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Toward the Development of a VR Simulator for Speed Sprayers

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■ About Me

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Research of interest

- VR simulator
- Machine learning

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Agenda

- Background
- Research Aims
- Development of a Speed Sprayer VR Simulator and Evaluation
  - Speed Sprayer in VR
  - Speed Sprayer in Physical Environments
- Experiments & Results
- Future Works
- Conclusion

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■ Background :: From manual sprayer to automatic sprayers

Pipe sprayer

Portable power sprayer

- Many workers are needed
- Works for a small area
- A considerable health effect

Speed sprayer

- Need only one driver for an area
- Works for a wide area
- Small effect to health

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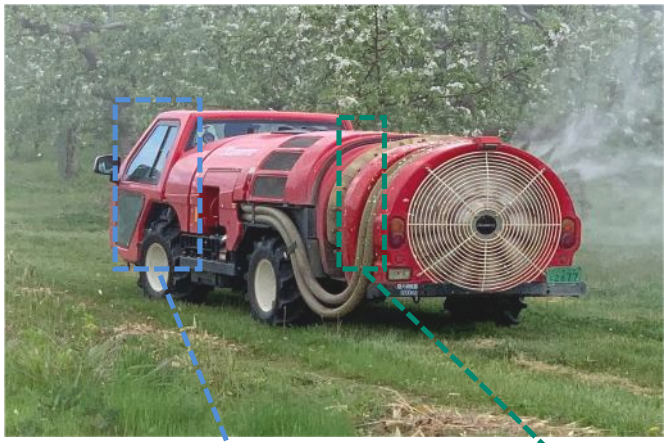
■ Background :: Issues with the speed sprayers



cockpit

Nozzle

Image of the cockpit.

Images of spraying in an orchard

Need to balance the travel speed, spray volume, and to avoid branches while driving

Skill drivers are required

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■ Background :: Toward the improvement of speed sprayers

Factors：

- Decreasing number of workers in the aging society
- Speed Sprayer problems

Requirements：

- Development of more efficient speed sprayers
  - ➢ Easy operation system
  - ➢ Easy to use interface for the elderly

Redesign the operation interface
Data of the driver behavior during operation is needed to find out the crucial issues in the current speed sprayer

- VR-based behavior analysis
- Field-based behavior analysis

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■ Background :: Previous research on agriculture vehicle simulators

	Enhancing Tractors' Comfortability [1]	Training simulator for accident prevention[2]
		
• Aim：	Enhancing the driving comfortability	Development of a training simulator to prevent accidents caused by misuse of protective mechanisms
• Type：	non-experience-based	practical experience
• Usage：	Evaluate the tractor's comfortability	Driving training

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Research Aims

Aims

- To build a Speed Sprayer VR simulator
- To Analyze of driving behavior in VR
- To Analyze of driving behavior in physical field environment

Data to Measure

- Head pose (6DoF)
- Hand movement
- Steering
- Button operation
- Pedal operation

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■ Development of a Speed Sprayer VR Simulator

- **Devices used in the VR simulator**

i. **Logitech G27 Racing Wheel**
   - Handle operation
   - Pedal operation

ii. **Oculus Quest**
   - Driver's head, finger movement (6DoF)

The VR simulator developed in this study

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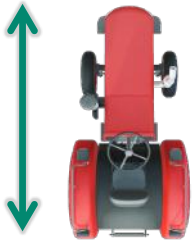
■ Development of a Speed Sprayer VR Simulator

