ROSCon DE '23 KARLSRUHE

AWARD
Scaling autonomous logistics

FFG
Forschung wirkt.

AIT AUSTRIAN INSTITUTE OF TECHNOLOGY
TOMORROW TODAY

ROS 2 AS BACKBONE FOR AUTONOMOUS OUTDOOR FORKLIFT OPERATIONS

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AUSTRIAN INSTITUTE OF TECHNOLOGY
Research & Technology Organisation
Research questions
Solutions
Science / Research
Business / Industry

AIT Austrian Institute of Technology

Ownership

49 %

INDUSTRIELLEN VEREINIGUNG

51 %

Bundesministerium
Klimaschutz, Umwelt,
Energie, Mobilität,
Innovation und Technologie

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AUSTRIAN INSTITUTE OF TECHNOLOGY

- Energy
- Health & Bioresources
- Digital Safety & Security
- Vision, Automation & Control
- Low-Emission Transport
- Technology Experience
- Innovation Systems & Policy

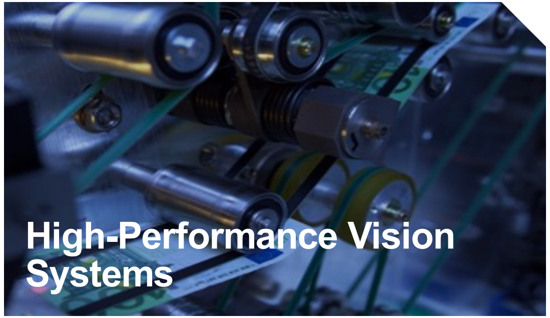
- Seibersdorf Labor GmbH
- Nuclear Engineering Seibersdorf GmbH

1.400
Employees

183 M€
Total Revenues as of Y 2022

OUR CENTER

Center for Vision, Automation & Control



MOTIVATION FOR AUTOMATION IN LOGISTICS

- Labour shortage
- Efficiency and productivity
- Safety and risk reduction
- Cost savings
- Intralogistics vs. outdoor environments

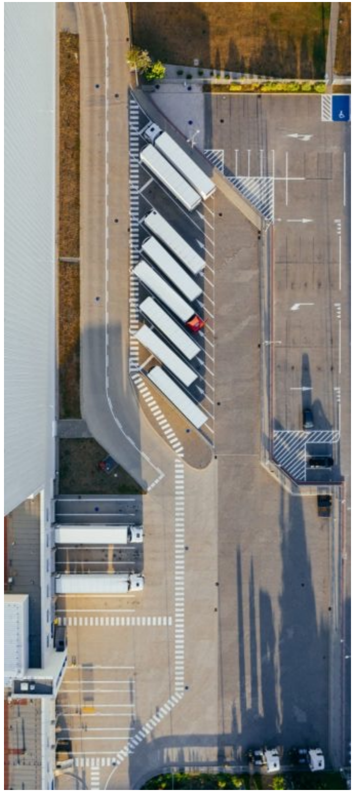


Foto: Pixabay - marcinjozwiak

PALFINGER CRAYLER BM 214

- Remotely controlled forklift
- Motivation for this vehicle
    - Outdoor capability
    - Robust construction
- Hydraulic system
    - steering
    - bending
    - mast actuation
    - driving the wheels

PROBLEM STATEMENT: TECHNICAL POINT OF VIEW

Hardware & Sensor Integration

- Power supply, processing hardware, …
- Proprioception: Wheel speed, hydraulic pressure, …
- Exteroception: LiDAR, cameras, ultrasonic, …

Control Systems

- Modelling & controlling the system ensuring stability and safety

Navigation and Mapping

- Efficient mapping and navigation solutions for partly unknown environments

Obstacle Detection and Avoidance

- Development of robust obstacle detection algorithms
- Ensure safe navigation in dynamic environments

