Semantic Perception for Safe Long-Term Operation of Robots for Intralogistics Applications

ERF Workshop
"Robotics for Logistics and Transport"
Perception for Safe Operation of Robots in Logistics

ERF Workshop
"Robotics for Logistics and Transport"
Mobile Robots for Logistics
2. Robotics for Logistics

- Mining (e.g., Atlas-Copco)
- Construction (e.g., Volvo CE)
- Logistics (e.g., Kollmorgen)

- Robots for flexible and efficient transport systems
Robots for Logistics

- Mining (e.g., Atlas-Copco)
- Construction (e.g., Volvo CE)
- Logistics (e.g., Kollmorgen)

Robots for flexible and efficient transport systems ... also in hospitals, supermarkets, etc.
Robotics for Logistics – Open Problems

○ Autonomous Industrial Vehicles: Where we are and what is missing.

  » Core requirements that point to shortcomings in SoA
     (distilled from experience in collaboration with several industrial partners)
2. Robotics for Logistics – Open Problems

- Deployment
  - Dep1: Avoid the need to hand-craft AGV paths for each new setting
  - Dep2: At least speed profiles should not be fully specified
  - Dep3: AGV system should avoid deadlocks automatically
  - Dep4: Perceptual functions should not rely on additional infrastructure
Robotics for Logistics – Open Problems

- Deployment
  - **Dep4**: Perceptual functions should not rely on additional infrastructure
  - Highly accurate localization against a map of the environment
    - standard Monte Carlo localization $\Leftrightarrow$ grid-MCL
    - use NDT map for measurement update instead of occupancy grid map (exploit that NDT is a likelihood model) $\Leftrightarrow$ NDT-MCL
    - compare grid-MCL and NDT-MCL (2D)
Robotics for Logistics – Open Problems

- Deployment
  - **Dep4**: Perceptual functions should not rely on additional infrastructure
  - Highly accurate localization against a map of the environment
    - standard Monte Carlo localization
    - compare grid-MCL and NDT-MCL (2D)
      - absolute error
      - static environment
      - trajectory: 120m
      - grid-MCL = amcl in ROS
Robotics for Logistics – Open Problems

- **Deployment**
  - **Dep4**: Perceptual functions should not rely on additional infrastructure
  - High accurate localization against a map of the environment
    - standard Monte Carlo localization
    - compare grid-MCL and NDT-MCL (2D)
      - absolute error
      - closed loop tests
        - grid map resolution: 0.03m
        - NDT map resolution: 0.5m
NDT-MCL

Normal Distributions Transform Monte Carlo Localization

Jari Saarinen
Henrik Andreasson
Todor Stoyanov
Achim Lilienthal
2. Robotics for Logistics – Open Problems

- Deployment
  - **Dep4**: Perceptual functions should not rely on additional infrastructure
  - Highly accurate localization against a map of the environment
    - standard Monte Carlo localization
    - compare grid-MCL and NDT-MCL (2D)
      - absolute error
      - closed loop tests
        - grid map resolution: 0.03m
        - NDT map resolution: 0.5m
Robotics for Logistics – Open Problems

- Deployment
- Non-holonomic vehicles
  - V1: Automatic trajectory generation for non-holonomic vehicles (even without considering obstacles and coordination)
  - V2: Consideration of challenging mechanical structures (e.g. articulated vehicles, detachable trailers, ...)
  - V3: Payload can change manoeuvring capabilities and dynamics
Robotics for Logistics – Open Problems

- Deployment

- Non-holonomic vehicles
  - \textbf{V1}: Automatic trajectory generation for non-holonomic vehicles (even without considering obstacles and coordination)

→ Highly Accurate Navigation with Non-Holonomic Vehicles

- calculate kinematically drivable paths with lattice-based motion planner for each vehicle
- post-process paths with continuous path smoother \(\rightarrow\) continuous drivable path
- generate trajectories by associating speed profiles consistent with dynamic and coordination constraints
Robotics for Logistics – Open Problems

- Deployment
- Non-holonomic vehicles
- Efficiency and safety
  - **ES1**: Reliable perception at high speeds (up to 30–40 km/h)
  - **ES2**: Generation of collision-free trajectories at high speeds
  - **ES3**: Autonomous vehicles in shared spaces should behave in a way comparable to human-operated vehicles
  - **ES4**: Actions of human drivers should be taken into account
Robotics for Logistics – Open Problems

- Deployment
- Non-holonomic vehicles
- Efficiency and safety
  - **ES1**: Reliable perception at high speeds (up to 30–40 km/h), people detection
  - NIR Flash Camera

![Diagram of NIR Flash Camera components](image-url)

- NIR Camera
- Wide-angle Lens
- Bandpass Filter
- 16 x NIR LEDs

1 Color Camera
For visualization purposes

2 NIR Camera Units
Robotics for Logistics – Open Problems

- NIR Flash Camera

![Image of People Tracking with the Stereo-Flash Camera](image)
People Tracking with the Stereo-Flash Camera
Robotics for Logistics – Open Problems

- Deployment
- Non-holonomic vehicles
- Efficiency and safety
  - **ES1**: Reliable perception at high speeds (up to 30–40 km/h), people detection
  - → Industrial Prototype (RefleX)
Perception for Safe Operation of Robots in Logistics

Prof. Achim J. Lilienthal
contact:
www.aass.oru.se/~lilien
achim.lilienthal@oru.se