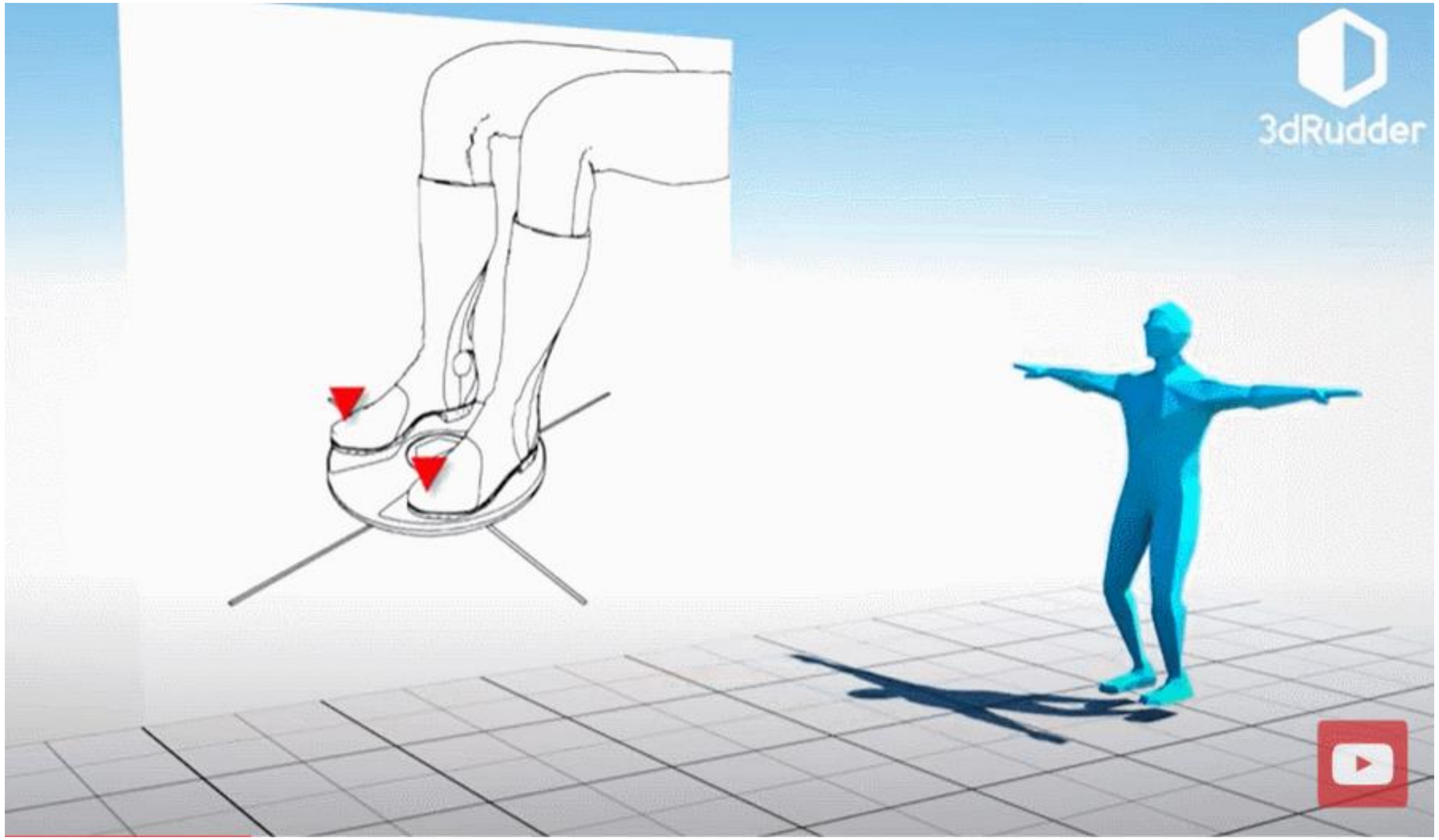
3D Rudder를 이용한 mecanum wheel mobile base 제어

