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Construction and validation of lean operable bicycle simulator

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Bicycles are a typical tool of transportation used for short distances in daily life and are attracting attention increasing health awareness and addressing environmental issues. While further increasing of bicycle usage is expected, bicycles are one of the major risk factors for traffic accidents. In addition, in recent years, development of automated driving systems have been progressing. Given the above background, analyzing bicycle driving behavior is a very important issue for realizing safe traffic and verifying the safety of automated driving systems. In order to analyze bicycle driving behavior safely and at a low cost, this paper focuses on a bicycle simulator.

In this study, we first conducted an actual cycling experiment to analyze the kinematic characteristics of bicycles. In the actual cycling experiment, the posture and steering angle of the bicycle, including the roll angle, were measured using motion-capture sensors. From the experimental results, cyclists operate the roll angle so as to balance between the centrifugal force and the gravitational force. To further investigate the effect of the roll angle operation, the time deviation between steer and roll angles was calculated by cross-correlation functions. In the real vehicle experiment, the cyclist operated faster to the steer angle by 0.15 seconds on average. These results indicate that lean operation, which produces a roll angle, is an important factor in human bicycle operation.

Based on the knowledge obtained from the real vehicle driving experiments, we constructed a bicycle simulator as shown in Fig. 1. The feature of this simulator has leaf spring on the platform, allowing for a 6-degree roll rotation. This simulator has eight monitors cover all directions of the simulator to ensure a 360° field of view. The steering block attached to the front wheel measures the steering angle, and the rotational angle of the rear wheel is measured by a rotary encoder installed in the cycling trainer attached to the rear wheel, and the bicycle speed is calculated on a PC. Then a wire potentiometer is connected to the brake pad of the rear brake to measure the amount of the brake. The distance between the frame and the plate spring is measured by wire potentiometers, and the roll angle is calculated by a PC. Using the measured steer angle, speed, roll angle, and brakes, the equations of motion are calculated by combining the Kinematic Bicycle Model and the inverted pendulum model to calculate the behavior in the simulation, which is reflected on the display.

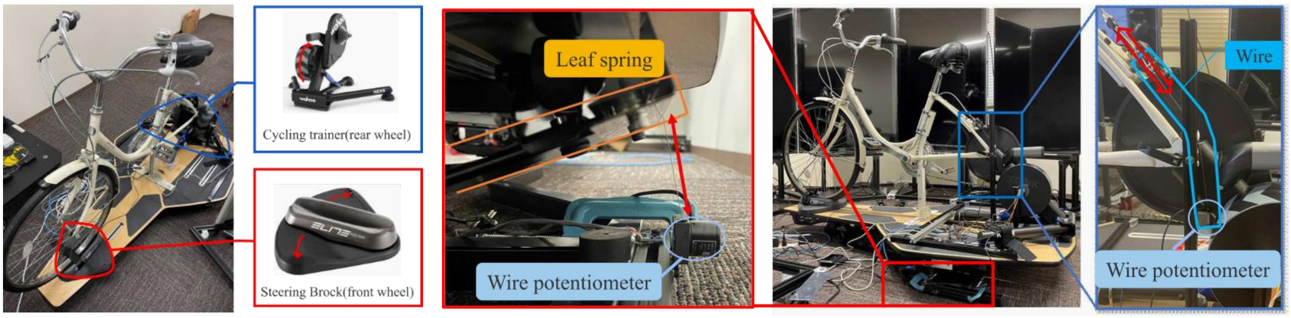

Fig.1 Bicycle Simulator Structure

Finally, a cycling test was conducted using the constructed simulator. As a result of the test, a negative correlation between the steer angle and roll angle was confirmed, and the simulator reproduced behavior similar to that of the actual vehicle.

Future work is to analyze the driving behavior and decision of cyclists based on the constructed simulator and to analyze interactions by traffic simulation including other traffic participants (automobiles and pedestrians).