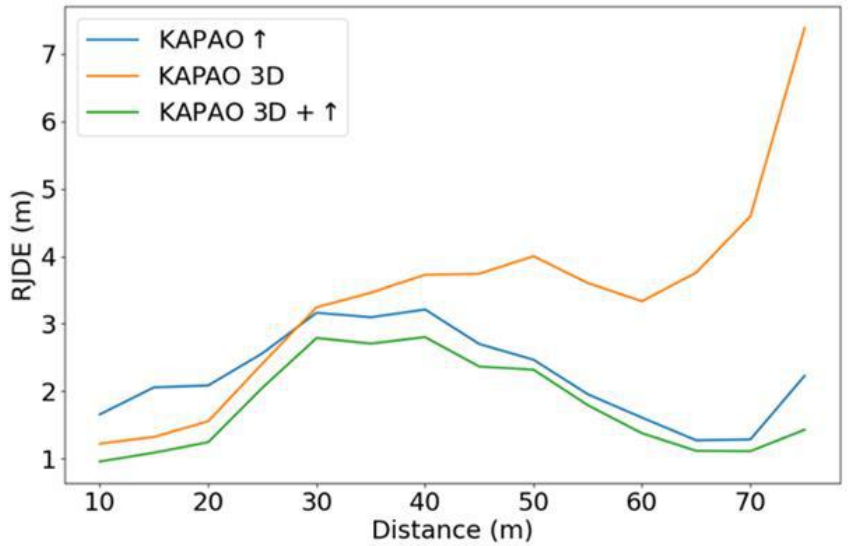
- > Absolute errors lower with LiDAR data
- > Relative position errors better with camera



Performance analysis

> Quantitative analysis, part 2

- > Evaluate each metric over distance between sensor and person



Example: absolute depth error (RJDE) over distance

> Summary

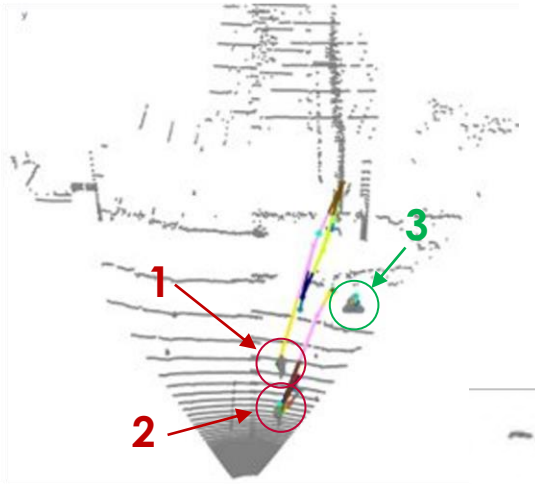
- > Accuracy of camera decreases over distance
- > Lidar produces better results at higher distances
- > **KAPAO 3D + Lift delivers satisfying performance**

Performance analysis

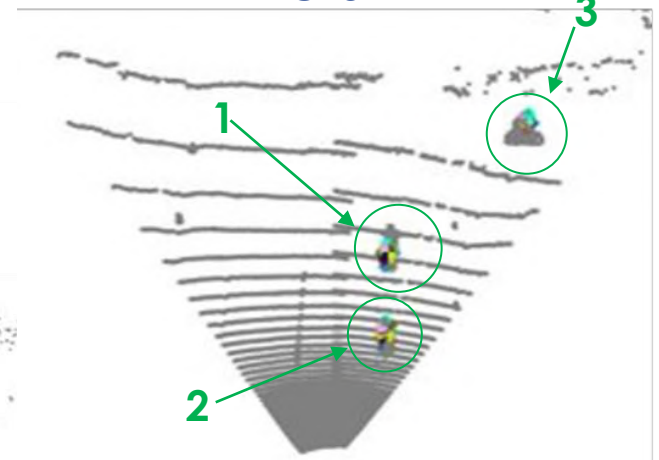
> Qualitative analysis
  > Take measurement data and process them through KAPAO 3D + Lift