아바타 팀 인턴 공영경

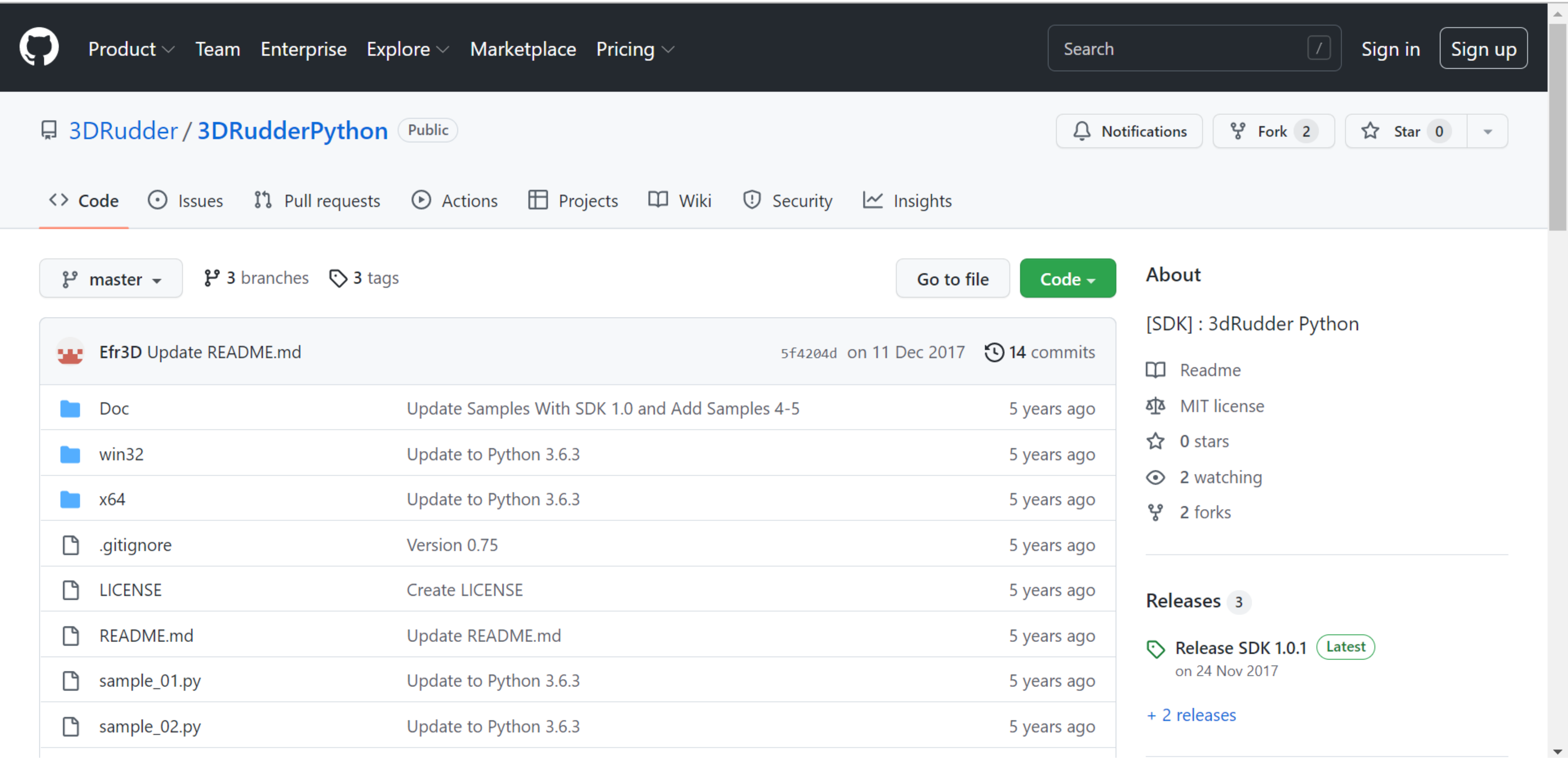
3D Rudder

사진 출처 : 3dRudder for VR & PC foot-powered gaming controller expands accessibility options » Gadget Flow (thegadgetflow.com)
Amazon.com: 3dRudder Foot Motion Controller for VR and PC Games and Applications with VR Mode, Foot Keyboard Mode, Foot Mouse Mode, Foot Joystick Mode : Video Games

3D Rudder



동영상 출처 : 3D Rudder youtube channel https://youtu.be/2-UESms-nFY



웹사이트 : [GitHub - 3DRudder/3DRudderPython: [SDK] : 3dRudder Python]

