Wearable ROS:

Development of wearable robot system using ROS 2

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R&D Center

Angel Robotics

ANGEL PRODUCTS

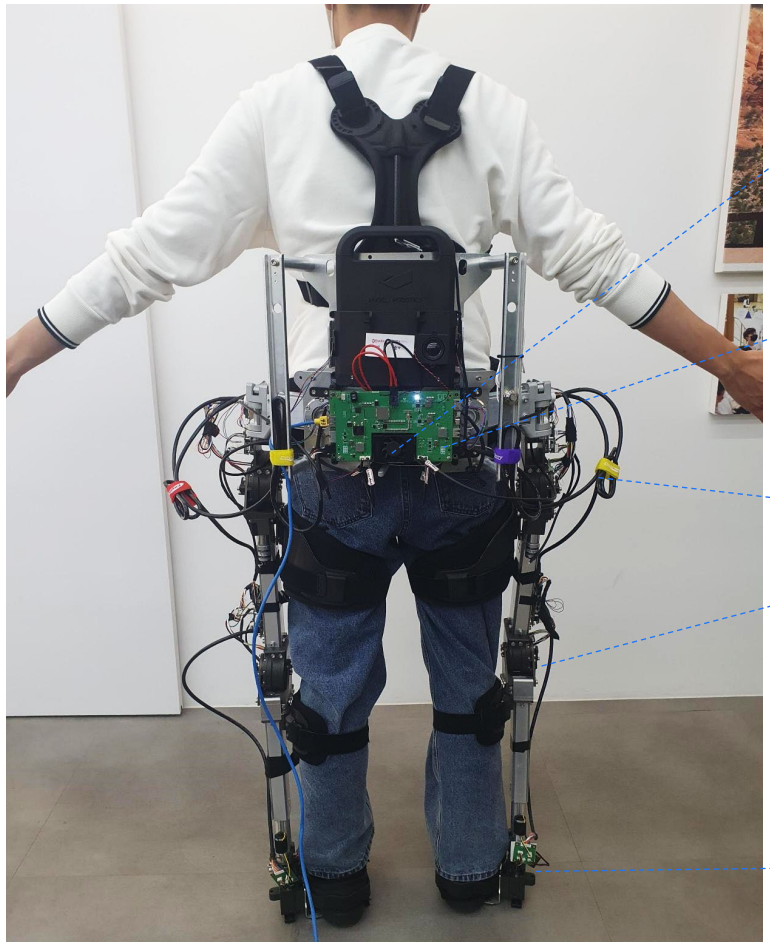
fitness, military, …

industry

elderly

rehabilitation

Angel Legs M-series

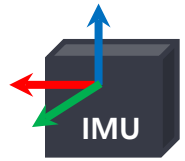


NVIDIA
Jetson Xavier

TCP/IP

STM32H7

I2C

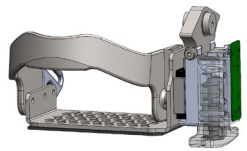


FDCAN

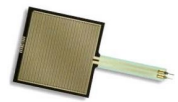
Motor Driver
48V/10A

BLDC 10Nm/360rpm
planetary gears 20:1
with encoder

I2C, SPI, ADC, ...



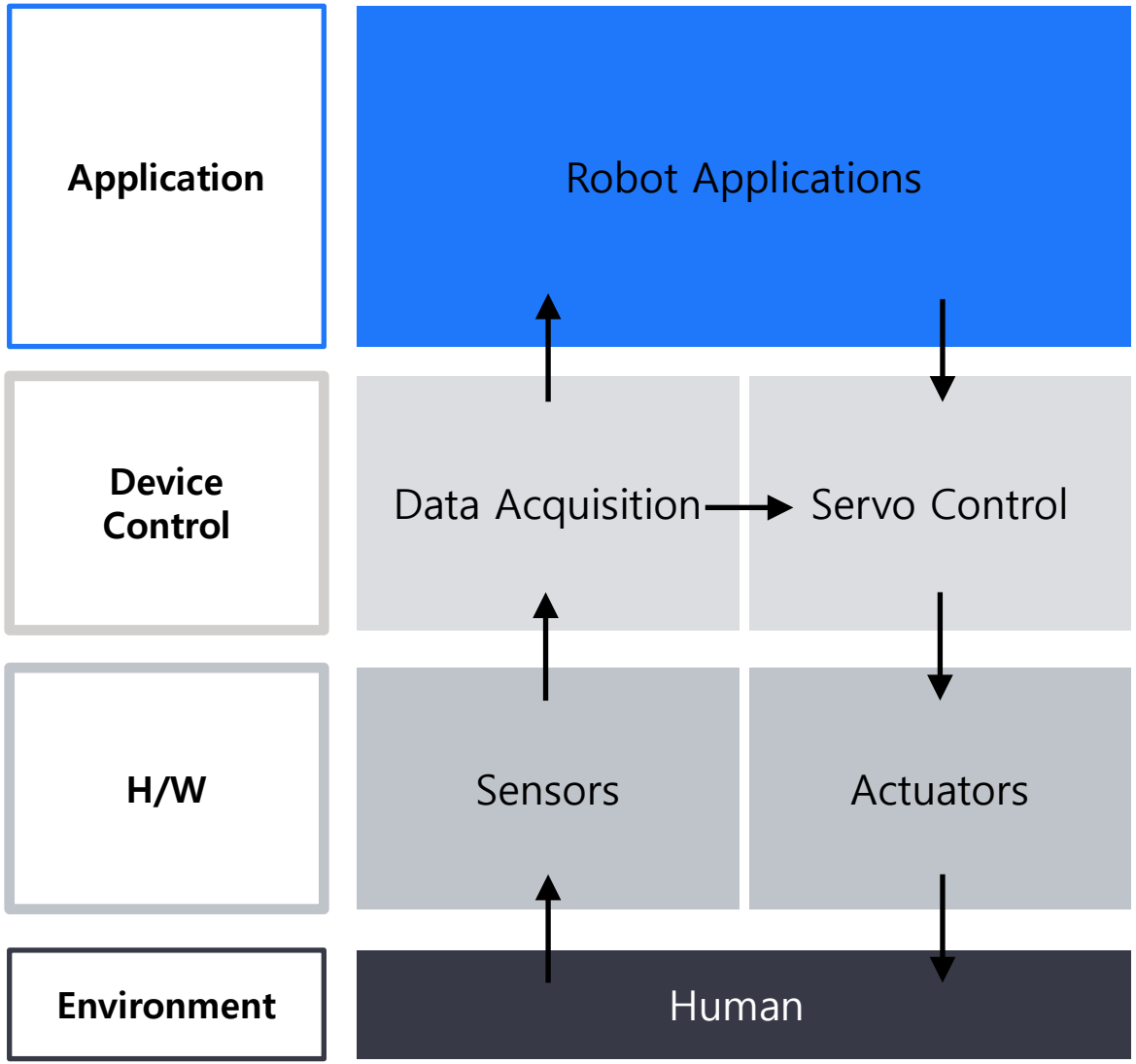
Foot Module

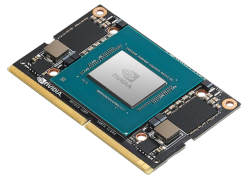


FSR

Bump sensor

SW Architecture



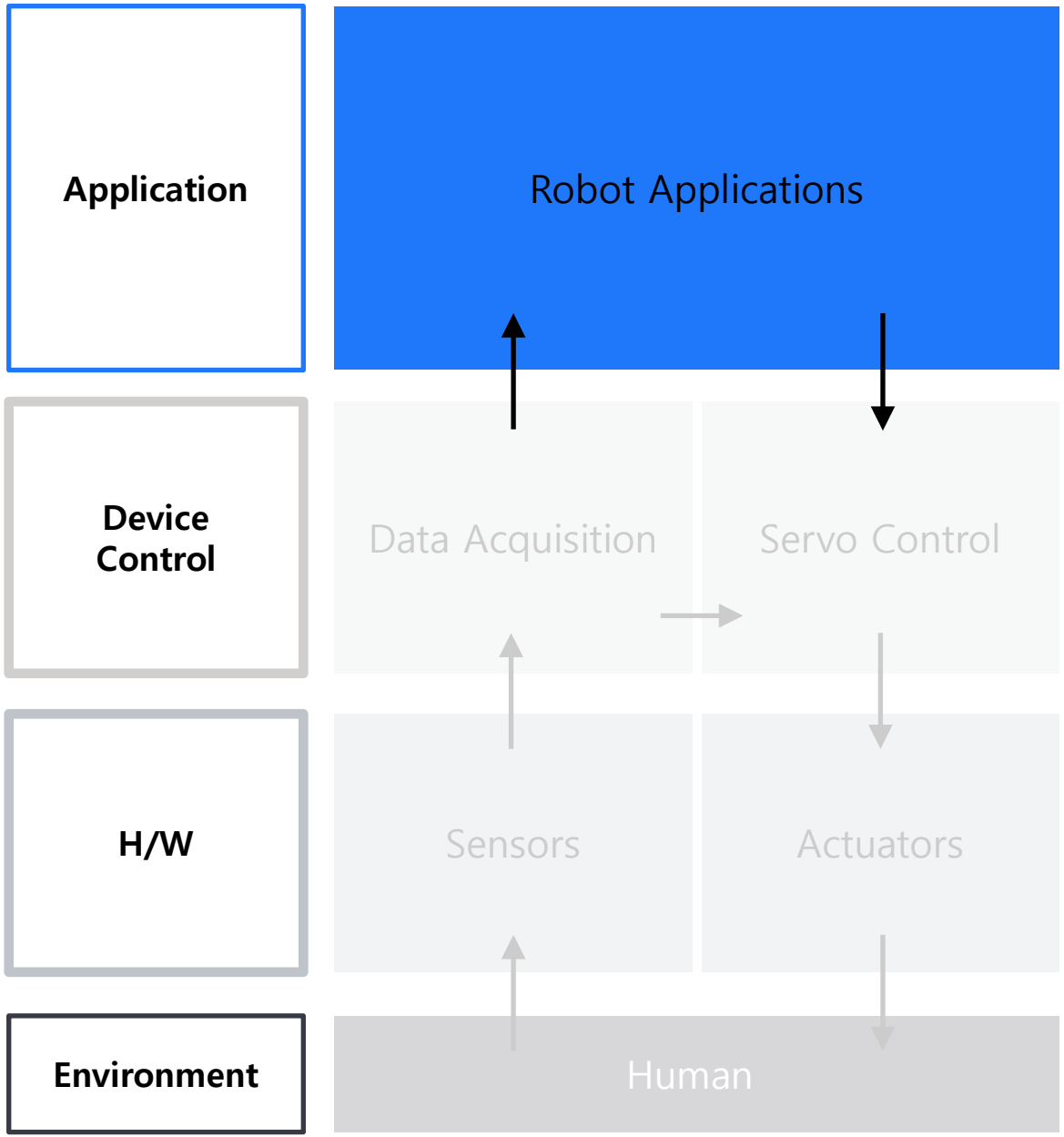


NVIDIA
Jetson Xavier

- Ubuntu 20.04
- Soft real-time
- Robot Services (application)
  - Gait training
  - Squat training
  - etc.
- Better network, dev-env, resource

