Practical steering control for an autonomous docking based

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Outline

- Background
- Motivation and Purpose
- Steering control
- Experiments
- Conclusions

Next Generation Urban Transportation System Concept
- ART: Advanced Rapid Transit -

Japanese government initiated a research project on automated driving systems under Cross-M IP).

ART will expand from the traditional limited operations to provide more transportation convenient service in advanced road transportation systems. Especially, automation of a high-precision docking to bus stop is required.

Experimental step and gap limit evaluation to establish wheelchair friendly conditions

Research subjects: 12-persons (6 male and 6 female)
Age-range: 20-60 years

Experimental verdict: Step value:3cm Gap value:6cm


EXPERIMENT IMAGE


MANUAL WHEELCHAIR


ELECTRIC WHEELCHAIR

Estimate index	
○	Easy access
△	Requires some effort (reasonable)
▼	Outer limit
X	Assistance required

1. The allowable step limit

Step value	MANUAL WHEELCHAIR						Evaluation
	A	B	C	D	E	F	
6mm	○	○	○	○	○	○	○
18mm	○	○	○	○	○	○	○
30mm	△	△	○	○	X	△	△
42mm	X	▼	▼	▼	X	▼	X

Step value	ELECTRIC WHEELCHAIR						Evaluation
	A	B	C	D	E	F	
6mm	○	○	○	○	○	○	○
18mm	○	○	○	○	△	○	○
30mm	△	○	○	○	○	○	○
42mm	X	▼	▼	▼	X	▼	X

2. The allowable gap limit

Gap value	MANUAL WHEELCHAIR						Evaluation
	A	B	C	D	E	F	
30mm	○	○	○	○	○	○	○
45mm	○	○	○	○	○	○	○
60mm	○	○	○	○	○	○	○
75mm	▼	○	○	▼	▼	△	▼

Gap value	ELECTRIC WHEELCHAIR						Evaluation
	A	B	C	D	E	F	
30mm	○	○	○	○	○	○	○
45mm	○	○	○	○	○	○	○
60mm	△※	○	○	○	○	○	○
75mm	X※	○	○	▼	▼	▼	▼