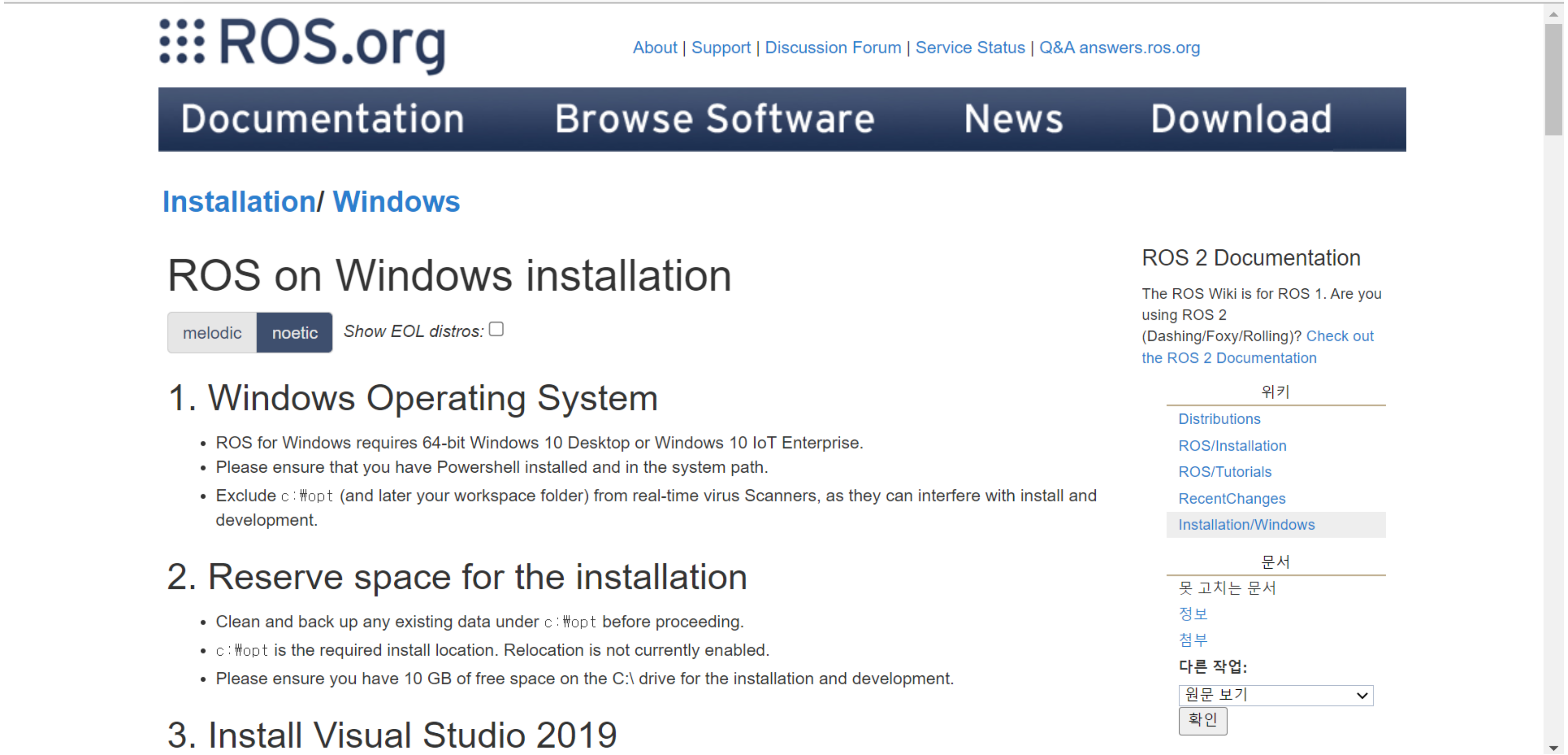
3D Rudder에서 측정 가능한 값

- 6개의 압력 센서로 측정하는 힘 (단위 : g)
- Initial calibration pose를 기준으로 한 roll, pitch, yaw angle

3D Rudder 실행 제약 조건

- Windows 환경
- Python 3.6.3 버전으로만 실행 가능

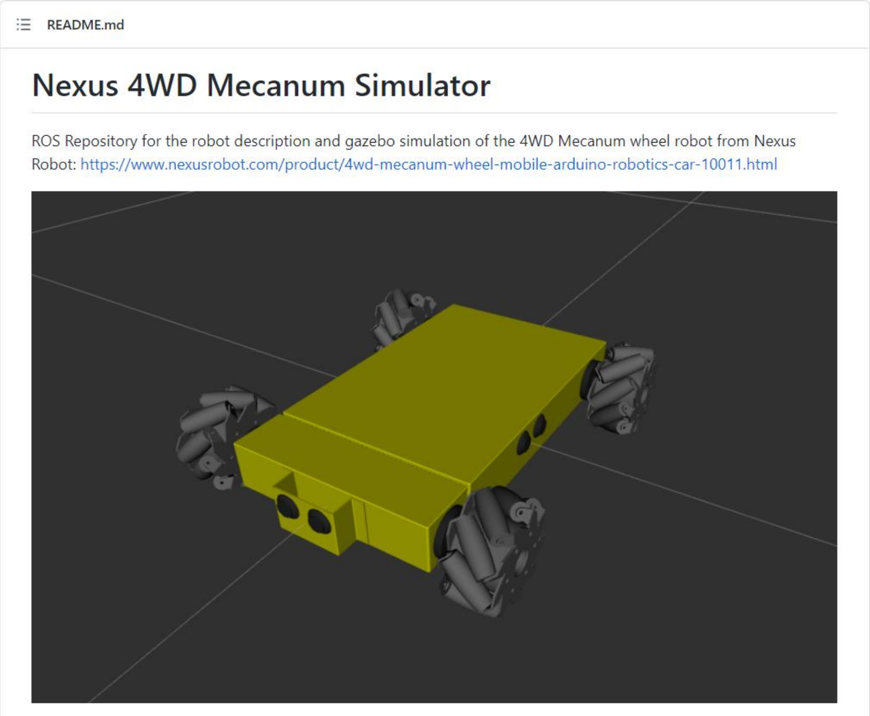
ROS on Windows



웹사이트 : [Installation/Windows - ROS Wiki]

