Development of precise docking system contributing to Next Generation Transportation in SIP

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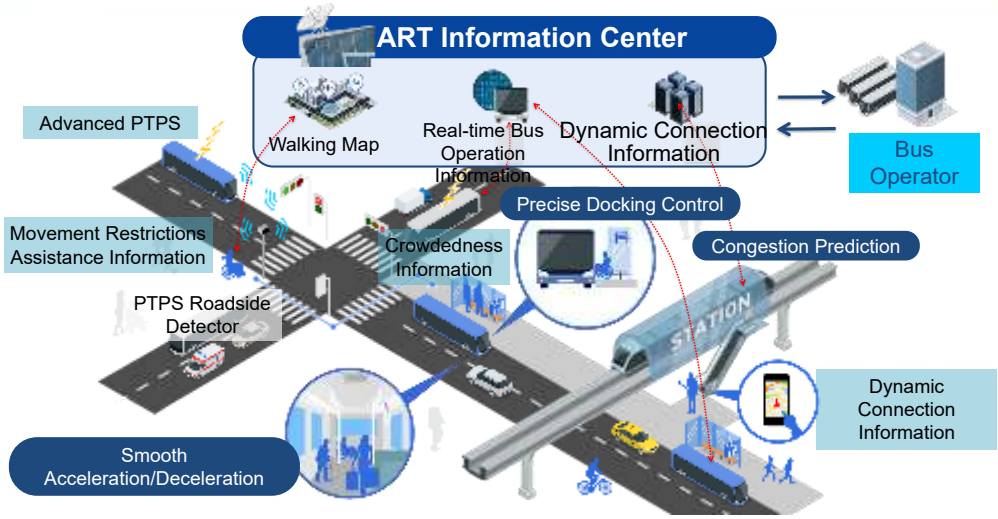
SIP

1. Next generation transport in SIP
2. Precise docking control technology
3. Sensor fusion technology
4. Cooperative docking control with driver
5. Field operational test

Next generation transport in SIP

Next Generation Transport in SIP



Realize consistent accessibility for all people including elderly and handicapped person

Next Generation Transport in SIP

Precise docking control technology

Development of sensing and control technology for ART docking system

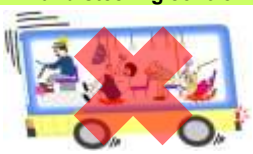
>Sensor fusion technology : Vehicle position, surroundings (pedestrian, bicycle and others)
>Control technology : Integrated control of steering and braking

Target

① Smooth embarkment at station

② Robust control in various environments

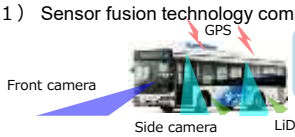
③ Smooth braking and steering control



④ Cooperative docking control with driver

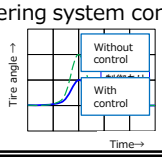
Development item — *Technology*

1） Sensor fusion technology compatible with current road marking



>Robustness in various environments
>Small infrastructure investment
>Fast image processing

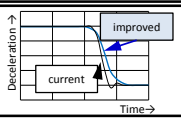
2） Improvement of steering system control performance



>Advanced steering control reducing dead band or delay caused by mechanical issue

3） Reducing jerk at braking and cornering

>Sophisticated and integrated steering and braking control



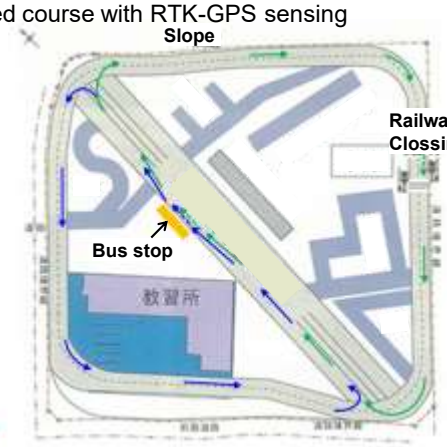
4） Harmonizing driver and automated operation