Logitech G27 Force Feedback Wheel and Pedal

Steering

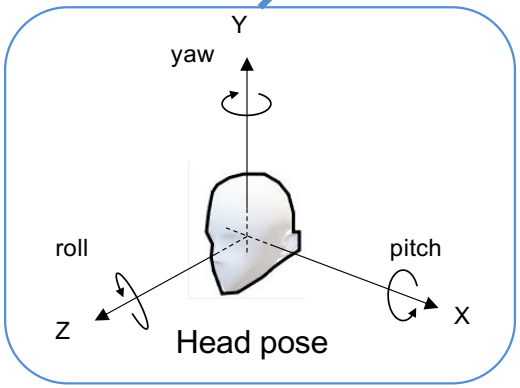
Virtual vehicle

pedal



Virtual vehicle

Oculus Quest



Head pose

hand gesture

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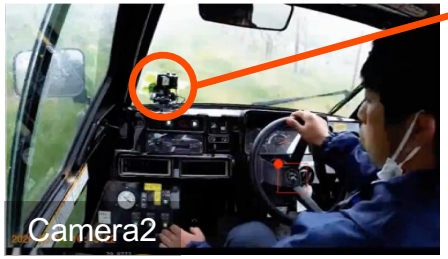
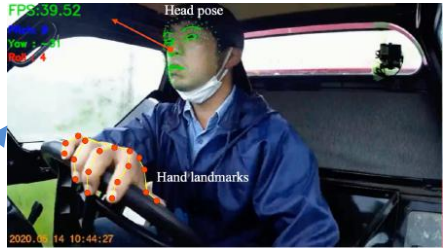
■ Development of sensors and analysis system in the physical environment

- **Sensors and Software Analysis System**

hardware	Software
   GoPro Hero8	 • Head posture, hand movements → Media Pipe[3][4]   • Steering wheel, button operation → Deep Learning

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■ Development of sensors and analysis system in the physical environment

- **Measuring head and hand movements and detecting pressed-button**

Hand and hand movements	Button
	
i. Detecting face and hand landmarks using Mediapipe ii. Estimating face orientation from landmarks using PnP (Perspective-n-Point)	i. Specify the range coordinates and fingertip coordinates of the button. ii. Detect the button-pressed action when fingertip is in range

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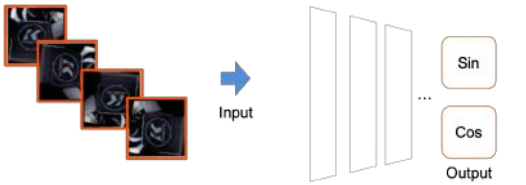
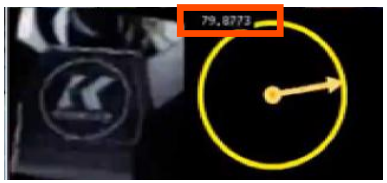
■ Development of sensors and analysis system in the physical environment

- **Measuring Steering Wheel Rotation**

Step1	Step2	Step3
		
• Image cropping • Get a 64x64 image	• Network: FCN • Input image: 64x64 • Based on ResNet18 • Change the output of all coupled layers to two (Sin, Cos)	• Estimating angle

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Experiments & Results :: VR simulator

- **Purpose of the experiment**
  i. Is it possible to reproduce the pesticide spraying operation?
  ii. Is it possible to quantify the work operation using the simulator?

- **Subject**
  - Number of subjects: 5
  - Age: 20 to 23 years old
  - No experience with VR simulator

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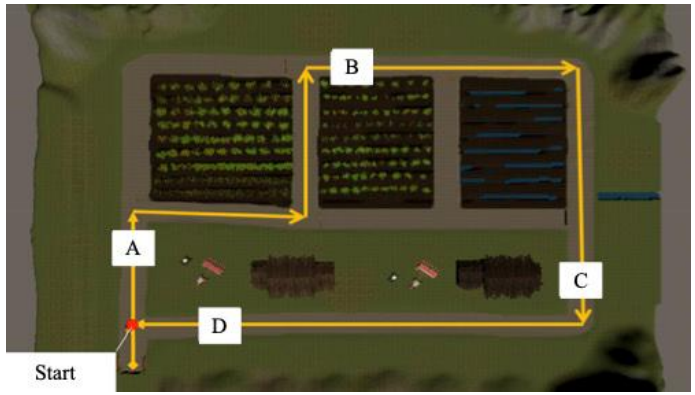
■ Experiments & Results :: VR simulator

- **Method**
  - i. Driving practice and operation explanation
  - ii. Four tasks to complete on the virtual farmland

