



Efforts of AD-URBAN* project for safety evaluation of autonomous vehicles

*FOT project of Automated Driving system under Real city environment based on Academic Researcher's Neutral knowledge.



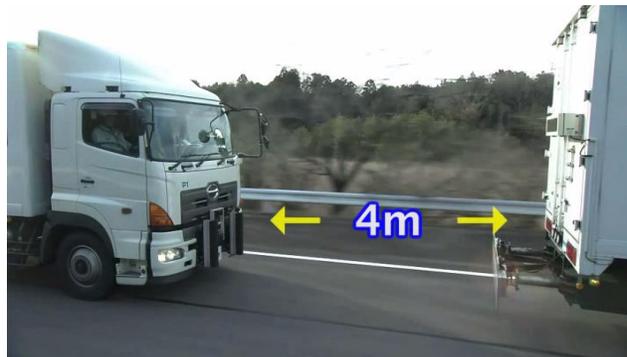
Naoki Suganuma, Kanazawa University

Kanazawa University's Initiatives in Autonomous Driving Technology

- Conducting comprehensive research on autonomous driving
 - Initiated R&D on autonomous vehicles around 1998
 - **Developed a proprietary autonomous driving system from scratch**
 - Covers the full stack: from foundational mapping to perception, decision-making, and control
- Demonstrated autonomous driving on public roads
 - **First university in Japan** to begin public road testing (February 2015?)
 - Field trials conducted in Kanazawa and Komatsu (Ishikawa), Abashiri (Hokkaido), Tokyo waterfront area, etc.
 - Widely featured in major media outlets (e.g., The Wall Street Journal)
 - **Over 10 years of autonomous driving experience on public roads**
- Participation in multiple national projects
 - Involvement in the Cabinet Office SIP Program (Phase 2 and Phase 3), among others



Unmanned demonstration driving
(2008, closed-course environment)



Energy ITS Promotion Project
(2008–2012, Shin-Tomei Expressway, etc.)



Deployment in depopulated areas
(from 2015, Suzu City, Ishikawa)



Urban public road demonstrations
(from 2016, Kanazawa City, Ishikawa, etc.)

Cabinet Office SIP Phase 2: Initiatives in Autonomous Driving (FY2018–FY2022)

- Development of autonomous driving systems
 - Advancement of perception and decision-making technologies required for autonomous driving
 - Construction of test vehicles and implementation of field validation trials
- Evaluation of perception technologies on public roads
 - Field testing in the Tokyo waterfront area and central Kanazawa, among others
 - **Identification of performance limits** from a perception-focused perspective through demonstration experiments
 - FY2019–FY2021: 182 operational days, 3,212.8 km of autonomous driving on public roads
- Assessment of cooperative driving with infrastructure (V2I/V2N)
 - Development of infrastructure-cooperative autonomous driving technologies
 - Verification of infrastructure effectiveness
 - Speed control in dilemma zones using remaining signal time information

Open Academic Research Framework



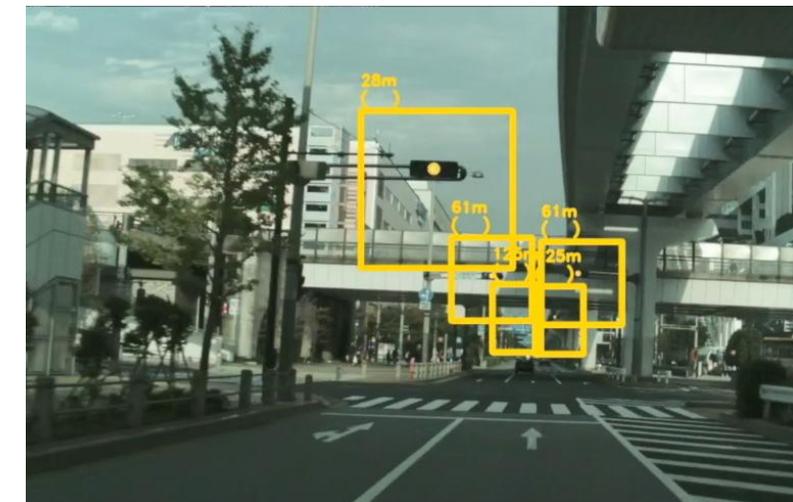
Kanazawa, Chubu, Meijo University

Large-scale field operational tests in the Tokyo waterfront area

The minimum required infrastructure, and
Performance limits of perception and decision-making technologies



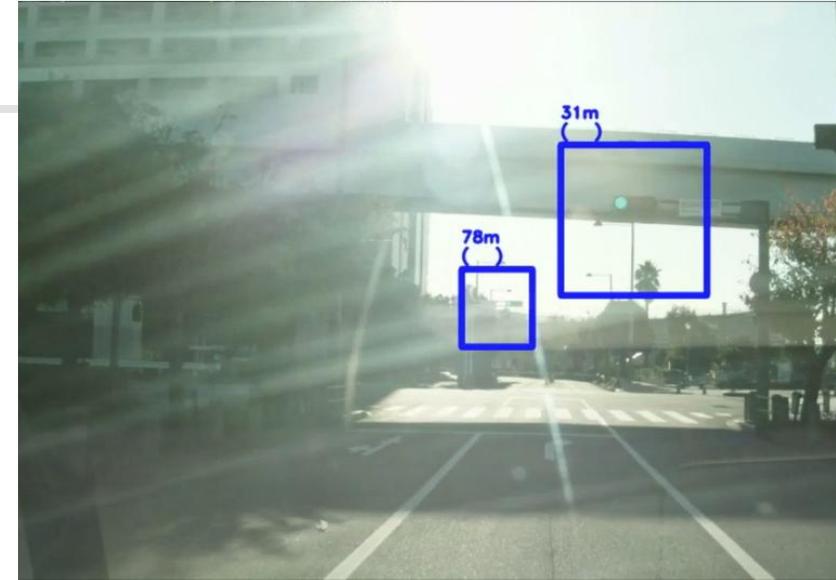
Autonomous driving in Tokyo waterfront area