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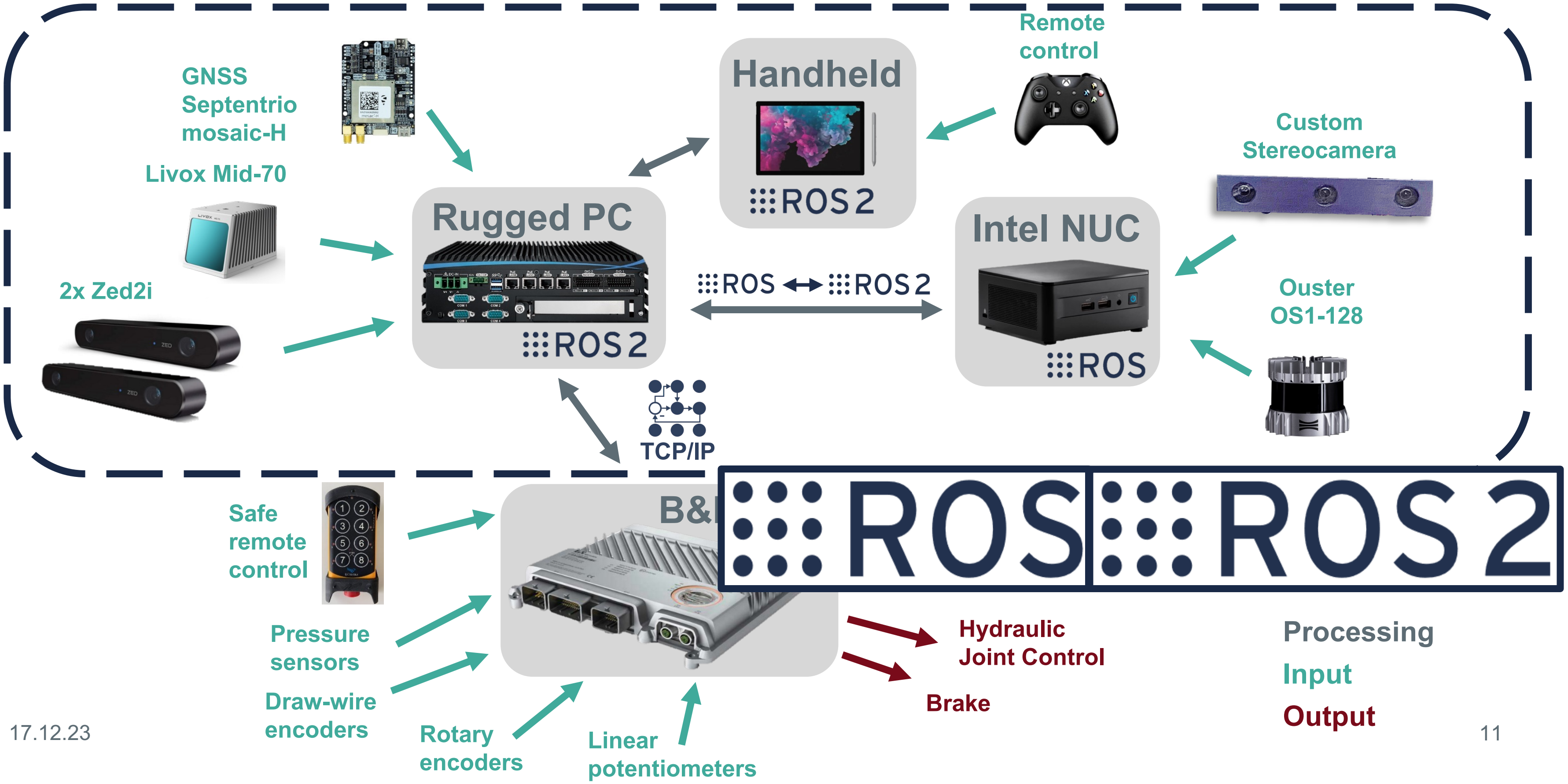
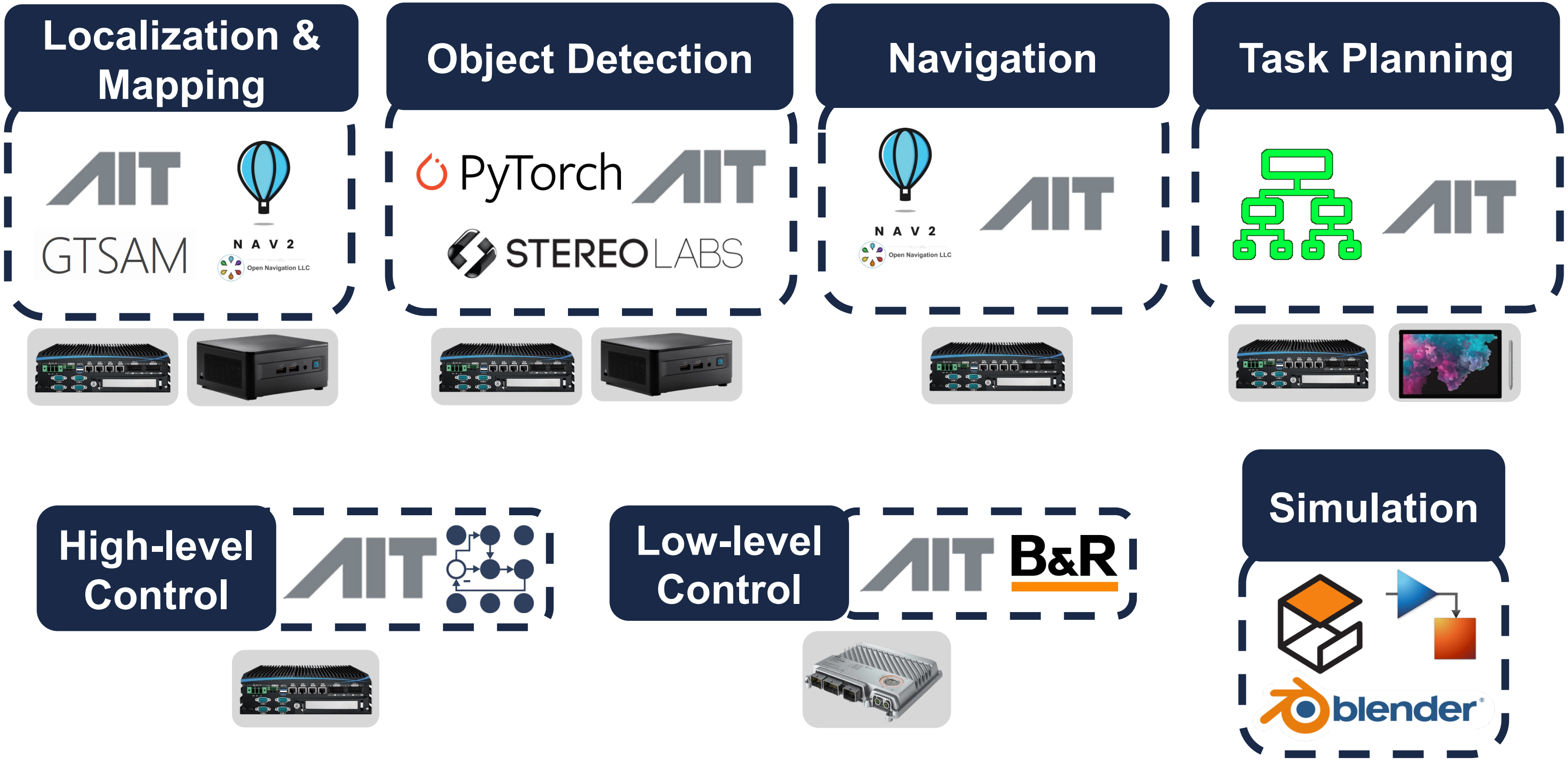
HARDWARE ARCHITECTURE



