

工業技術研究院

Industrial Technology
Research Institute



Bus ODD and Autonomous Bus projects in Taiwan

Dr. Huei-Ru Tseng
Manager

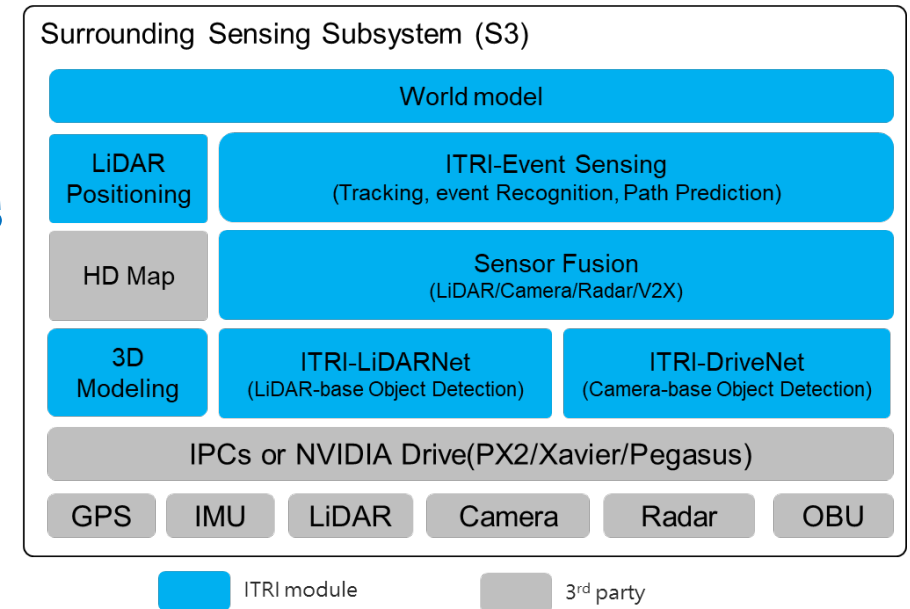
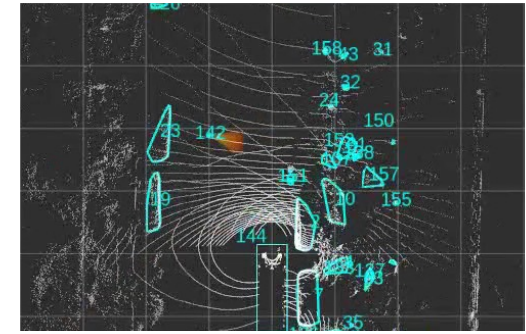
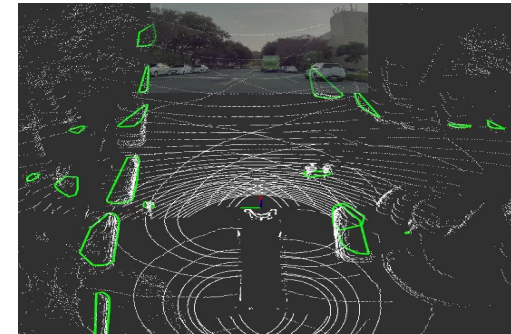
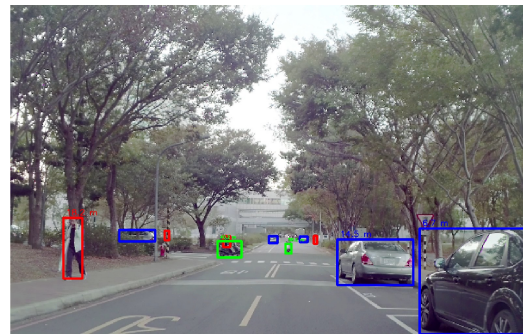
Division for Unmanned Vehicle Networks & Sensing System
Information and Communication Lab.,
Industrial Technology Research Institute

2023/12/5



Autonomous Driving Vehicle (ADV) Solution

- With support from MOEA, ITRI is designed for self-driving vehicles based on Autoware. Empowered by S3, ITRI AD Bus provides fully autonomous driving abilities in urban area. ITRI AD Bus has already been tested on the public road without dedicated/priority lanes at maximum speed 30km/h.



Autoware Foundation Activities

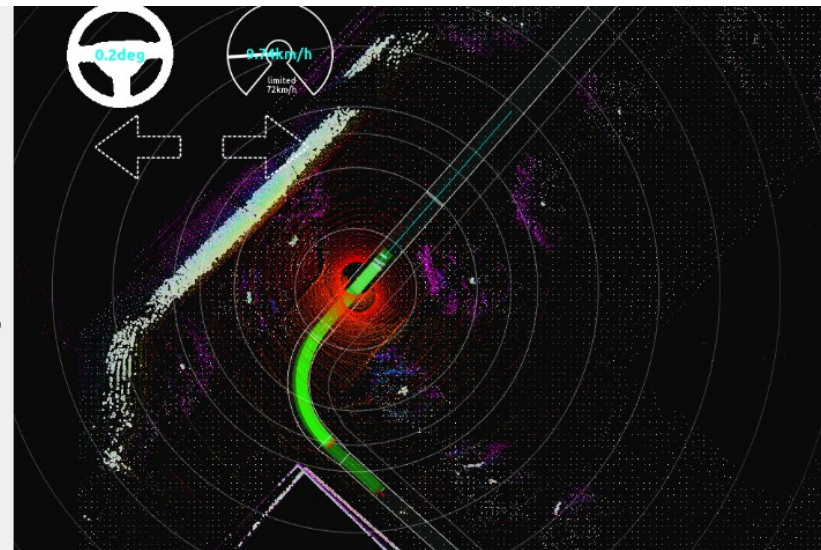
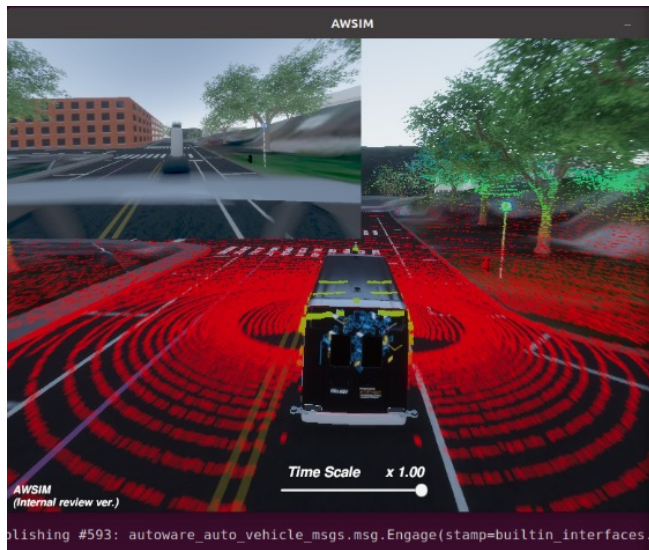
autowarefoundation/
cbus_vehicle_launch



