SIP-adus Workshop 2022

Driving Intelligence Validation Platform (DIVP®) for AD Safety Assurance

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Weather Forecast

AD safety Assurance*

For Validation & Verification Methodology

The Japanese team on AD-safety assurance has a high motivation to progress AD-safety through international corroborations. DIVP is responsible for the virtual validation field.

Initiative status for AD-safety assurance in Japan

SIP · Cabinet Office · METI Ministry of Economy, Trade and Industry · MLIT Ministry of Land, Infrastructure, Transport and Tourism

International collaborations

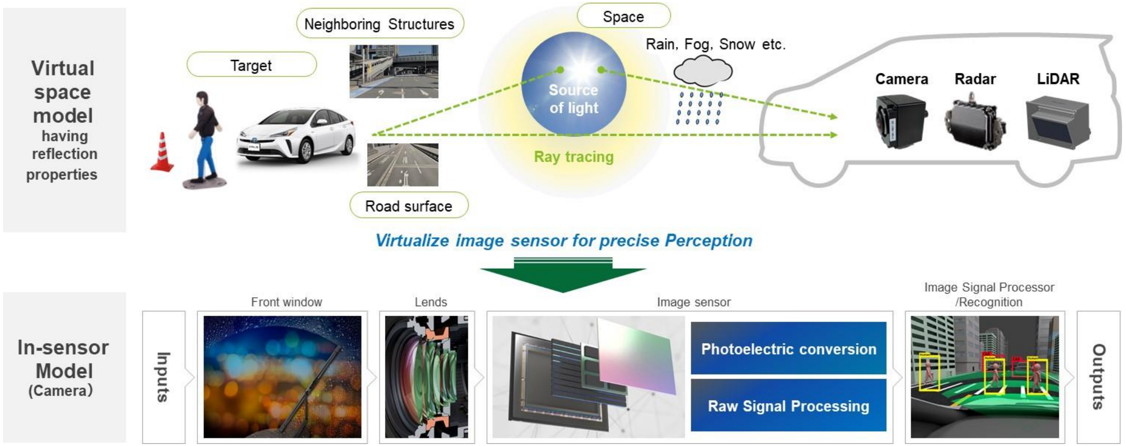
Federal Ministry for Economic Affairs and Climate Action · Federal Ministry of Education and Research · VDI|VDE|IT

DIVP

Building a virtual space simulation platform having highly consistent sensor models with real-world phenomena to contribute to the safety assessment of automated driving.

DIVP motivation

- Sensor modeling that is highly consistent with physical phenomena.
- Platform that enables AD-evaluations throughout “scenario creation” , “verification of recognition” , “validation of vehicle control”.
- Enhanced connectivity with existing simulation software.