>Precise estimation of driver intention from steering torque or deviation of steering torque

ITS Asia-Pasific forum Fukuoka

Technical visit
Training center of Nishitetsu bus
May 8-10th,2018
About 120 Participants

Autonomous driving and precise docking
at closed course with RTK-GPS sensing



Course for demonstration

ITS Asia-Pasific forum Fukuoka

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Development at The University of Tokyo

The University of Tokyo
ITS R&R Experiment Fields at Kashiwa
Demonstration at October 16th, 26th, 27th, 2018
Over 500 Participants
Autonomous driving and precise docking
at closed course with RTK-GPS sensing

Test mule for precise docking control

Specification

- ○Blue Ribbon City (Hybrid)/Hino motors, Ltd
- ○Number of seats：20
- ○Attachments for wheel chair： 2
- ○Length:10.5m×Width:2.5m×Height:3.3m
- ○Number of doors： 2
- ○Height of floor：About 340mm (Non step)

Additional equipment

- ○Autonomous steering actuator
- ○Autonomous brake actuator
- ○GNSS、QZSS receiver
- ○Front and side camera
- ○Lidar

Appearance

Seat layout

Seat

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Optimization of control gain

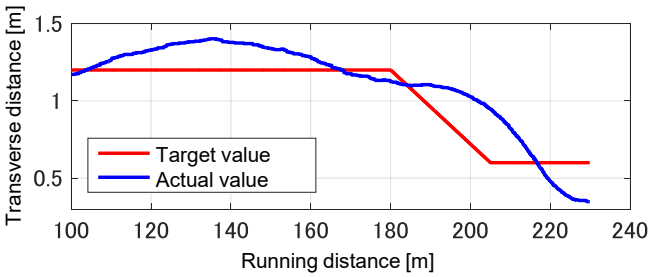
Control gain k2（term of decreasing transverse deviation）

k2 value was Constant → Switch k2 values (straight / docking)

⇒ Optimum vehicle behavior in each situation

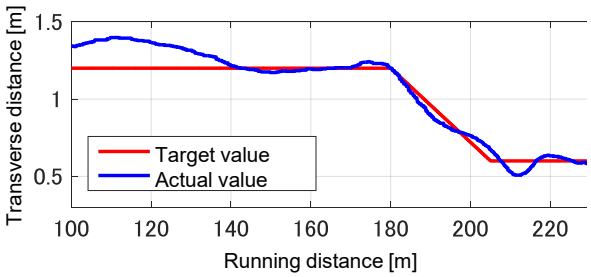
Constant

Optimized gain in straight situation.



Switching (straight / docking)

Optimized gain in each situation.



◎Tracking performance is considerably improved.

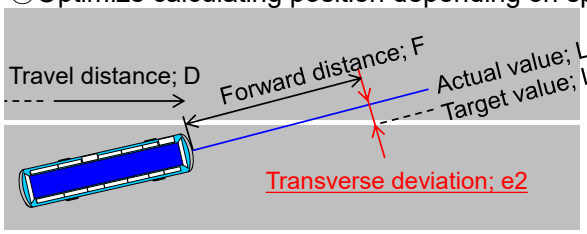
Optimization of calculating transverse deviation

Transverse deviation

①Change calculating position (vehicle forward) for target value.

(Last year, calculating position for actual value was already changed.)

②Optimize calculating position depending on speed, situation (straight/ docking).



$$e2 = Lt(D + F) - L(D + F)$$

Transverse deviation

Travel distance

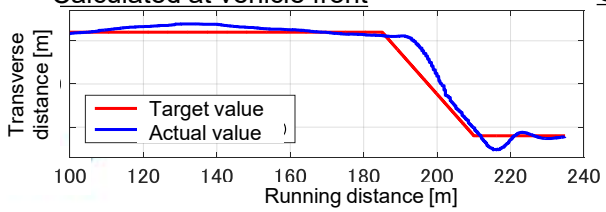
Target value

Actual value

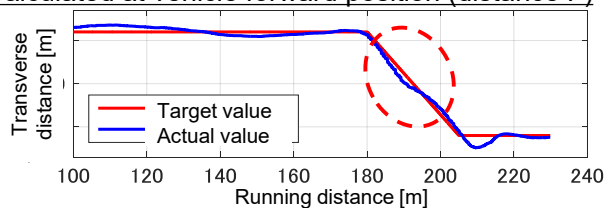
Distance between calculating position and vehicle front

