Preliminary Experiments on Driver Assistance System in Remote Control

-Effects of Communication Delays, Video Resolution and Frequency-

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***Abstract*— Automated vehicles are expected to solve traffic issues. We proposed a prototype of remote type automated vehicle system. However, the lack of information due to the limited number of cameras and signal delay makes the system difficult to control. To improve accurate remote control and compensate the delay, a method of trajectory prediction with changing fps or resolution is proposed. This demonstration paper introduces the automated vehicle system and explains the system configuration, communication and results. The experiment in this paper is measuring the delay at each fps and resolution.**

Keywords—Smart mobility; Automated Vehicles; Remote Control System; Vehicle to Infrastructure; Communication Network; Intelligent Transport System.

I. INTRODUCTION

There are researches in areas of intelligent vehicles in a roadway environment, and in particular in automated vehicles [1]. Introduction of automated vehicles for smart city is expected to solve traffic problems [2][3]. Figure 1 shows the concept image of the smart mobility [4]. The objectives of the mobility are the establishment of public acceptance, the clarification of business model, the establishment of social system and the establishment of automated driving technology [5][6]. However, automated vehicles without a driver is not allowed under current low in Japan. National police agency released the new guideline for remote type automated vehicle system for the real world experiments in 2017 [7]. In order to proceed them, a prototype of remote type automated vehicle system is proposed. In the system, the automated vehicle moves above a magnetic wire. The intensity of the signal from the wire is captured by the vehicle with algorithm of feedback control scheme. The scheme makes the vehicle able to follow the wire. However, if obstacles on the way, the vehicle must be remotely controlled to avoid the obstacles and go back to the magnetic wire again. The remote driver watches the live video from the front camera at the same time to operate the vehicle.

Remote type automated vehicle system has two main problems: the lack of information due to the limited number of cameras and signal delay. These problems makes operating vehicles difficult. Therefore, the assistance of driving is necessary for the remote driver to better understand the surrounding environment. By showing the trajectory prediction of the vehicle, the remote driver is assumed to better control the vehicle to avoid the obstacles [8]. The experiments in this paper are designed for the assistance system using video camera and OpenCV (ver.3.4.2). In the system, the video consists of still images that are captured consecutively and played back in quick succession. A frame is a single one of those images, and the frame rate is a measure of frequency: how often the video is updated with a new frame. Frame rate is measured in Frames Per Second (FPS). FPS is the number of frames of video in one second.

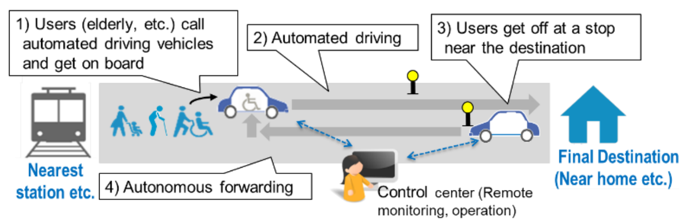

Figure 1. Concept image of the project.

1 pixel of an image has 8 bits, which shows depth of color and 3 channels, which shows 3 primary colors of light. The more pixels an image contains, the more transmission takes long time. Also, the more frames are sent, the more transmission takes long time. few frames and pixels make transmission quickly. This system is supposed to be used mainly in depopulated areas where the communication system is not well established. Communication delay is the trade-off between image resolution and frame rate. This paper shows limit value of image resolution and FPS to control cart correctly. Section 2 shows the configuration of the remote control system. Section 3 shows the experiments to quantify the correctness of prediction by using Global Positioning System (GPS).

II. REMOTE TYPE AUTOMATED VEHICLE

This section shows how to remote control the cart and calculate future prediction.

A. System Configuration

Figure 2 shows the system configuration. The system consists of automated vehicles, a remote-control server, a monitors and communication tools. Wi-Fi or Long-Term Evolution (LTE) is used for wireless communication in this system. If an operator changes the mode to take over an automated vehicle, the operator teleoperate the vehicle by using speed and steering controller. The whole program is composed of three functions running in parallel. User Datagram Protocol (UDP) sender function keeps sending the current steering angle and speed obtained from the game controller. UDP receiver function keeps listening to the message which is sent from the vehicle and updates the real time steering angle and speed. Show function captures the input of the controller and calculates the

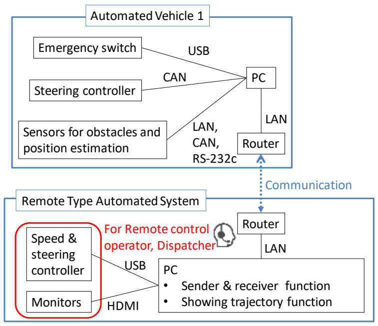

Figure 2. System Configuration

future path based the steering angle and speed of the vehicle then project to the image captured from the stream data.