※front wheels to fall into the gap

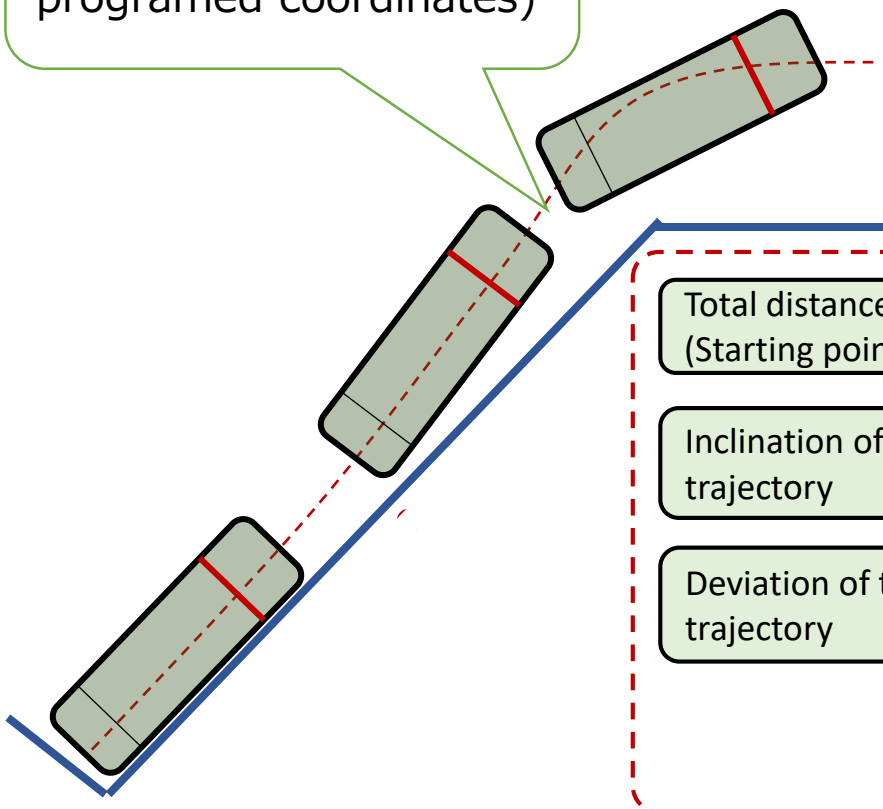
Control System for Autonomous Docking

$$\theta = \frac{K_f l_f - K_r l_r}{K_f v}\gamma + \frac{Mv}{2K_f}\omega_c$$

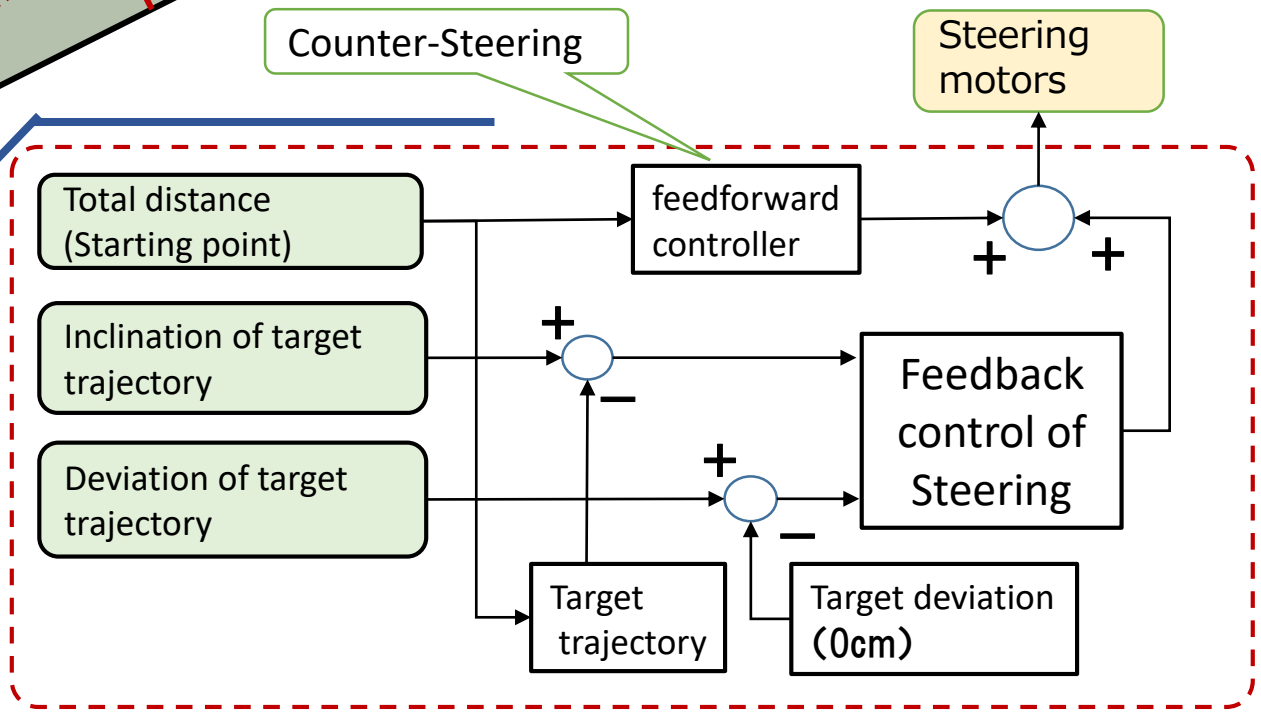
$$\omega_c = -K_2 e_2 v_r - K_3 \sin e_3$$

$$v_r = v\cos e_3$$

Target trajectory (Geometrically programed coordinates)