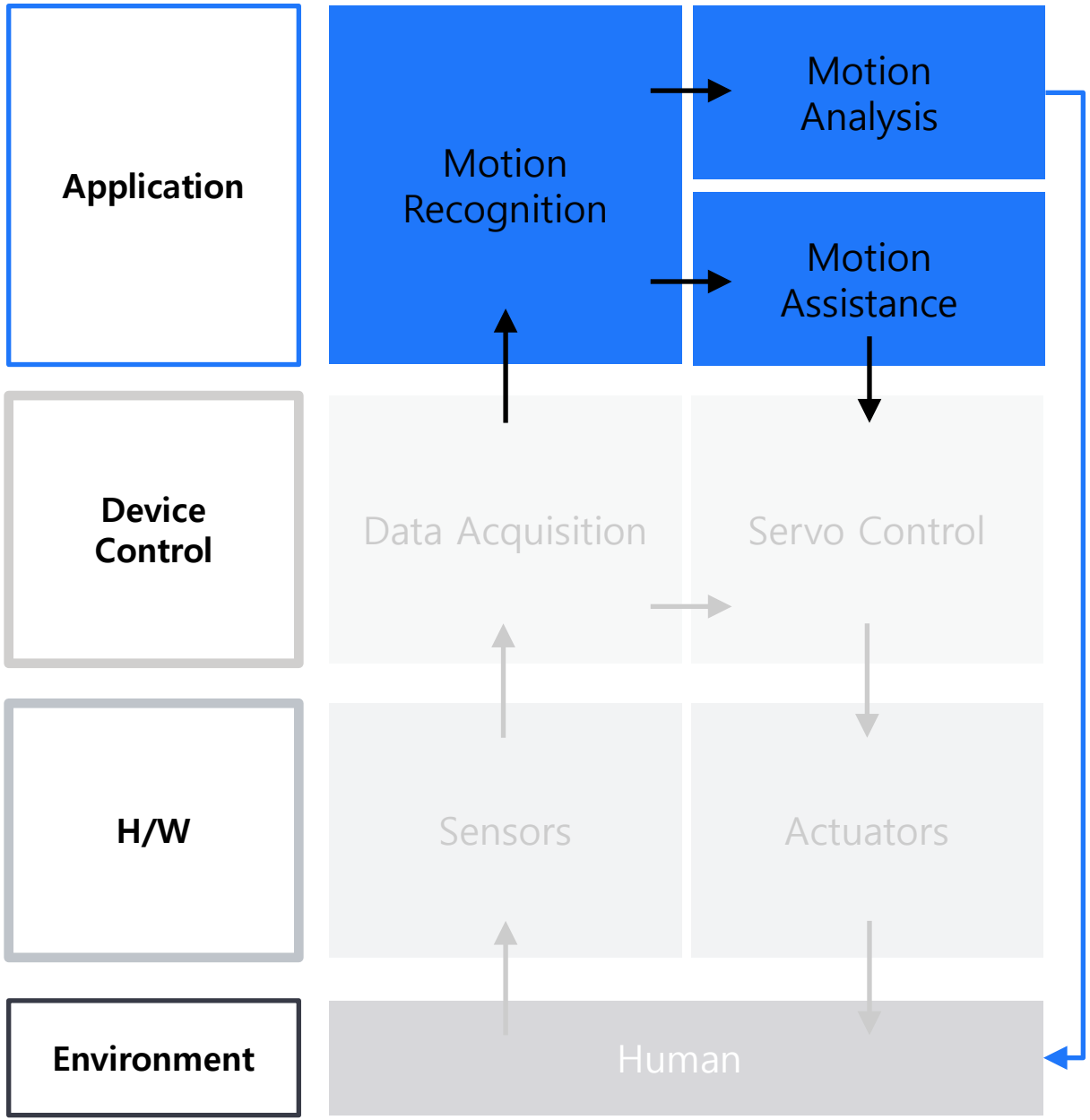
STM32H7

- FreeRTOS
- Hard real-time
- Robot Control
  - Torque/Position control
  - Gravity compensation
  - etc.
- Extra safty



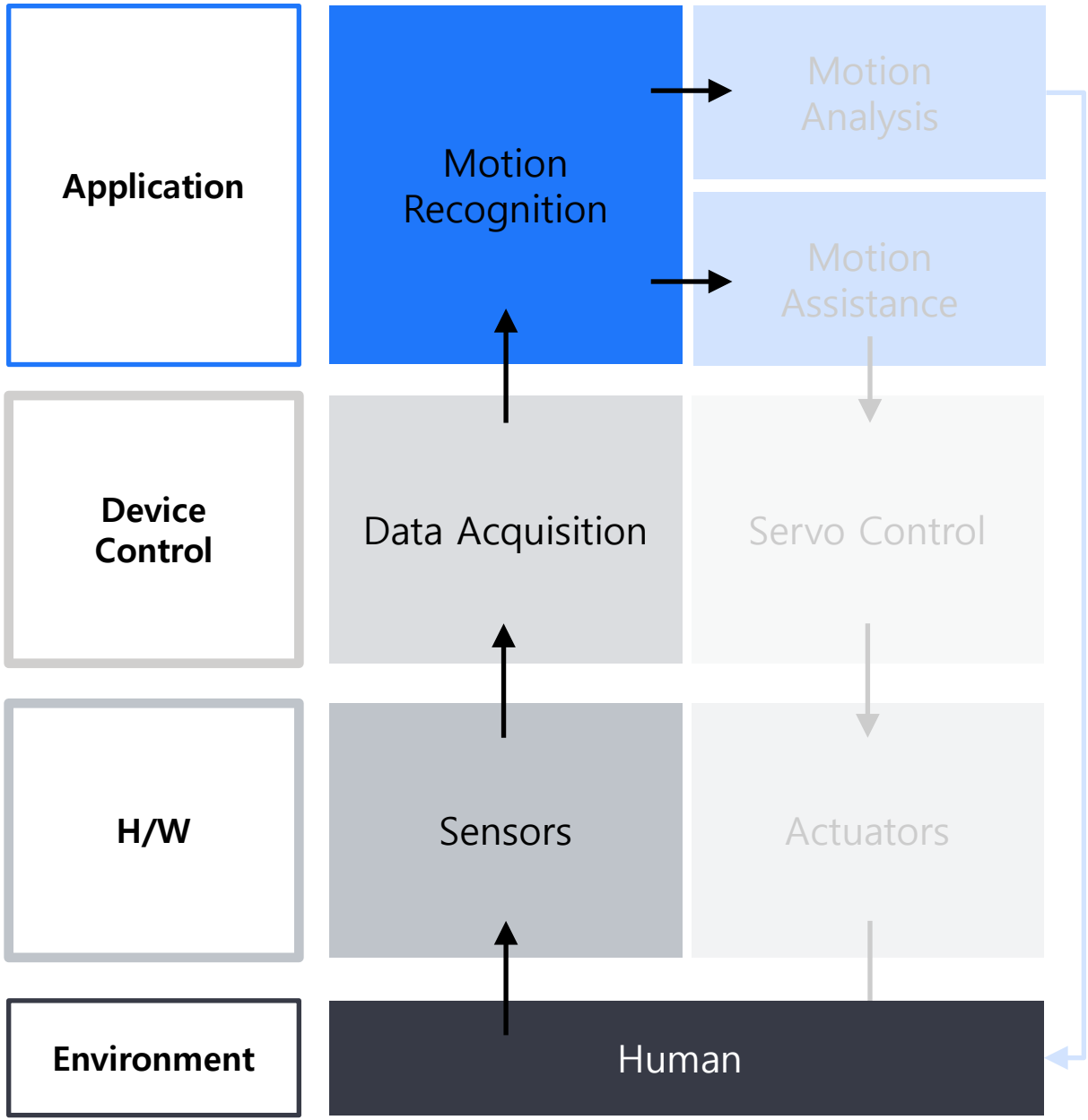
Wearable Robot Application

... with ROS2!



Wearable Robot Application

... with ROS2!



Motion Recognition

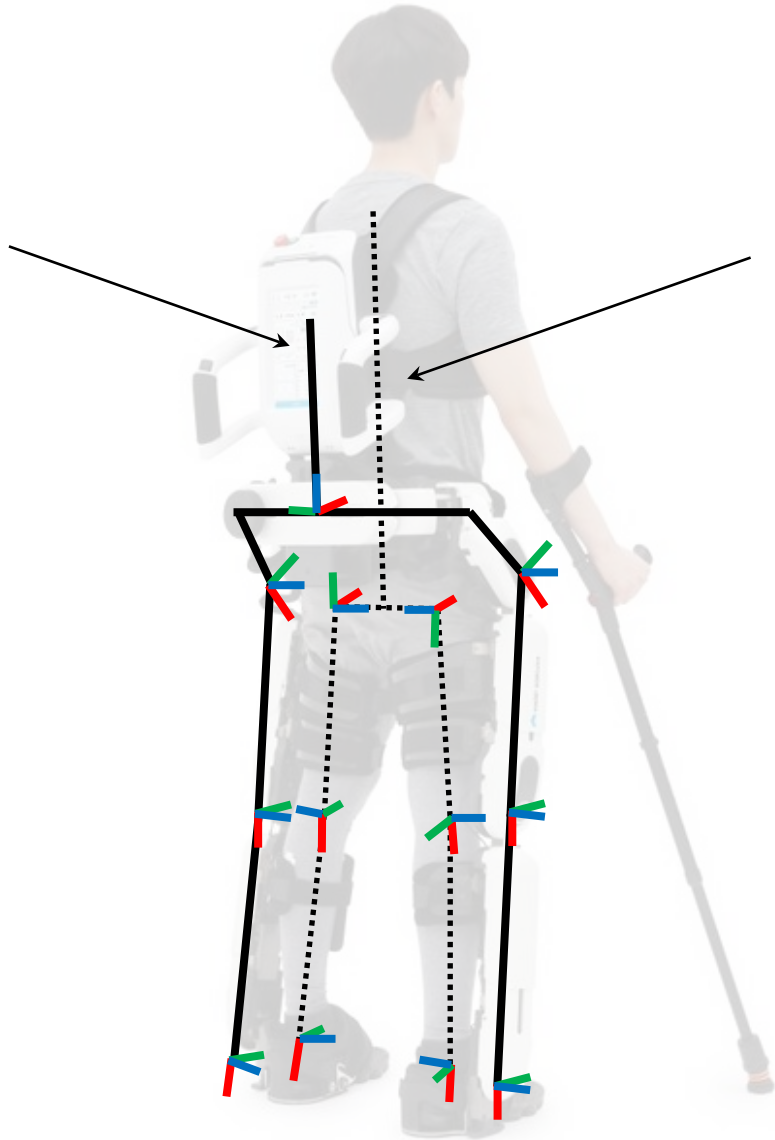
What is the wearer's **current/intended motion**?