Vehicle launch for the vehicle used in ITRI project

- Since 2021, ITRI proposed Bus ODD to AWF based on the pilot run experiences on public roads, and continued to contribute the ODD scenarios, reference design, and HD maps. ITRI has actively joined TSC, ODD WG, Software WG, API WG for defining further autonomous core technologies, requirements, and specifications.

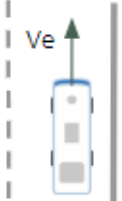
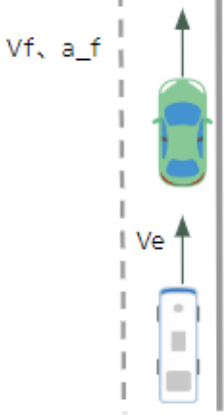
AWSim



MORAI



Bus ODD Use Cases

Use Cases #	Ego Vehicle Behavior	Simulation Scenario	Parameters
UC-PB-001-001	<ul style="list-style-type: none"> Stay in the lane Constant EGO speed 	<ul style="list-style-type: none"> Initial condition <ul style="list-style-type: none"> No NPCs, No obstacles Action <ul style="list-style-type: none"> EGO runs at the constant speed of V_e Success condition <ul style="list-style-type: none"> EGO reaches the destination 	<ul style="list-style-type: none"> V_e: [10-50] km/h by20 3 patterns 
UC-PB-001-002	<ul style="list-style-type: none"> Follow the preceding vehicle in the same lane Minimum distance to the preceding vehicle 	<ul style="list-style-type: none"> Initial condition <ul style="list-style-type: none"> Stay in the lane following the NPC Action <ul style="list-style-type: none"> The initial speed of the preceding NPC is V_f and its acceleration is a_f, and EGO runs at the speed of V_e V_e, V_f, a_f are set to the values in the right cell, and when the distance to the preceding vehicle is less than $V_e[m/s]*3.0[sec]$ [m], decelerate appropriately and maintain the safe distance Success condition <ul style="list-style-type: none"> EGO reaches the destination EGO decelerates when the distance to the preceding vehicle is less than the set value Failure condition <ul style="list-style-type: none"> Collide with the preceding vehicle 	<ul style="list-style-type: none"> V_e: [30,50] km/h V_f: [30,50] km/h a_f: [-0.2G ~ 0.2] G by 0.1 (excluding 0G) 8 patterns (see the table below) 

V_e	30	30	50	50
V_f	30	50	30	50
a_f	0.1G	0.2G	-0.2G	-0.1G

Source: Autware Foundation ODD WG

Autoware Evaluator (cont.)

SCENARIO MAP EDIT VERIFY/SAVE ACCOUNT UTILITY SETTING 2D 3D Grid: 51Q Square: TF

Summary

ProjectId	AWF
Map	Shalun with road shoulders (859-20231012061426986683)
ScenarioId	a54d78b1-1ffc-4948-bd58-2f8f5f1e5841
ScenarioType	planning_sim_v2

Entity

- ego (Ego)

Initial pose	/Car/Car0/Pose
Destination	/Route/RoutePoint0/Pose
Initial speed	m/s
Controller properties	
Speed	8.4 m/s
Dimensions	length: 4.77 m, width: 1.83 m, height: 2.5 m
Center	x: 1.355 m, y: 0 m

Map

Position

- Car
 - Car0 (ego)

position	lane=630, s=1.0441, t=0.2209
quaternion	[0, 0, 0 1]
 - Car1 (Npc1)

position	lane=461, s=22.3806, t=0.1094
quaternion	[0, 0, 0 1]
 - Misc
 - Misc0 (Misc0)

position	lane=649, s=5.7223, t=0.326
quaternion	[0, 0, 0.0207 0.9998]
 - Misc1 (Misc1)

Success

- ReachPosition

Parameter	/Route/RoutePoint0/Positi (Trigger=ego, Tolerance= Delay=
__ego_dimensions_length__	
__ego_dimensions_width__	
__ego_dimensions_height__	

Failure

Parameter

Whole map

Camera

Autoware Evaluator

Autoware Evaluator A AWF LOGOUT

Scenarios

Search: Name Simulator Review Status [+ NEW SCENARIO](#) ACTIONS Rows per page: 20

<input type="checkbox"/>	NAME ↑	TYPE	DESCRIPTION	VERSION	UPDATED
<input checked="" type="checkbox"/>	LEO-UC-A-01-0001	planning_sim_v2	Driving on slope (uphill) S_road = 1 % Ve: [10, 20, 30] km/h ■Initial condition · ...	1	30 November 2023
<input checked="" type="checkbox"/>	LEO-UC-A-01-0002	planning_sim_v2	Driving on slope (uphill) S_road = 5 % ■Initial condition · EGO is running...	1	30 November 2023
<input checked="" type="checkbox"/>	LEO-UC-A-01-0003	planning_sim_v2	Driving on slope (uphill) S_road = 10 % ■Initial condition · EGO is running...	1	30 November 2023

Autoware Evaluator (cont.)