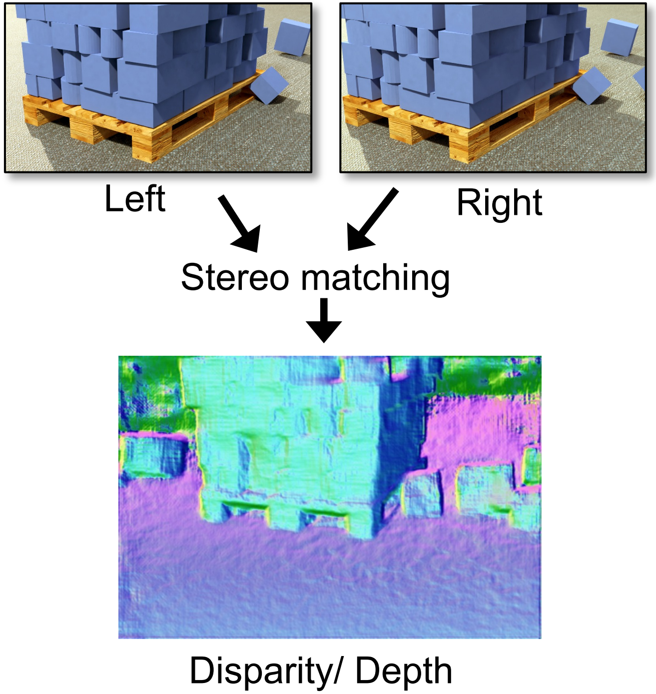
SOFTWARE ARCHITECTURE



AI-BASED OBJECT DETECTION

Objects of interest: Pallets (EPAL)