B. Contents of Communication

Table 1 shows the contents of communication between the remote server and automated vehicles. Automated vehicles in the system communicate with the remote server by using shared memory. If the communication between the remote server and automated vehicles is unavailable for some reasons, automated vehicles stop.

TABLE I. CONTENTS OF COMMUNICATION (LEFT: FROM VEHICLE TO REMOTE SERVER, RIGHT: FROM REMOTE SERVER TO VEHICLE)

sm[n]	Contents (from vehicle to server)
10	Vehicle mode
11	Shift position
12	Vehicle speed
13	Vehicle steering angle
14	Brake status
15	Alive counter (not used)
16	Winker status
17	Obstacle information
18	Obstacle position X
19	Obstacle position Y
20	Flasher
21	Counter

sm[n]	Contents (from sever to vehicle)
500	Datacount
501	Target speed
502	Target steering angle
503	Shift position
504	Brake status
505	Driving mode
506	Winker status
507	Permission from oparator
508	Horn instruction

In the system, an occurrence of no communication in 2 seconds leads to communication failure and automated vehicles automatically stop.

C. Trajectory Prediction

The trajectory prediction is calculated based on the steering angle and velocity by applying the simplified vehicle dynamic model. Figure 3 shows the procedure of calculating the coordinates of 10 discrete points in the case of turning procedure and Figure 4 shows the motion of turning vehicle. Trajectory prediction in this paper are composed of three parts: left wheel, right wheel and middle between both wheels. Each trajectory is composed of 10 discrete points which are calculated with speed and steering angle. Once the trajectory is obtained, by projecting the trajectory in real world coordinates, the ideal path will be shown in the 2D image from the front camera, which will help the driver to better predict where the vehicle is going.

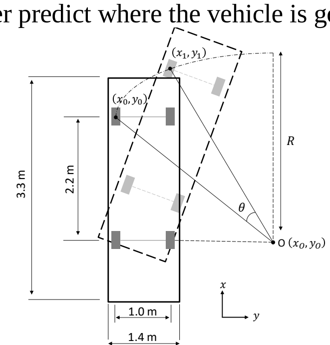

Figure 3. Motion model of vehicles

The program needs to project a path by taking account the operator's input and must be able to track any obstacle in the environment, as well as determine if the current trajectory may lead to a collision.

1. Input: Tread W, wheelbase L, current speed spd, current steering angle α
2. Output: 10 discrete points of trajectory (x_i, y_i), $i \in (0, 1, \cdots, 9)$
3. Step1: calculating turning radius R
4. $$R = \begin{cases} \sqrt{L^2 + \left(r + \frac{W}{2}\right)^2}, r = \frac{L}{\tan\alpha} & left \\ \frac{L}{\tan\alpha} & middle \\ r - \frac{W}{2} \qquad , r = \frac{L}{\tan\alpha} & right \end{cases};$$
5. Step2: calculating the length S of the trajectory in 3 second.
6. $S = spd * 3;$
7. Step3:caluculating the central angle θ
8. $\theta = \frac{S}{R*10};$
9. Step4: calculating (x_i, y_i) for each point
10. If $(\alpha > 0)$ then
11. $$\begin{bmatrix} x_i \\ y_i \end{bmatrix} = \begin{bmatrix} (x_0 - x_O)\cos(\theta * i) - (y_0 - y_O)\sin(\theta * i) + x_O \\ (x_0 - x_O)\sin(\theta * i) + (y_0 - y_O)\cos(\theta * i) + y_O \end{bmatrix};$$
    $i \in (0, 1, \cdots, 9)$
12. If $(\alpha < 0)$ then
13. $$\begin{bmatrix} x_i \\ y_i \end{bmatrix} = \begin{bmatrix} (x_0 - x_O)\cos(\theta * i) - (y_0 - y_O)\sin(\theta * i) + x_O \\ (x_0 - x_O)\sin(\theta * i) + (y_0 - y_O)\cos(\theta * i) + y_O \end{bmatrix};$$
    $i \in (0, 1, \cdots, 9)$
14. end if