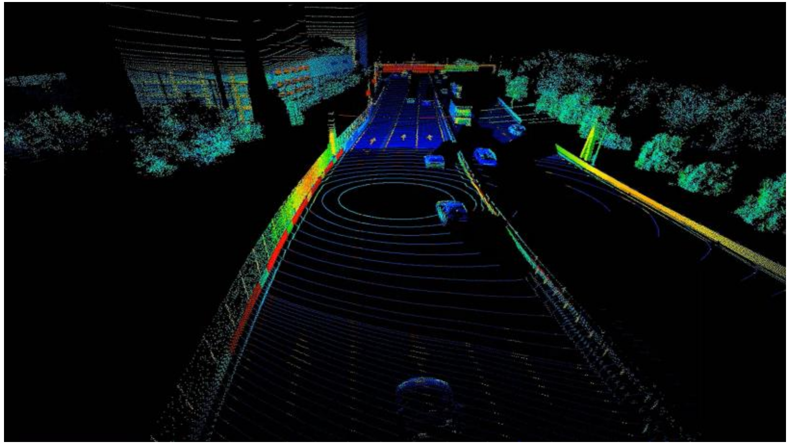


Real world | **Virtual space and Sensor model**

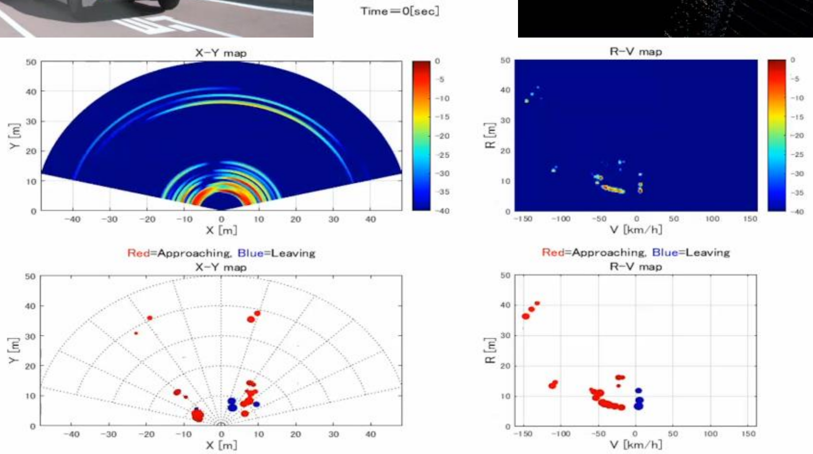
DIVP

Virtual sensor views on CI expressway & Odaiba AD-FOT area produced by DIVP simulator

Camera



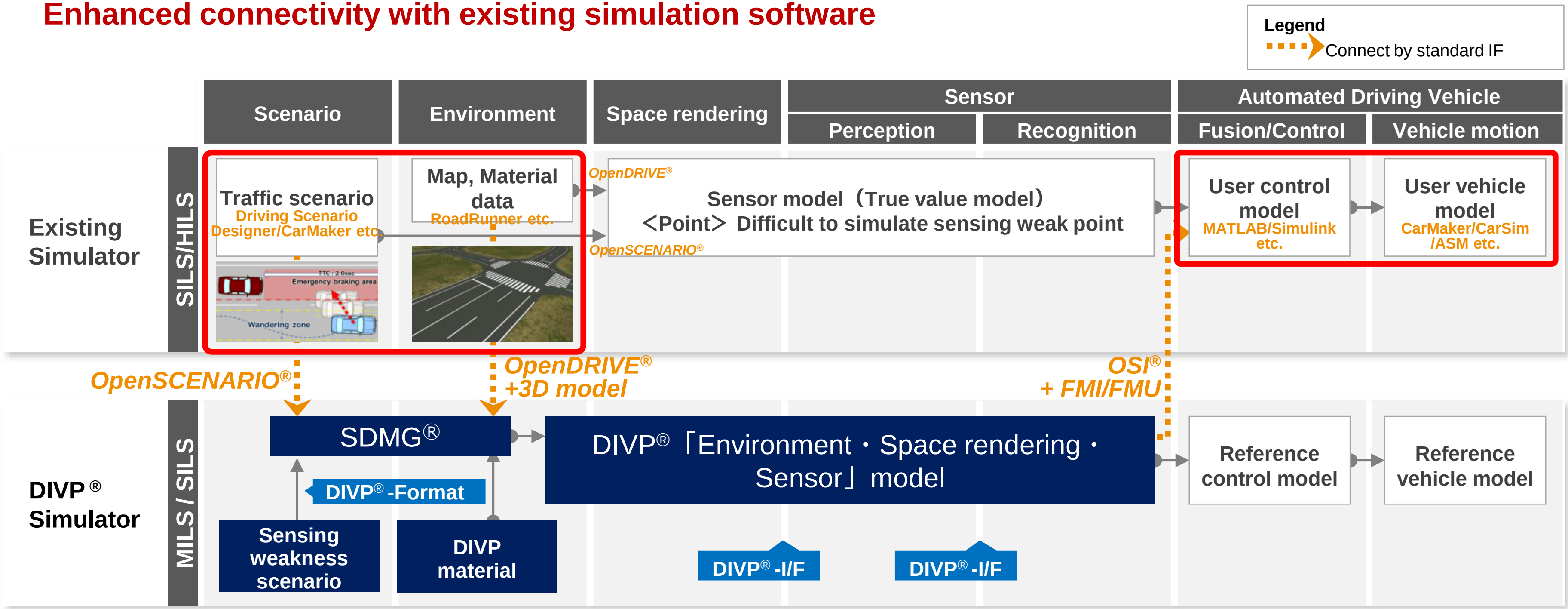
LiDAR



Radar

Comply with OpenSCENARIO® , OpenDRIVE® and other standards of ASAM. Ensure the connectivity with existing simulation software to provide tool chain.