Point	Task
A	Press the button to spray to the left
B	Press the button to spray to the right
C	Press the button to turn off the fan
D	Press the button after parking

A view from the cockpit in a virtual environment



The virtual farmland for this study

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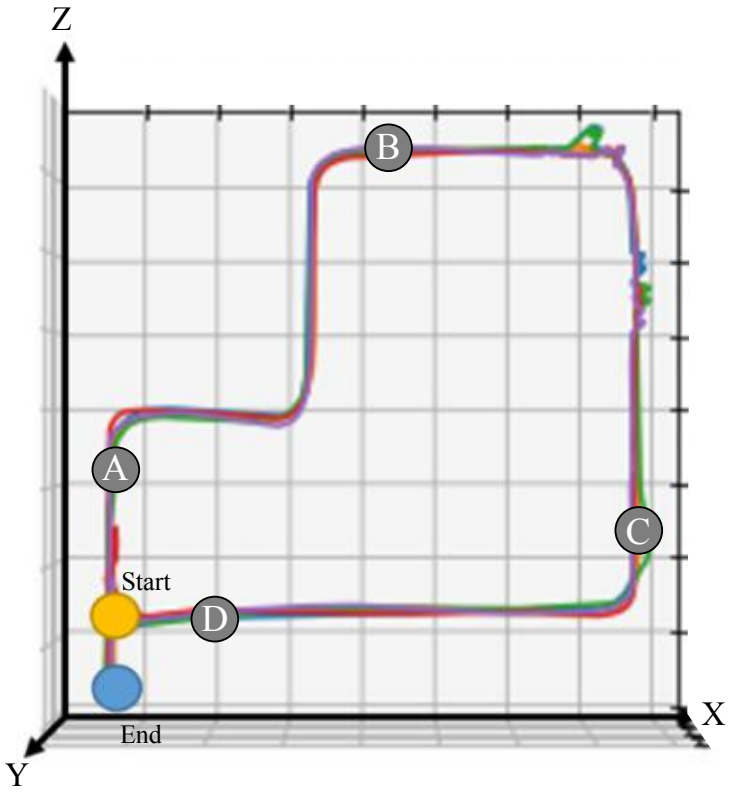
■ Experiments & Results :: VR simulator

- **Subject's travel route**

No variation in subjects' routes.

→Able to maneuver the vehicle along a predetermined route regardless of the surrounding environment

The physical environment behavior of the subject can be accurately reflected in the virtual environment



Subject's travel route

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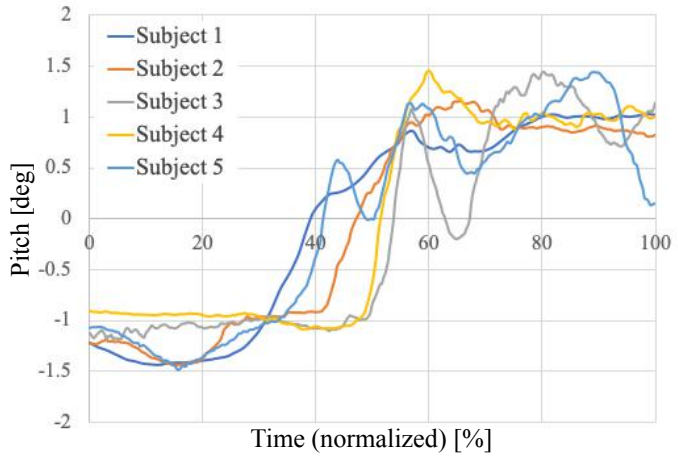
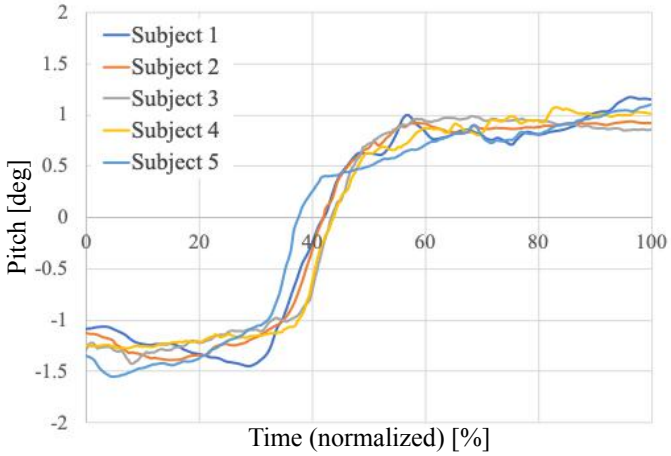
■ Experiments & Results :: VR simulator