Effect of changing calculating position (target value)

Calculated at vehicle front

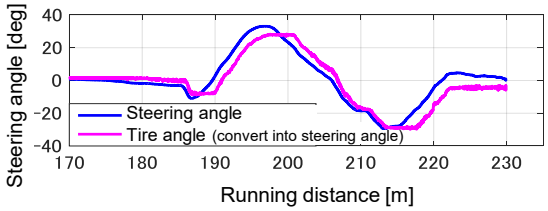


Calculated at vehicle forward position (distance F)

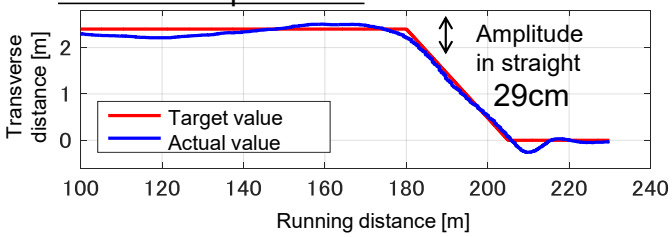


Steering control which compensate the tire angle response to the steering angle behavior

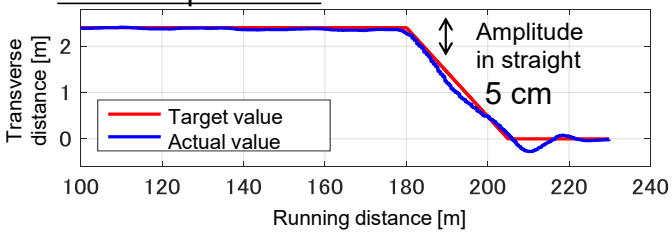
Dead zone between steering angle and tire angle is about 11degrees.
⇒ Correct target steering angle.



Without compensation



With compensation



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Stop to the bus stop with high accuracy

Braking control method

- Calculate target acceleration using assumed stop point.

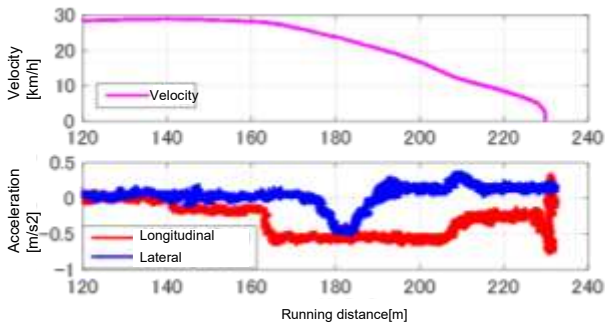
$$a = \frac{v^2}{2(St - S)}$$

※a : target acceleration, v : velocity
S : runnig distance, St : assumed stoppingpoint

- Set different values of assumed stop point in the first half and the latter half of lateral moving

Result

Longitudinal deviation:±0.2m
※Allowable range: ±0.5m.



Precise docking control (Driver's view)

Sensor fusion technology

Sensor fusion technology

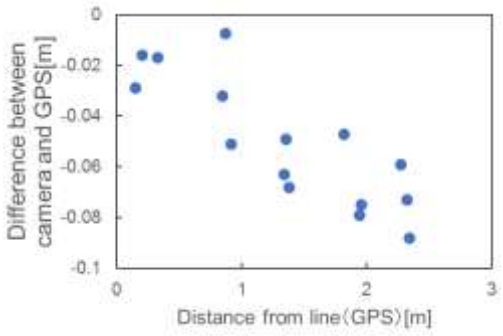
Comparison of RTK-GPS／Front camera

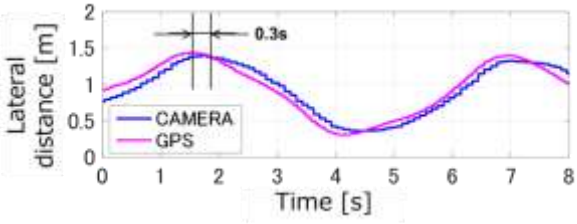
Fundamental study for multiple sensing method selection or cooperation is progressed.