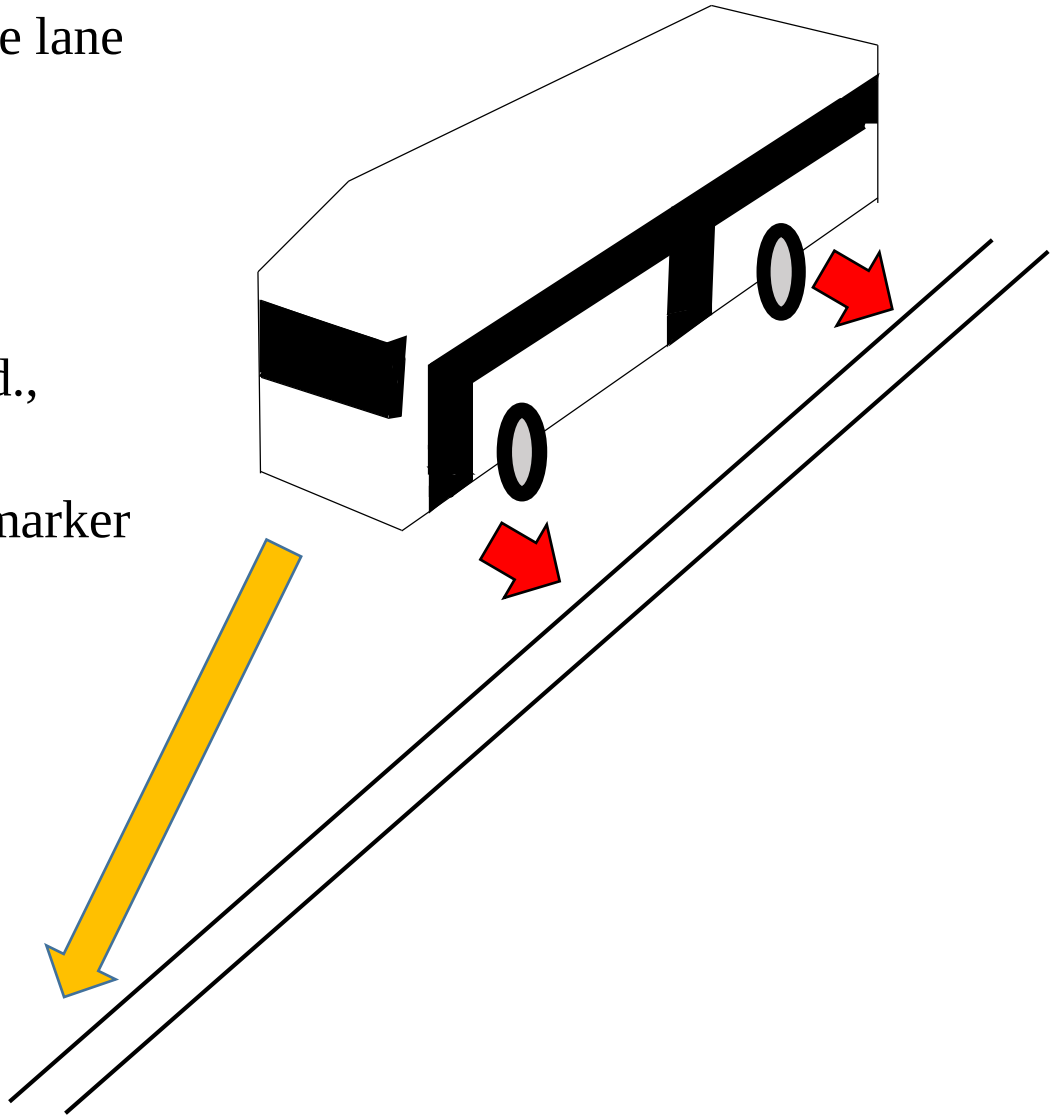


Control Model

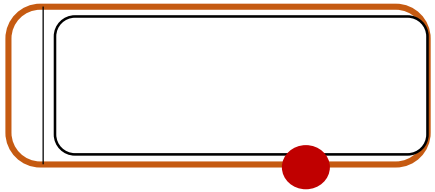
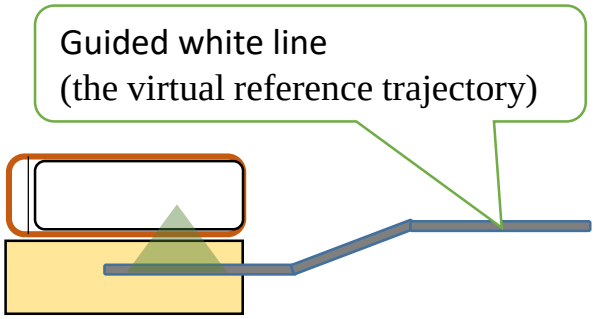
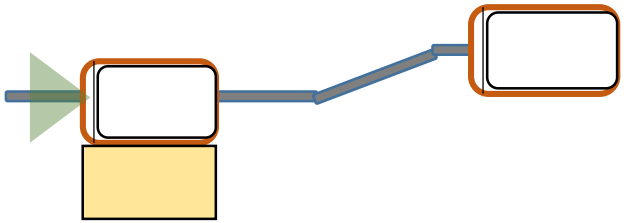
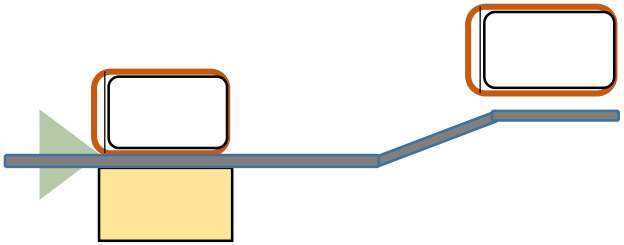


Lane Keeping for Automatic Steering

- In general, a camera foresees the lane marker .
- There are some driver model to control the vehicle position.
- It is difficult to see a marker in various situations: weather cond., close space.
- Another way is to see the lane marker in just side of the vehicle.