Enhanced connectivity with existing simulation software



Contribute to international standardization activities, for example, proposing standard format to ASAM utilizing Japan=German cooperation flamework.

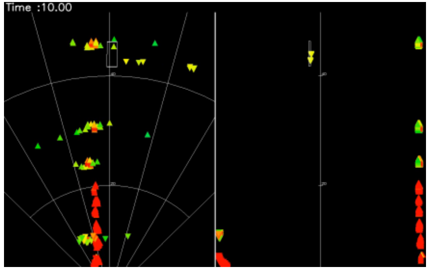
ASAM2）：Association for Standardization of Automation and Measuring Systems / OSI3) : Open Simulation Interface

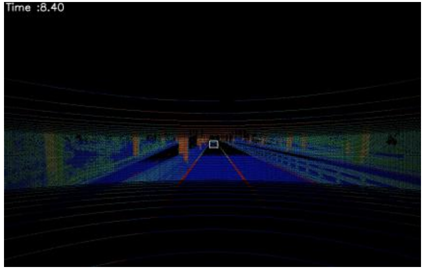
DIVP® simulation demonstration of AD virtual validation with sensing weakness scenario package on Odaiba & C1 expressway, is planned thru FOT in the Tokyo Waterfront Area

■ Modelling for Sensing weakness scenario packages

Simulation validation on scenario packages

Sensing Weakness Scenario Packages on Odaiba, C1





Various sensing weakness scenes

Hard-to-detect objects

Passing between adjacent vehicles

Black Leather Jacket

Black vehicle

Upward structure

Low reflective road objects

Highly reflective road objects

Environment that affects reflection and propagation

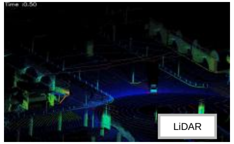
Backlighting, background light

Reflections on pronto glass

Rain condition

Blurred white lines

Thermal barrier painted road surface



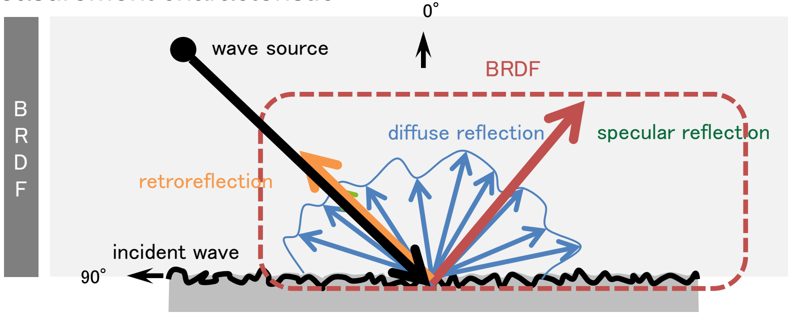
Wall multi-path

[Modeling of Odaiba waterfront area] Reflection characteristics were modeled based on experimental measurements, and detailed Virtual-Community Grand was reproduced.

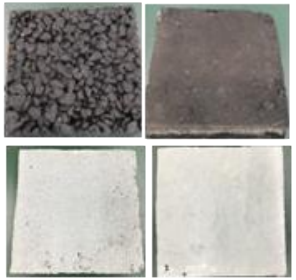
Modeling based on physical properties

Modeling Reflection Characteristics

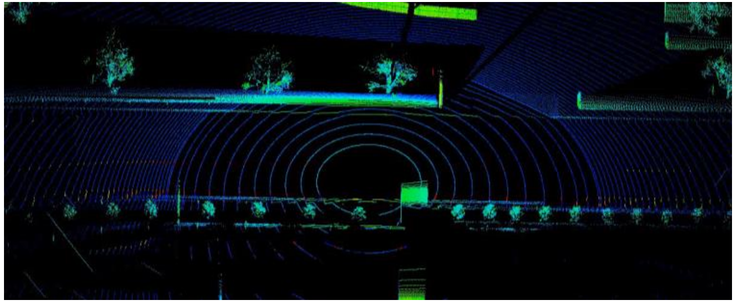
- Measurement characteristic



- Measuring asphalt used locally

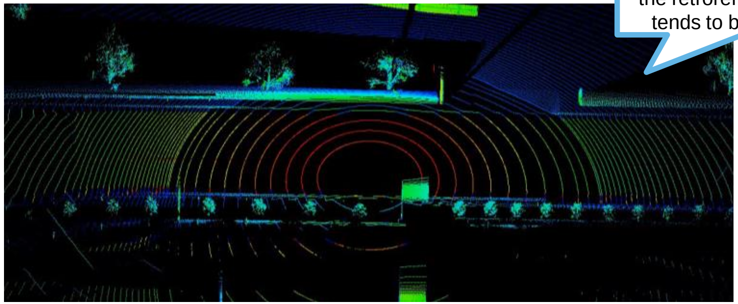


DIVP® Sim (usually asphalt)