Output value of lateral position is different between RTK-GPS and front camera.

It is related to the actual distance.

The value from camera is delayed to the value from RTK-GPS (0.3sec)





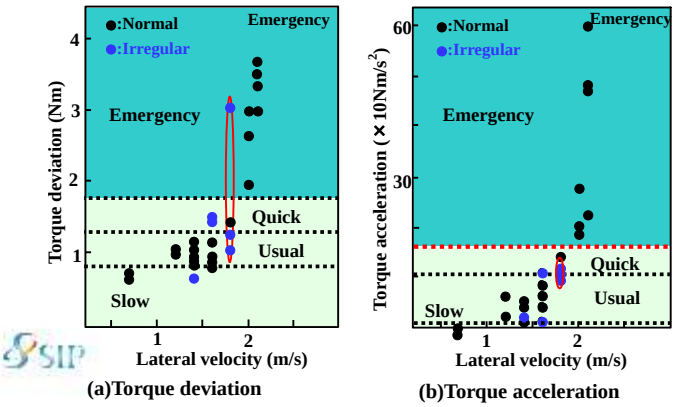
When the sensor switches, it should be taken into account for sensor characteristics.

Cooperative docking control with driver

Cooperative docking control with driver

Sharing control method between vehicle system and driver
is developed using Steer-by-wire system without mechanical linkage

In the case of avoidance at emergency on level 3,
additional function to autonomous avoidance will be possible
by precise estimation method of driver's intention from steering internal parameter.



Example ;
Estimation of driver intention
from the deviation of
steering torque or torque acceleration

JSAE journal
Vol.31,No1,January 2000.
20004035

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Intervention by driver（Avoidance at emergency）

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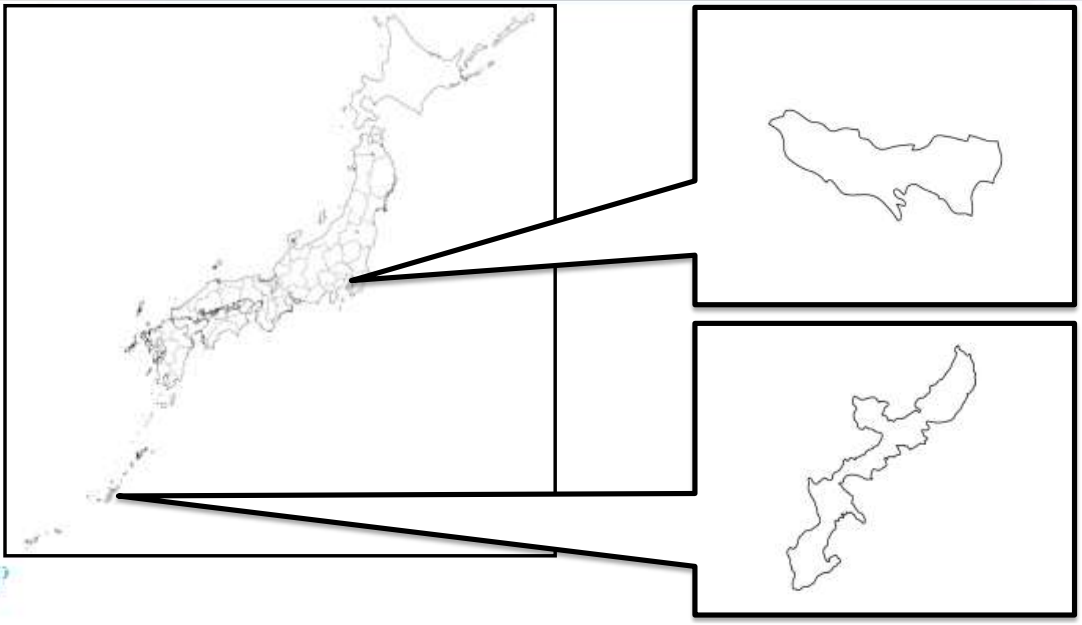
Field operational test