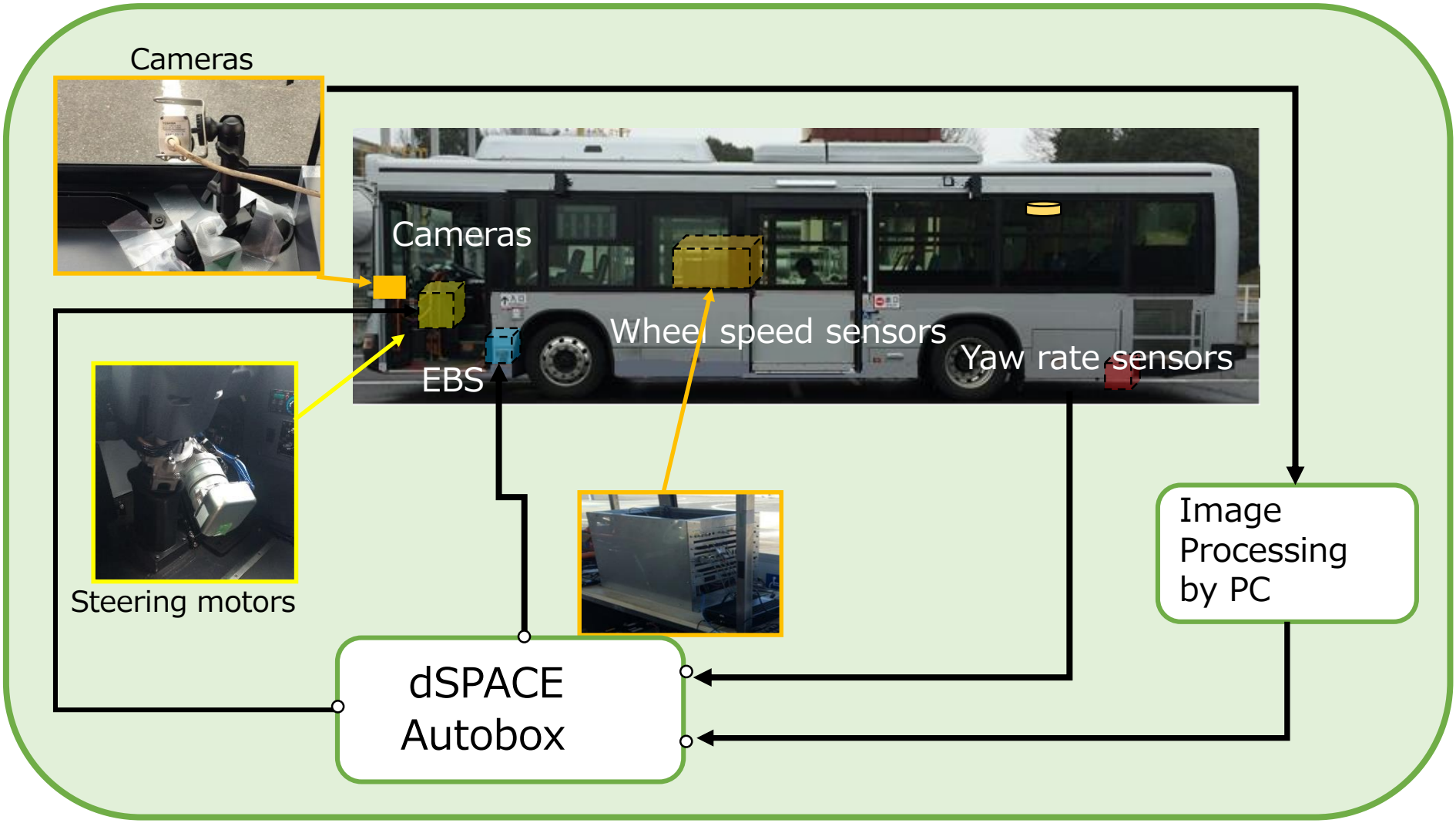


Control with Road white line

Camera position	Position of Guided white line	merit and demerit
1. Near the Vehicle rear door 		○Merit ・Performance improvement near the rear door ○Demerit ・draw a white line at the bus stop
2. Near the Vehicle tip center 		○Merit ・Feedback control with white line is always possible ○Demerit ・Performance drops near the rear door ・Mixed with ordinary road white lines
3. Near the front left end of the vehicle 		○Merit ・Feedback control with white line is always possible ○Demerit ・Performance drops near the rear door

Since it is difficult to realize No.1,2, it is evaluated at No3

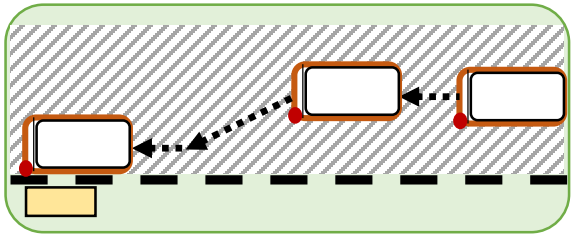
Test Bus and System Architecture



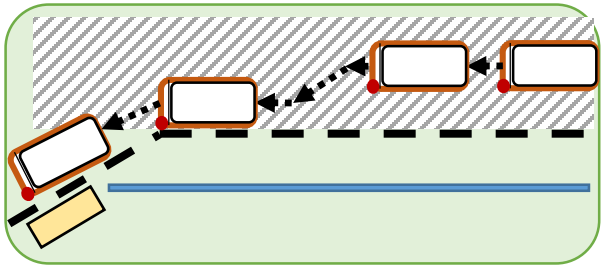
Experiments

- The operations of acceleration and deceleration are performed manually by a driver
- Only the steering is controlled
- The velocity of the truck is from 20 or 30 km/h to 0 km/h
- The controlled bus follows to the reference trajectory and the reference heading angle determined from the results of manual operation.
- The reference trajectories are three types

