Group Meeting

Lightweight Models for Real-Time Applications

Problem Statement

Collision Avoidance in Crowded Environments for AGV

Problem Statement Review

15 minutes

The Challenge

An AGV must operate **safely** in a factory where forklifts, workers, and other robots are constantly moving.

Discussion Points

- Context: factory environment with dynamic obstacles
- Key objectives and success criteria
- Safety requirements and constraints

What is an AGV?

Automated Guided Vehicle

Mobile robots used in industrial facilities to transport materials without human intervention

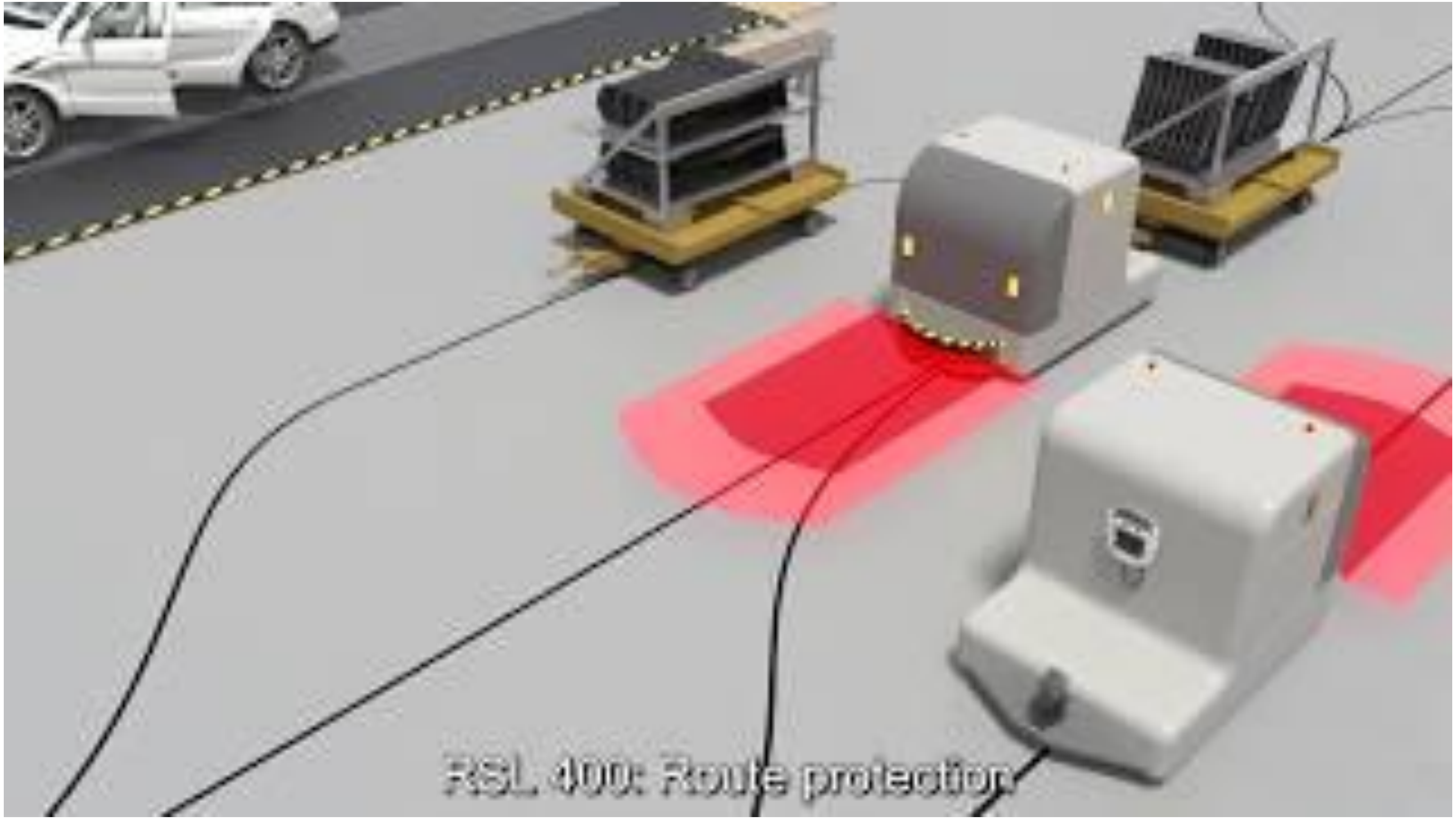
Key Features

- Autonomous navigation
- Load carrying capability
- Safety systems
- Fleet coordination

Applications

- Manufacturing facilities
- Warehouses
- Distribution centers
- Hospitals

What is an AGV?



AGV Navigation Methods

Line Following

- Magnetic strips
- Colored tape
- Inductive wires

Beacon-Based

- Laser reflectors
- RFID tags
- UWB beacons

Natural Navigation

- **LiDAR mapping**
- **Vision systems**
- SLAM algorithms

Natural navigation provides the most flexibility for dynamic environments and is our focus for collision avoidance

AGV Challenges in Crowded Environments

Key Challenges

Dynamic obstacles: Workers, forklifts, and other robots move unpredictably

Real-time response: Decisions must be made in milliseconds

Safety criticality: Human safety is paramount

Occlusion handling: Objects may be temporarily hidden from sensors

Varying speeds: Different entities move at different velocities

Solution requires robust sensor “fusion” + lightweight ML models for real-time prediction

Sensor Fusion for AGVs

Why Multiple Sensors?