Process sensor data into motion information

Describing **Human/Robot** Body Coordinates

Human Coordinates System

- **For Motion Recognition**



Robot Coordinates System

- **For Robot Control**

Describing **Human/Robot** Body Coordinates

Human Coordinates System

- For Motion Recognition
- **Common configuration, Specific guidelines**

Robot Coordinates System

- For Robot Control

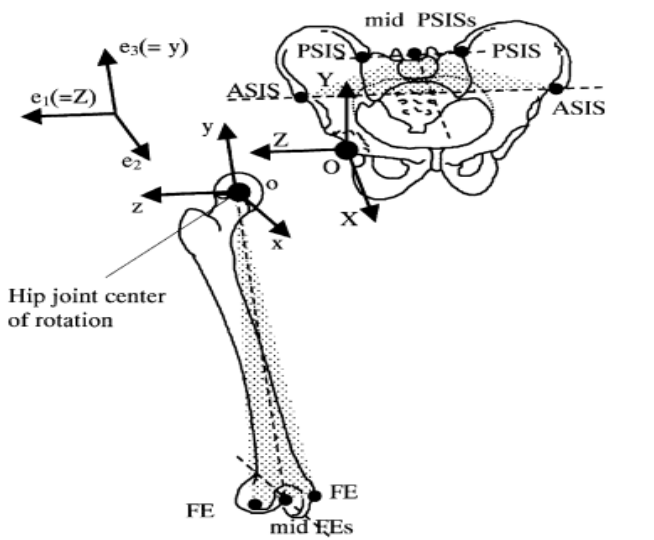


Fig. 3. Illustration of the pelvic coordinate system (*XYZ*), femoral coordinate system (*xyz*), and the JCS for the right hip joint.

Wu, G., Siegler, S., Allard, P., Kirtley, C., Leardini, A., Rosenbaum, D., … Stokes, I. (2002). ISB recommendation on definitions of joint coordinate system of various joints for the reporting of human joint motion—part I: ankle, hip, and spine. Journal of Biomechanics, 35(4), 543–548. doi:10.1016/s0021-9290(01)00222-6

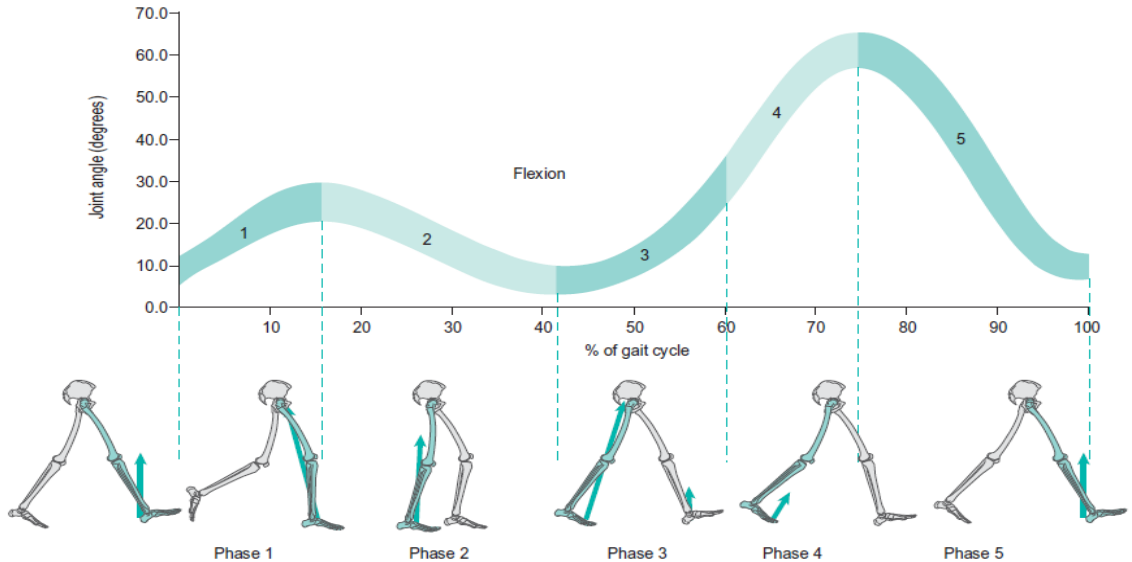


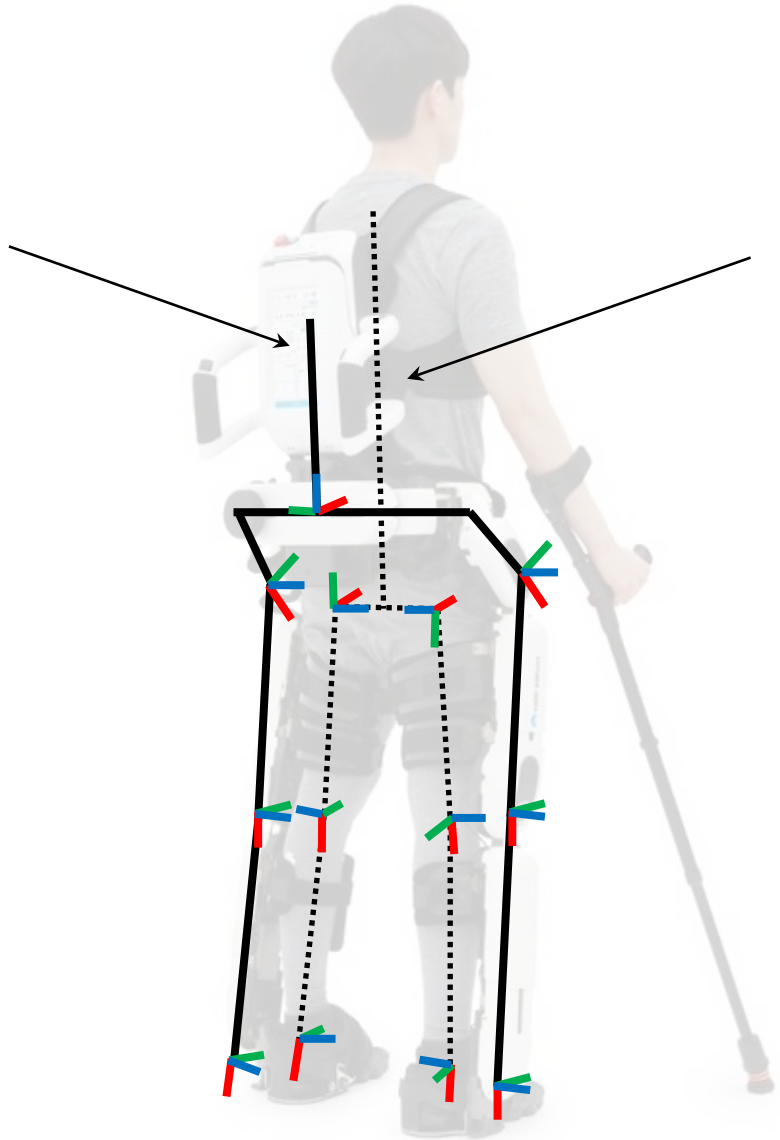
Figure 15.5 Knee movement through the gait cycle.

Richards, J., Chohan, A., & Erande, R. (2013). Biomechanics. Tidy's Physiotherapy, 331–368. doi:10.1016/b978-0-7020-4344-4.00015-8

Describing **Human/Robot** Body Coordinates

Human Coordinates System

- For Motion Recognition
- Common configuration, Specific guidelines
- **Estimated based on Robot Coordinates**



Robot Coordinates System

- For Robot Control
- **Depends on HW configuration**
- **Different than a human's**

Describing **Human/Robot** Body Coordinates

Human Coordinates System

- For Motion Recognition
- Common configuration, Specific guidelines
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Robot Coordinates System

- For Robot Control
- **Depends on HW configuration**
- **Different than a human's**