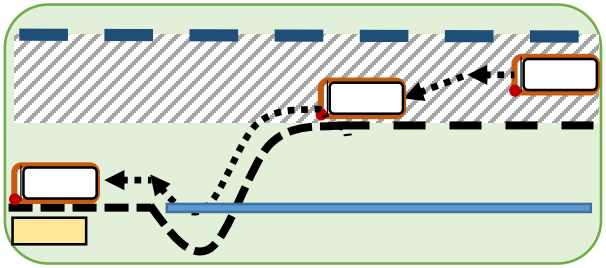
Type 1



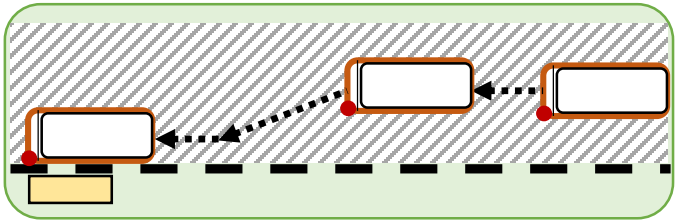
Type 2



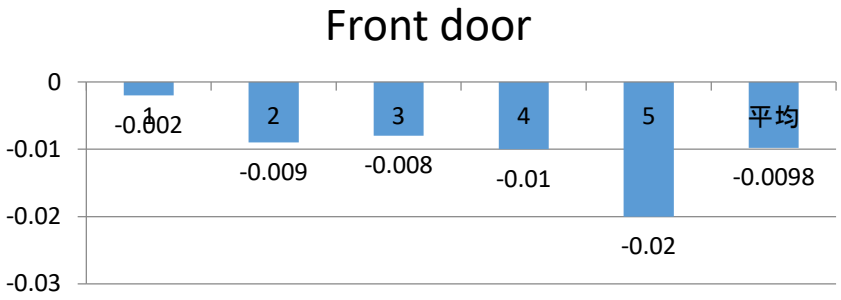
Type 3

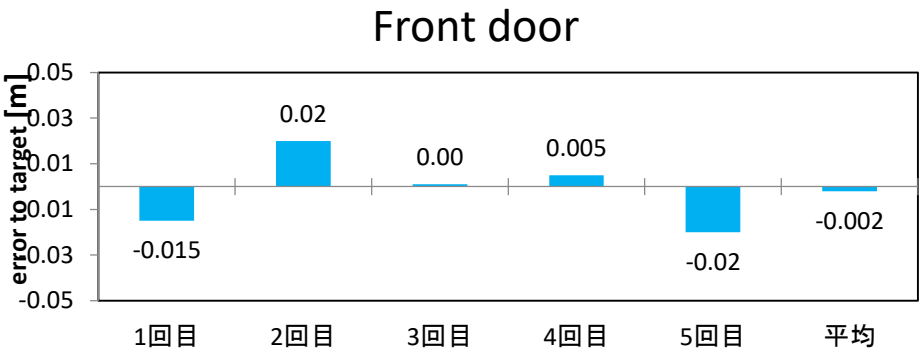


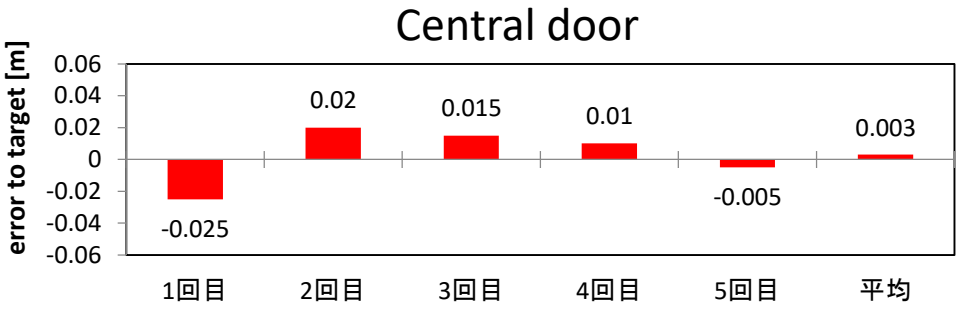
Reference trajectory Type1

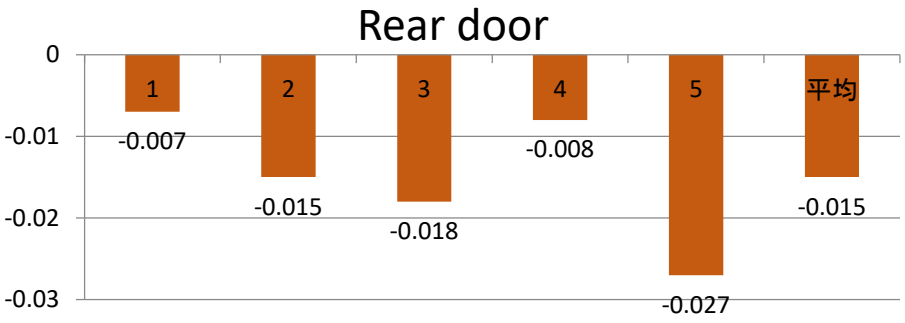


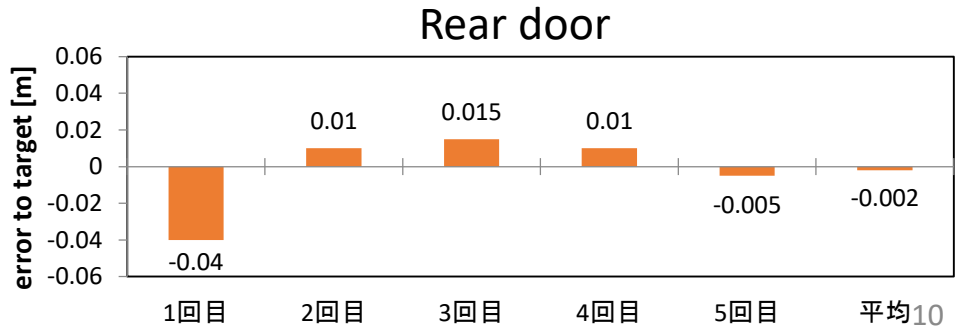
● **The error to target is ±0.02m**



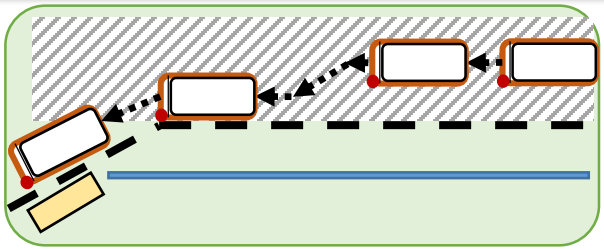






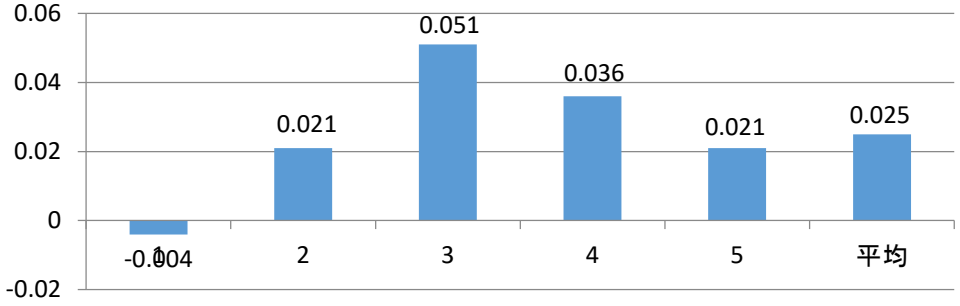


Reference trajectory Type2

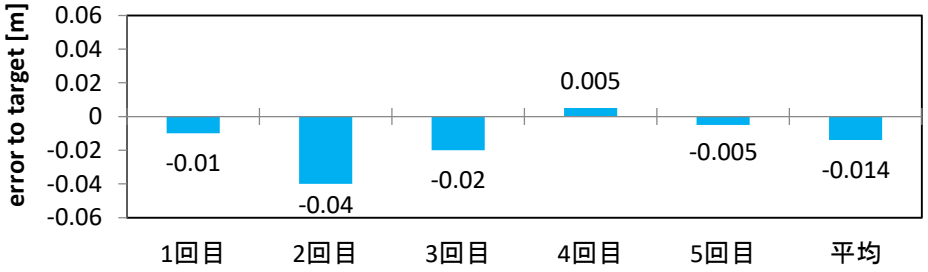