The screenshot displays the Autoware Evaluator web interface. At the top, there is a teal header with the title "Autoware Evaluator" and a user profile "A AWF" with a "LOGOUT" button. On the left, a sidebar contains navigation icons for Reports, Scenarios, Catalogs, Suites, Maps, ML Packages, and ML Experiments. The main content area shows a "Reports" tab with a search bar and filters for "Status" and "User". The table below lists two reports, both with a status of "succeeded".

STATUS	RELEASE	TIME	USER
346/390 succeeded no description (Started at 2023/12/4 下午 1:50:56) Catalog: public road bus:1 Source: github.com/autowarefoundation/autoware (894fd0b0)	-	19 hours ago 1h 58m 14s	Hiros
199/217 succeeded no description (Started at 2023/12/3 上午 8:00:13) Catalog: public road bus:1 Source: github.com/autowarefoundation/autoware (894fd0b0)	-	2 days ago 2h 11m 21s	-

Pilot Run in Taiwan

- In 2018, Taiwan government rolled out the Unmanned Vehicles Technology Innovative Experimentation Act, and launched the Unmanned Vehicles Technology Innovative Experimentation Project in 2019. Fifteen projects passed the review and tested on the public roads.



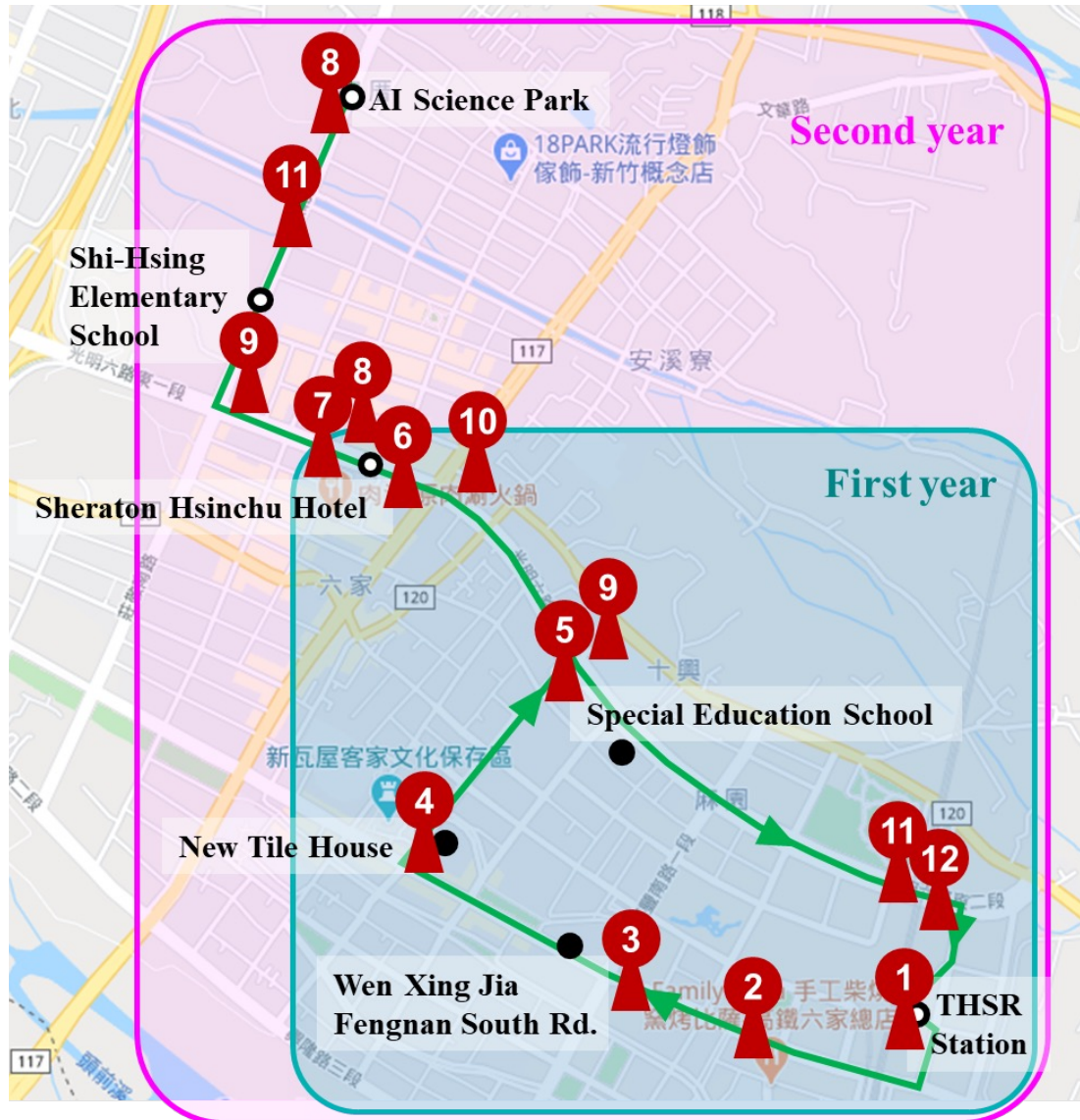
Pilot Run in Hsinchu

- ITRI collaborated with Yosemite Bus, Mobiletron, and Maxwin to develop **the first autonomous bus pilot run in urban area with high traffic without bus priority lane.**
 - The 1st year: Provide the shuttle services between Taiwan High Speed Rail Hsinchu Station and Sheraton Hsinchu Hotel (5.3 km)
 - The 2nd year: Extend to International AI Science Park. (8.1 km)



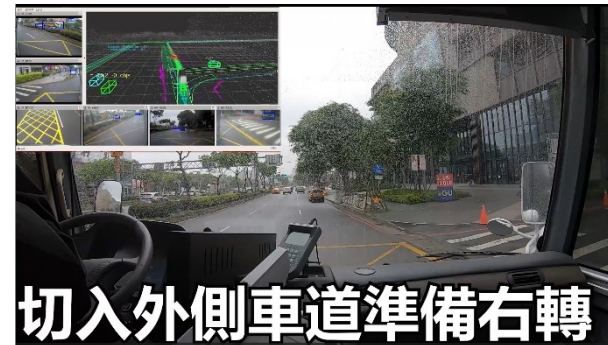
Daily Operation	First Year	Second Year
09:30-15:30	THSR Hsinchu Station ↔ Sheraton Hsinchu Hotel (5.3 km)	THSR Hsinchu Station ↔ International AI Science Park (8.1 km)
22:00-01:00		