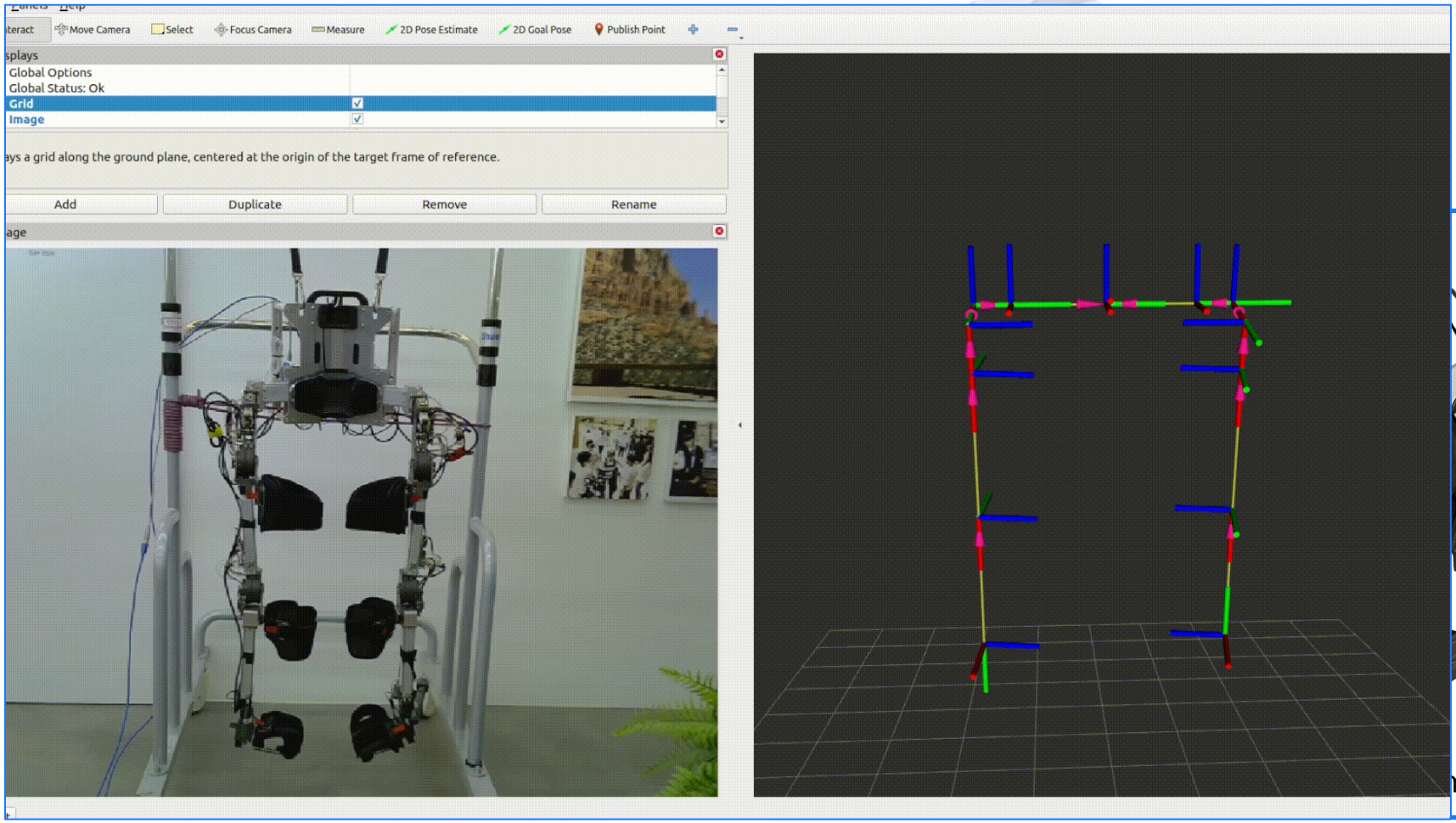
Anthropomorphic

Quasi-anthropomorphic

Non-anthropomorphic

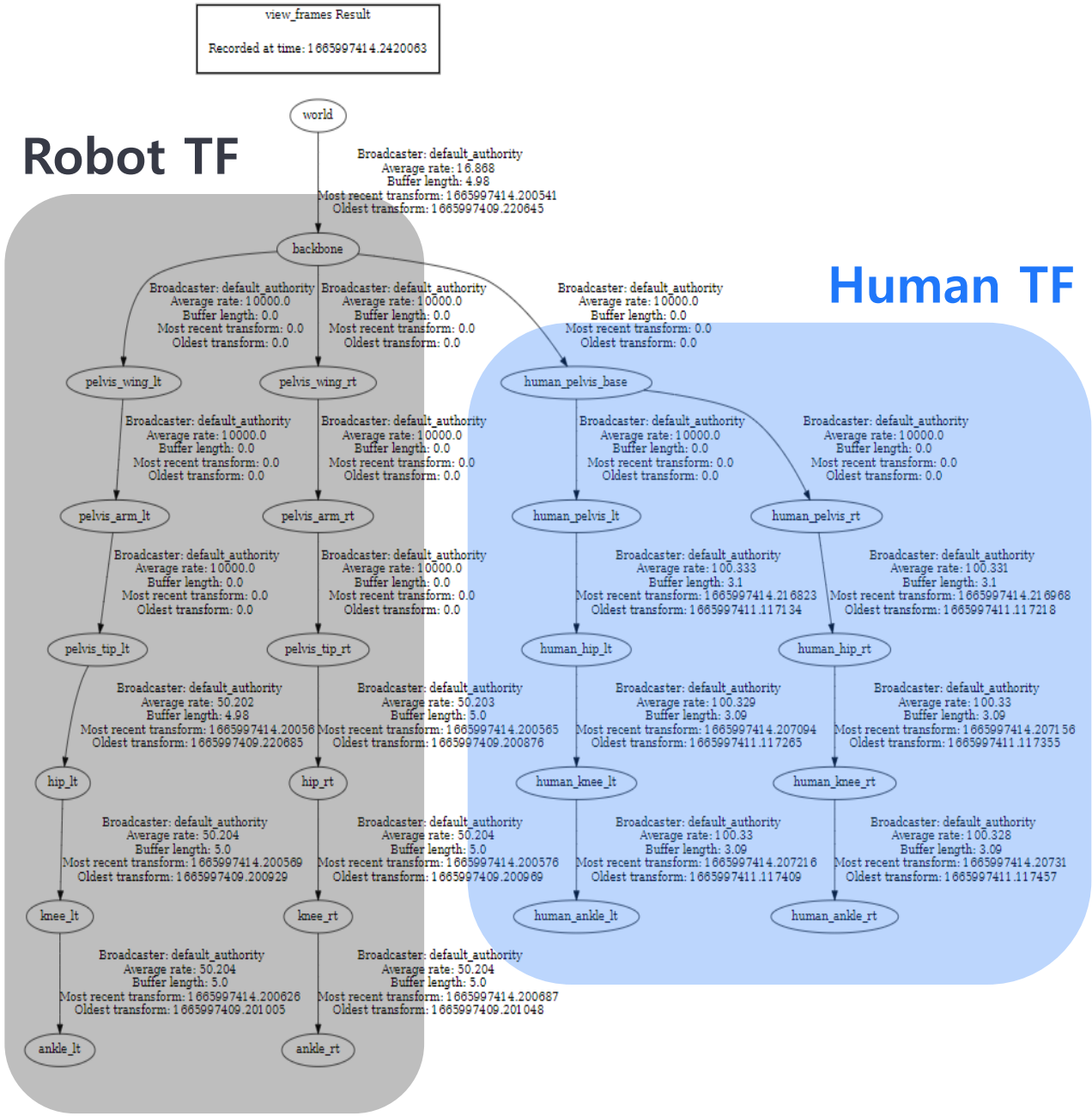
Describing **Human/Robot** Body Coordinates

Human Coordinates System



Robot Coordinates System

For Robot Control
Depends on HW configuration
Different than a human's


view_frames Result
Recorded at time: 1665997414.2420063
Robot TF
Human TF
world
Broadcaster: default_authority
Average rate: 16.868
Buffer length: 4.98
Most recent transform: 1665997414.200541
Oldest transform: 1665997409.220645
backbone
Broadcaster: default_authority
Average rate: 10000.0
Buffer length: 0.0
Most recent transform: 0.0
Oldest transform: 0.0
pelvis_wing_lt
pelvis_wing_rt
pelvis_arm_lt
pelvis_arm_rt
pelvis_tip_lt
pelvis_tip_rt
Broadcaster: default_authority
Average rate: 50.202
Buffer length: 4.98
Most recent transform: 1665997414.200565
Oldest transform: 1665997409.220685
Broadcaster: default_authority
Average rate: 50.203
Buffer length: 5.0
Most recent transform: 1665997414.200565
Oldest transform: 1665997409.200876
hip_lt
hip_rt
Broadcaster: default_authority
Average rate: 50.204
Buffer length: 5.0
Most recent transform: 1665997414.200569
Oldest transform: 1665997409.200929
Broadcaster: default_authority
Average rate: 50.204
Buffer length: 5.0
Most recent transform: 1665997414.200576
Oldest transform: 1665997409.200969
knee_lt
knee_rt
Broadcaster: default_authority
Average rate: 50.204
Buffer length: 5.0
Most recent transform: 1665997414.200626
Oldest transform: 1665997409.201005
Broadcaster: default_authority
Average rate: 50.204
Buffer length: 5.0
Most recent transform: 1665997414.200687
Oldest transform: 1665997409.201048
ankle_lt
ankle_rt
human_pelvis_base
human_pelvis_lt
human_pelvis_rt
Broadcaster: default_authority
Average rate: 100.333
Buffer length: 3.1
Most recent transform: 1665997414.216823
Oldest transform: 1665997411.117134
Broadcaster: default_authority
Average rate: 100.331
Buffer length: 3.1
Most recent transform: 1665997414.216968
Oldest transform: 1665997411.117218
human_hip_lt
human_hip_rt
Broadcaster: default_authority
Average rate: 100.329
Buffer length: 3.09
Most recent transform: 1665997414.207094
Oldest transform: 1665997411.117265
Broadcaster: default_authority
Average rate: 100.33
Buffer length: 3.09
Most recent transform: 1665997414.207156
Oldest transform: 1665997411.117355
human_knee_lt
human_knee_rt
Broadcaster: default_authority
Average rate: 100.33
Buffer length: 3.09
Most recent transform: 1665997414.207216
Oldest transform: 1665997411.117409
Broadcaster: default_authority
Average rate: 100.328
Buffer length: 3.09
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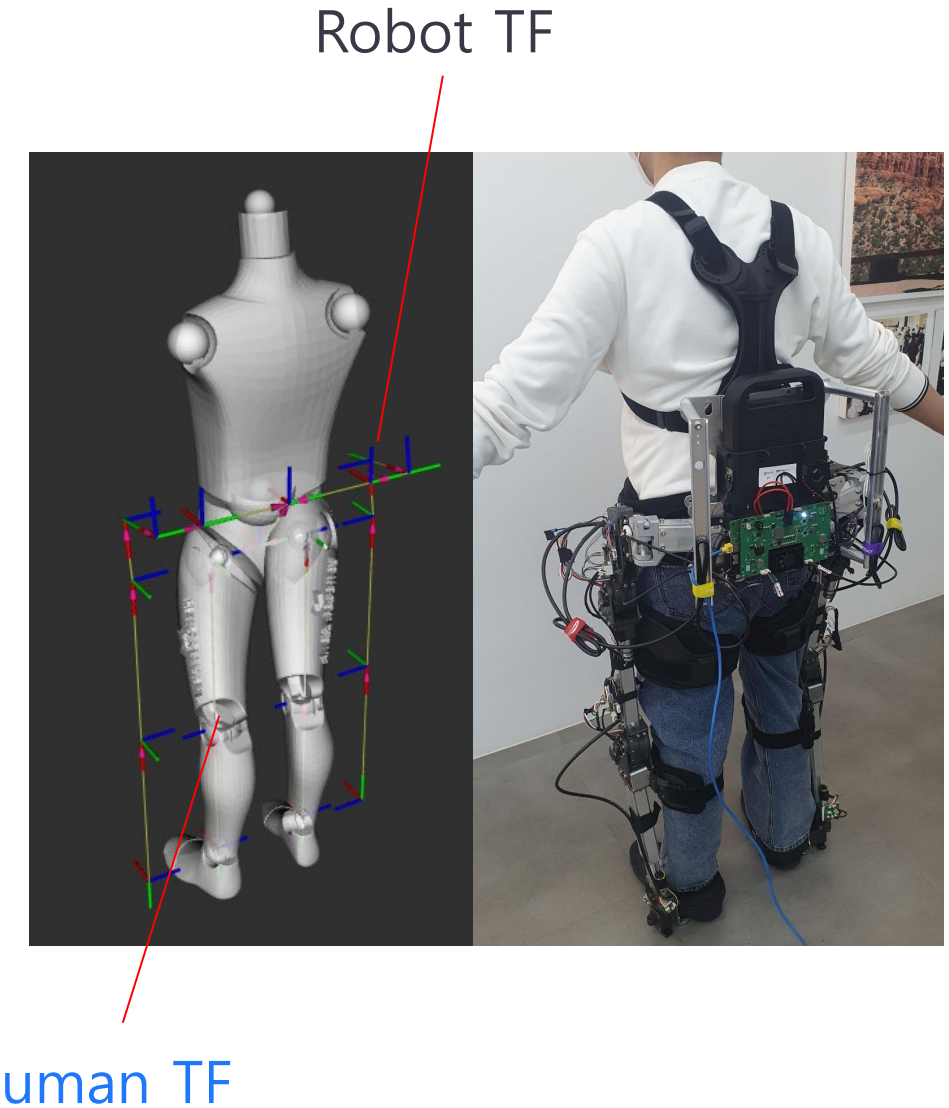
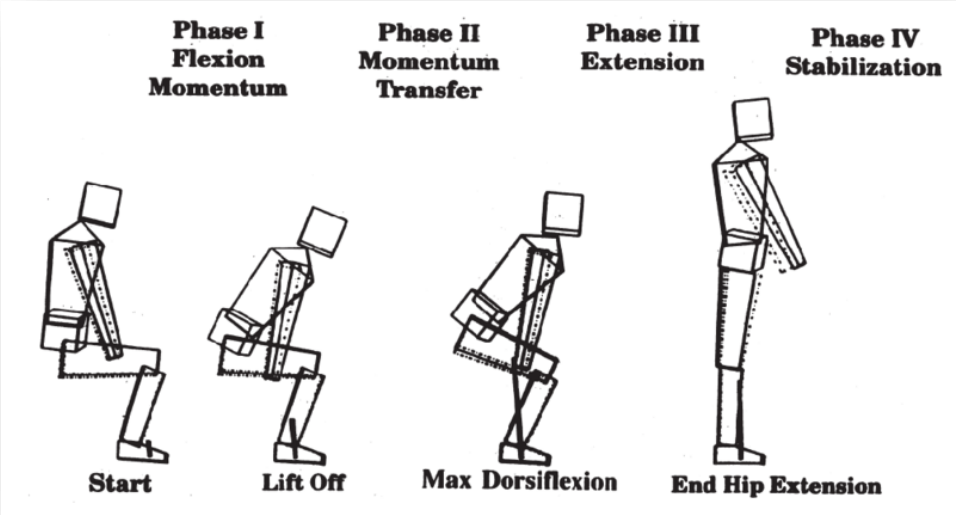
Oldest transform: 1665997411.117457
human_ankle_lt
human_ankle_rt