Feature extraction



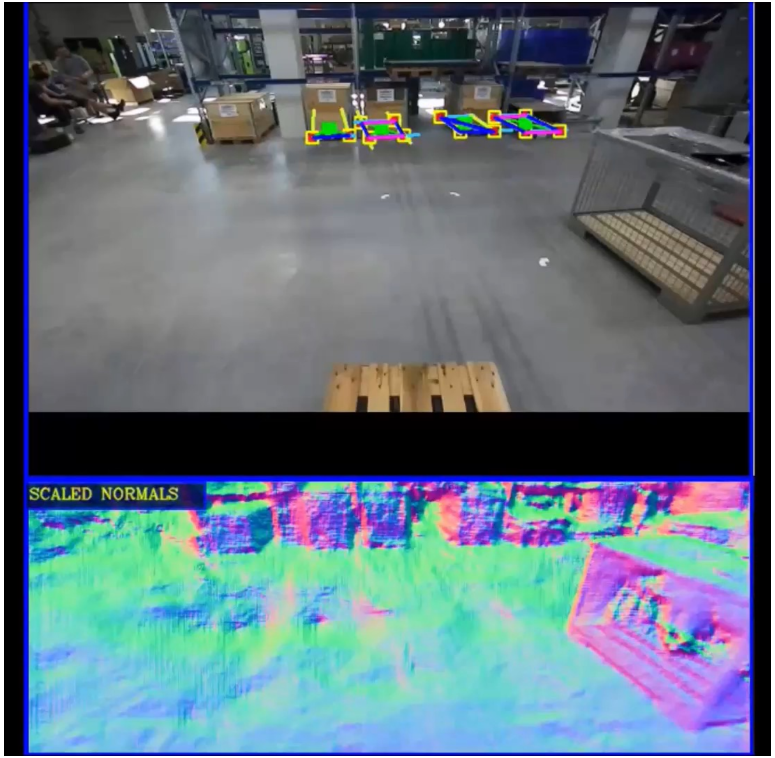
C. Beleznai, et. al, "Automated pallet handling via occlusion-robust recognition learned from synthetic data," *2023 IEEE Conference on Artificial Intelligence (CAI)*, Santa Clara, CA, USA, 2023, pp. 74-75, doi: 10.1109/CAI54212.2023.00039.