Each sensor type has unique strengths and weaknesses. Combining data from multiple sensors provides comprehensive environmental understanding.

Complementary Capabilities

- LiDAR: Accurate 2D distance measurements
- Cameras: Visual recognition and classification
- Ultrasonic: Close-range obstacle detection

LiDAR Sensors

Light Detection and Ranging

Strengths

- High-precision 2D mapping
- Works in various lighting
- Long-range detection
- Fast scanning rates
- Accurate distance measurement

Limitations

- Expensive hardware
- Large data volumes
- Struggles with reflective surfaces
- Limited object classification

LiDAR Sensors

Light Detection and Ranging

Camera Sensors

Vision-Based Perception

Strengths

- Rich visual information
- Object classification
- Color and texture recognition
- Cost-effective
- Human-interpretable data

Limitations

- Lighting dependent
- Depth estimation challenges
- Computationally intensive
- Occlusion problems

Ultrasonic Sensors

Sound-Based Detection

Strengths

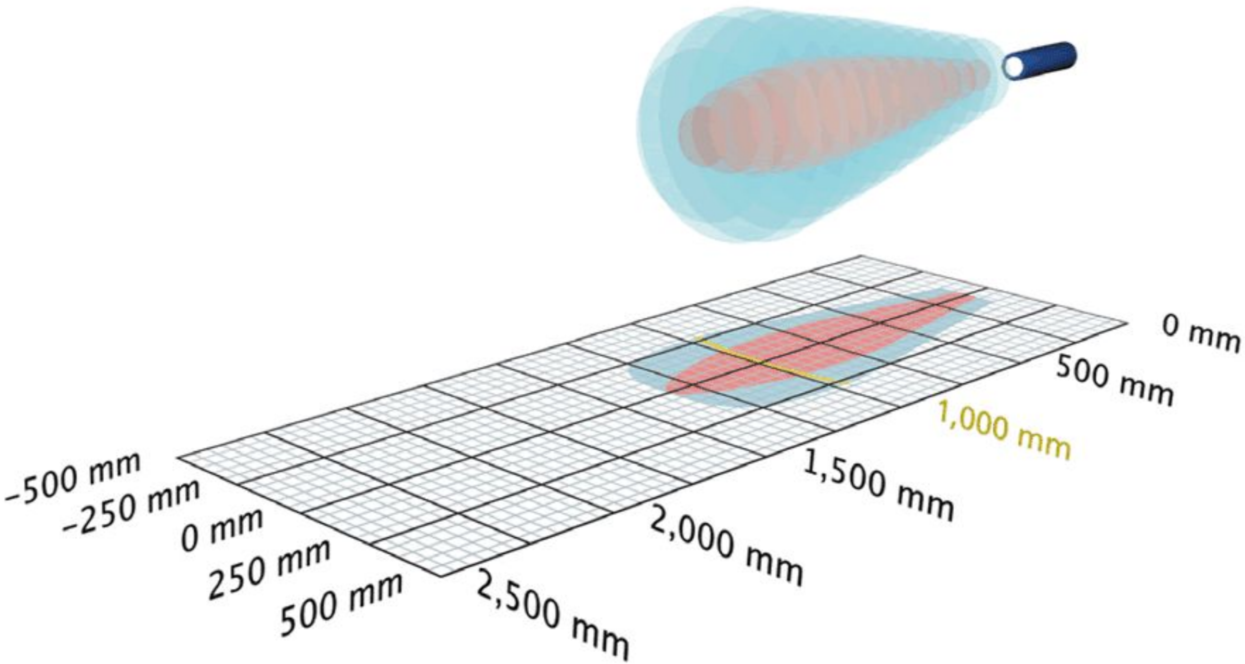
- Very low cost
- Close-range accuracy
- Works in any lighting
- Simple integration
- Detects transparent objects

Limitations

- Limited range (few meters)
- Wide beam angle
- Affected by temperature
- Slow update rate
- No object identification

Ultrasonic Sensors

Sound-Based Detection



Sensor Integration Strategy

Sensor Combination

LiDAR: Primary sensor for environment mapping and precise distance measurement in **(180°)** 360° field of view

Cameras: Object classification and trajectory prediction using computer vision and ML models

Ultrasonic: Safety backup for close-range detection and blind spot coverage

Work Environment & Resources

20 minutes

Technical Infrastructure

- Available hardware (GPUs, computing resources)
- Software tools and frameworks
- Development platforms and version control

Collaboration Tools

- Shared documentation platforms
- Code repository setup
- Data storage and sharing solutions

Timeline & Milestones

15 minutes

Key Dates

07.11.25: Collaborate & Discuss research findings

21.11.25: Propose solutions & discuss data **(initial proof of concept implementation)**