> Digitrans data
  > Reference image at daytime

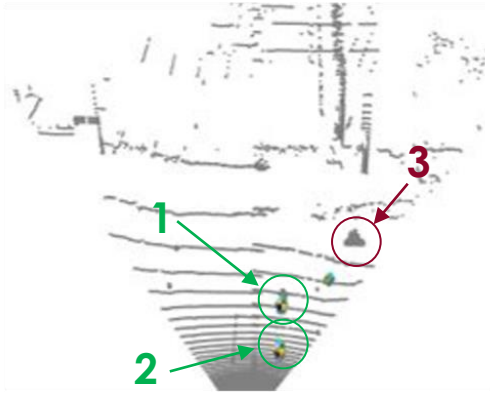
KAPAO Lift



KAPAO 3D + Lift

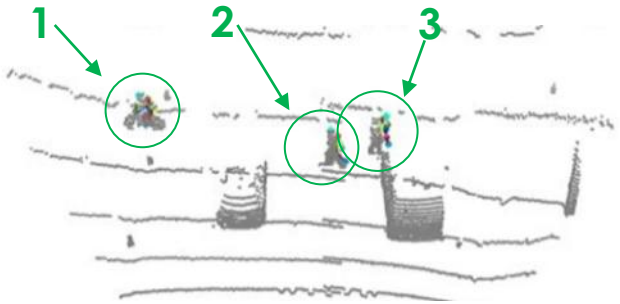


KAPAO 3D



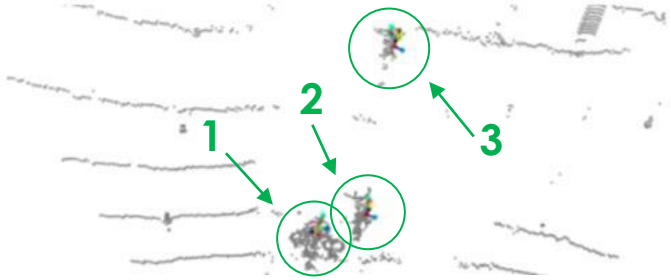
Performance analysis

- Digitrans data
  - Reference image at night-time



KAPAO 3D + Lift

  - Night-time + rain



KAPAO 3D + Lift

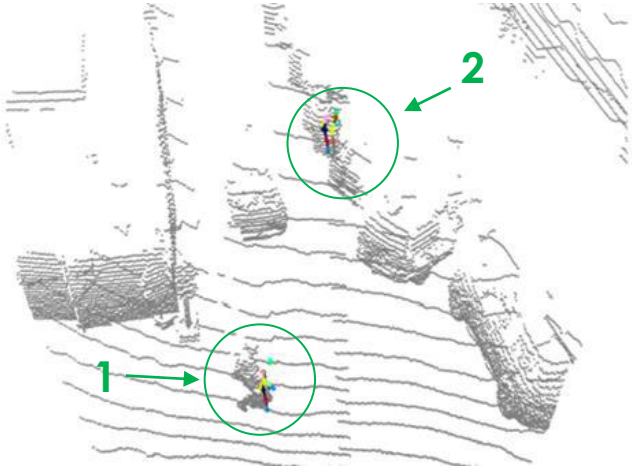
Performance analysis

> Zalazone data

KAPAO 3D + Lift

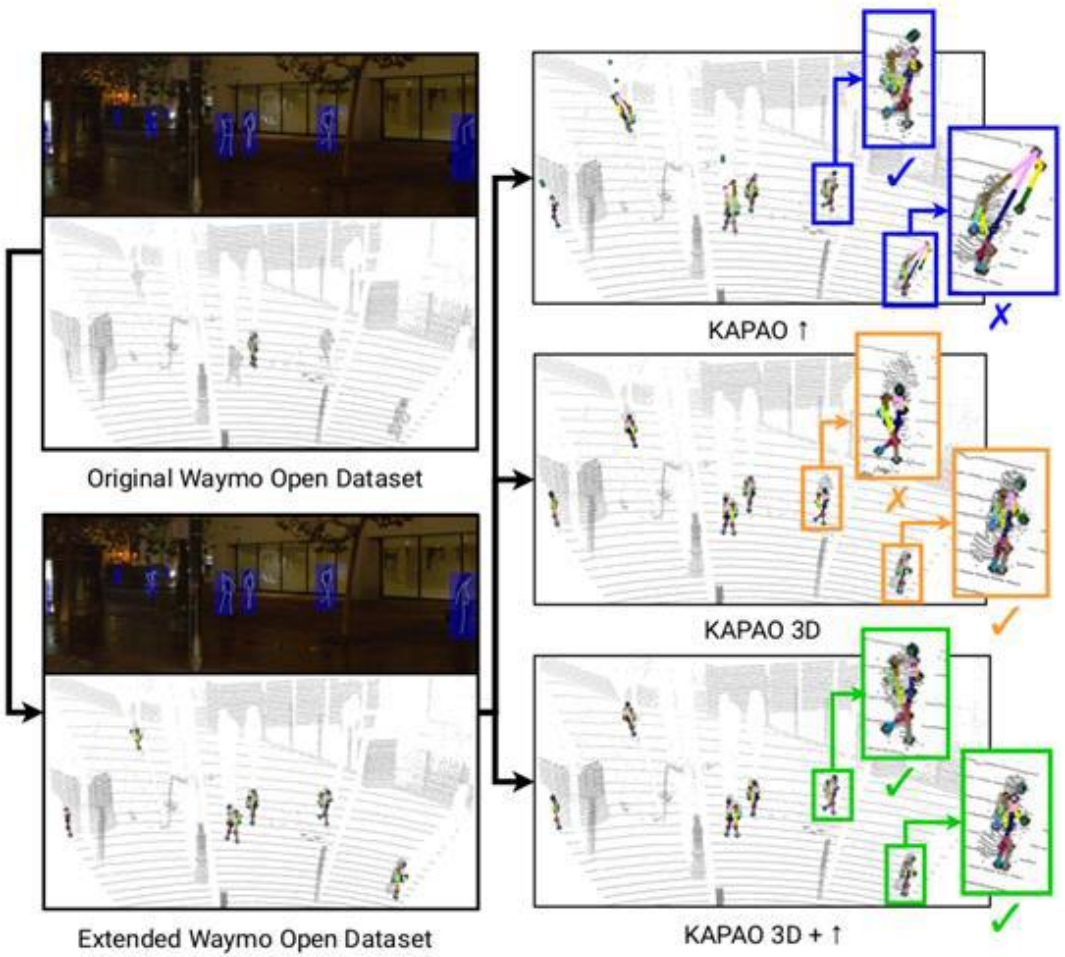
> Vienna data

KAPAO 3D + Lift



Summary of performance analysis

- Fused data from cameras and LiDAR
- Processed by “KAPAO 3D + Lift” approach
- Increases detection accuracy while neglecting unplausible results
- Robust foundation for intention prediction



Final comment on Lidar utilization

- **Combining LiDAR with camera**(s) gives a **significant improvement** of **pose interpretation** compared to camera-only
- **Realtime execution possible** on embedded hardware architectures with **trade-off** between **performance and necessary resolution**
- Further improvement by light support in dark / unlit environment

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THANK YOU