Bus ODD



No.	Scenarios
1	Depart from THSR and enter the lane
2	Work zone
3	Pass non-signalized intersections with vehicles coming from the right
4	Right turn with crosswalk
5	Traffic light waiting
6	Overtake temporary parking / motorcycle in parallel
7	Vehicles from the right merging into the same lane
8	Bus stop (precision docking)
9	Left turn with crosswalk
10	Vehicles from the left merging into the same lane
11	Pass intersections with flashing amber at night
12	Vehicles from the right merging into the same lane at night

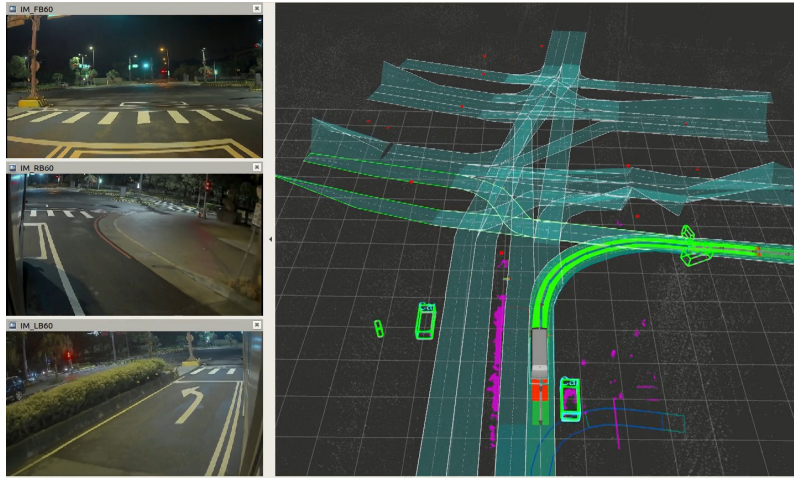
Challenging Test Cases



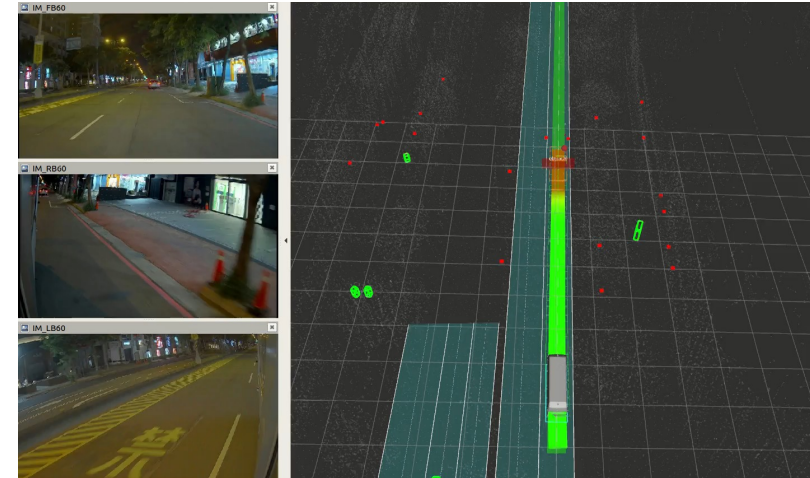
Challenging Test Cases (cont.)



Challenging Test Cases (cont.)