1. Gazebo simulation

Mecanum Simulator



- Topic : /cmd_vel

- 실행 :

roslaunch nexus_4wd_mecanum_gazebo nexus_4wd_mecanum_world.launch

웹사이트 : [GitHub - RBinsonB/nexus_4wd_mecanum_simulator: ROS Repository for the robot description and gazebo simulation of the Nexus 4WD Mecanum wheel robot]

문제점

- ROS on Windows에서 node를 Python 3.6.3 버전으로 실행하여야 함

- Simulator가 Ubuntu 환경에서만 동작함

해결방안

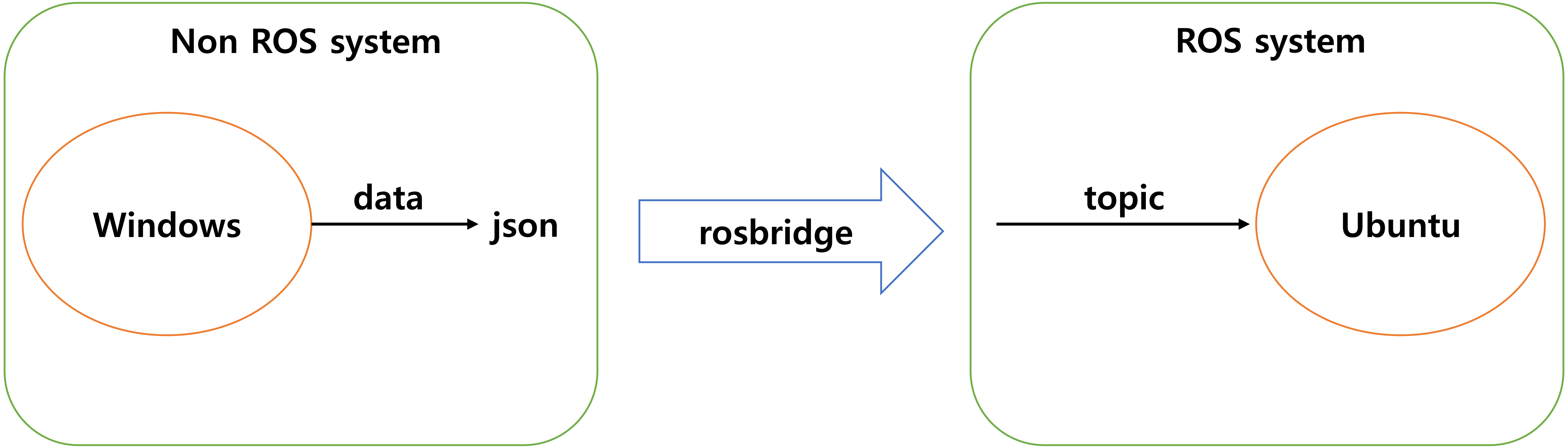
- rosbridge, roslibpy 라이브러리를 이용해서 Windows 환경에서의 데이터를 wsl Ubuntu 환경으로 받아옴