Traffic signal recognition

Evaluation of Performance Limits from a Perception Perspective

- Development of perception technologies using onboard sensors
 - Traffic signal recognition and self-localization
 - Object detection, including emergency vehicle recognition
- Evaluation of perception performance on public roads
 - Field testing in the Tokyo waterfront area and central Kanazawa
 - Identification and analysis of perception failure scenarios
- Quantitative assessment of performance limits in virtual environments
 - Impact of adverse conditions such as backlighting and rain
 - Effects of physical occlusions (e.g., blind spots)
 - **Collaboration with the DIVP project**



Real-world testing



Virtual environments testing



Sharing of perception failure scenarios

improvement of autonomous driving technologies

Quantitative assessment of performance limits



Virtual environment testing

Initiatives Toward Safety Evaluation in Virtual Environments Utilizing Sensor Data from Autonomous Vehicles

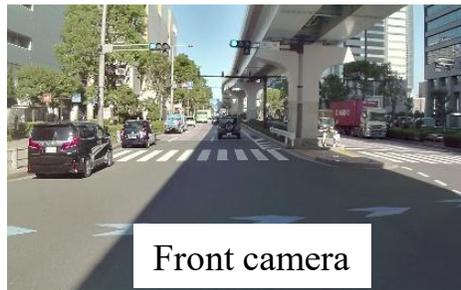
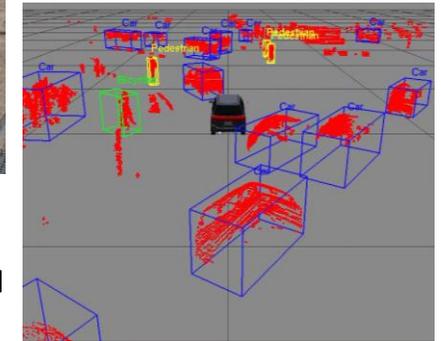
- Sensor Data Collection
- Data Annotation

- Importance of annotation
 - Training of various AI models
 - Evaluation of perception, and decision-making results
- Annotation of public road driving data
 - Object classification, shape, and orientation labeling
 - **Application to safety assessment in virtual environments**

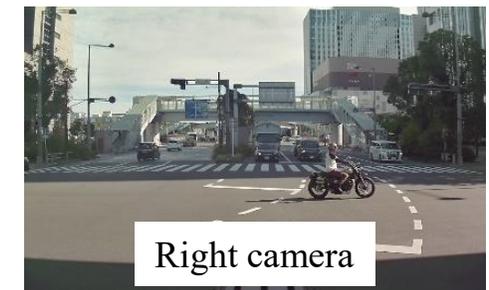
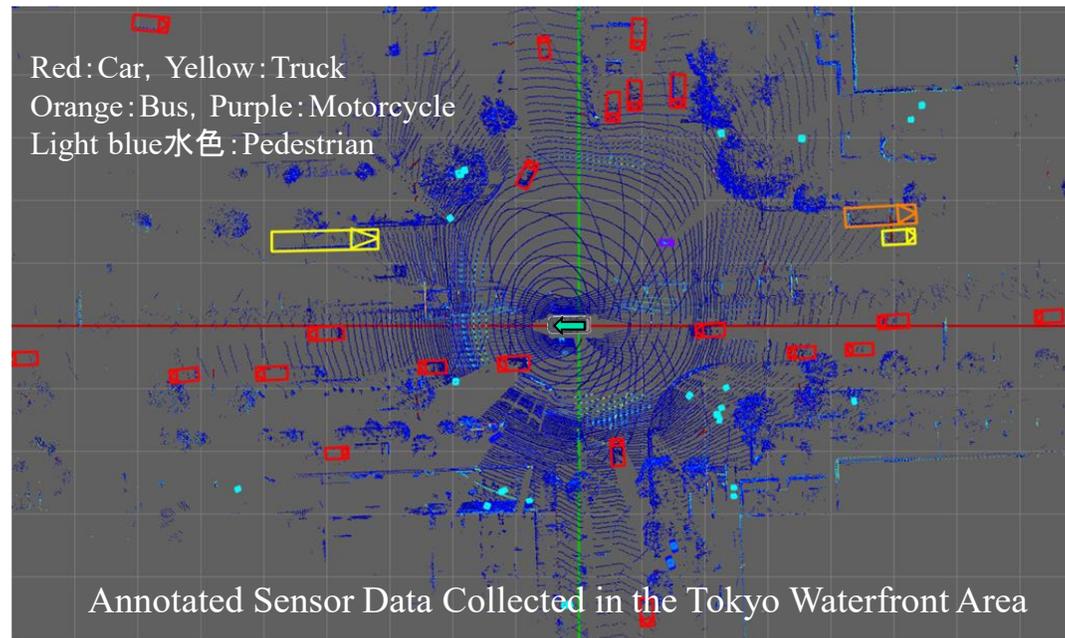


- AI Model Training
- System Evaluation

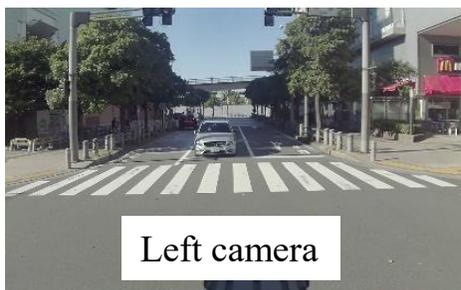
- Sensor Data Collection
- Data Annotation