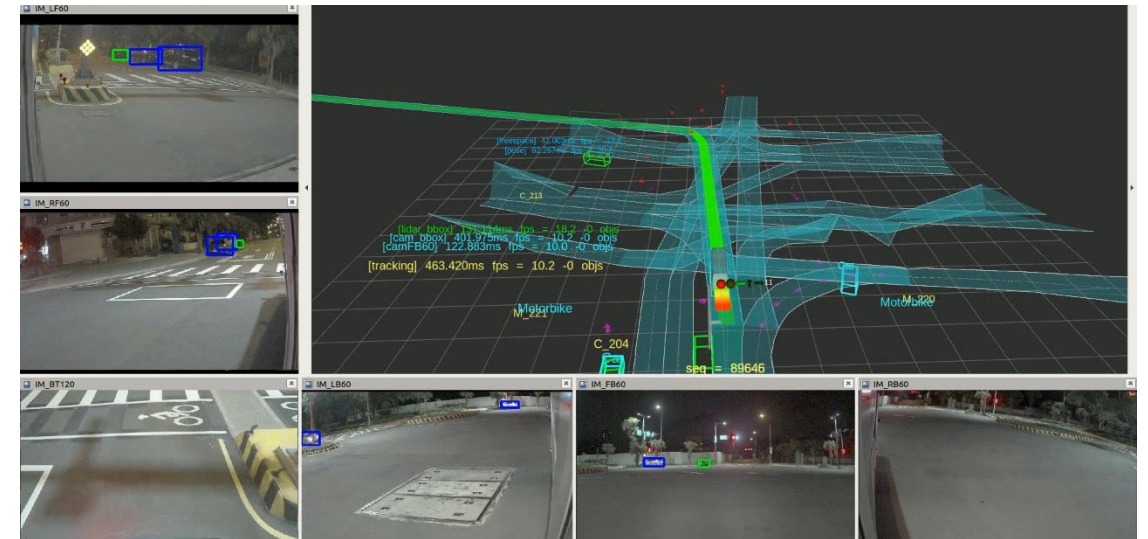
Right turn into narrow lane



Overtake temporary parking



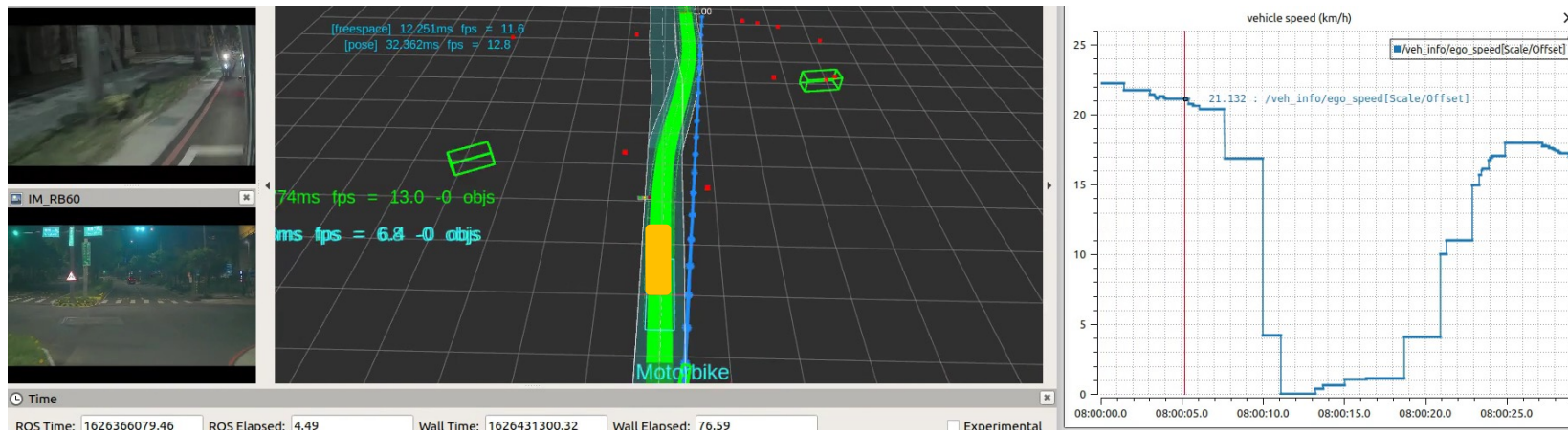
Lane changing



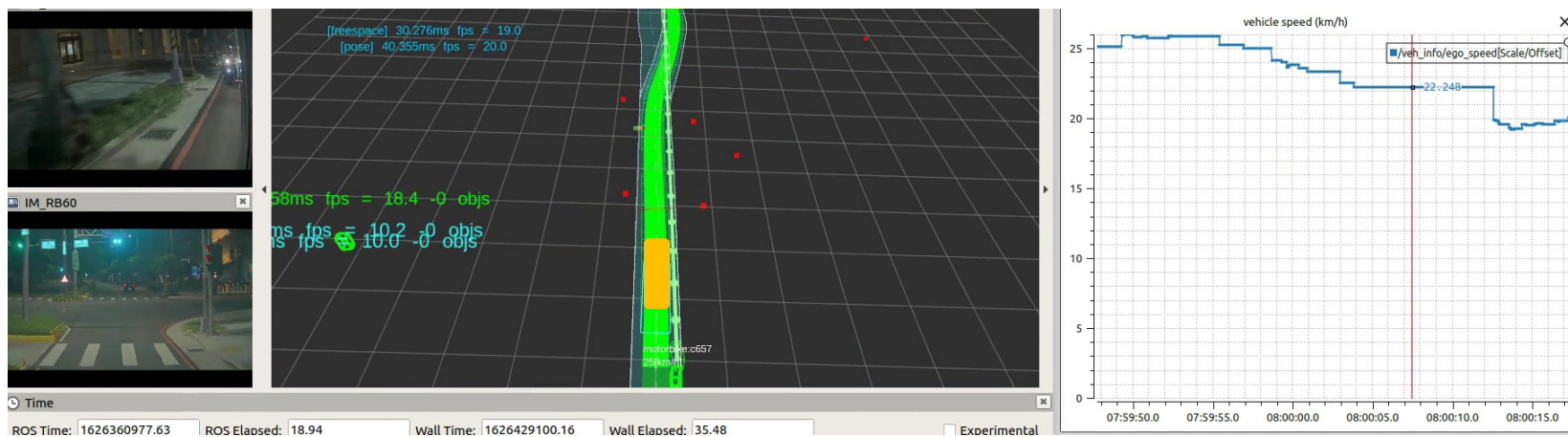
Left Turn

Challenging Test Cases (cont.)

- Avoid false positive from path prediction by calculating crossover time and time-to-collision (motorcycle case)