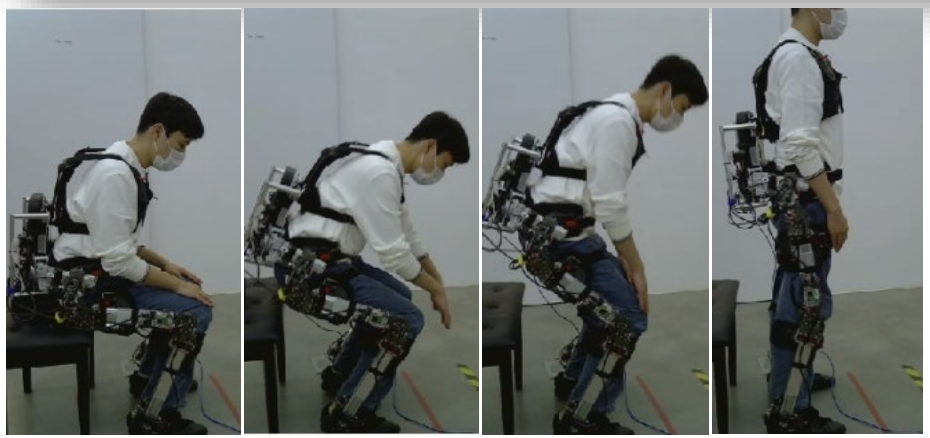

Robot TF
Human TF

Describing Motion

Sit to Stand Phases

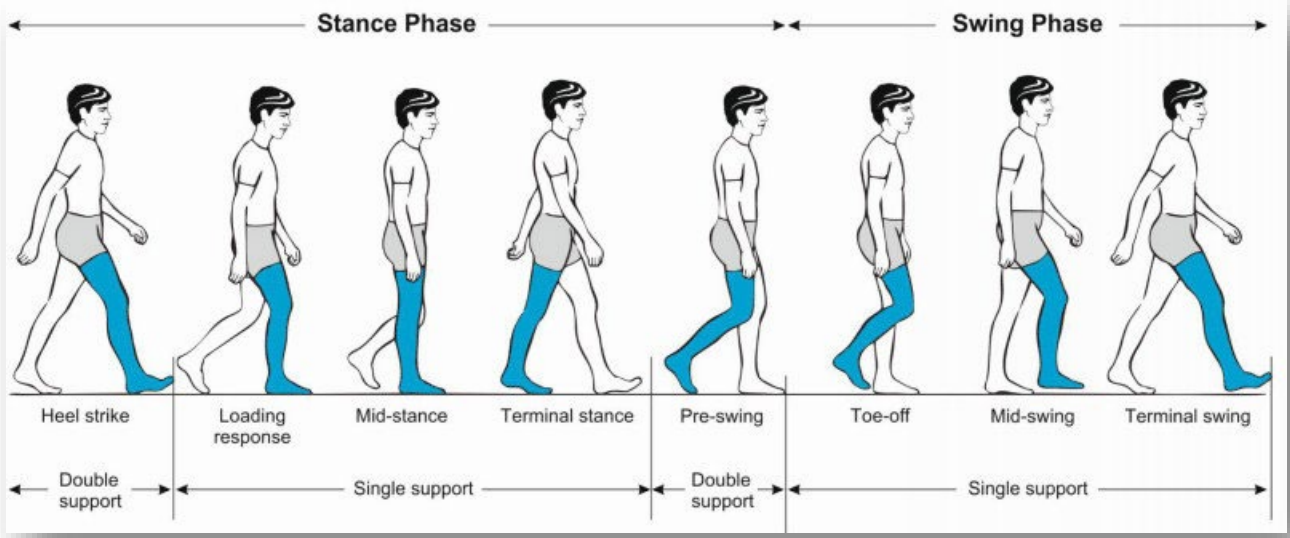


https://www.semanticscholar.org/paper/Sit-To-Stand-movement-analysis-using-the-Kinect-Fernandes/bc264dbebb3a1d43882c2d0ba6083f1c45ae608d