DIVP® Sim (Thermal shielding painting)

In the thermal shielding painting, the retroreflective component tends to become stronger.



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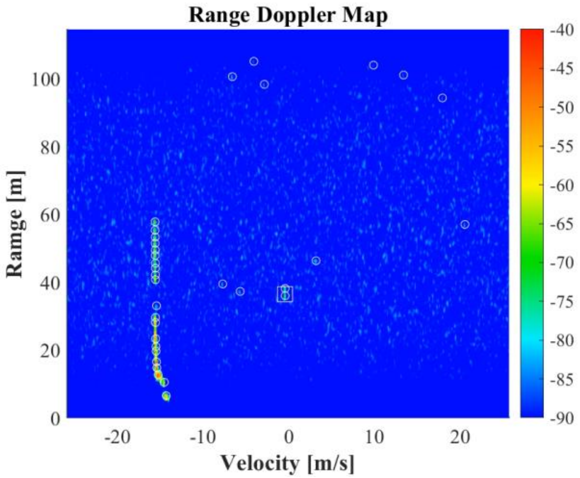
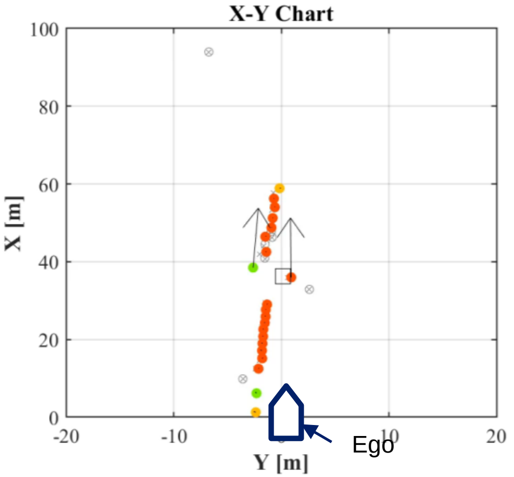
DIVP® can evaluate complex traffic environment scenarios in virtual proving ground

Millimeter wave radar simulation example (multipath ghost)