Field operational test in Japan



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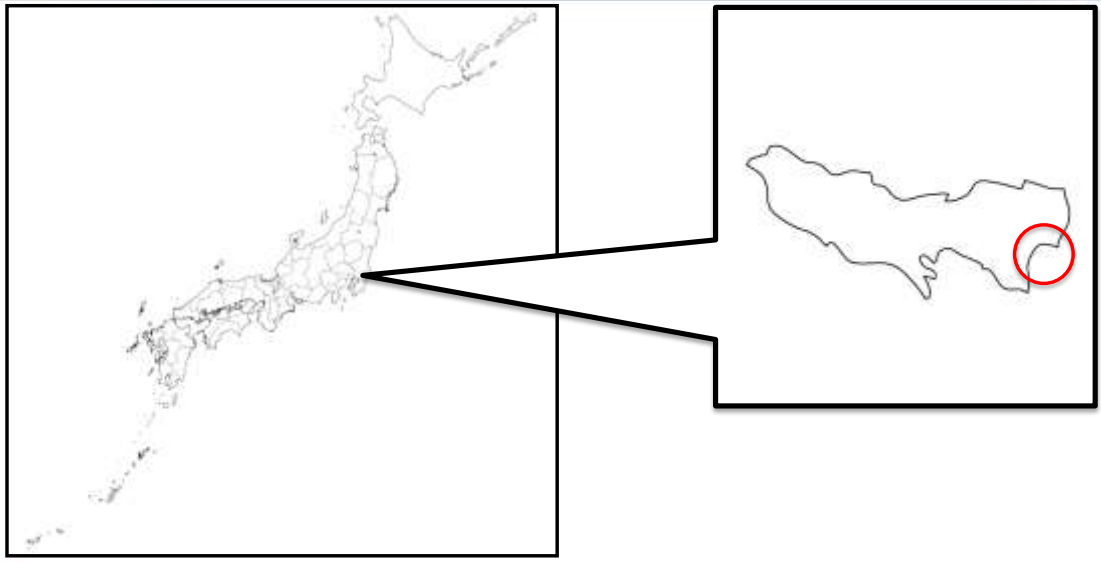
Field operational test in Tokyo bay area



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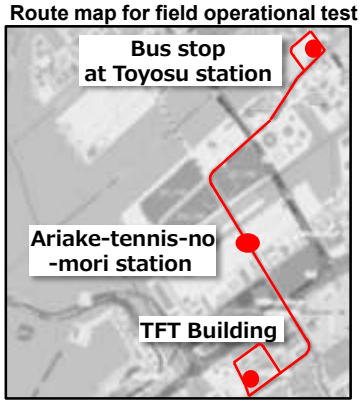
Field operational test in Tokyo bay area

Field operational test ; 20th November – 21th December
Demonstration of ART ; 6-7th February

Route map for field operational test



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We are here.