I. Sit II. Transfer III. Extension IV. Stand

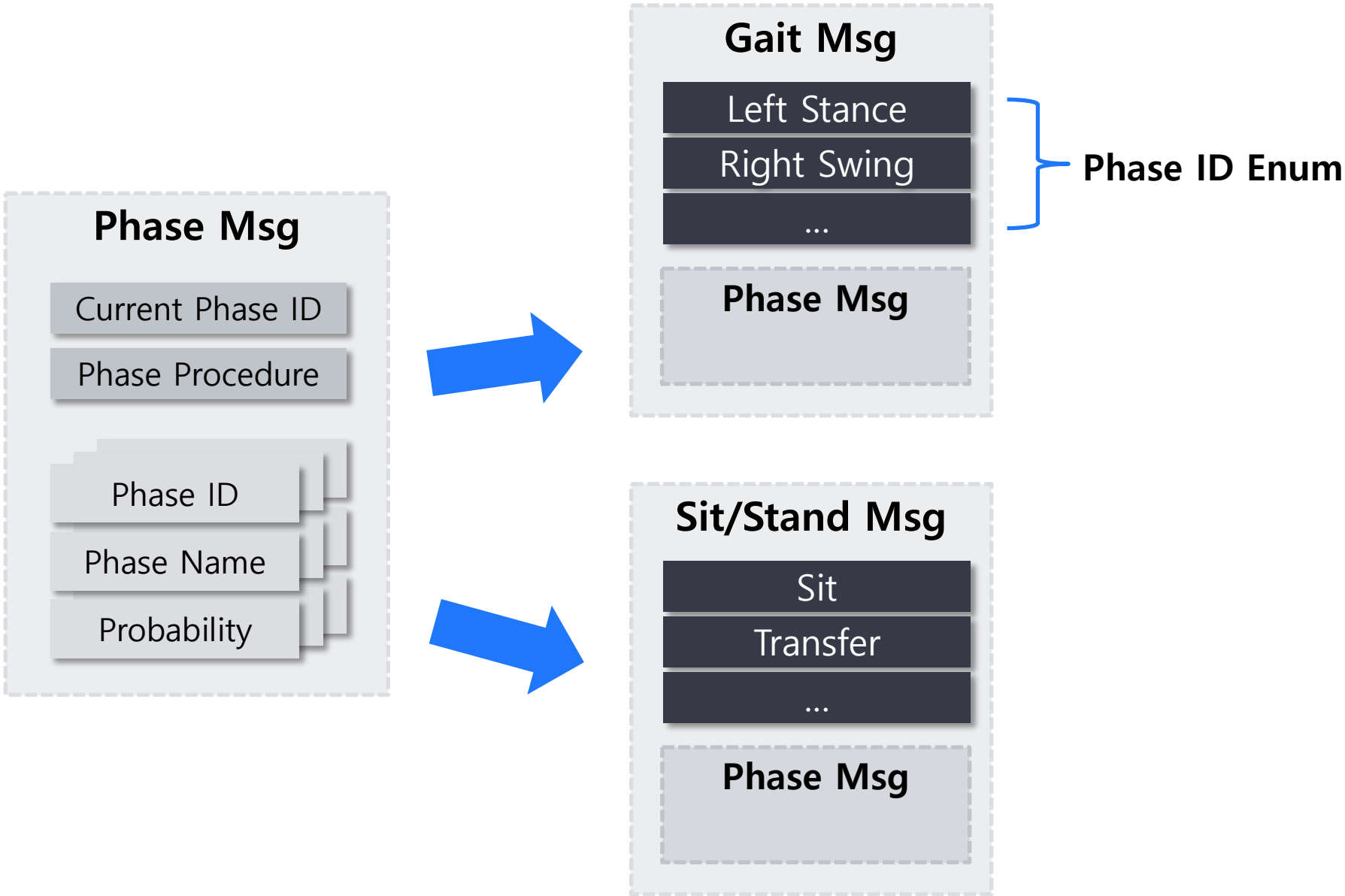
Gait Phases

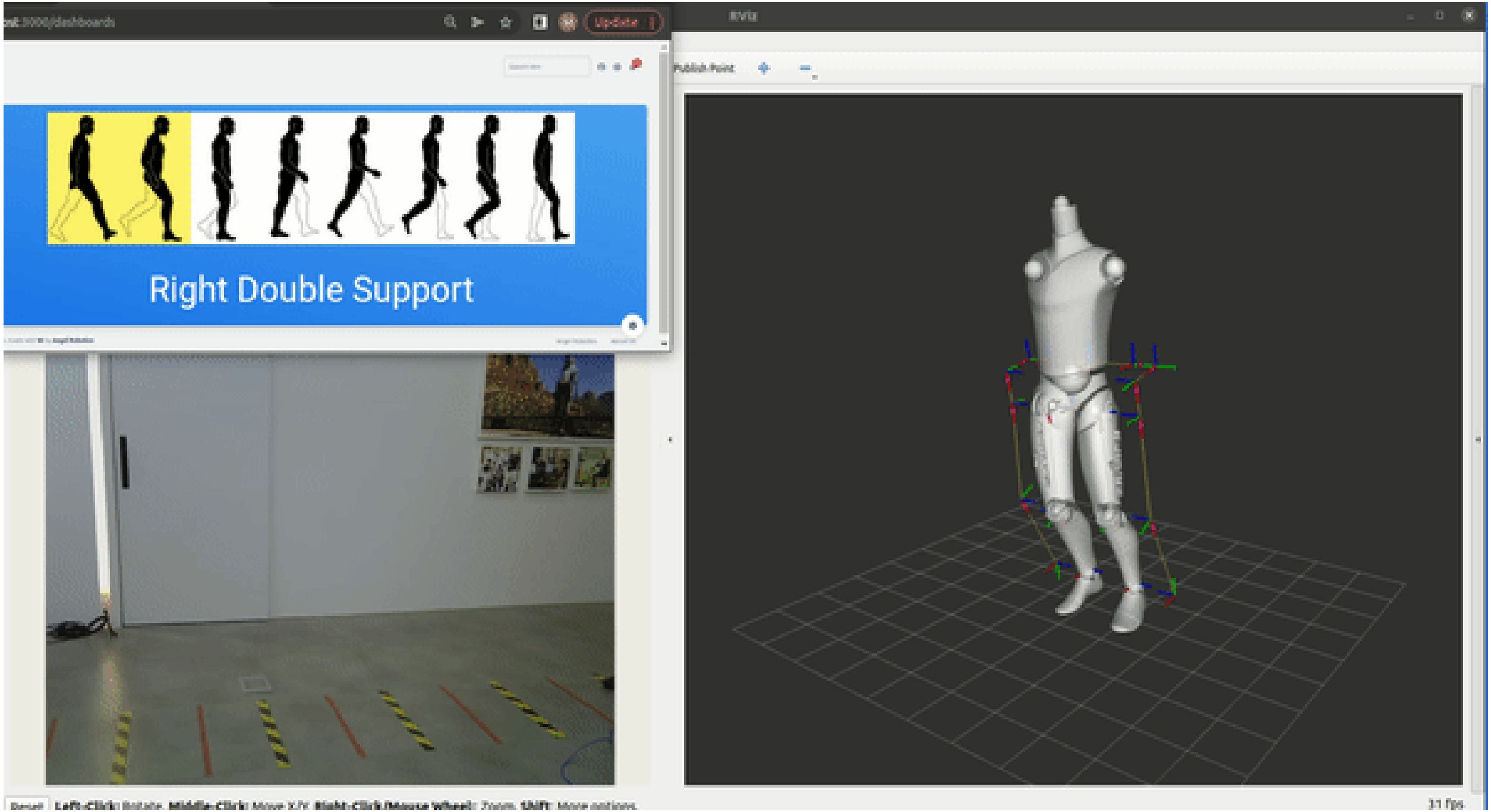


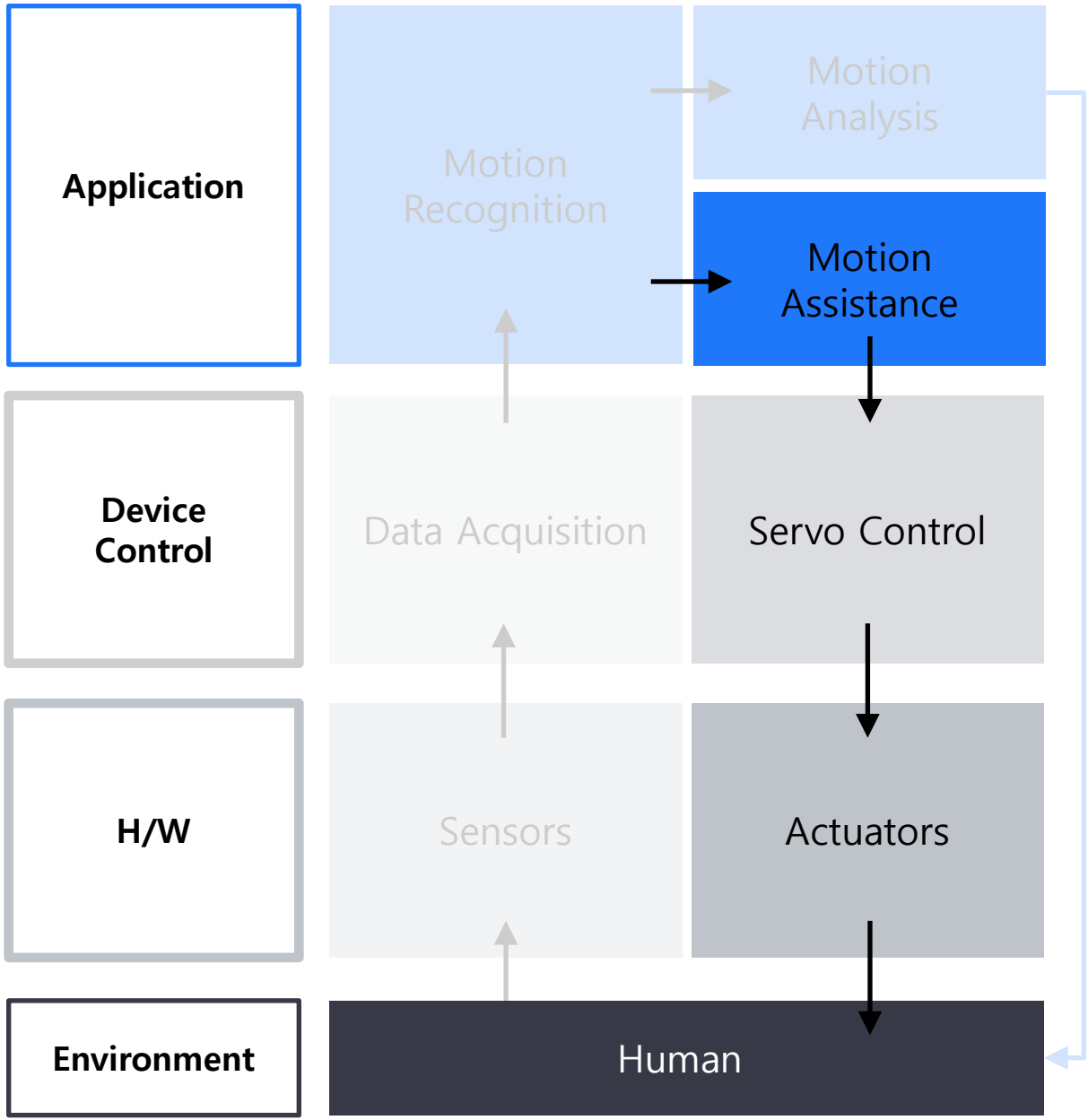
Pirker, Walter & Katzenschlager, Regina. (2016). Gait disorders in adults and the elderly: A clinical guide. Wiener klinische Wochenschrift. 129. 10.1007/s00508-016-1096-4.

I. Right Double Support II. Right Single Support III. Left Double Support IV. Left Single Support

Describing Motion




Update
RViz
Publish Point
Right Double Support
Reset
Left-Click: Rotate. Middle-Click: Move X/Y. Right-Click/Mouse Wheel: Zoom. Shift: More options.
31 fps