다음 슬라이드 넘어가기 전에 roslibpy 간단히 설명

rosbridge

- 비ROS 시스템과 ROS 시스템 사이의 통신

rosbridge

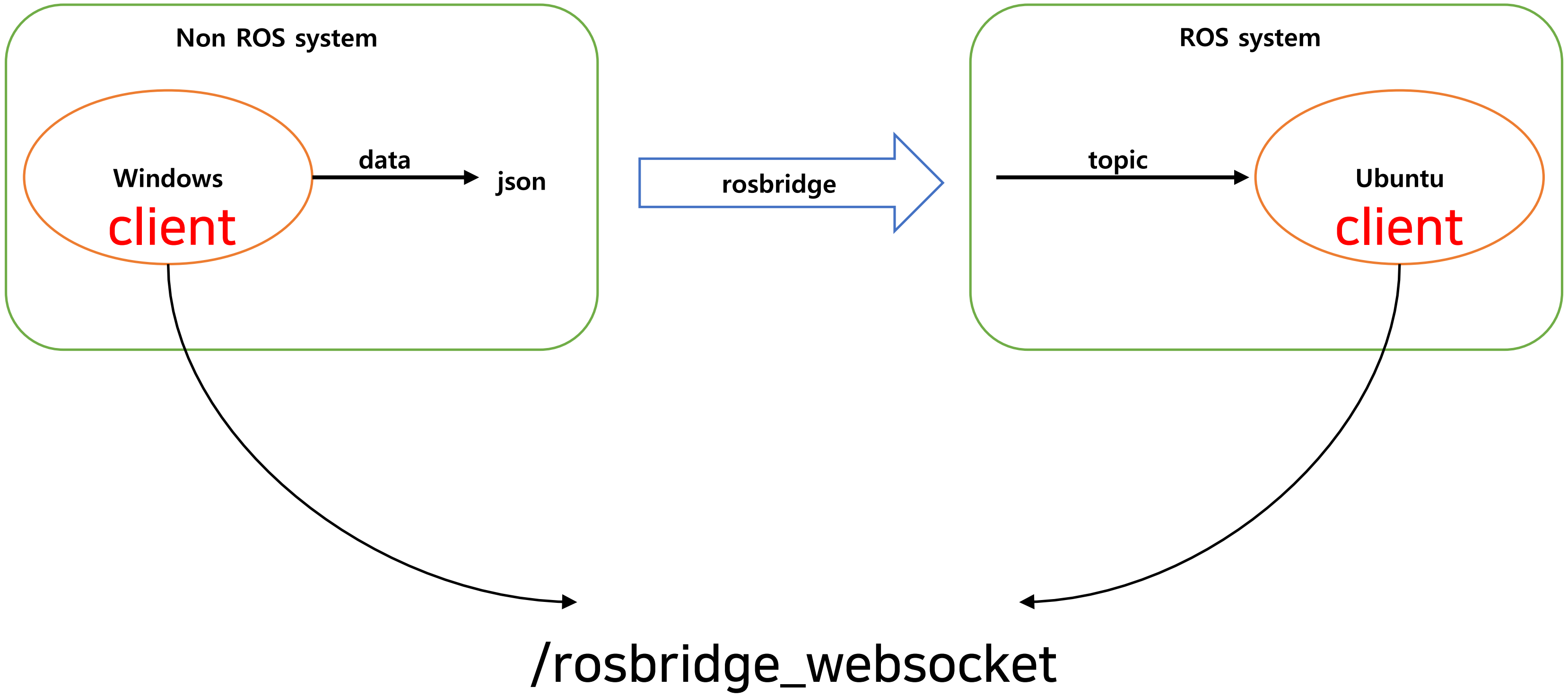

Non ROS system
Windows
data
json
rosbridge
ROS system
topic
Ubuntu

rosbridge

ws://0.0.0.0:9090

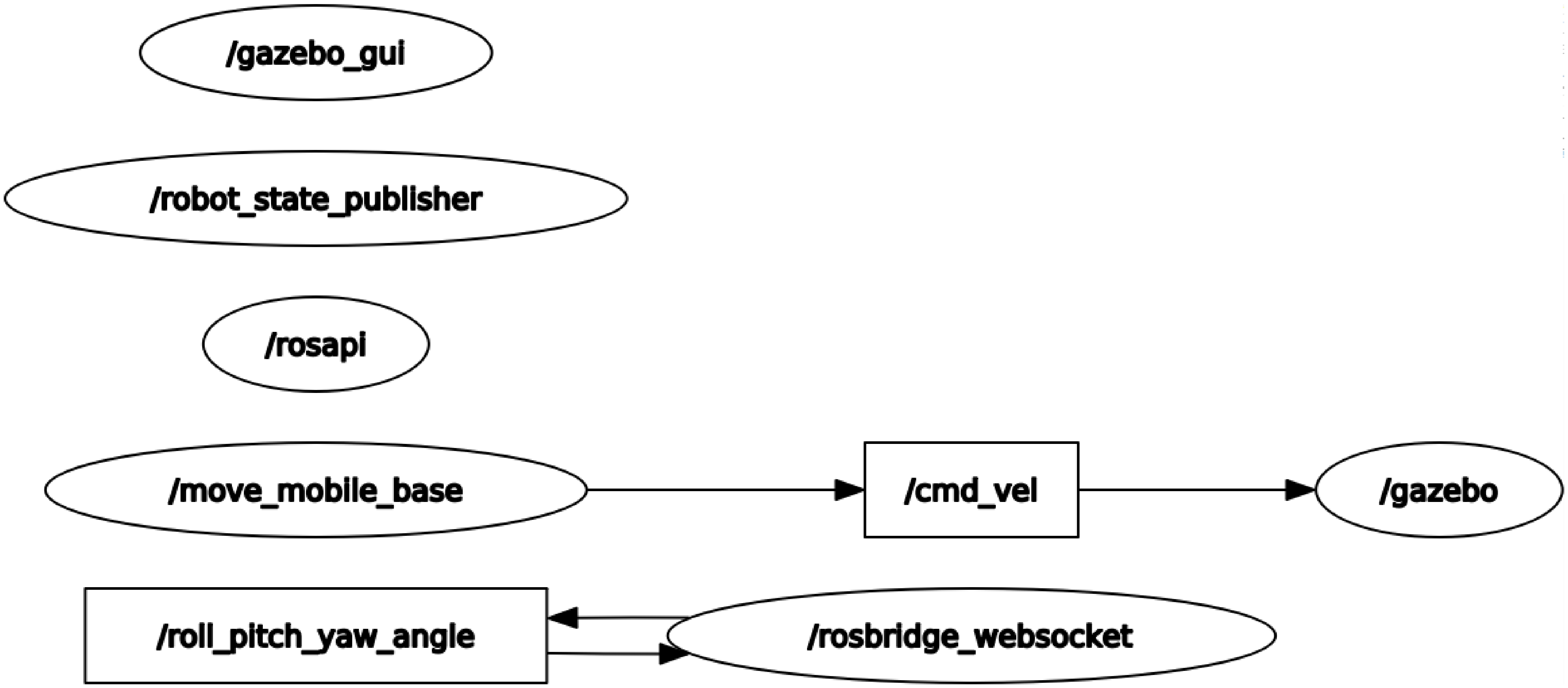
웹사이트 : [웹 소켓 통신 (Web Socket) :: Joker (tistory.com)]