Front camera



Right camera



Left camera

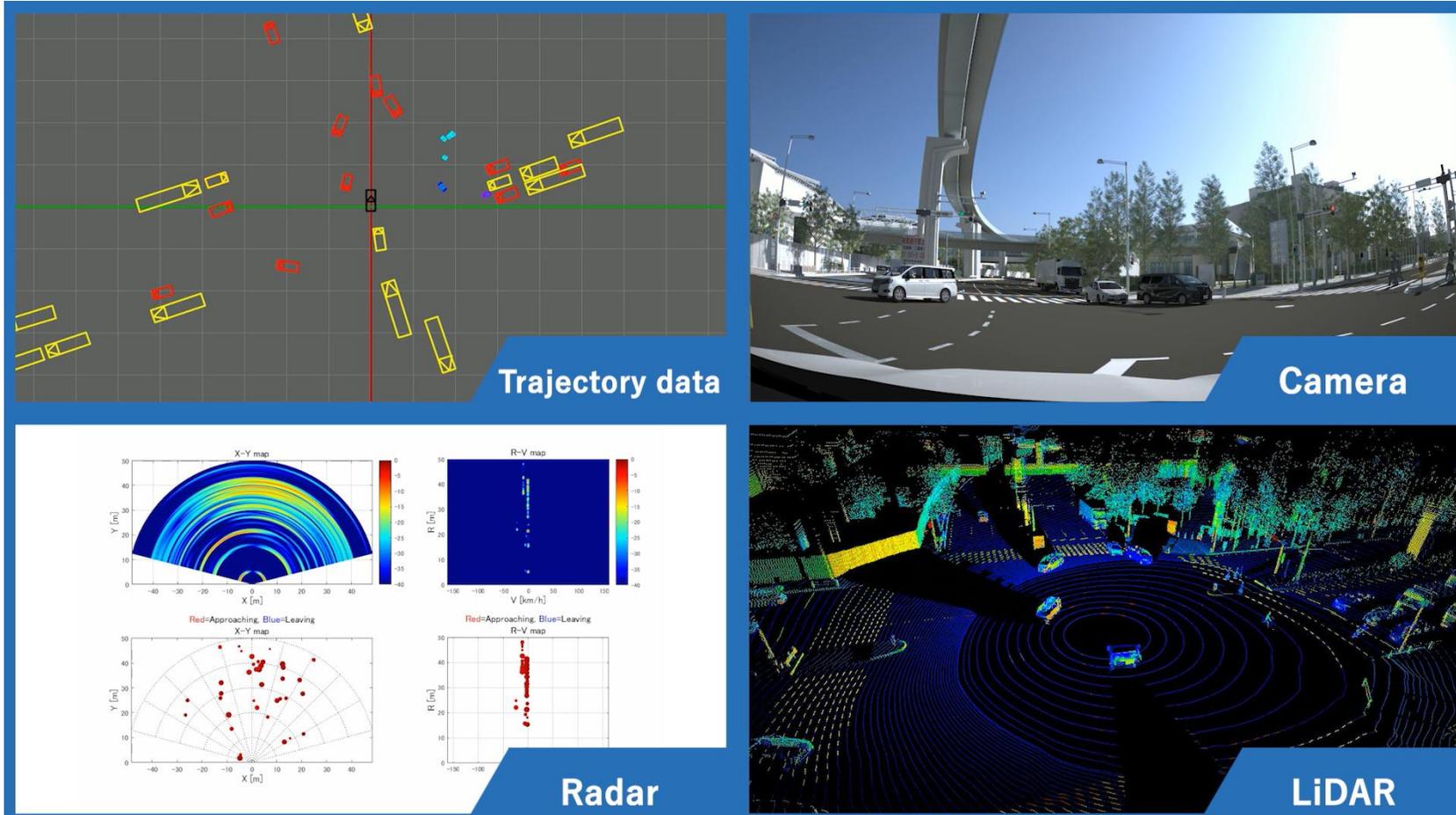


Rear camera

Safety Evaluation of Autonomous Driving Systems

Using Virtual Environments

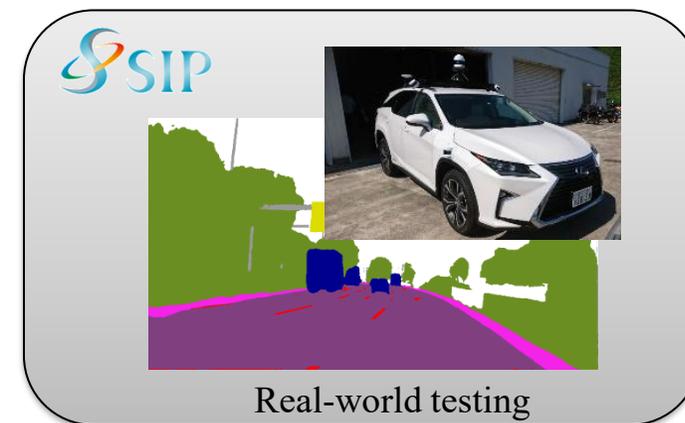
- Verification of diverse scenarios that are difficult to reproduce in real-world testing
 - Vehicle positioning and interaction timing, Weather and environmental conditions
- Efficient safety assessment through virtual simulation



Objective of AD-URBAN (FY2023–FY2025)

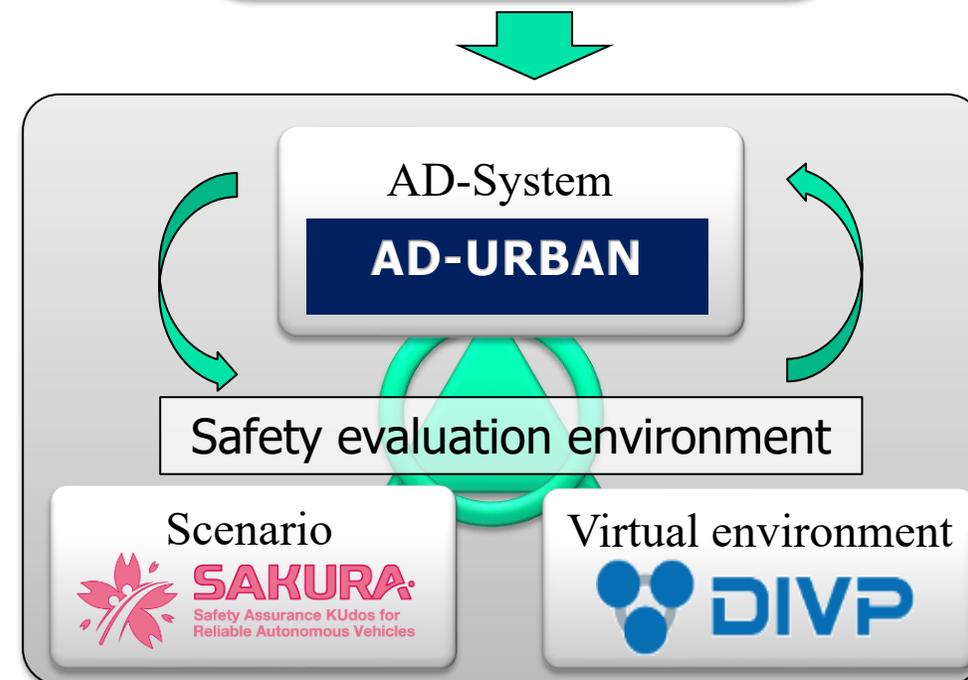
■ Project Objectives

- Establish a safety evaluation framework for public roads
 - Need for more efficient and effective safety assessment methodologies
- **Collaboration with the DIVP and SAKURA projects**
 - Evaluation of sensor limitation scenarios and mixed traffic scenarios
 - Development of a comprehensive and efficient safety evaluation methodology integrating real-world and virtual environments