Camera Simulation

Radar Simulation

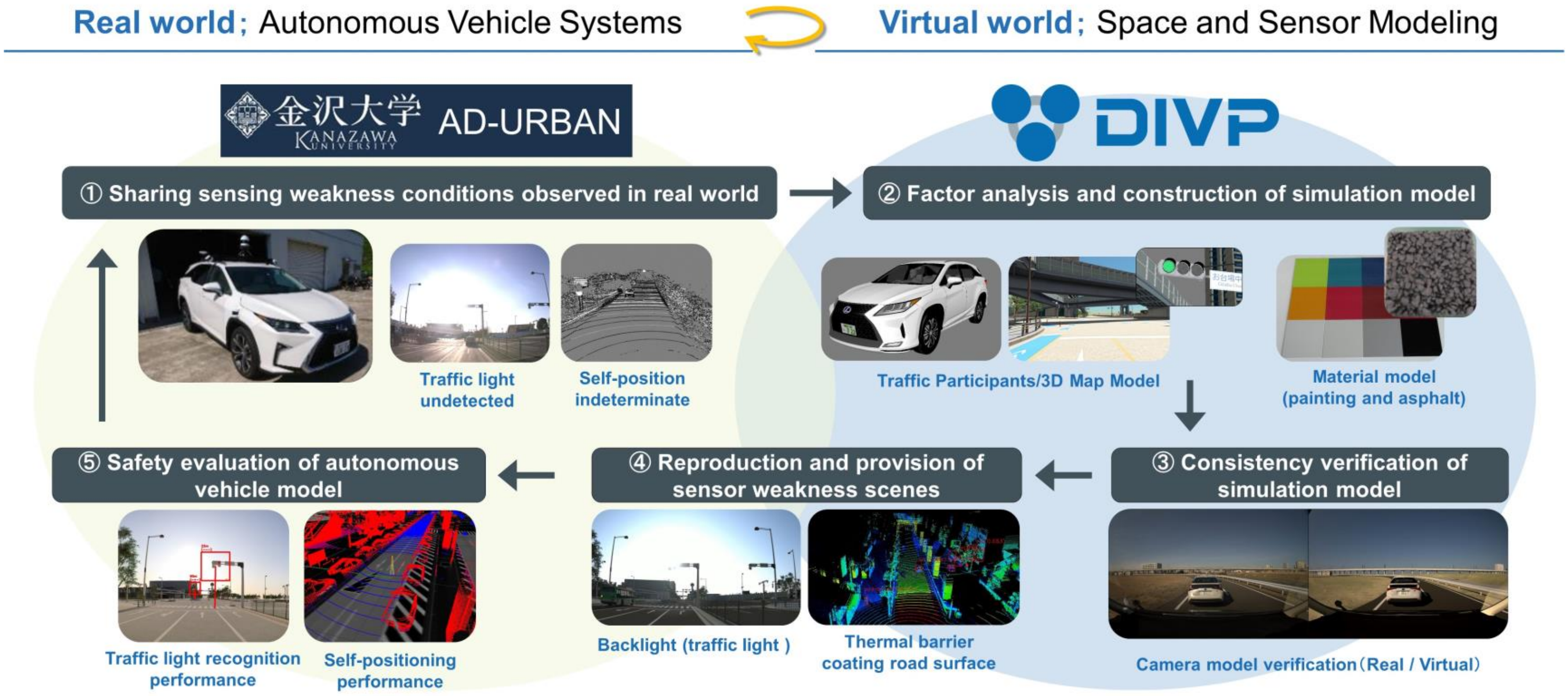




DIVP® simulation able to reproduce the precise multipath due to tunnel walls of the millimeter-wave radar and the ghosting of the vehicle ahead.

We are working on simulation reproduction and safety evaluation based on the sensing weakness conditions observed by AD-URBAN in the Tokyo waterfront area.

Effectiveness verification of autonomous vehicle evaluation using DIVP simulation



Traffic signal recognition in rainy weather; verification of recognition limit performance is possible with virtual space simulation

Contribution to safety assessment for AD-system evaluation using virtual space model

Difficult to catch signal recognition limit conditions in public road due to lack of control over rainfall condition levels

Public road tests	Normal weather	Rainy weather (a few mm/h)
Recognition rate	0.982	0.984

DIVP® simulation allows for intense rainfall settings
→ Signal recognition limit verification is possible

DIVP® simulation	Normal weather	Intense rainy weather
Recognition rate	0.989	0.868

Evaluation by extrapolation is possible

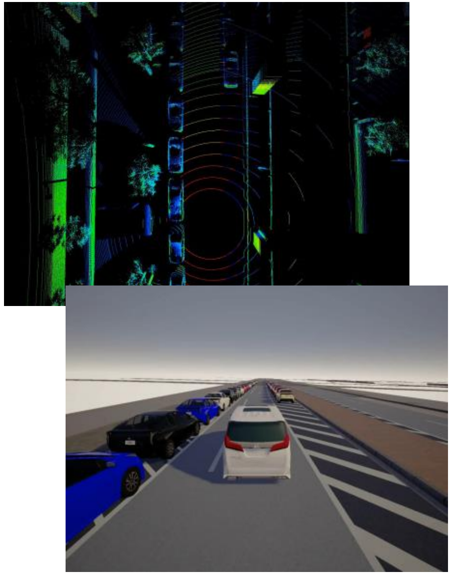
The overall recognition rate deteriorated with increasing rainfall in DIVP® simulation.