04.12.25: AGV Lab visit & Aiut Company tour **(basic implementation & validation)**

09.01.26: Mid-term presentations & milestone decisions **(full implementation & validation on AGVs)**

23.01.26: Final presentations & results analysis **(prepare a document + publication)**

Plan buffer time for challenges and iterations

Initial Research Plan

20 minutes

Research Topics

- Sensor fusion techniques for multi-modal data
- Real-time object detection models (YOLO, SSD, MobileNet)
- Lightweight model design and optimization
- Path prediction and collision avoidance algorithms

Divide topics and set research deadlines before next meeting (07.11.25)

1. Core System Requirements

What	How	Why	Comments
Multi-Sensor Utilization	● **Sensors to integrate**: LiDAR, ultrasonic sensors, cameras ● **Additional data streams**: Energy charge level, payload weight (after basic implementation)	Comprehensive environmental awareness and better prediction accuracy	
Unified World Representation	● Create a single "map" that consolidates all sensor data in real-time ● Update continuously as new sensor data streams in ● Use this unified representation for all decision-making	Avoids direct sensor fusion complexity, provides a clear state representation	The idea should be refined by the corresponding sub-team
Safety Architecture	**Multiple protective zones**: ● Warning zone (pre-emptive detection) ● Slowdown zone (reduce speed) ● Emergency stop zone (immediate halt) ● Real-time constraints: Define maximum acceptable latency (suggest <100ms for detection-to-response)	Graceful degradation: The System must handle sensor failures safely	
Single-AGV Considerations Focus on fleet orchestration in the future	Focus on single-AGV collision avoidance	Fleet coordination is typically handled at a higher level (fleet management system)	Future extensions: ● AGV-to-AGV communication ● Priority assignment ● Conflict resolution protocols ● Federated learning

2. Development Strategy

What	How	Why	Comments
Simulation-First Approach	**Strategy**: ● Develop and test algorithms in simulation ● Integrate with a real AGV as the final stage ● Plan for sim-to-real transfer techniques **Simulators**: Gazebo, Webots, or NVIDIA Isaac Sim	Real-world data is difficult to obtain initially	
Modular Architecture	**Example:** Sensor Layer (modular interfaces) ↓ Perception Layer (object detection, tracking, classification) ↓ World Model (unified representation) ↓ Decision Layer (risk assessment, behavior selection) ↓ Control Layer (speed/trajectory adjustment)	Easy transition from simulated to real sensors	● Myroslav Mishc… Use ROS (Robot Operating System) or similar middleware?

3. Perception & Detection

What	How	Why	Comments
Obstacle Classification	● Static obstacles: Walls, equipment, fixed structures ● Dynamic obstacles: Moving workers, forklifts, other robots	Different handling strategies for each type	
Motion Prediction **(not the high-priority goal)**	Estimate object speed and direction Predict trajectories for dynamic obstacles	Proactive collision avoidance	
Environmental Challenges to Address	Add these challenges to the simulation	● Lighting variations ● Reflective surfaces ● Transparent obstacles (glass, plastic) ● Sensor occlusions	

4. Decision-Making & Control

What	How	Why	Comments
Intelligent Activation	● Principle: Only activate collision avoidance when necessary ● Trigger collision avoidance module when: ○ Obstacles detected in the warning zone ○ Trajectory conflict predicted ○ Uncertainty levels increase	Don't interfere with main navigation during regular operation	
Speed Management	Dynamically adjust speed based on: ● Proximity to obstacles ● Risk level of the current maneuver ● Environmental uncertainty ● Available stopping distance		
Resource-Aware Planning **(not top priority)**	● Account for the current payload when calculating: ○ Braking distances ○ Maximum safe speeds ○ Turning capabilities	Consider available energy for avoidance maneuvers	This may be a future extension, depending on the scope
Explainability & Transparency **(not top priority)**	Keep models interpretable where possible	Essential for: ● Debugging and testing ● Regulatory compliance (ISO 3691-4, ANSI B56.5)	

5. Validation & Testing Strategy

What	How	Comments
Success Metrics (to be defined)	• Collision avoidance rate • False positive rate (unnecessary stops) • Response time • Path efficiency (deviation from optimal route) • System uptime and reliability	
Test Scenarios	• Static obstacle detection • Dynamic obstacle avoidance • Multi-obstacle environments • Sensor failure conditions • Edge cases (reflective surfaces, lighting changes)	
Safety Validation	• Compliance with industrial safety standards • Emergency stop testing • Fail-safe behavior verification	

6. Summary of Priorities

High Priority (Core Functionality)

- Simulation environment setup
- Multi-sensor fusion architecture & Unified world model
- Static/dynamic obstacle differentiation

Medium Priority (Important but Can Iterate)

- Trajectory modification algorithm
- Intelligent activation logic
- Speed management

Lower Priority

- Motion prediction
- Explainable decision-making
- Validation framework
- Resource-aware planning

Future Extensions:

- Federated learning
- Multi-AGV coordination

7. Team Work Division Strategy

Phase 1 (Weeks 1-2): Foundation

- **2 people:** Simulation environment
- **2 people:** Research & prototype perception algorithms