■ Role of the AD-URBAN Project

- Effective deployment of a safety evaluation environment
 - Integration of AD-URBAN as a reference system
 - Acceleration of safety evaluation framework development in virtual environments
- Advancement of autonomous driving systems
 - Ensuring the validity and robustness of safety evaluation results
- Identification of system-level challenges
 - Feedback to safety evaluation scenarios and performance metrics



Overview of AD-URBAN

■ Organizational Structure

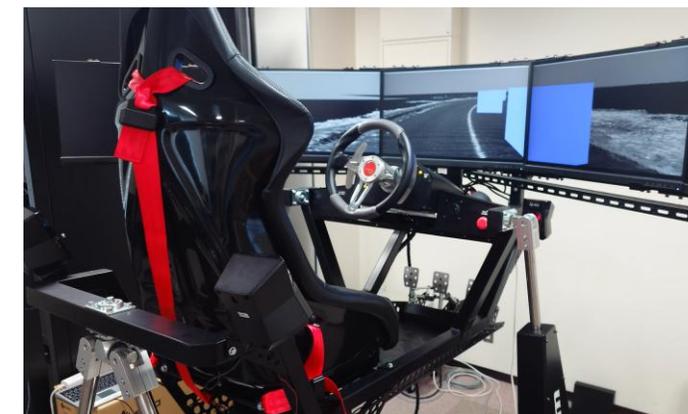
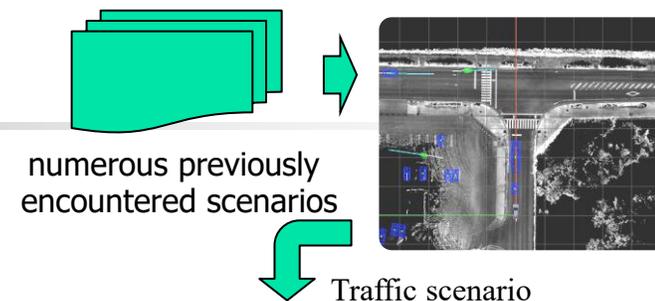
- Kanazawa University:
 - Extensive experience in autonomous driving technology
- Chubu University:
 - Advanced expertise in deep learning technologies
 - Engagement in autonomous driving development and safety evaluation

■ Autonomous Driving Development and Safety Evaluation

- Development of perception and decision-making technologies
 - Recipient of a Best Paper Award at a leading international conference in autonomous driving
 - Development of perception technologies using imaging radar
 - Proposal of safety evaluation metrics from a perception perspective
- Construction of a vehicle behavior validation environment
 - Continuous evaluation of numerous previously encountered scenarios
- Field operational testing
 - Conducted in Kanazawa City and the Tokyo waterfront area, among others

■ Establishment of a Safety Evaluation Environment

- Development of an integrated safety evaluation framework in collaboration with DIVP and SAKURA
- Scenario generation utilizing generative AI

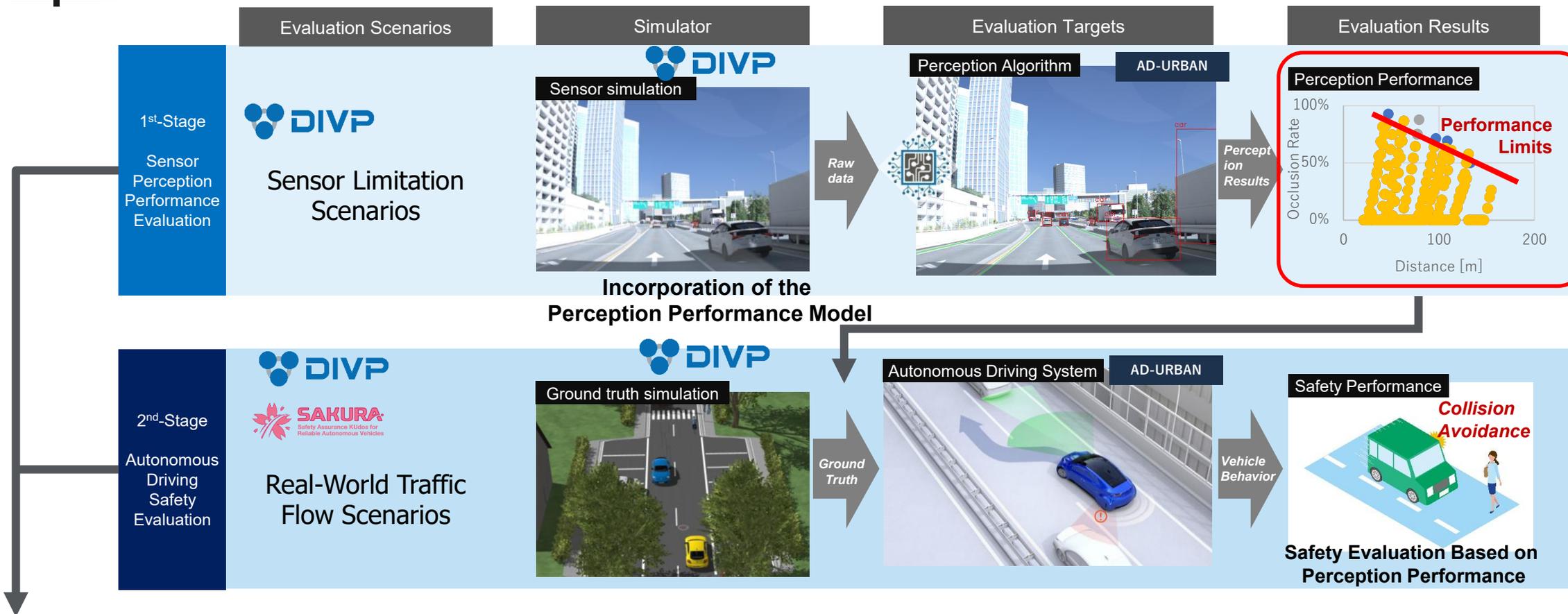


Behavior validation using motion-simulator



Real world testing of ADS

Construction of a Safety Evaluation Framework through Collaboration with DIVP and SAKURA