rosbridge



Non ROS system
Windows
client
data
json
rosbridge
ROS system
topic
Ubuntu
client
/rosbridge_websocket

rqt_graph



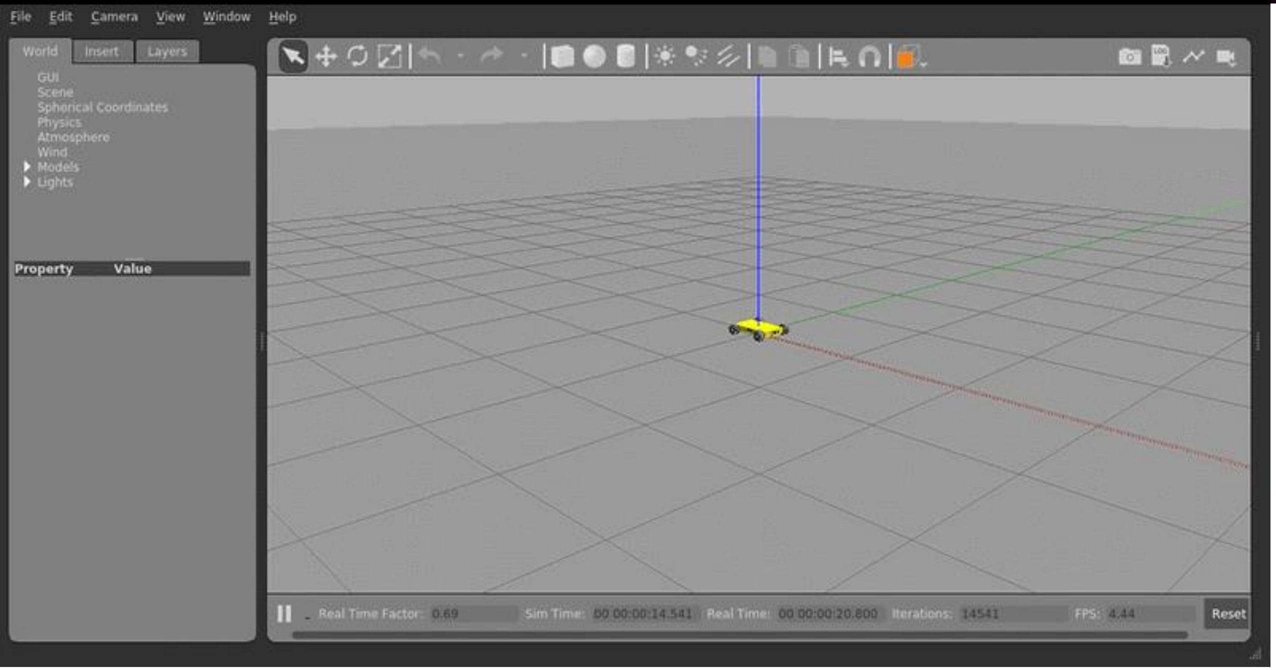
/gazebo_gui
/robot_state_publisher
/rosapi
/move_mobile_base
/cmd_vel
/gazebo
/roll_pitch_yaw_angle
/rosbridge_websocket