AI-BASED OBJECT DETECTION

Training on synthetic data blender

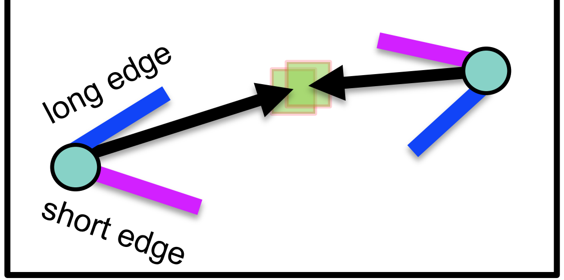
AI-BASED OBJECT DETECTION

Detection results



Input representation

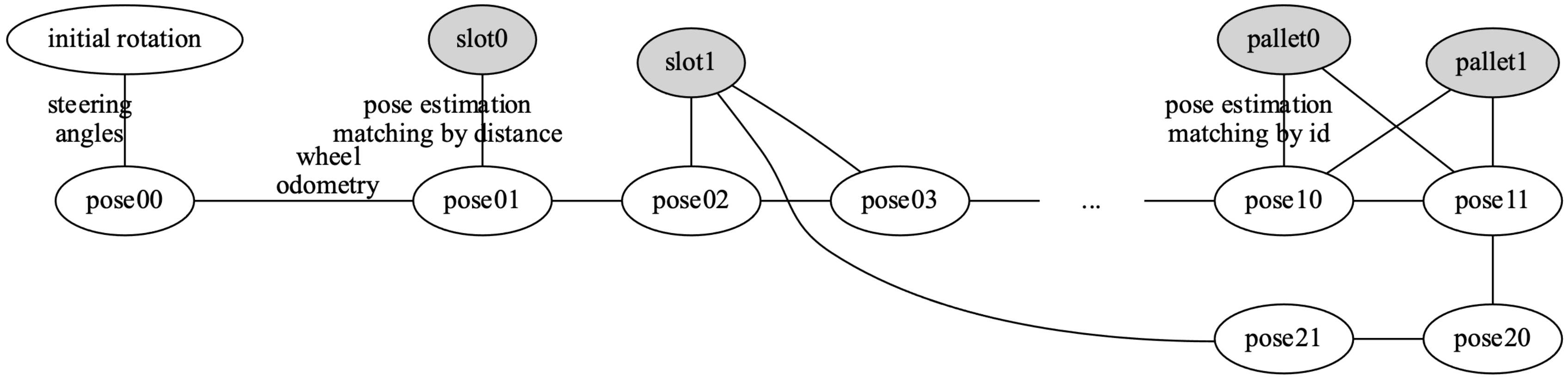
PART-BASED VOTING



FACTOR GRAPH BASED LOCALIZATION GTSAM

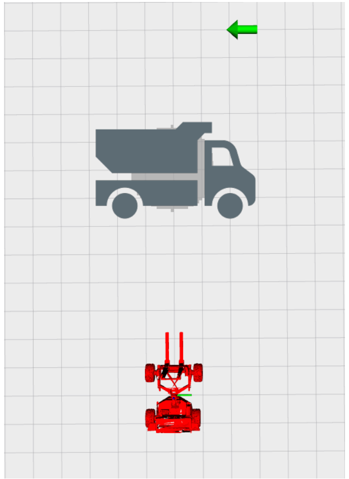
Fusing measurements

- Wheel odometry, GNSS positions
- Pallet + Slot detections

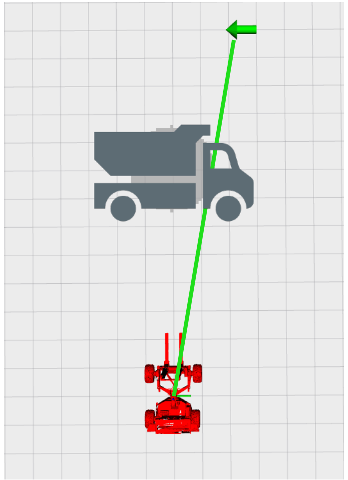


NAVIGATION

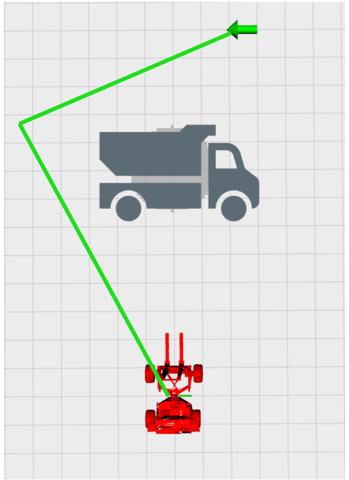
Initial situation



Unsafe



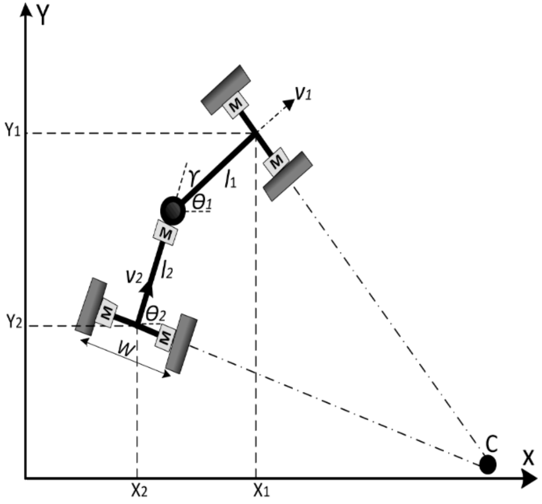
Safe, Infeasible



Vehicle kinematics

VEHICLE KINEMATICS

Modelling the articulated vehicle



Source: Nayl, Thaker (2013).