- Efficient evaluation through a two-stage framework
 - Stage 1: Modeling perception performance
 - Stage 2: Real-time evaluation of planner functionality

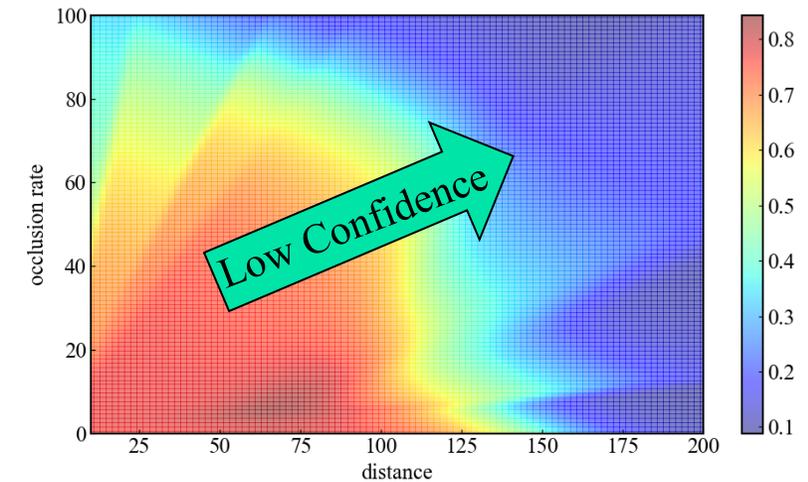
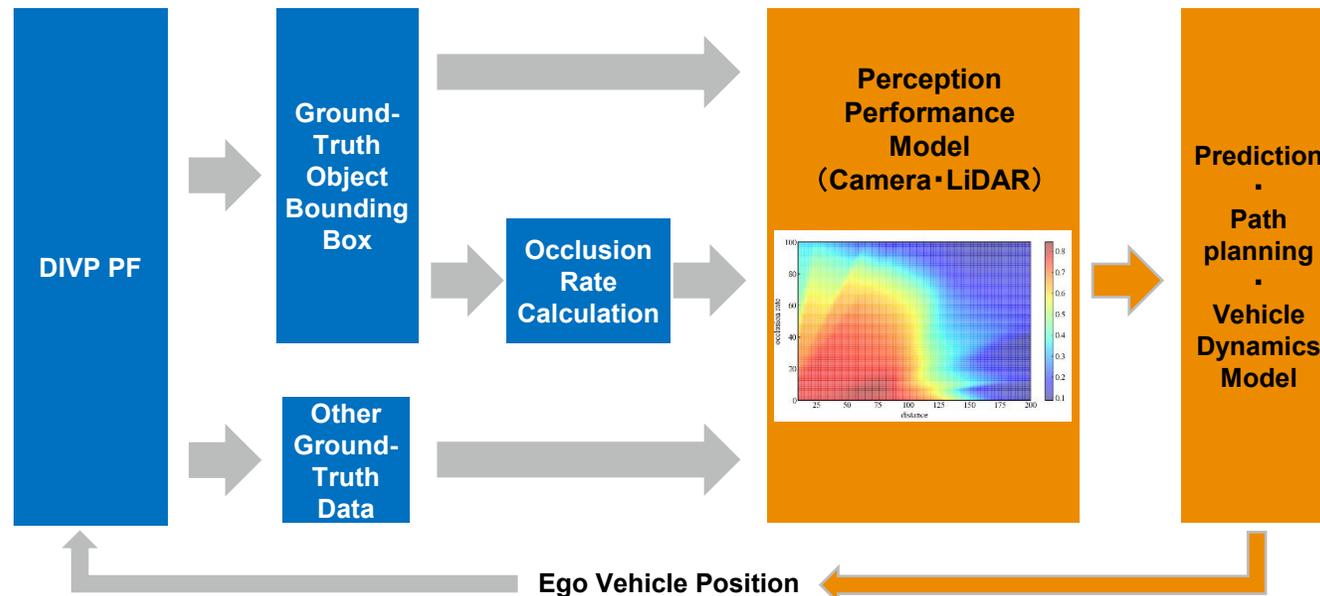
Establishment of an integrated evaluation environment from sensor perception assessment to planning-level safety evaluation

Construction of a Perception Performance Model for 1st-Stage Evaluation

- 1st-Stage Evaluation Framework
 - Generation of a large number of sensor evaluation scenarios in the DIVP virtual environment
 - Automatic assessment of perception performance based on ground truth and recognition results
- Development of a method to model perception performance
 - Neural network-based model that outputs confidence levels from occlusion rate and distance
 - Realization of closed-loop planner evaluation
 - Enables 2nd-stage evaluation without time-consuming sensor simulation