Figure 4. Trajectory prediction for turning

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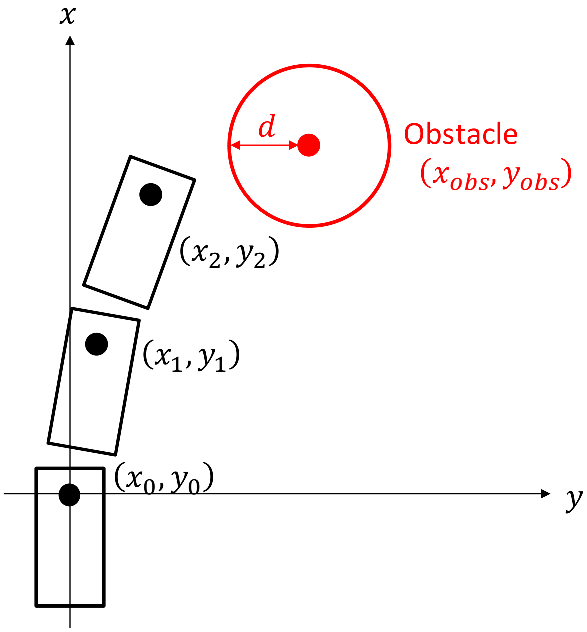

Figure 5. Relative distance model of vehicle and obstacle

The program is designed to display a project path to aid an operator when remotely maneuvering a vehicle through an obstacle course. Figure 5 shows the model of relative distance of vehicle and obstacle and the distance is calculated in

$$\sqrt{(x_i - x_{obs})^2 + (y_i - y_{obs})^2} \leq d. \quad (1)$$

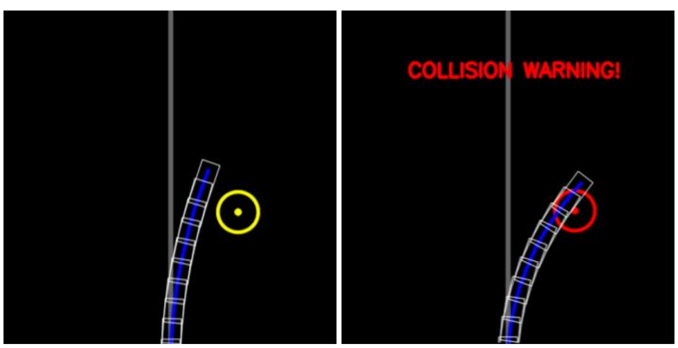

Figure 6. World coordinate (Left: Avoided obstacle, Right: Collided obstacle)

Figure 6 shows the result of collision detection from equation (1).

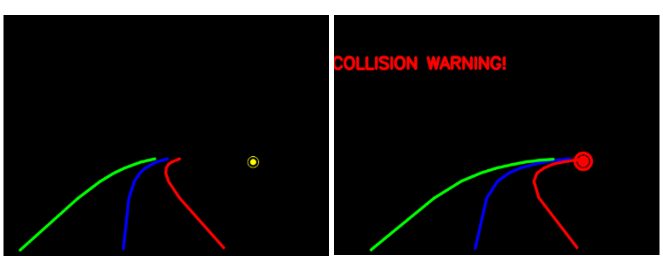

Figure 7. Image coordinate (Left: Avoided obstacle, Right: Collided obstacle)

The result of the transformation between world coordinate and image coordinate can be seen in Figure 7.

III. EXPERIMENTS

Figure 8 shows the automated vehicle which is controlled by an operator and the camera on the front of the vehicle. There are two laser range finders on front edge of the vehicle and GPS antenna on the top of the vehicle.

Figure 8. Automated vehicle (Left: Electronic vehicle, Right: Front camera)

Remote type automated system is on another vehicle which is shown in Figure 9. The system shows the trajectory which calculated by the speed and steering angle obtained from the automated vehicle on the monitor. During experiments, the data value of time, speed, steering angle, resolution and fps are logged.

Figure 9. The vehicle with remote type automated system

Experimental scene is shown in Figure 10. A slalom course was employed in the experiment. There are 10 obstacles which are putted in zigzag on the course. An operator needs to operate the vehicle to avoid the obstacles.

Figure 10. Test course

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The experiment is to check whether low resolution of small fps makes the signal delay short. However, low resolution and small fps also makes teleoperation difficult. Figure 11 shows high and low resolution images from camera.

Figure 11. Camera images (Left: 1001×667, Right: 100×67)

In this experiment, there are 2 patterns of resolutions, 2patterns of frequency of frames, and 2 patterns of communication delay before sending value of velocity and steering angle from operator to cart. This system can change the timing of sending input data, thus this system can add the communication delay intentionally in addition to the constant delay. First, The GPS data of the target course is taken by driving the cart. Second, the subject control the cart to drive on the course by remote control system while taking GPS real data. In this experiment, the quantity of correctness of prediction in each frame rate and image resolution is shown as the difference of the GPS target data and real data. Each experiment was done 10 times.

IV. CONCLUSION

This paper introduces the driving assistance system for remote control and explained the system configuration, contents of communication, results and the plan of experiments in the real field, as a short paper. The results of the experiments have not been concluded yet. The experiment will be continued, analyzed and shared the experimental results after the completion of the project as a future work.

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