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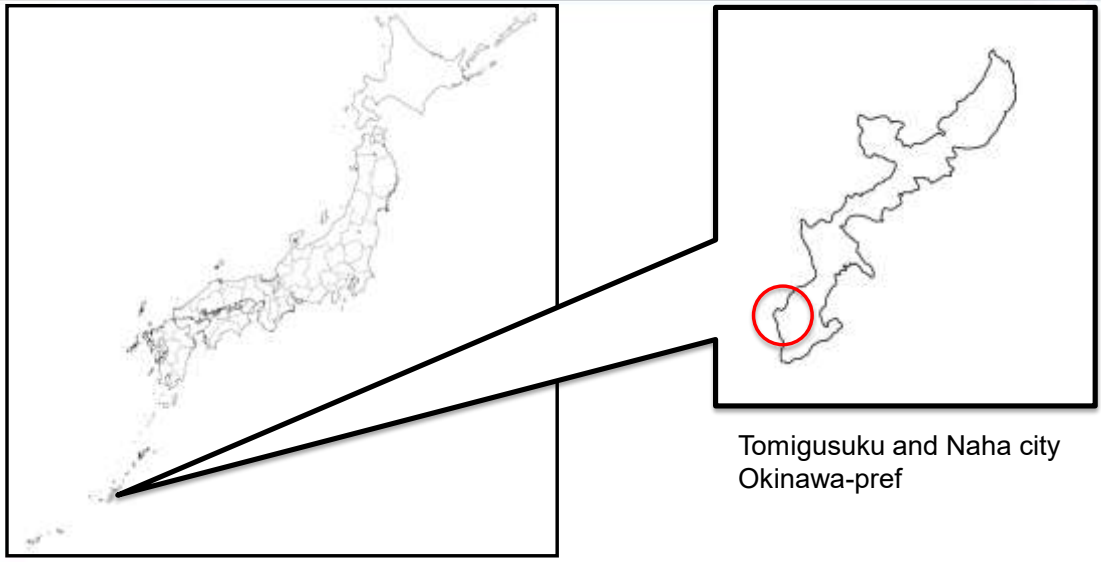
Field operational test in Okinawa

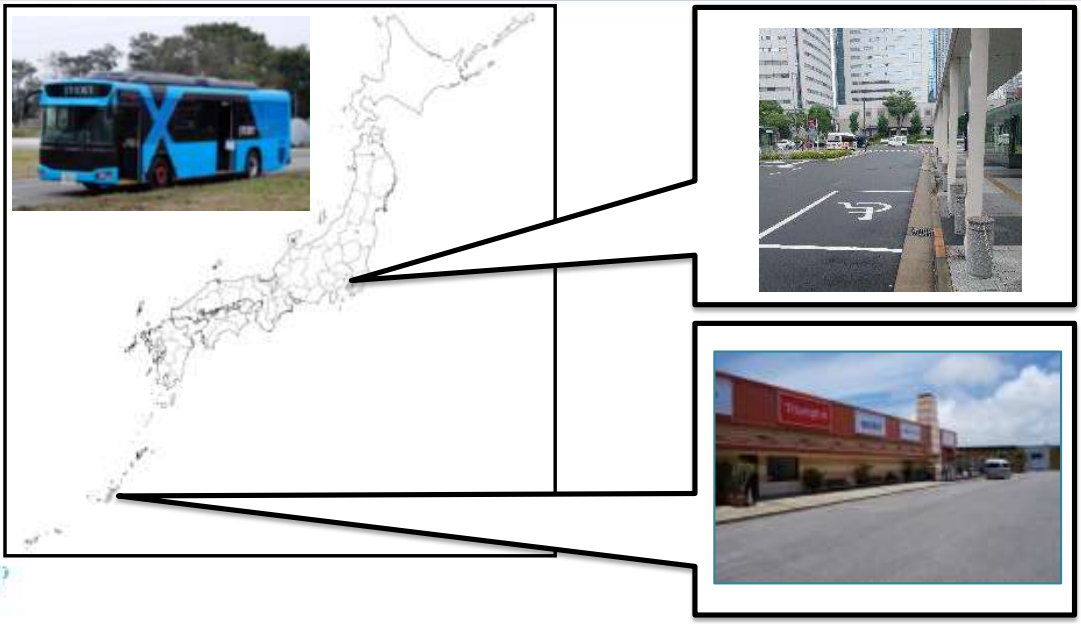


Tomigusuku and Naha city
Okinawa-pref

Field operational test in Okinawa

Schedule (Temporary)
Field operational test ; 13th February – 8th March
Pre-test ; 31th October- 15th November
6th January – 24th January

Field operational test in Japan



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Thank you