Generated Data for Approaching Vehicles at an Intersection



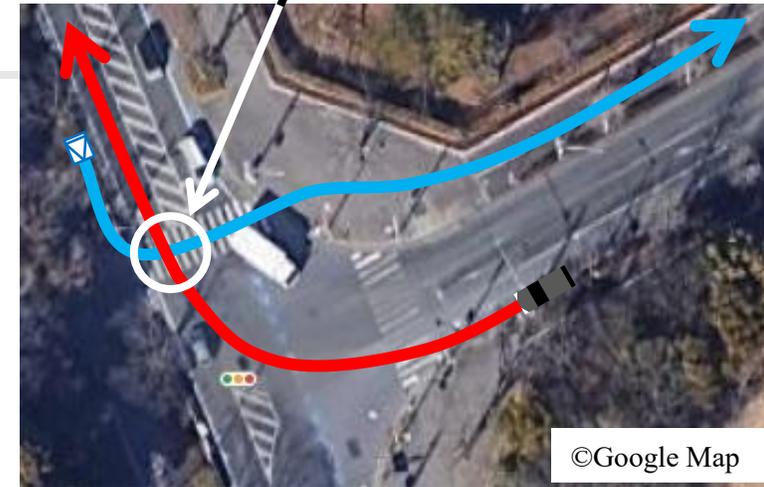
LiDAR Perception Performance Model

*Neural Network

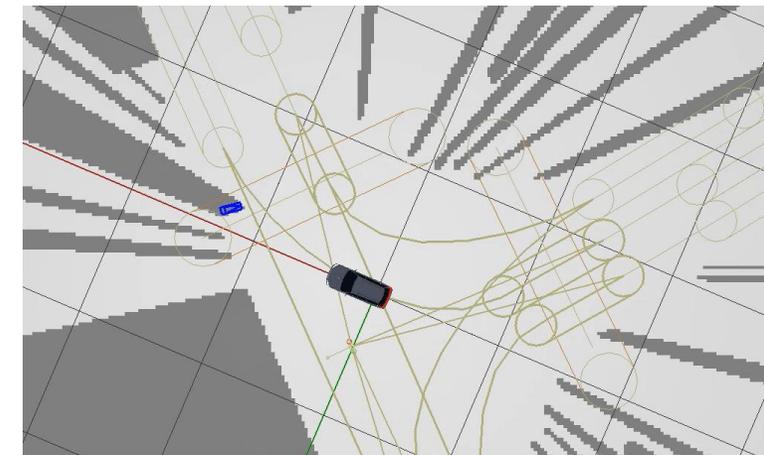
2nd-Stage Evaluation: Case Study and Outlook

Safety Evaluation of Pedestrian
Crossing at intersection

- Development of the 2nd-Stage Evaluation Environment
 - Deployment of a cloud-based evaluation platform
 - Closed-loop evaluation utilizing the perception performance model
 - **Safety assessment leveraging SAKURA project outcomes**
 - Statistical pedestrian crossing behavior patterns
 - Validation at real-world intersections studied in the Road to the L4 project
 - Verification of the effectiveness of the two-stage framework
 - **Expected broader application from the perspective of AD system developers**
- Required Safety Evaluation Scenarios
 - Comprehensive safety assessment through a deductive approach
 - Scenario-based evaluation in collaboration with the SAKURA project
 - **Efficient AD system development through an inductive approach**
 - Identification of edge cases, including system-specific weaknesses and critical scenarios
- Toward Efficient Generation of Concrete Scenarios
 - (1) Extraction of traffic scenarios from real-world driving data
 - (2) Generation of map-based traffic scenarios using generative AI
 - (3) Generation of traffic scenarios from natural language descriptions using LLMs