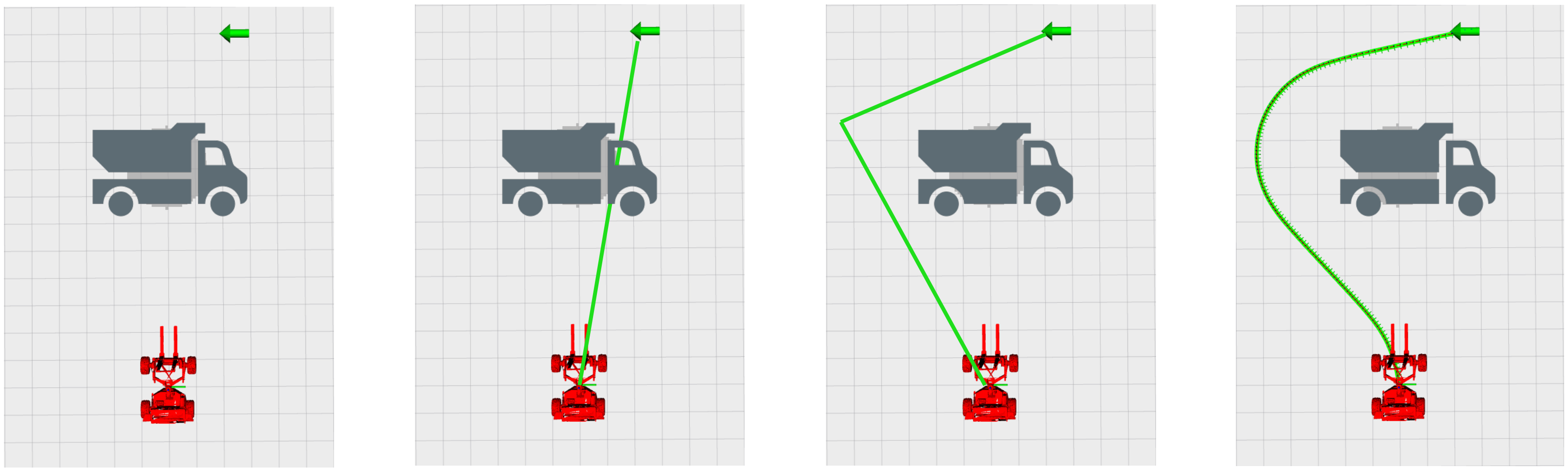
Kinematic model:

$$\begin{pmatrix} \dot{x}_1 \\ \dot{y}_1 \\ \dot{\Theta}_1 \\ \dot{\gamma} \end{pmatrix} = \begin{pmatrix} \cos\Theta_1 & 0 \\ \sin\Theta_1 & 0 \\ \dfrac{\sin\gamma}{l_1\cos\gamma + l_2} & \dfrac{l_2}{l_1 \sin\gamma + l_2} \\ 0 & 1 \end{pmatrix} \begin{pmatrix} v_1 \\ \dot{\gamma} \end{pmatrix}$$

v_1 ... velocity of front axle
$\dot{\gamma}$ ... steering rate
$x_1,\ y_1,\ \Theta_1$ ... vehicle front axle coordinates
l_1, l_2 ... center-to-axle lengths

NAVIGATION

Initial situation | Unsafe | Safe, Infeasible | Safe, Feasible



→

Vehicle kinematics

PATH PLANNING

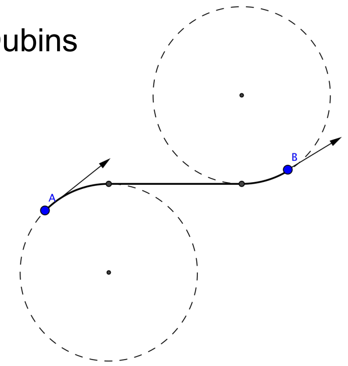
Concept:

- Two dimensional path planning using Hybrid A*
- Combination of A* and Dubins/Reeds-Shepp curves

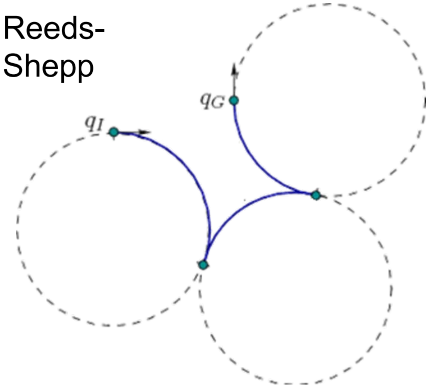
- Dubins:
    - Shortest curve that connects two poses (x, y, θ)
    - Constrained by path curvature
    - Single direction driving