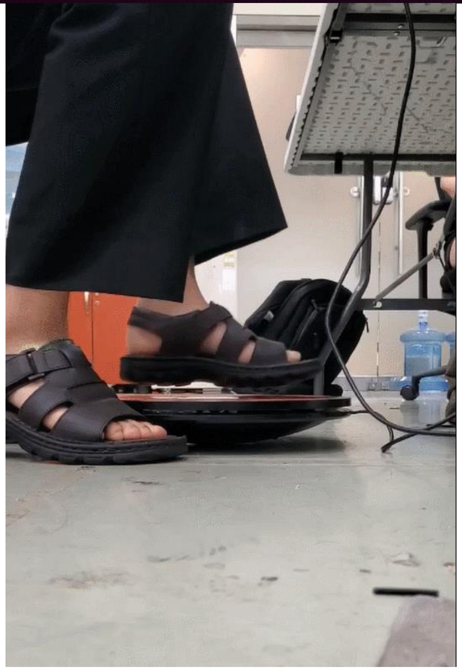
Settings

- roll, pitch는 ±18도를 넘으면 속력 1m/s, yaw는 ±25도를 넘으면 속력 1rad/s
- Roll, pitch가 ±7도 이하, yaw가 ±12도 이하이면 속력 0 (아바타 로봇을 태워야 하므로 값을 보수적으로 설정)
- Roll, pitch motion이 있을 때는 yaw값을 0, yaw motion이 있을 때는 roll, pitch값을 0으로 세팅하여 각각 독립적으로 동작하게 함


C:₩opt₩ros₩noetic₩x64₩ns3drudder_roslibpy>py -3.6 pub_angle.py


youngkyoung@LAPTOP-TB1P7TSR:~/mecanum_wheel_ws/src/control_mecanum_wheel$ python3.6 subs_and_pub_angle.py


File
Edit
Camera
View
Window
Help
World
Insert
Layers
GUI
Scene
Spherical Coordinates
Physics
Atmosphere
Wind
Models
Lights
Property
Value
Real Time Factor: 0.69
Sim Time: 00 00:00:14.541
Real Time: 00 00:00:20.800
Iterations: 14541
FPS: 4.44
Reset



2. Mobile base control

Kinematics 제어기 설계

- 주어진 속도를 만들기 위한 모터의 각속도 구하기

Forward kinematics

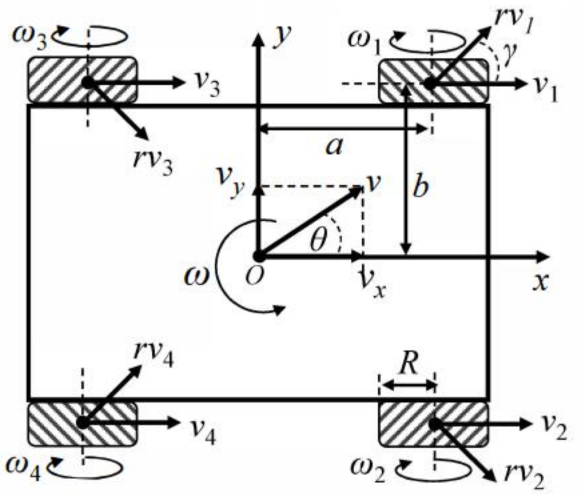
$$V = J\,\dot{\theta}$$

V : mobile base의 spatial velocity
J : Jacobian matrix
$\dot{\theta}$: 모터의 각속도

Forward kinematics

$$\begin{bmatrix} v_x \\ v_y \\ w \end{bmatrix} = \frac{R}{4} \begin{bmatrix} 1 & 1 & 1 & 1 \\ -1 & 1 & 1 & -1 \\ \frac{-1}{a+b} & \frac{1}{a+b} & \frac{-1}{a+b} & \frac{1}{a+b} \end{bmatrix} \begin{bmatrix} \dot{\theta}_1 \\ \dot{\theta}_2 \\ \dot{\theta}_3 \\ \dot{\theta}_4 \end{bmatrix}$$

R : wheel의 반지름
a : O와 wheel 중심 사이 x축 방향 거리
b : O와 wheel 중심 사이 y축 방향 거리



출처 : Maulana, Eka & Aziz Muslim, Muhammad & Hendrayawan, Veri. (2015). Inverse kinematic implementation of four-wheels mecanum drive mobile robot using stepper motors. 51-56. 10.1109/ISITIA.2015.7219952.