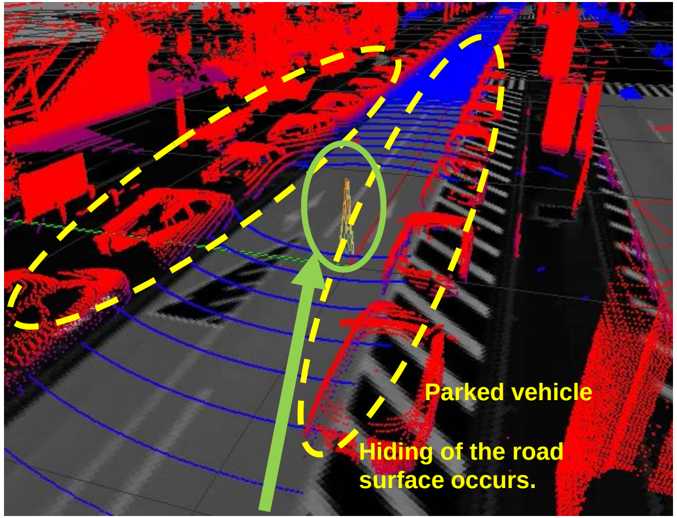
- Undetected due to shielding by raindrops
- Misrecognition due to color change, etc.

System control robustness for edge case conditions and validation example of performance limit Search sensor using

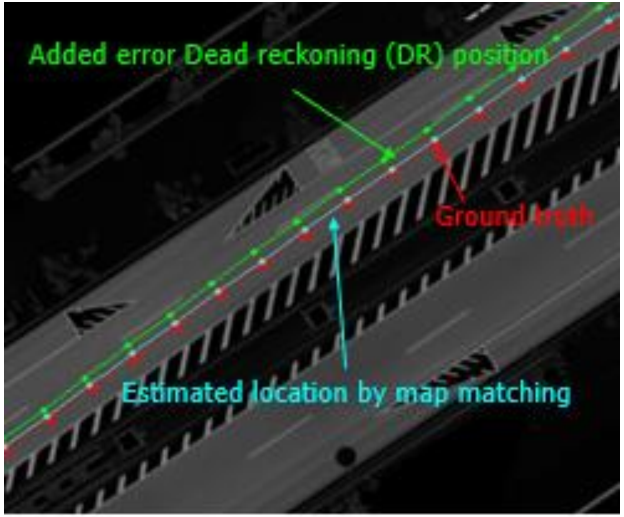
Localizing Algorithm Robustness Verification using DIVP®

DIVP® LiDAR & Camera Sim. → **LiDAR & Algorithm output** → **Effect on localizing accuracy**





Estimated location
(posterior probability density distribution)



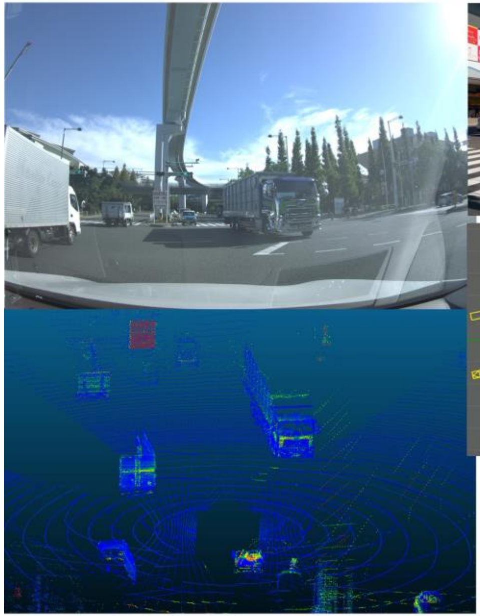
DIVP® simulation provides adverse conditions that the system wants to validate but is difficult to set in reality
We were able to verify the high robustness of the self-position estimation algorithm of AD-URBAN (Kanazawa University Proj.).

金沢大学 KANAZAWA UNIVERSITY AD-URBAN DIVP

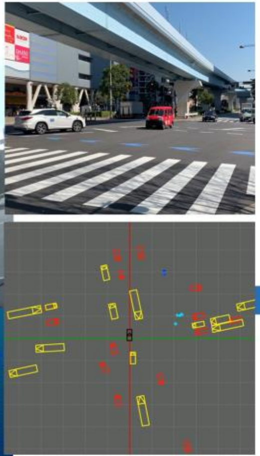
Reproduce intersection driving scenarios using DIVP simulator based on traffic data from AD vehicles’ FOT, and evaluate safety by changing various environmental conditions.