- Reeds-Shepp:
    - Extension of Dubins with reversing

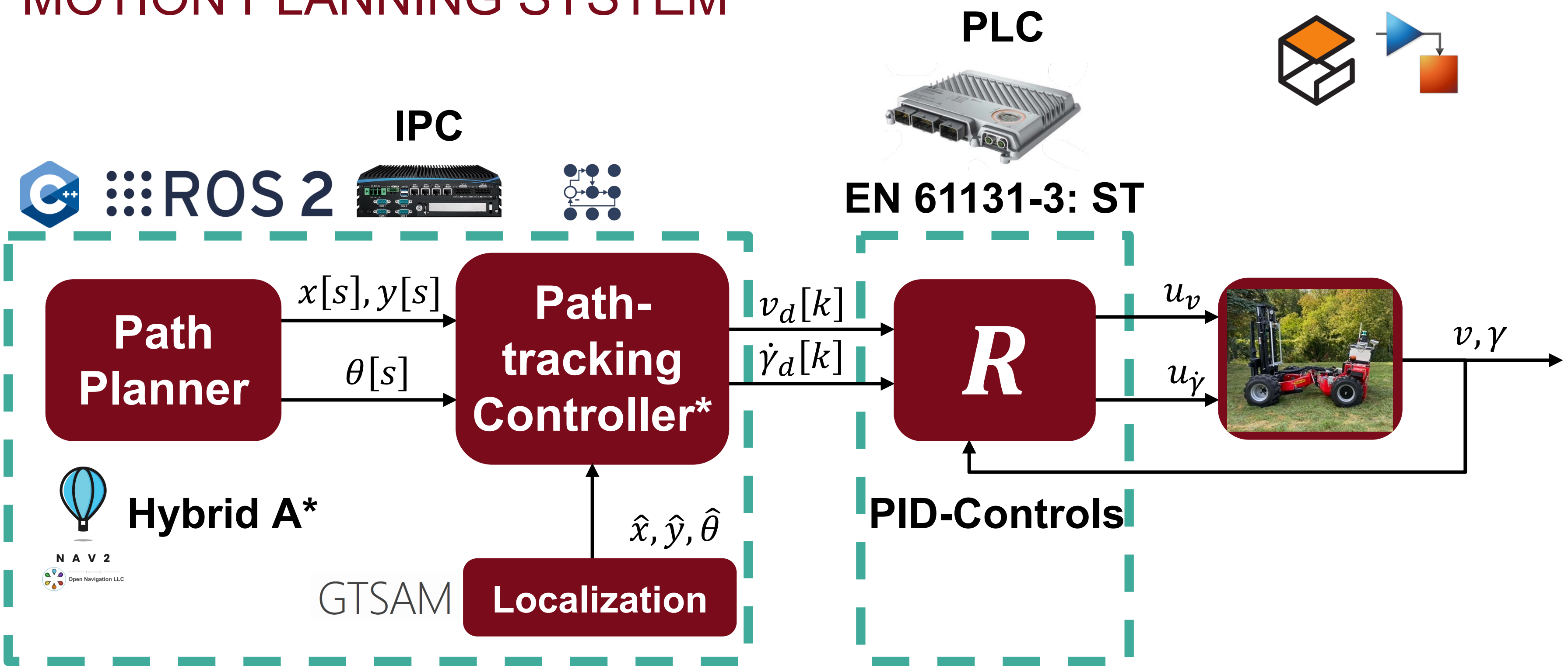
Dubins



Reeds-Shepp

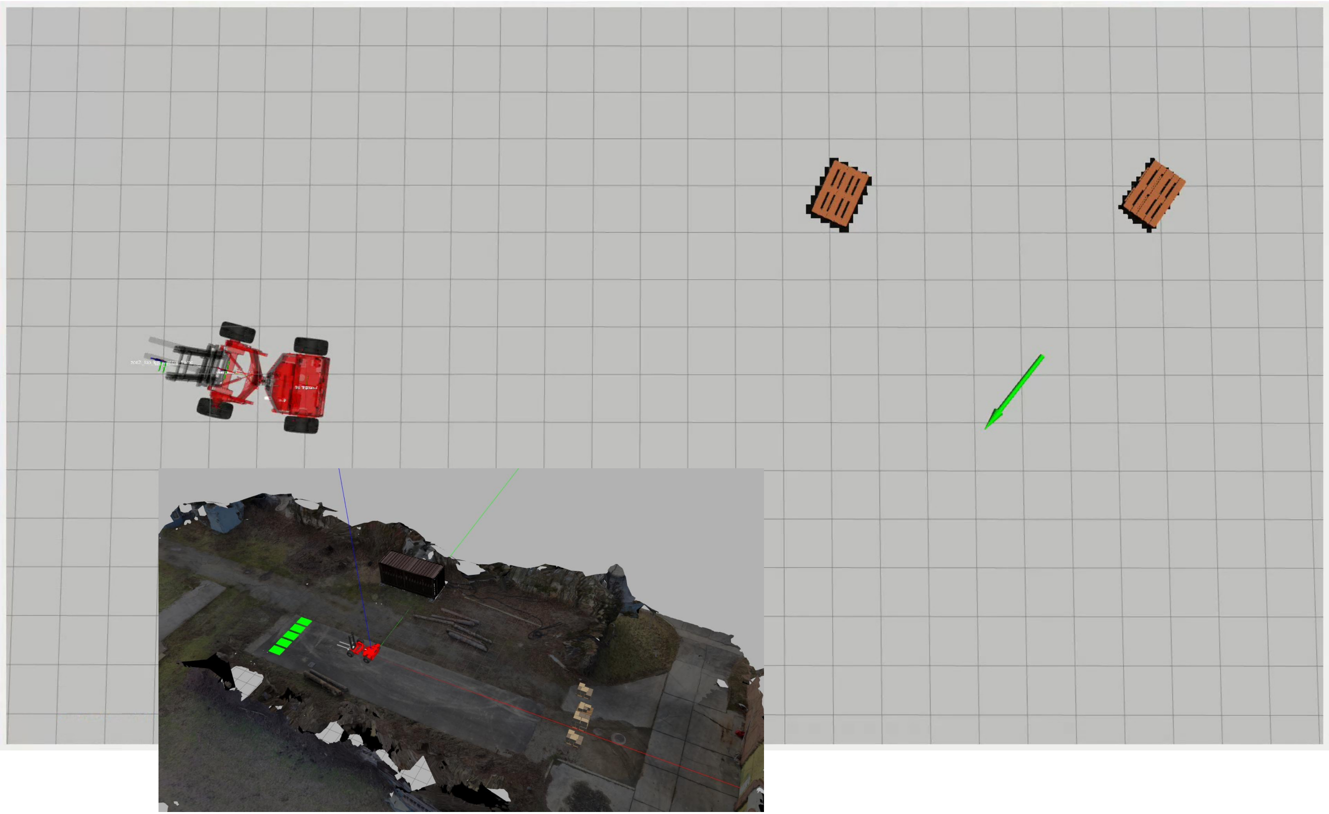


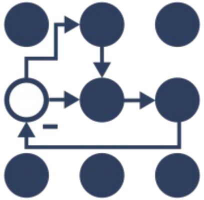
MOTION PLANNING SYSTEM



* Bian, Y., Yang, M., Fang, X. et al, "Kinematics and Path Following Control of an Articulated Drum Roller," 2017 Chin. J. Mech. Eng. 30, pp. 888–899. https://doi.org/10.1007/s10033-017-0102-8

DIGITAL TWIN AND SIMULATION





NAV2

Open Navigation LLC

Hybrid A*

PROTOTYPE TESTING AND VERFICATION

POSSIBLE CONTRIBUTIONS
AIT + ROS 2 SUMMARY

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Summary

- ROS 2 is great as common language for roboticists with different background

Possible Contributions for ROS 2 community

- TCP/IP-based hardware component for **ros2_control**
- Articulated vehicle path-tracking controller as **ros2_controller**
- **nav2_costmap_2d::CostmapLayer** plugin, which adds polygons from ROS messages

Reach Out

- Large-Scale Robotics Lab
- AIT as cooperation partner for co-funded projects (Horizon Europe, national programs, …)

PROJECT TEAM

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TOMORROW TODAY

AWARD
Scaling autonomous logistics

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UNIVERSITY OF APPLIED SCIENCES UPPER AUSTRIA

INDUSTRIE-LOGISTIK-LINZ

FFG
Forschung wirkt.

PALFINGER