Example of an Intersection Scenario

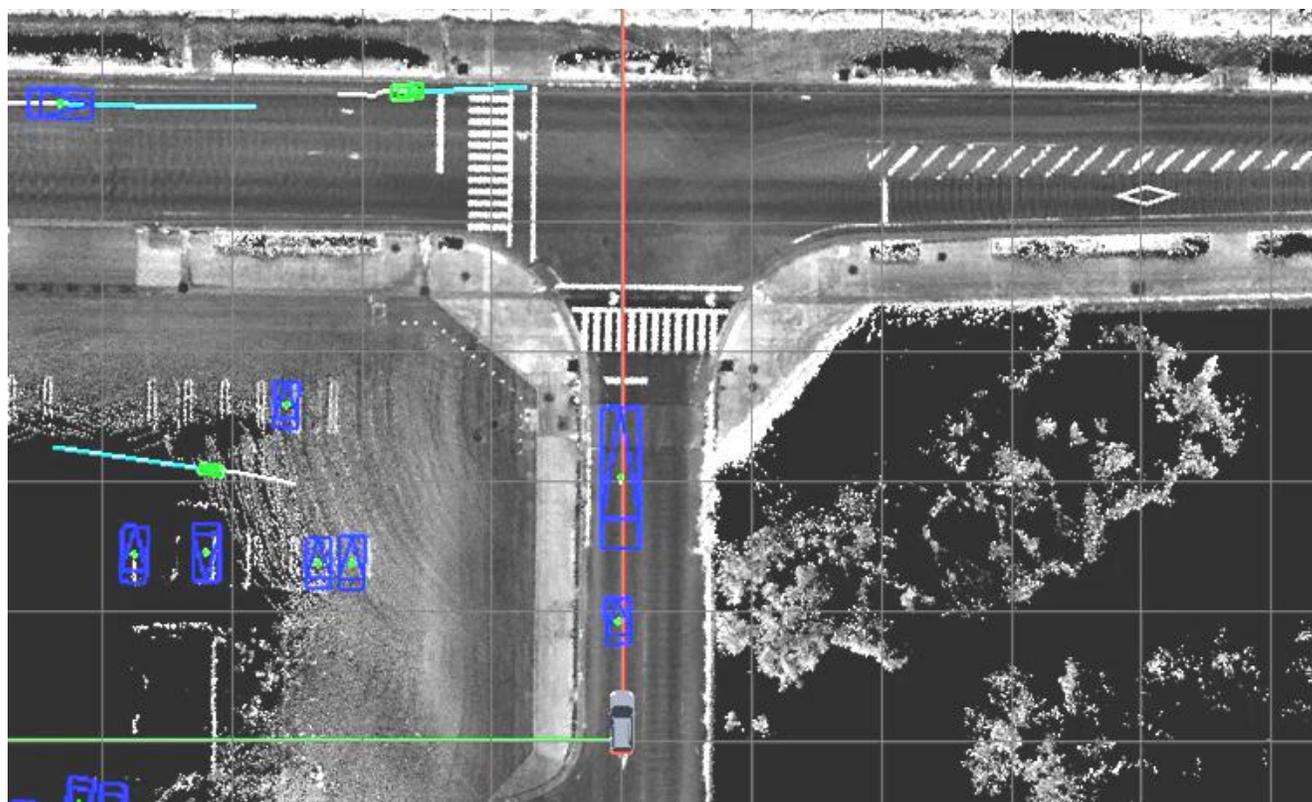


Closed-Loop Safety Validation Process

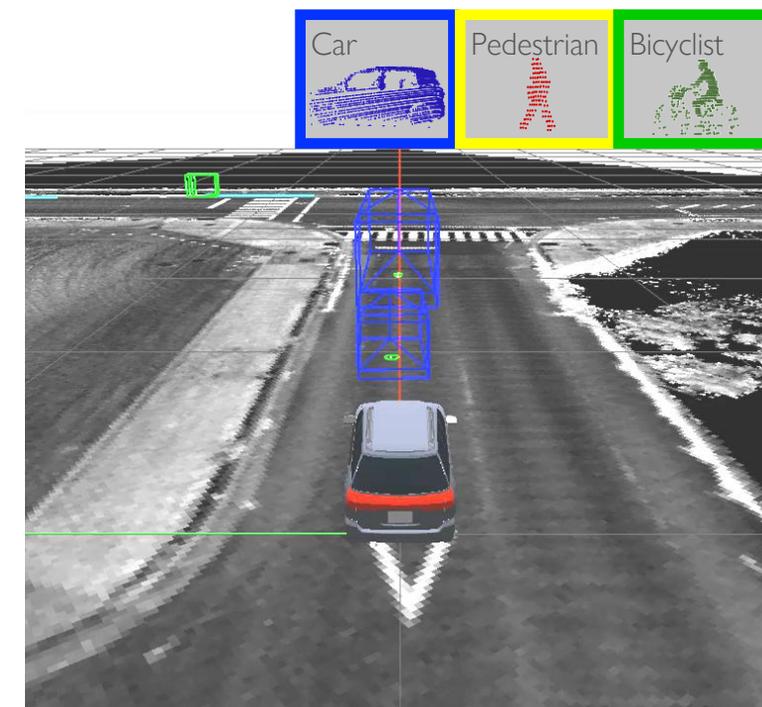
■ : Ego vehicle ■ : Ego vehicle route
■ : Pedestrian ■ : Pedestrian route

(1) Extraction of Traffic Scenarios from Real-World Driving Data

- Automated extraction of concrete traffic scenarios from real driving data
 - Results of Ego-vehicle localization, Dynamic object detection and Traffic signal recognition
- Execution of simulation tests in virtual environments that closely replicate real-world conditions
 - Efficient validation of challenging scenarios encountered during autonomous driving field tests

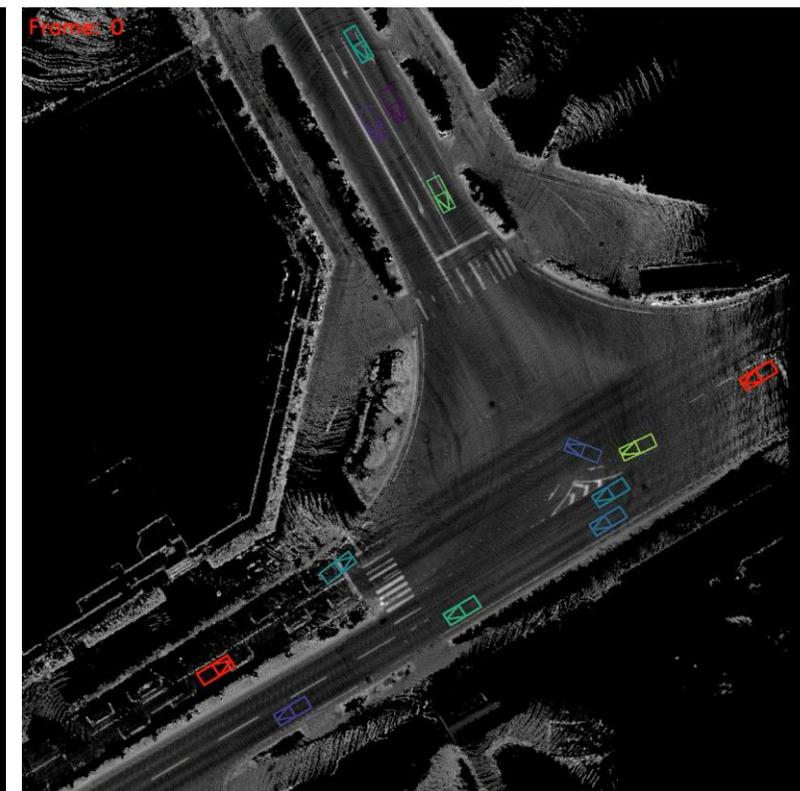
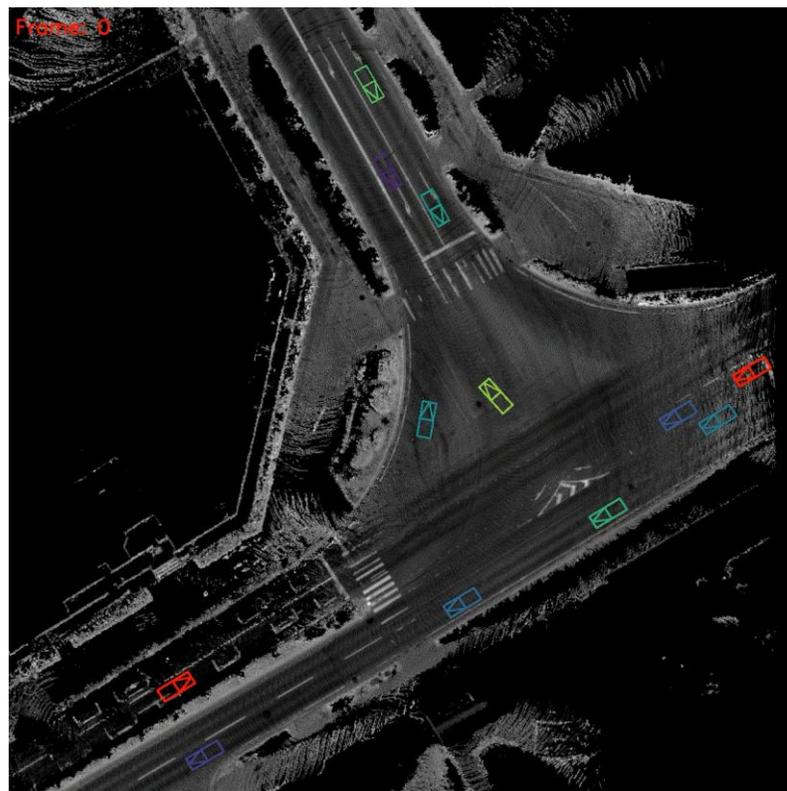
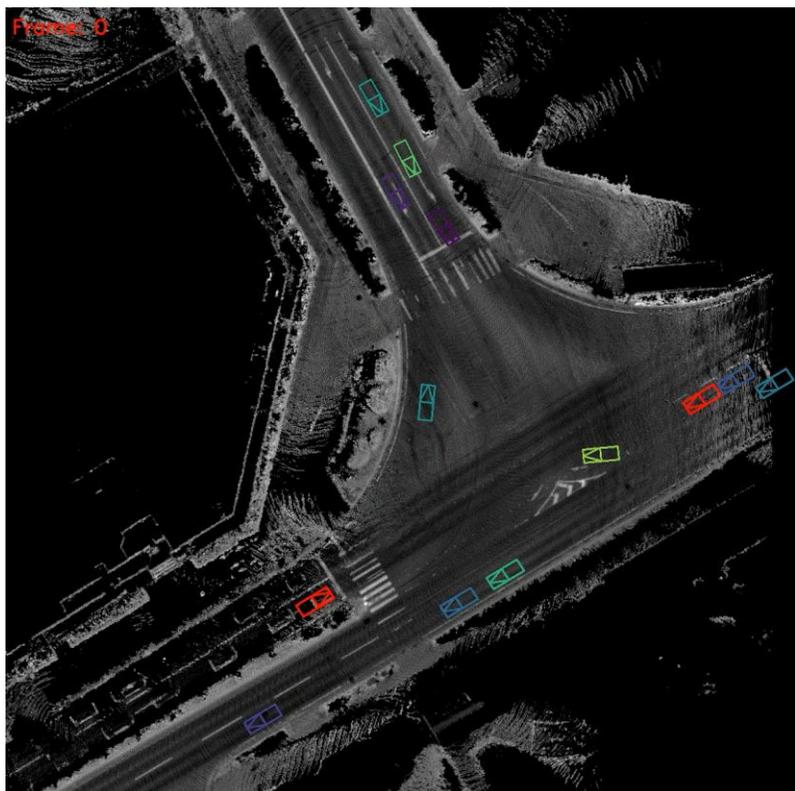