●**The error to target is ±0.02m**

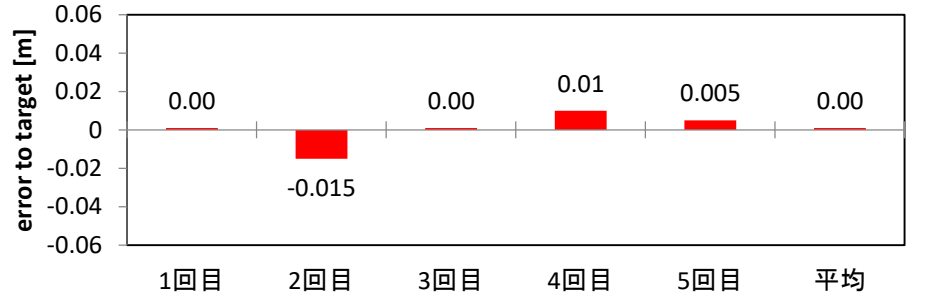
Front door



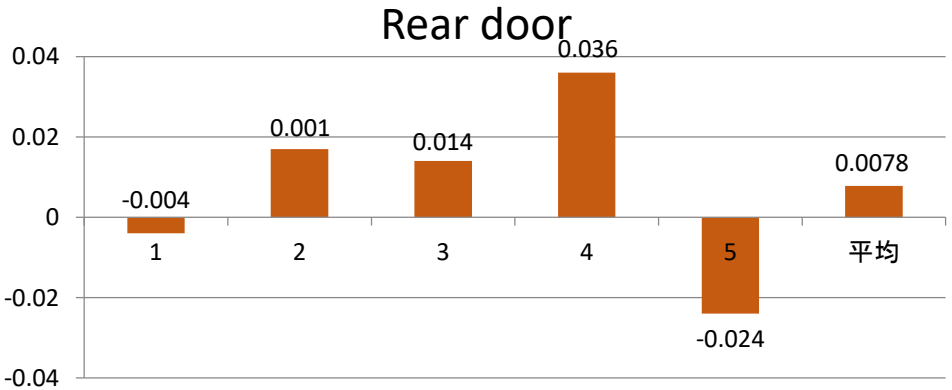
Front door



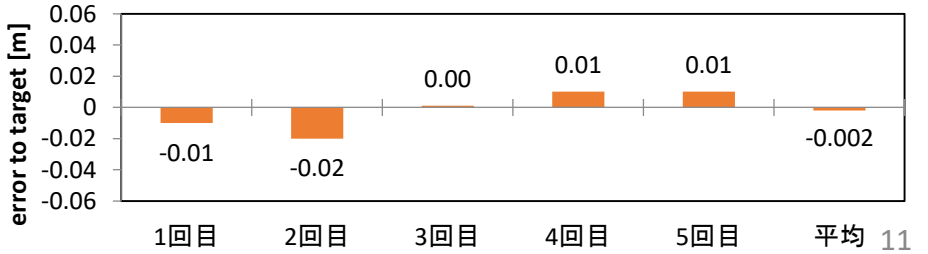
Central door



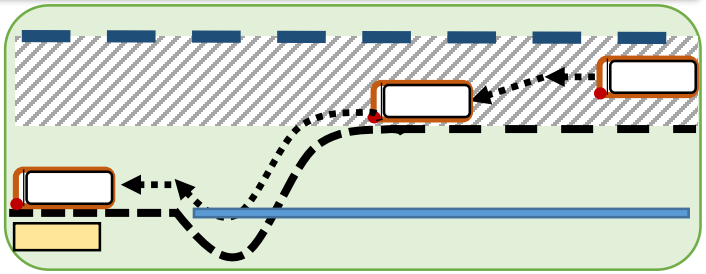
Rear door



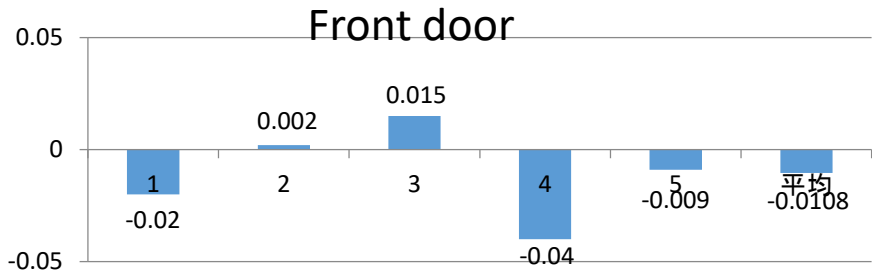
Rear door

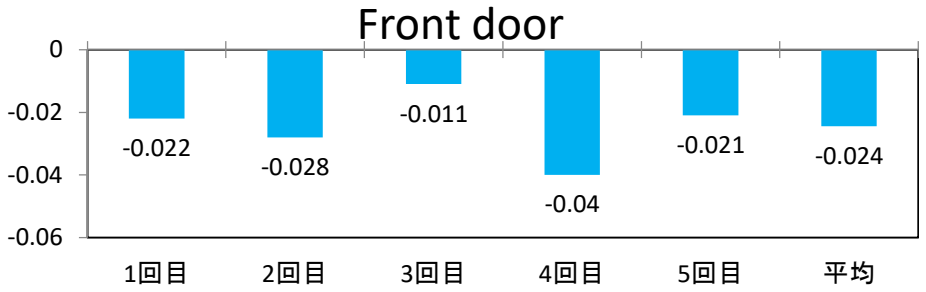


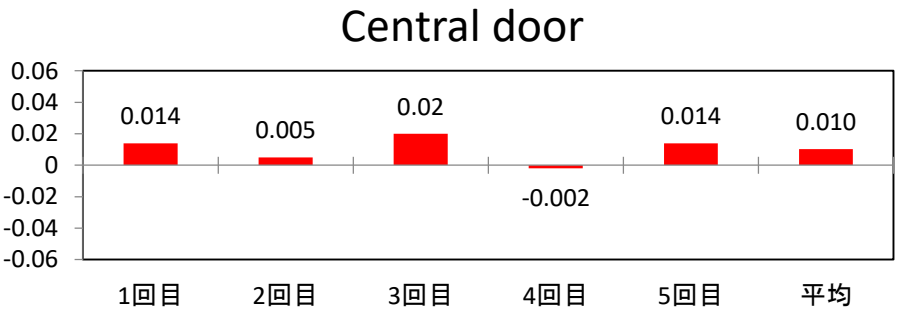
Reference trajectory Type3

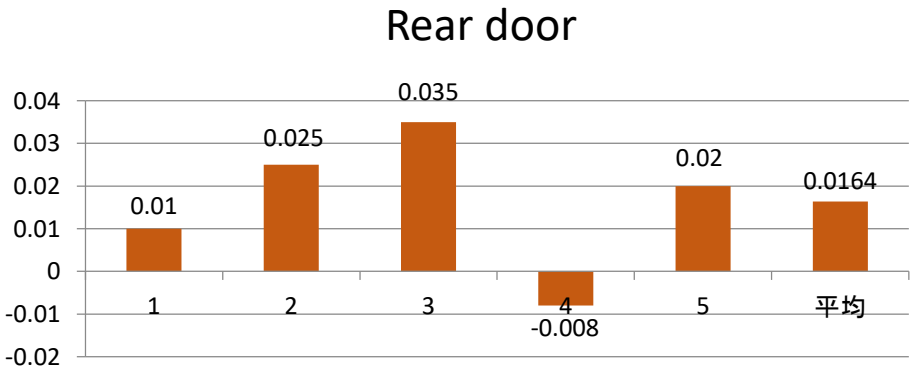


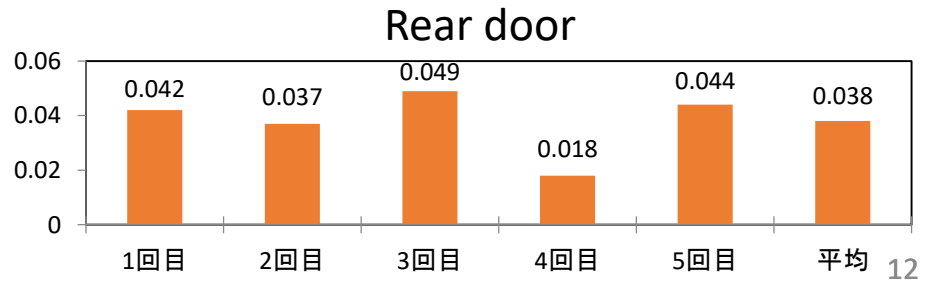
●**The error to target is ±0.02m**











Experimental Results

Reference trajectories	Door position	Stopping Distance [cm] Type of vehicle: Bus — Maximal value plus direction/minus direction	Bus — Average (N=5)	Articulated bus — Maximal value plus direction/minus direction	Articulated bus — Average (N=5)
Type 1	Front door	0/-2.0	-1.0	-1.1 / -4.0	-2.4
	Central door			+2.0 / -0.2	1.0
	Rear door	0/-2.7	-1.5	+4.9 / +1.8	3.8
Type 2	Front door	+5.1/-0.5	2.5	+0.5 / -4.0	-1.4
	Central door			+1.0 / -1.5	0.0
	Rear door	+3.6/-2.4	0.8	+1.0 / -2.0	-0.2
Type 3	Front door	+1.5/-4.0	-1.1	+2.0 / -2.0	-0.02
	Central door			+2.0 / -2.5	0.03
	Rear door	+3.5/-0.8	1.6	+1.5 / -4.0	-0.02

Conclusions

- As experimental performance evaluation on autonomous precision docking, the method of the autonomous precision docking based on path following control was described.
- The effectiveness of the proposed method was evaluated by the experimental results.
- We confirm that the controlled truck docked with precision within about ±0.05m in the virtual reference trajectories of three types.

Thank you for your attention!

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