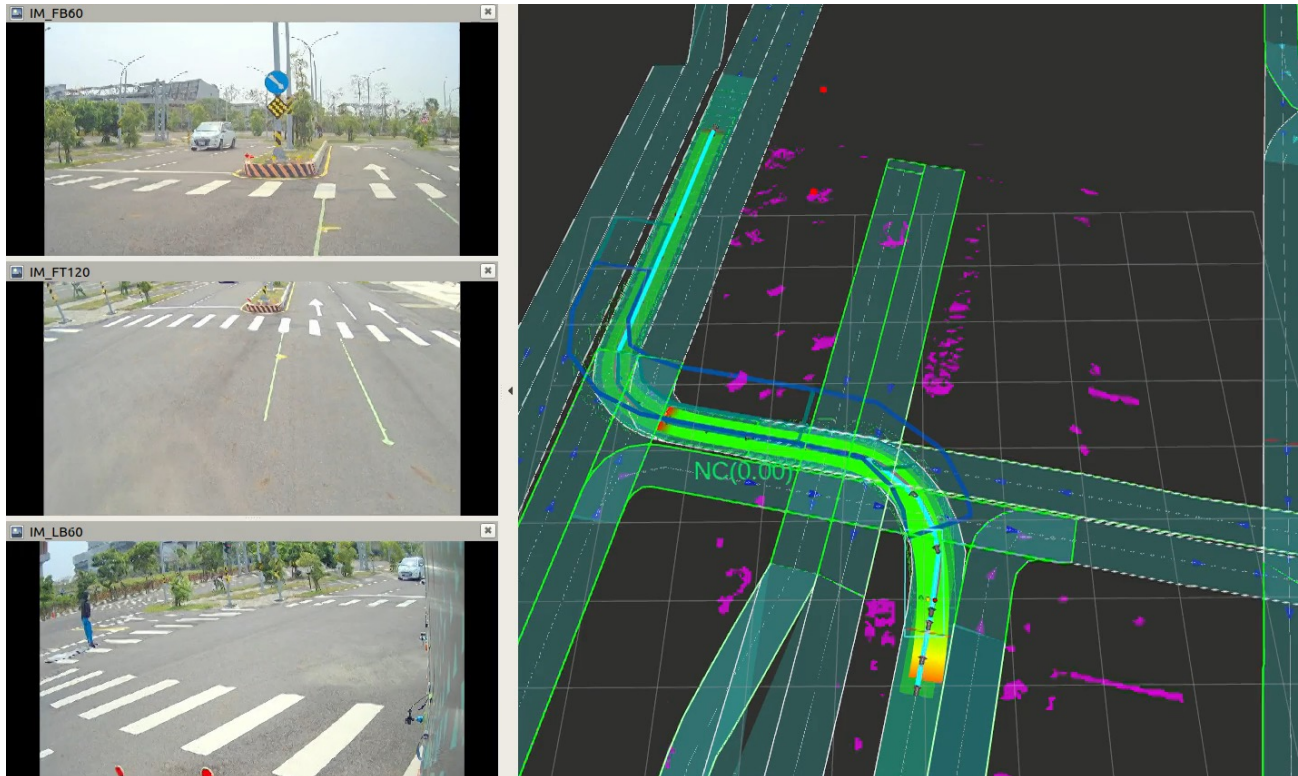


The ego vehicle triggers **preventive deceleration control** while a motorcycle overtakes from behind and cuts into the driving lane.

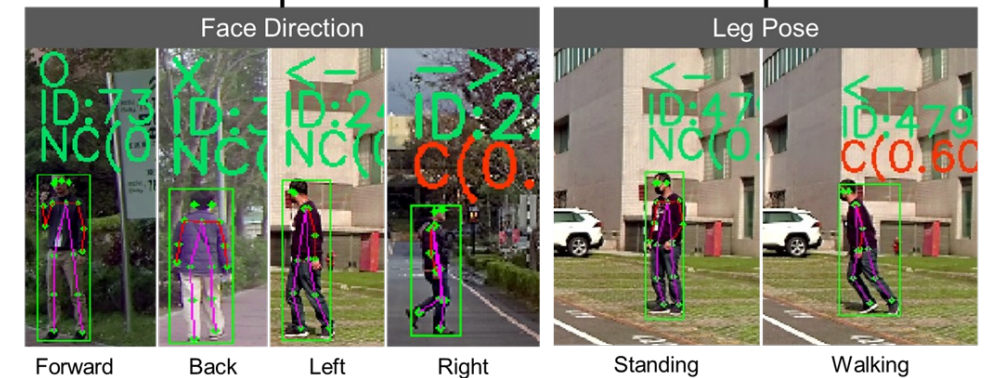
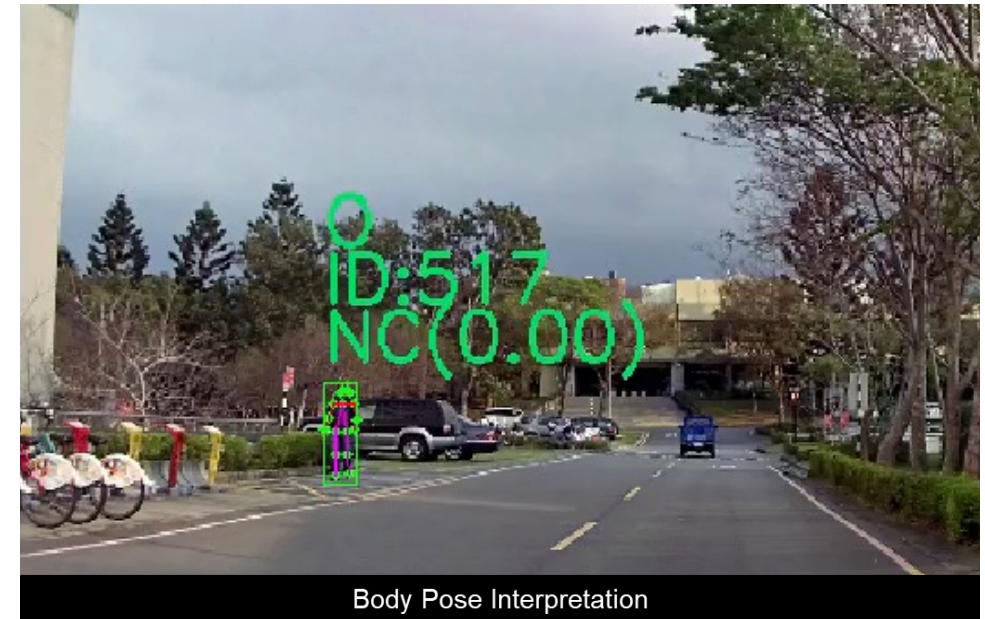


The ego vehicle does not trigger **deceleration control** while a motorcycle remains behind the ego vehicle.

Challenging Test Cases (cont.)