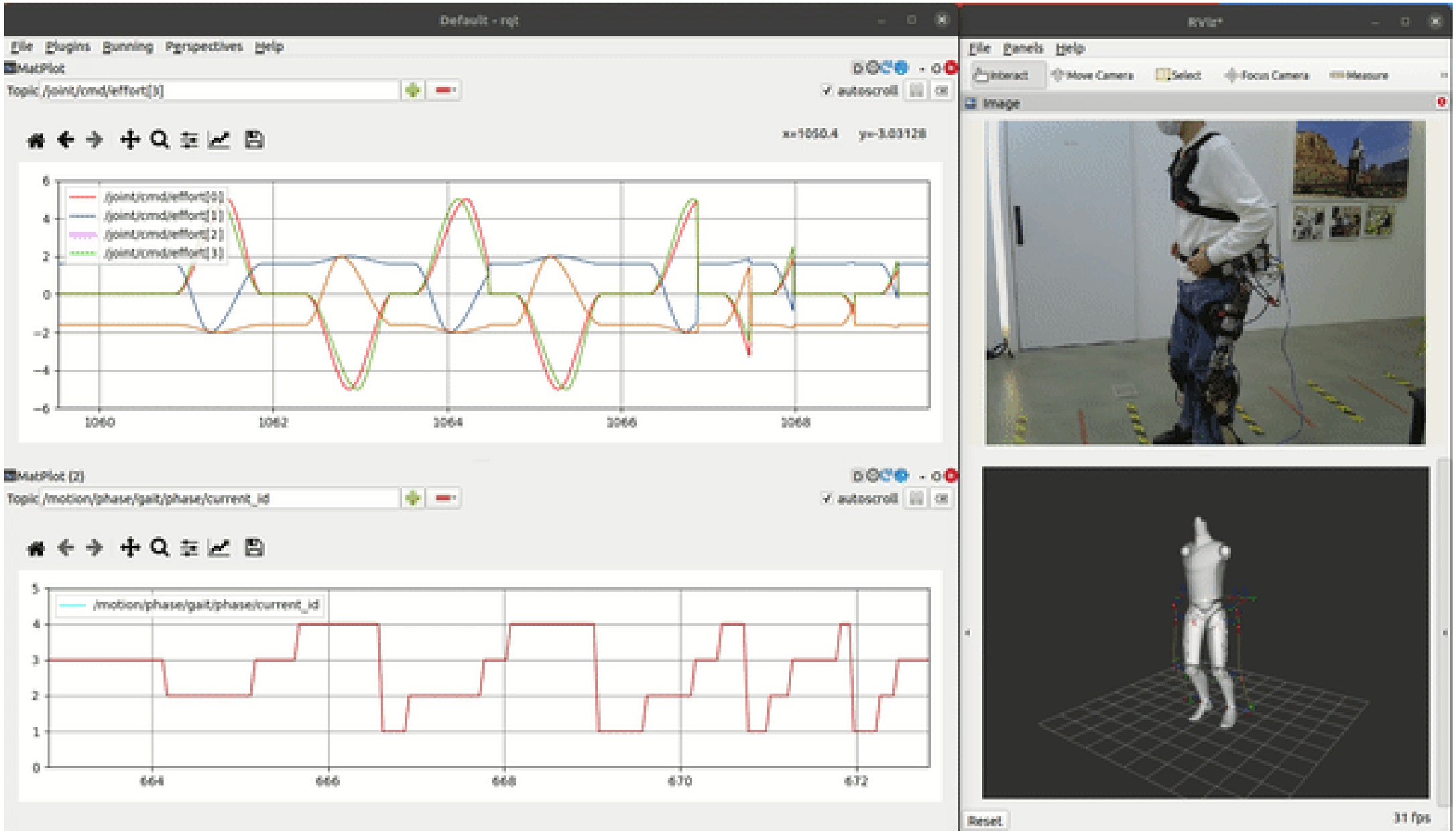


Motion Assistance

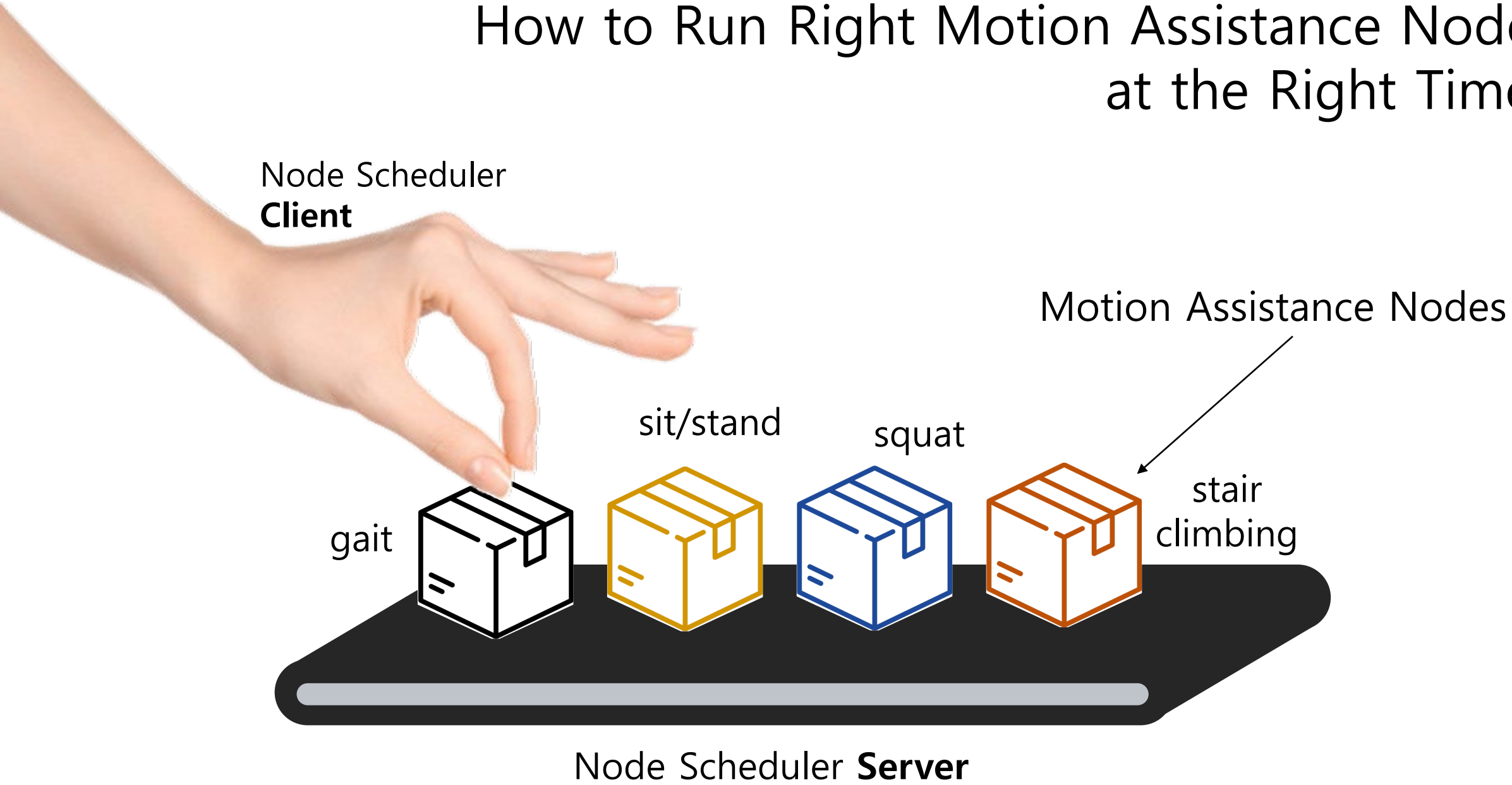
How to **assist** the wearer's **motion**?

Generate control command to assist recognized motion phase

Motion Assistance



How to Run Right Motion Assistance Nodes at the Right Time?



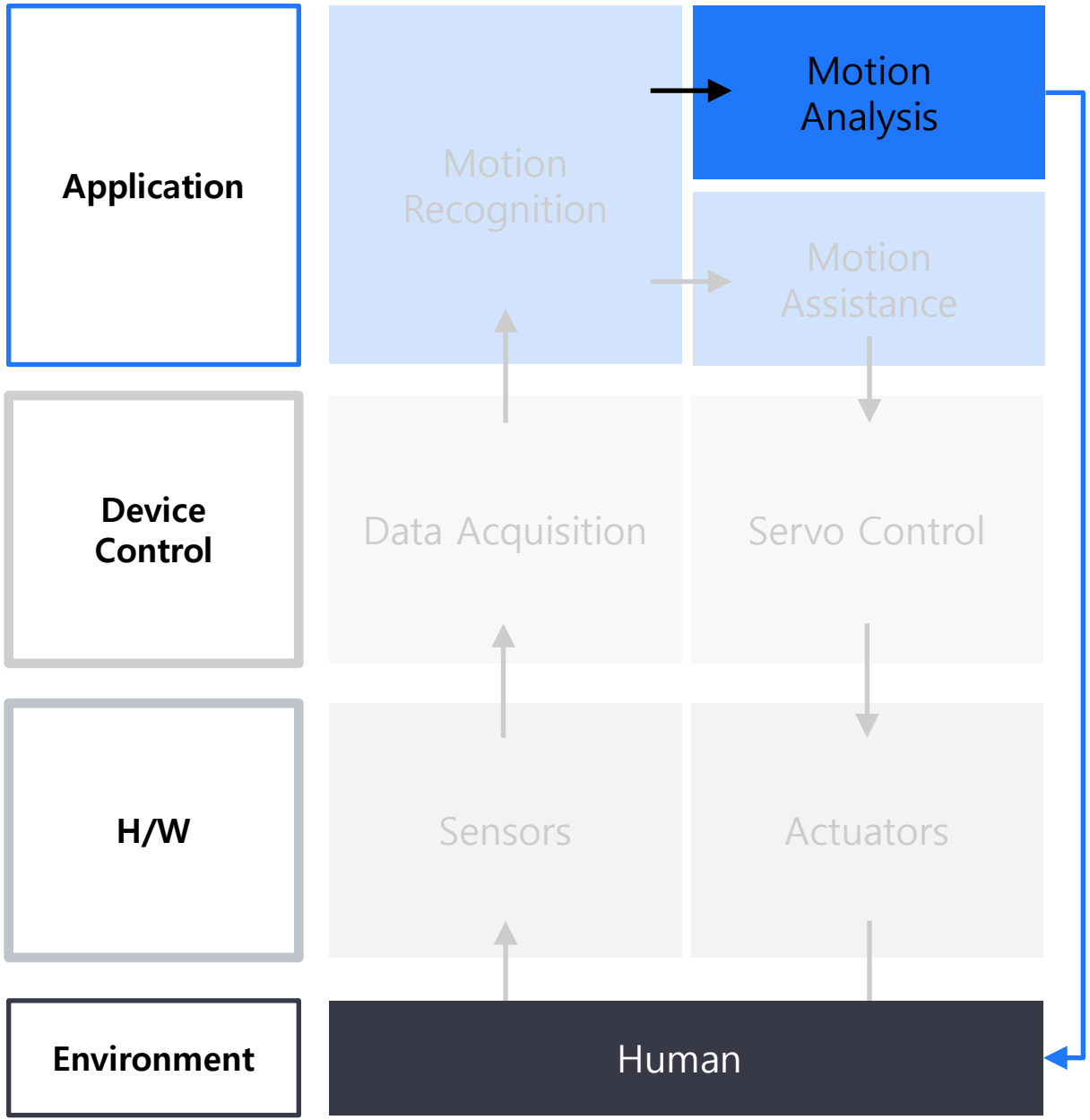
Why should the scheduler be defined as Action Node ?

Node Scheduler Server

Node Scheduler Client

1. Node Scheduler always alive
2. Execution functionality switch depending on topic
3. Node self-destruct possible if needed

Action Node, a perfect choice for node scheduler !



Motion Analysis

How the wearer's **motion performance** is like?