- **Head posture of the subjects at each point**

A	B
	

The pitch angle changed from negative to positive because the subject had to look down to see the position of the button in order to perform the task.

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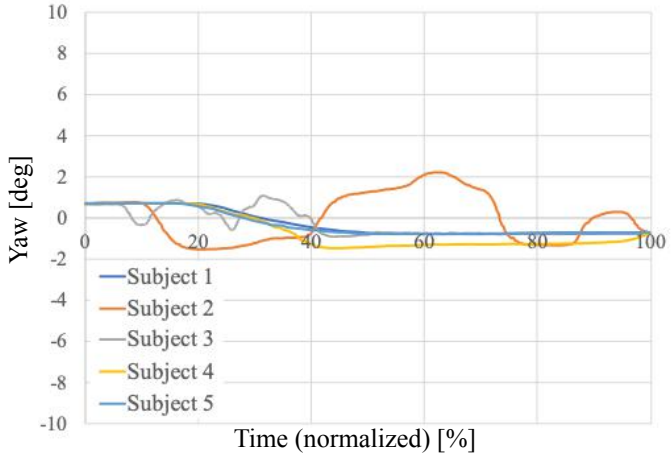
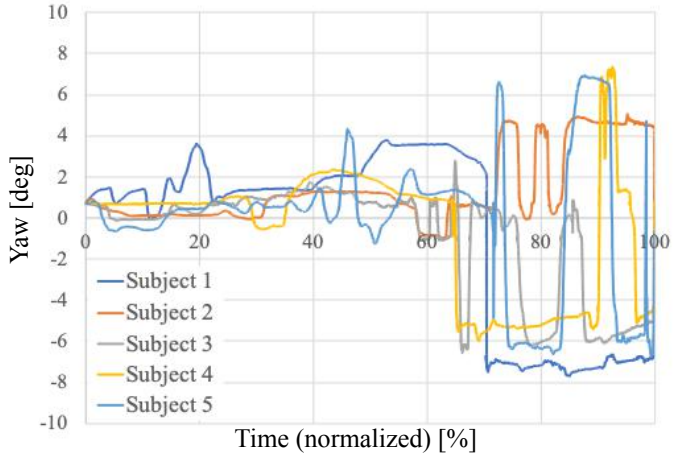
■ Experiments & Results :: VR simulator

- **Head posture of the subjects at each point**

C	D
	
In this task, the yaw angle did not change significantly as the driver used the rearview mirror to check the back.	In this task (parking), subjects had to check the left and right sides of the car, which resulted in a large change in the yaw angle.

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■ Experiments & Results :: VR simulator

- **Results for each task**

Variation in each task

In particular, task D is the largest

→Because task D is parking task

Requires Action:
- Forward
- Backward
- Stop

Time spent on each task

Subject	Task A	Task B	Task C	Task D
1	1.9	2.9	2.1	57.1
2	3.1	2.4	8.4	106.3
3	9.0	4.2	18.0	111.1
4	3.3	2.9	3.4	79.9
5	2.8	2.8	2.5	59.0
6	2.3	2.6	2.0	140.8
Mean	3.73	2.97	6.07	92.37
Std. Dev.	2.631	0.635	6.324	32.874

The developed simulator can reproduce the pesticide spraying operation and quantify the operator's behavior