— Predicted Trajectory
— Observed Trajectory



(2) Generation of Map-Based Traffic Scenarios Using Generative AI

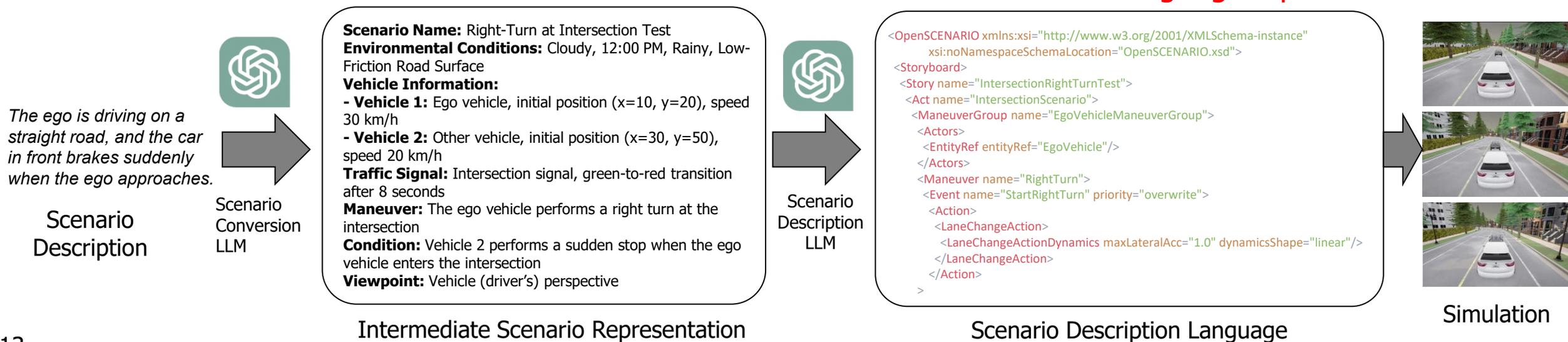
- Development of a model that generates concrete traffic scenarios by specifying road geometry and structural conditions
 - Scenario generation considering: Object placement and interaction, Vehicle speed and acceleration, Traffic signal states at intersections
 - Automatic generation of diverse and concrete scenarios within field operational test areas



Generated scenarios of intersection entry and right-turn maneuvers based on timing of oncoming vehicles

(3) Scenario Generation from Natural Language Using LLMs

- Utilization of LLMs
 - Efficient and intuitive creation of safety evaluation scenario
- Development of a method for automatic generation of scenario descriptions
 - Generation of an intermediate scenario representation from natural language descriptions
 - Enables flexible variation through structured intermediate representations
 - Automatic generation of scenario description language from the intermediate representation
 - Enables automatic creation of concrete scenarios based on natural language inputs



Establishment of Moveez, Inc. (May 30, 2024)

- Established as a startup leveraging Kanazawa University's core autonomous driving technologies
 - Built upon achievements from: Cabinet Office SIP Program, METI AD-URBAN Project
 - Implementation of efficient safety evaluation utilizing the developed safety assessment framework
- Toward Realization of Autonomous Mobility
 - Development and commercialization of robotaxi services, Enabling accessible and seamless mobility for all



MoveEz = Move Easy

moveez

Beyond the Human

<https://moveez-inc.com/>

Field Operational Testing in Makuhari New City



Conclusion

- Kanazawa University's Initiatives
 - Development of autonomous driving technologies since 1998
- Contributions to SIP Phase 2
 - Evaluation of perception performance limits
 - Safety assessment in virtual environments utilizing sensor data
- Initiatives under the AD-URBAN Project
 - Construction of a perception performance model within a two-stage evaluation framework
 - Efforts toward efficient generation of concrete traffic scenarios
- Establishment of MoveEz and Social Implementation
 - Social deployment of outcomes from the SIP and AD-URBAN projects
 - Field operational testing of robotaxi services
- Responding to driver shortages associated with an aging population
 - Recognizing mobility as a fundamental human need
 - Advancing socially accepted autonomous driving systems through:
 - Establishment of safe, efficient, and effective safety evaluation methodologies
 - Development of transparent and trustworthy autonomous driving systems



Autonomous Driving from Kanazawa University to Kanazawa Station
(Approx. 15 km at a Maximum Speed of 60 km/h; 3 × Playback Speed)



moveez

Beyond the Human