Pedestrian Crossing Prediction

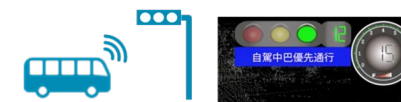


V2X Safety Applications

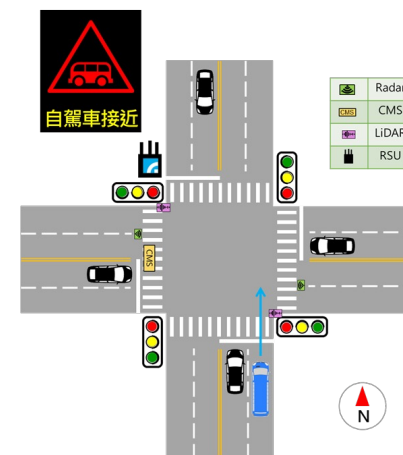
- **Signal Phase and Timing (SPaT) services**
 - Support signal compensation and adaptive signal mechanism
- **V2X-assisted Non-line-of-sight Detection**
 - Integrate roadside sensing information



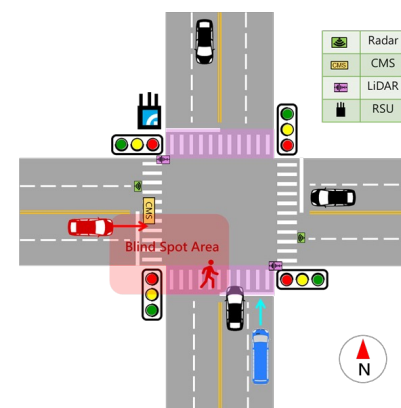
Transit Priority Signal



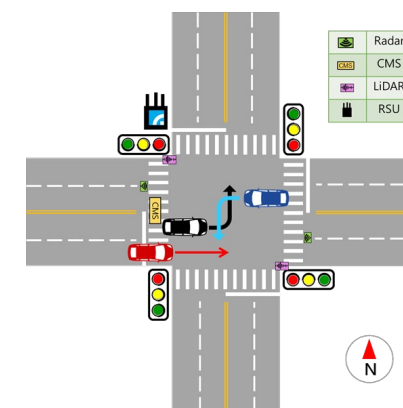
Autonomous Bus Approaching



Blind Spots/Pedestrian Detection

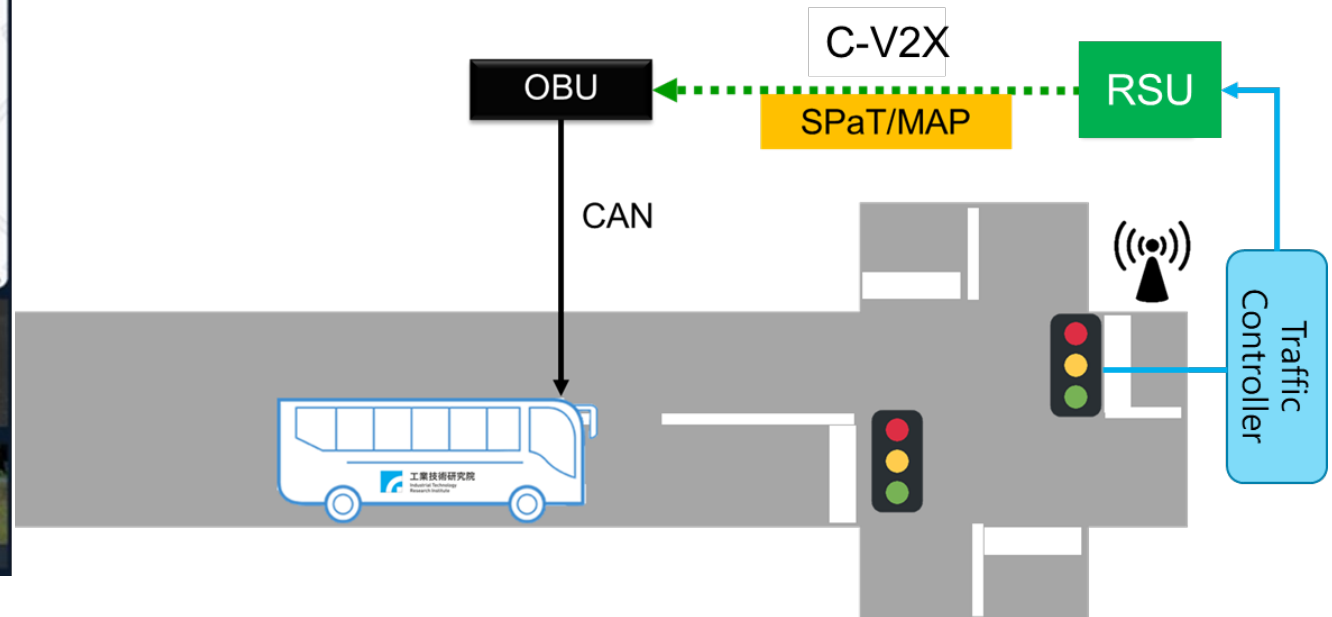
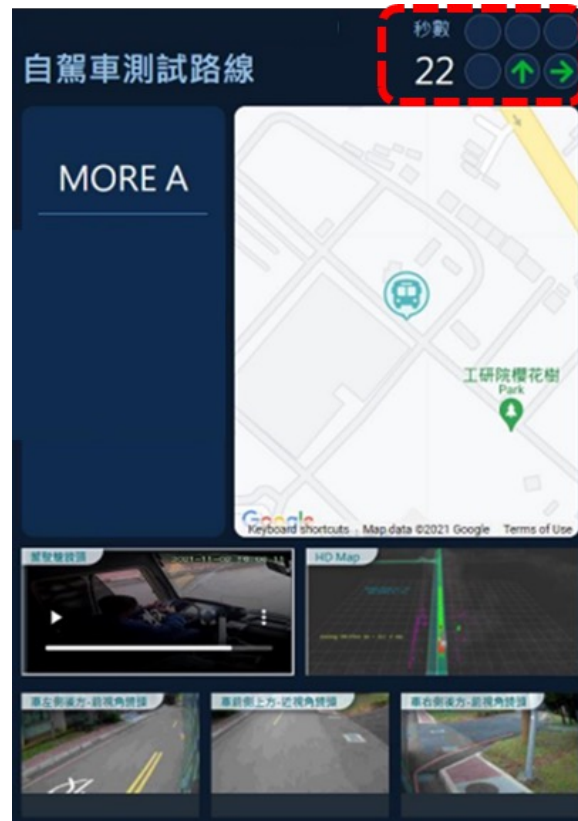
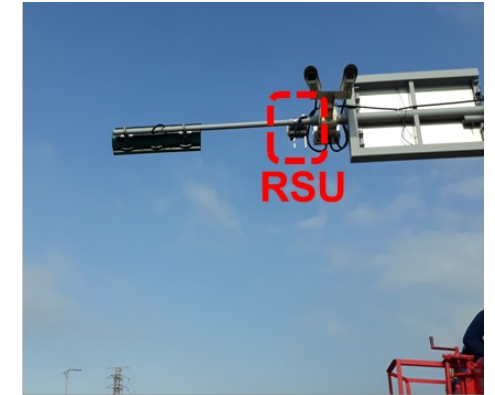


Left Turn Assist



V2X SPaT and Safety Applications (cont.)