Produce indicators for motion performance
Evaluation of motion assistance

MOTION ANALYSIS

LOG DATA

JOINT CMD/STATE DATA

MODE STATEMENT DATA

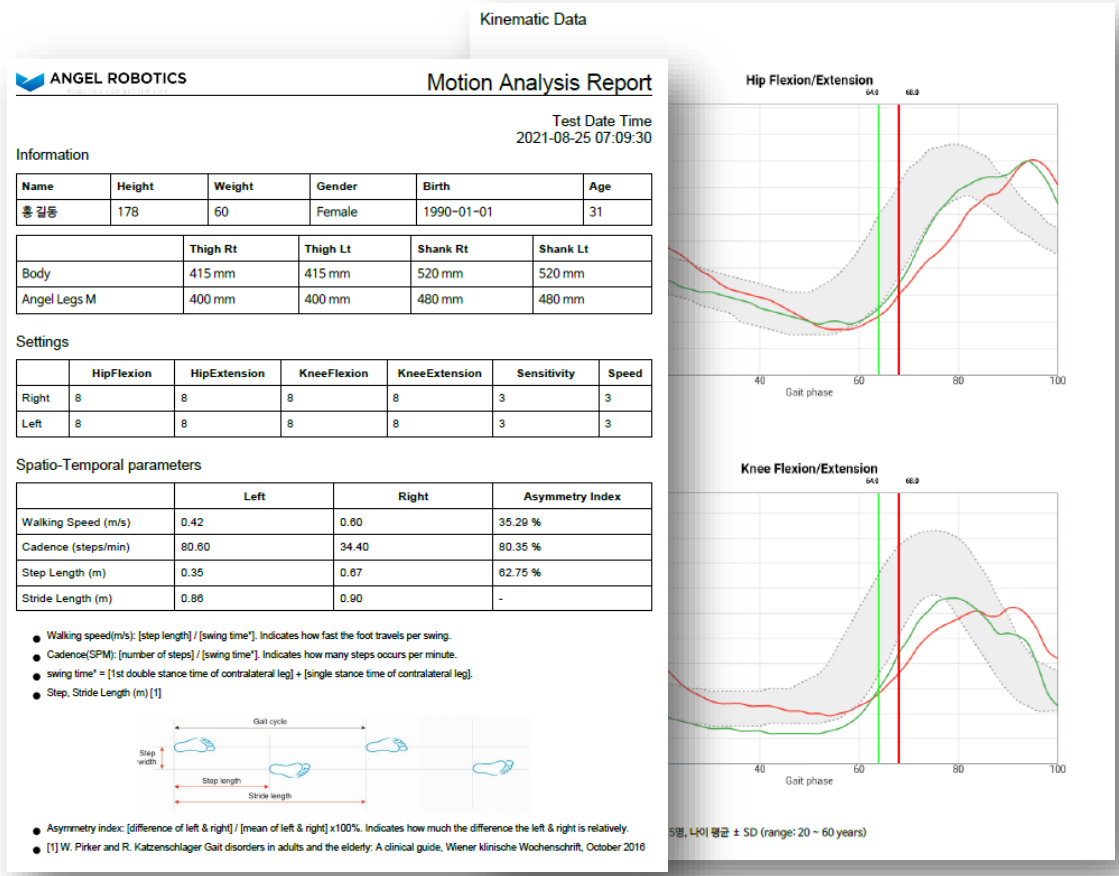
POWER STATEMENT DATA

SENSOR STATEMENT DATA

SOFTWARE VERSION DATA

⋮

PROCESSED DATA



ANGEL ROBOTICS

Motion Analysis Report

Test Date Time
2021-08-25 07:09:30

Information

Name	Height	Weight	Gender	Birth	Age
홍 길동	178	60	Female	1990-01-01	31

	Thigh Rt	Thigh Lt	Shank Rt	Shank Lt
Body	415 mm	415 mm	520 mm	520 mm
Angel Legs M	400 mm	400 mm	480 mm	480 mm

Settings

	HipFlexion	HipExtension	KneeFlexion	KneeExtension	Sensitivity	Speed
Right	8	8	8	8	3	3
Left	8	8	8	8	3	3

Spatio-Temporal parameters

	Left	Right	Asymmetry Index
Walking Speed (m/s)	0.42	0.60	35.29 %
Cadence (steps/min)	80.60	34.40	80.35 %
Step Length (m)	0.35	0.67	62.75 %
Stride Length (m)	0.86	0.90	-

- Walking speed(m/s): [step length] / [swing time*]. Indicates how fast the foot travels per swing.
- Cadence(SPM): [number of steps] / [swing time*]. Indicates how many steps occurs per minute.
- swing time* = [1st double stance time of contralateral leg] + [single stance time of contralateral leg].
- Step, Stride Length (m) [1]

- Asymmetry index: [difference of left & right] / [mean of left & right] x100%. Indicates how much the difference the left & right is relatively.
- [1] W. Pirker and R. Katzenschlager Gait disorders in adults and the elderly: A clinical guide, Wiener klinische Wochenschrift, October 2016

Kinematic Data

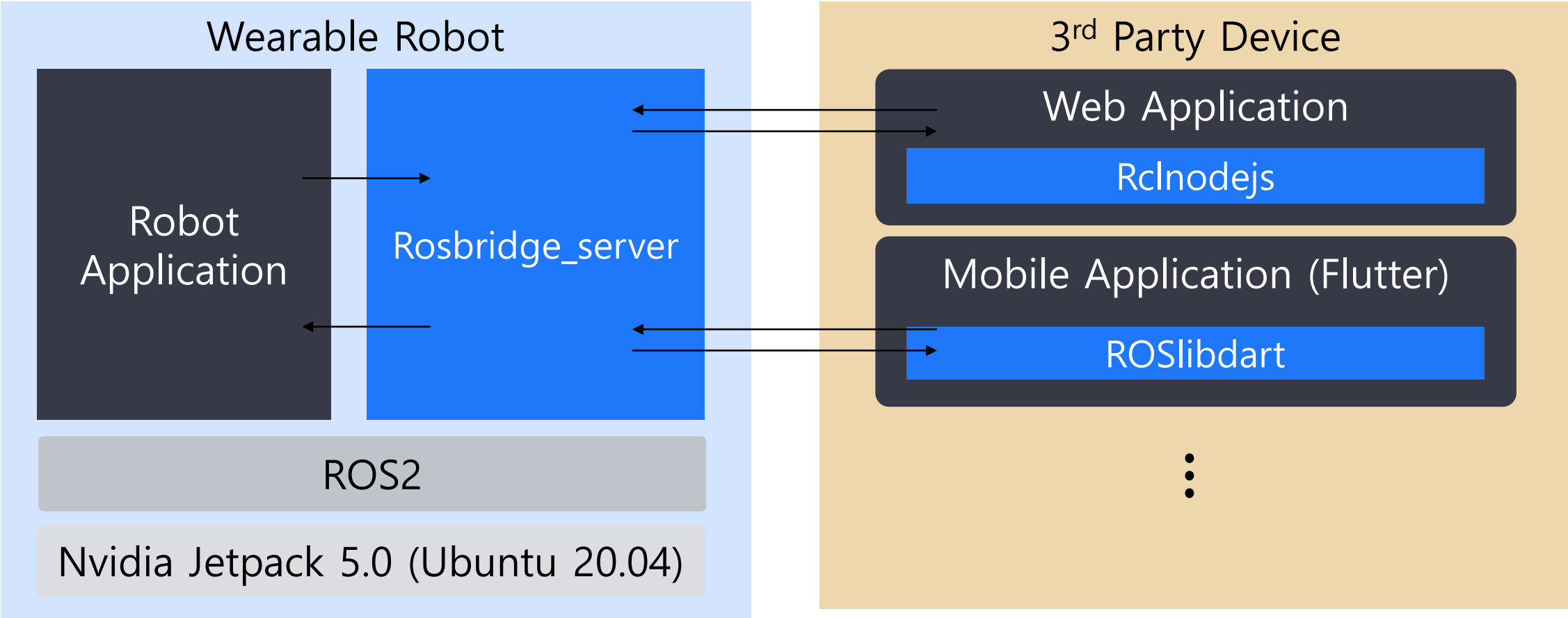
PERSONALIZED DATA

MOTION PERFORMANCE DATA

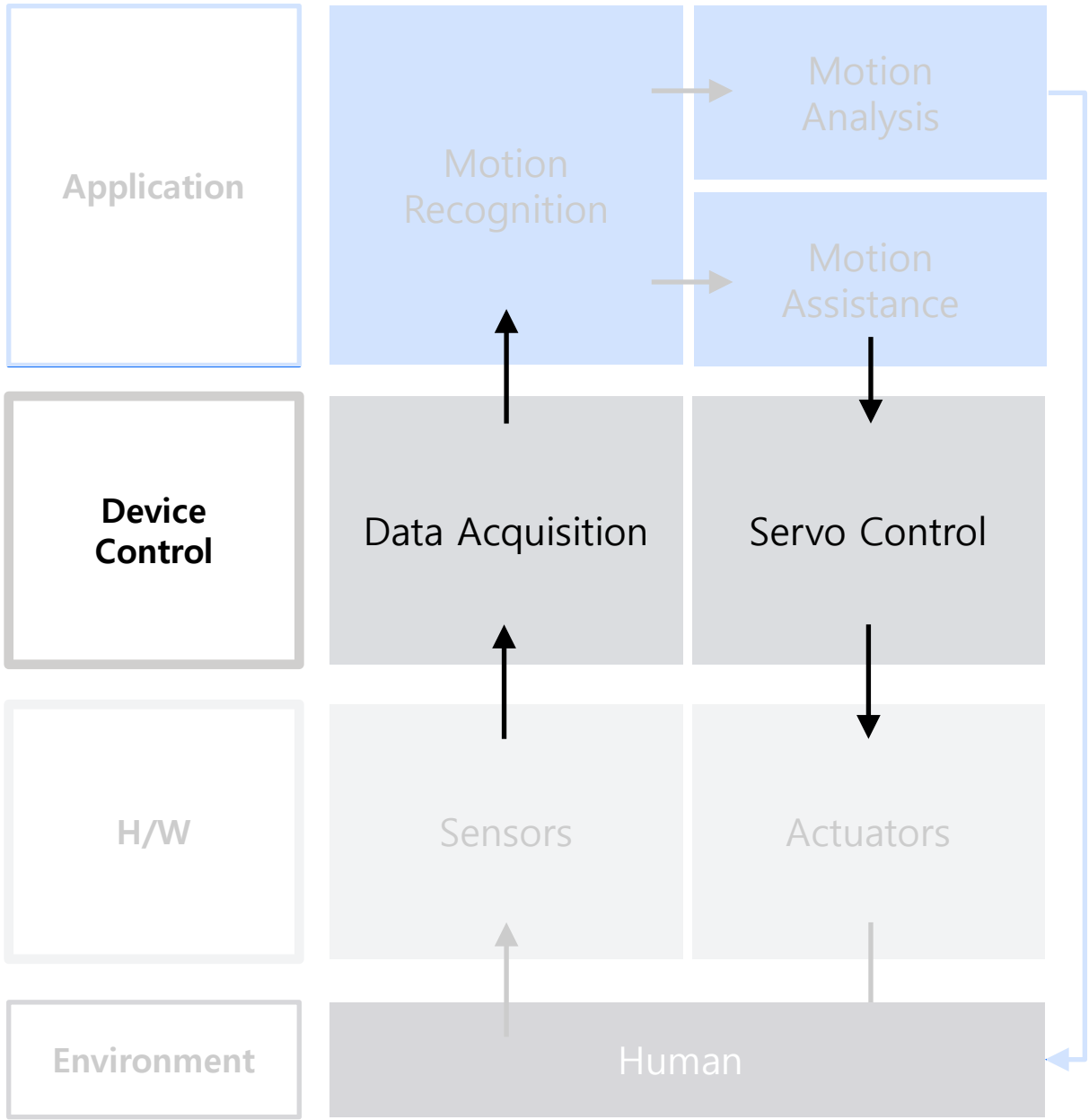
⋮

MOTION ANALYSIS

ROSBRIDGE SUIT



Web Application (Rclnodejs)



μ-ROS for Device Control Layer


AI
Monitoring system report
Angel X
Data Cloud
ANGEL CLOUD SERVICE
Angel Legs Outdoor
Angel Legs M
: Rehabilitation training
Angel Suit
Angel Legs Home

Thank you