Case study：Reproduction and utilization of trajectory data obtained on public roads at intersection

Trajectory data on public road

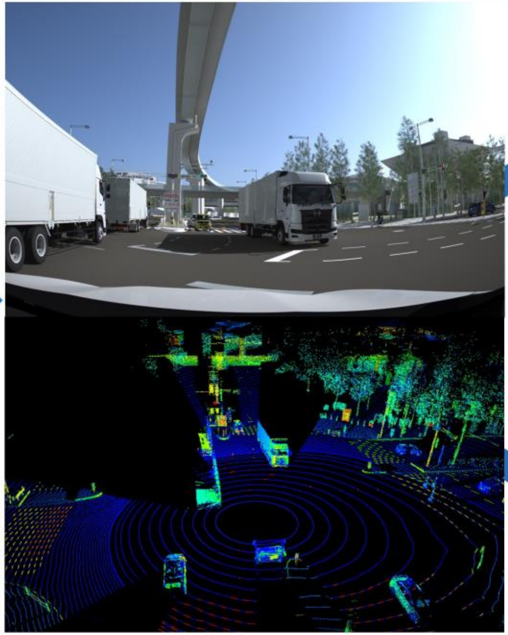


Real sensor data (Camera/LiDAR)



Trajectory data of ego-vehicle and surrounding vehicles

Simulation reproduction



Adding more severe conditions

Change to rainy condition

Additional vehicles in the vicinity

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Structuring coupled physical and functional simulation are needed for AD-safety assuarance. DIVP® focuses on modelling the physical properties of sensing.

Total validation framework for AD-safety assurance

	Scenario	Validation	Metrics
Functional Sim.	**Geometric scenario**	HILS; Actual vehicle	**Risk margin for accident**
DIVP **Physical Sim.**	**Sensing Weakness Scenario**	SDM -Generator*; **Hghly consist virtual simulation**	**Recognition performance**

Scenario

■ **Geometric scenario**

Validation

■ HILS

■ Actual vehicle

Combination and application of each method

Metrics

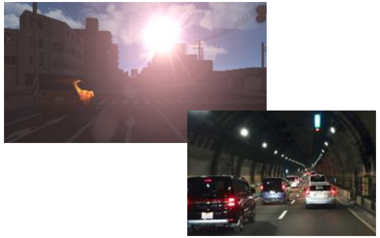
■ **Risk margin for accident**

Functional Sim.

DIVP

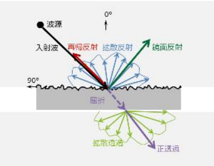
Physical Sim.

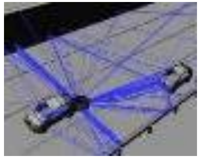
■ **Sensing Weakness Scenario**



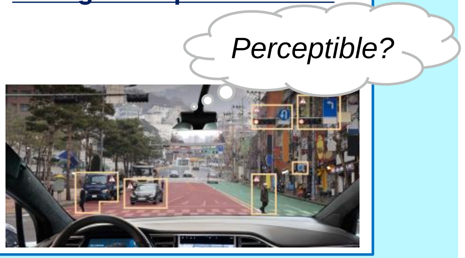
SDM -Generator*

■ **Hghly consist virtual simulation**





■ **Recognition performance**



DIVP

Through VIVID collaboration, DIVP® accelerates its original contributions to global standardization of simulation-based AD safety assurance methodology

Summary; DIVP® contributions

ASAM

jama

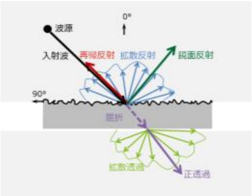
VIVALDI + DIVP

= VIVID_JTs

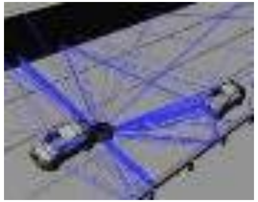
Interface standardization
AD Safety assurance

Sensing Weaknesses Scenario Package

Environmental models with physical properties



Raytracing for each sensors



Measurement technology / Verification technology
→ Consistency verification DB

- Sensing weakness scenario: JT2
- Environmental models with physical library: JT2
- Interface; JT3
- Sensor models with ray tracing:
  - Camera: JT3.1
  - LiDAR: JT3.2
  - Radar: JT3.3

- Sensor measurements & test metrics: JT4,
- Tool chain: JT1

DIVP

DIVP

SIP

Cabinet Office

SIP-adus Workshop 2022

Thank you for your kind attention!

Tokyo Odaiba → Virtual Community Ground

END