- **V2X Signal Phase and Timing (SPaT) services**
 - Provide signal status to autonomous bus (with OBU) via RSU for 29 intersections



V2X SPaT and Safety Applications (cont.)

- **V2X Non-line-of-sight detection for non-signalized intersection**
 - Integrate C-V2X RSU, radar, and LED CMS (changeable message sign)
 - Provide the autonomous bus (with OBU) warning message sent from RSU
 - Provide the vehicle (without OBU) warning message showed on CMS

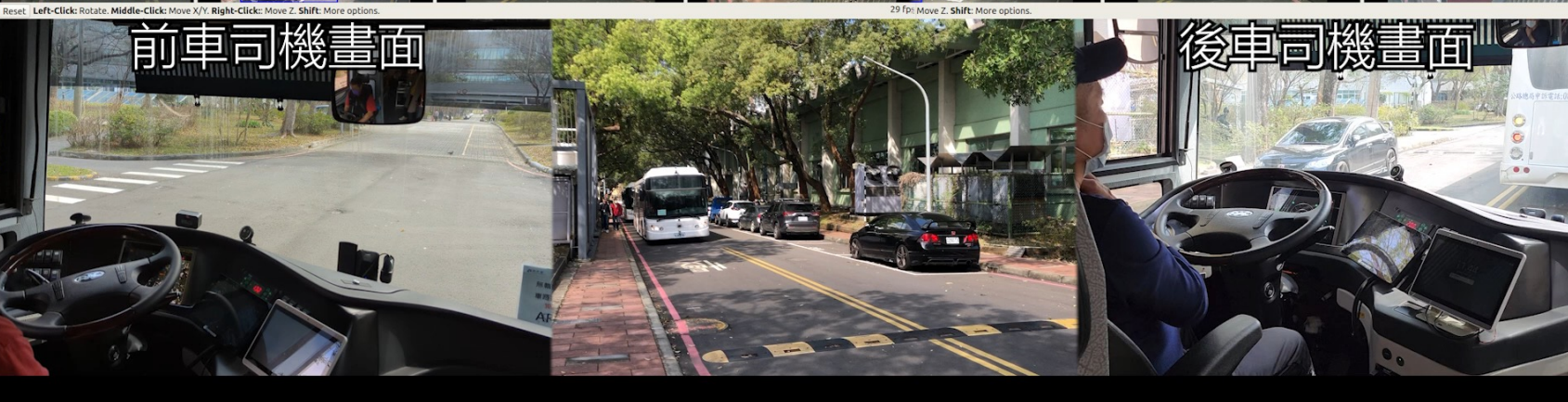
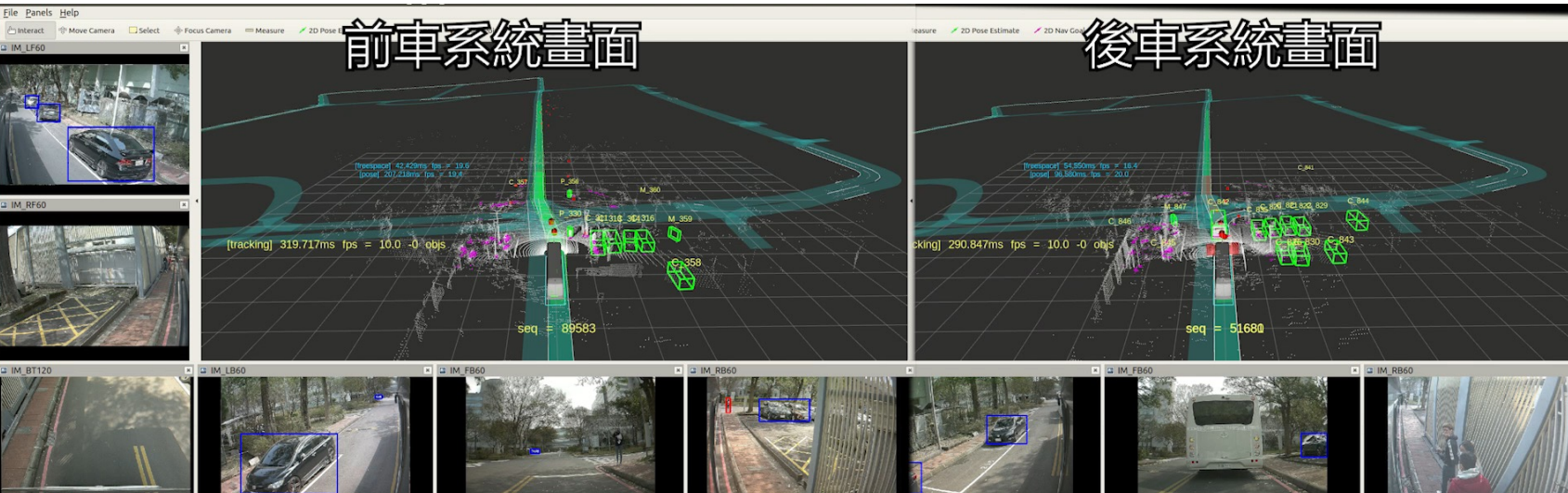




張目
張目
張目



Bus Platooning



Thank You for Listening

ITRI ADV

E-mail: hueiru@itri.org.tw