The developed simulator can be used to improve the operation interface

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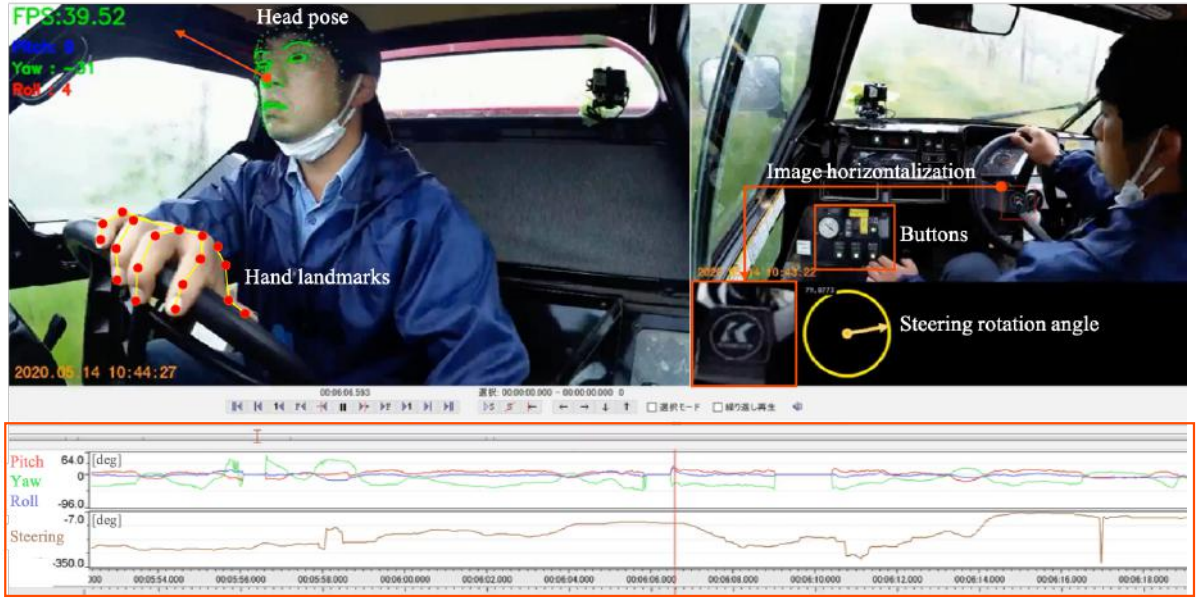
■ Experiments & Results :: Physical Environments

The acquired data was analyzed using ELAN

- Head posture (Pitch, Yaw, Roll)
- Hand landmarks
- Steering

This data was labelled and analyzed to find out the operations that cause fatigue and how to overcome them.



Integrated data labeled by ELAN (EUDICO Linguistic Annotator) [5]

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Future Works

i. Next, we will experiment with many tasks using the developed simulator to find valuable data to improve the speed sprayer's operating interface
ii. We plan to verify the differences between the two environments by implementing similar tasks in the simulator using labeled tasks corresponding to the operator's behavior obtained in the physical environment

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■ Conclusion

Result

- We have developed a simulator that can visualize and analyze the working behavior of speed sprayers in a virtual environment
- The simulator can analyze the speed sprayer's operation in the physical environment and find out the problematic behavior

Future Works

- Improving the operation interface using a simulator
- Differences in Operation by Environment

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Reference

1. M. Watanabe and K. Sakai, “Development of a Nonlinear Tractor Model Using in Constructing a Tractor Driving Simulator,” 2017 ASABE Annual International Meeting, pp. 1–6, 2017

2. D. O. Gonzalez et al., “Development and Assessment of a Tractor Driving Simulator with Immersive Virtual Reality for Training to Avoid Occupational Hazards,” Computer and Electronics in Agriculture, 143, pp. 111–118, 2017.

3. C. Lugaresi et al., “Mediapipe: A Framework for Building Perception Pipelines,” arXiv preprint arXiv:1906.08172, pp. 1-9, 2019.

4. F. Zhang et al., “MediaPipe Hands: On-device Real-time Hand Tracking,” http://arxiv.org/abs/2006.10214, 2020.

5. ELAN (Version 6.0), “The Language Archive,” https://archive.mpi.nl/tla/elan [retrieved: June, 2021]