Inverse velocity kinematics

여유 자유도 최적화 -> 모터의 각속력 합 최소화

$$\min \frac{1}{2}\dot{\theta}^T\dot{\theta} \quad \text{subject to} \quad V = J\,\dot{\theta}$$

Inverse velocity kinematics

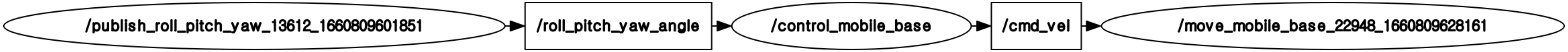
Use Moore-Penrose pseudoinverse matrix

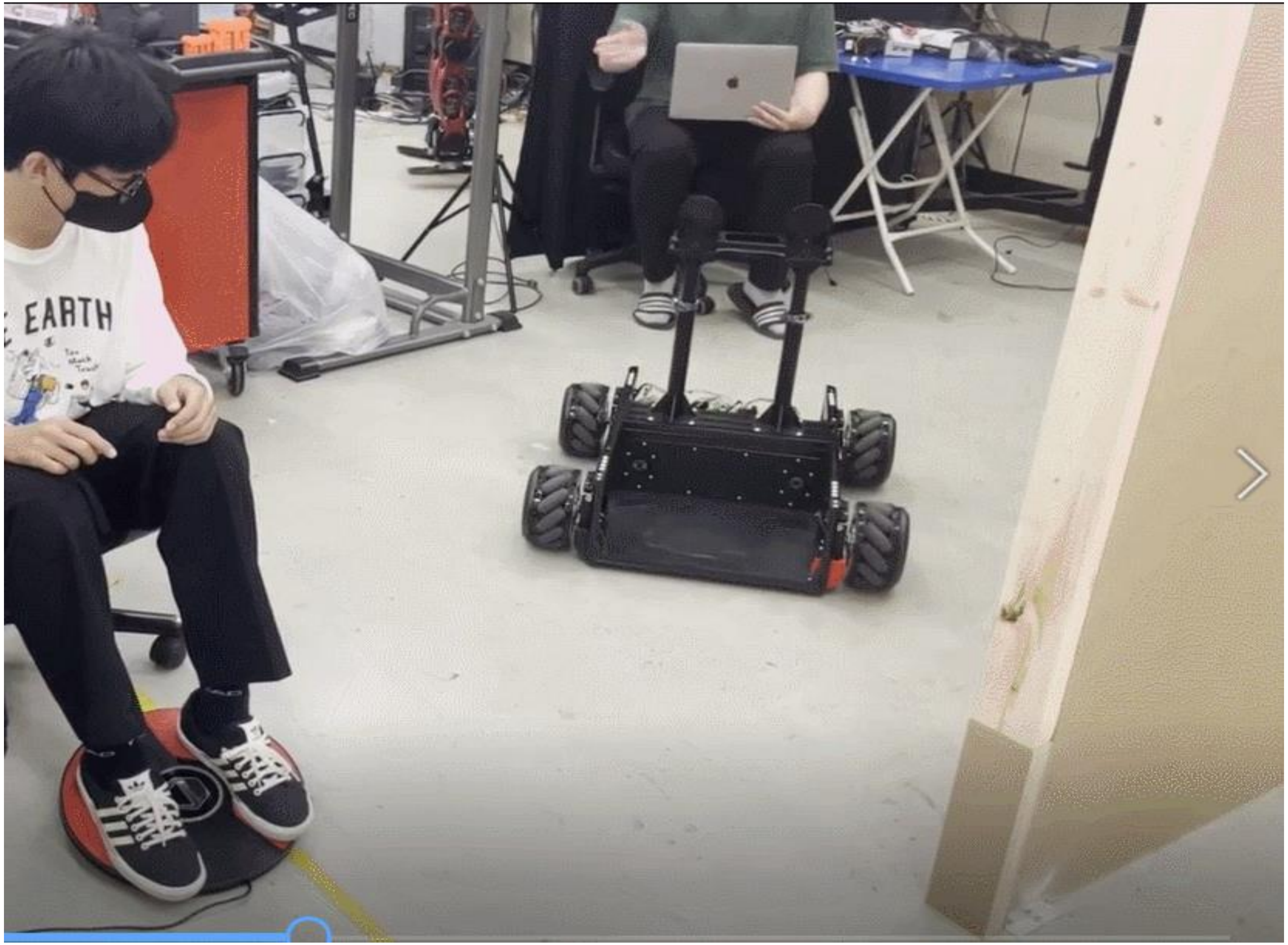
$$\dot{\theta} = J^T(JJ^T)^{-1}V = J^{\dagger}V$$

Inverse velocity kinematics

$$\begin{bmatrix} \dot{\theta}_1 \\ \dot{\theta}_2 \\ \dot{\theta}_3 \\ \dot{\theta}_4 \end{bmatrix} = \frac{1}{R} \begin{bmatrix} 1 & -1 & -(a+b) \\ 1 & 1 & a+b \\ 1 & 1 & -(a+b) \\ 1 & -1 & a+b \end{bmatrix} \begin{bmatrix} v_x \\ v_y \\ w \end{bmatrix}$$

Connect


/publish_roll_pitch_yaw_13612_1660809601851
/roll_pitch_yaw_angle
/control_mobile_base
/cmd_vel
/move_mobile_base_22948_1660809628161


EARTH

감사합니다