ROS Framework Tutorial

Walking Module

Walking Module

Background

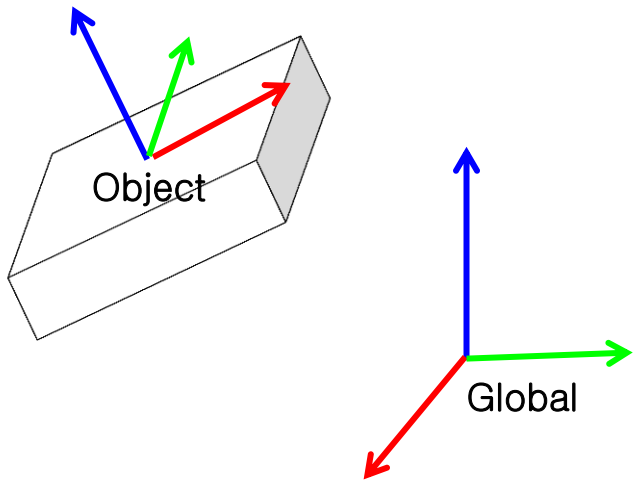
Contents

Background

1) Representation of Pose

- the walking module is using global coordinate system.
- All pose is represented x, y, z, roll, pitch, yaw.
- All unit is meter and radian.

$$
\begin{aligned}
&{}^{G}T_{O} \\
&= {}^{G}t_{O}(x,y,z)\,{}^{G}R_{O}(\phi_{roll},\theta_{pitch},\psi_{yaw}) \\
&= t(x,y,z)R_{z}(\psi)R_{y}(\theta)R_{x}(\phi) \\
&= \begin{bmatrix} c\psi c\theta & c\psi s\theta s\phi - s\psi c\phi & c\psi s\theta c\phi + s\psi s\phi & x \\ s\psi c\theta & s\psi s\theta s\phi + c\psi c\phi & s\psi s\theta c\phi - c\psi s\phi & y \\ -s\theta & c\theta s\phi & c\theta c\phi & z \\ 0 & 0 & 0 & 1 \end{bmatrix}
\end{aligned}
$$



G : Global Coordinate

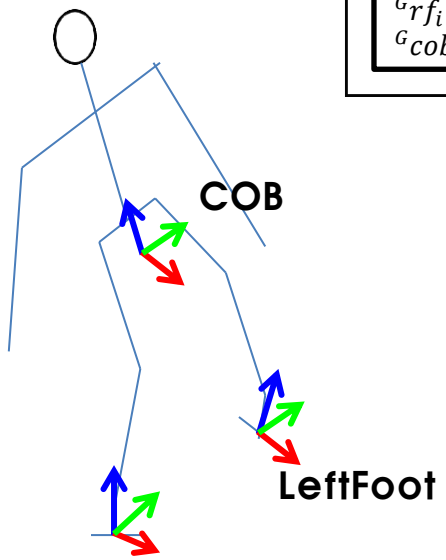
O : Object Cooridinate

$c\phi$: $\cos\phi$

$s\phi$: $\sin\phi$

2) Pattern Generation

- COB(Center of Body) is at the middle of hip joints.
- LF(Left Foot) and RF(Right Foot) is at the middle of each feet.



Foot Step Data

$^{G}lf_i\ (x, y, z, \phi, \theta, \psi)$
$^{G}rf_i\ (x, y, z, \phi, \theta, \psi)$
$^{G}cob_i\ (z, \phi, \theta, \psi)$

FIFO

$ZMP^*_{k+N_p}$ ... ZMP^*_{k+1}

k : Idx.
N_p : Preview Size
x_LIPM_k : Position of COB at k
ZMP^*_k : target ZMP at k

Preview Controller With Integrator

$$u_k = -Ks\sum_{j=0}^{k}\left(c \cdot x_{LIPM\,j} - ZMP^*_j\right) - Kx \cdot x_{LIPM\,k} + [f_1\ f_2\ \cdots f_{N_p}]\begin{bmatrix} ZMP^*_{k+1} \\ \vdots \\ ZMP^*_{k+N_p} \end{bmatrix}$$

$$x\_LIPM_{k+1} = A * x_{LIPM\,k} + b * u_k$$

$^{G}cob_{present}\ (x, y)$

Sigmoid Pattern

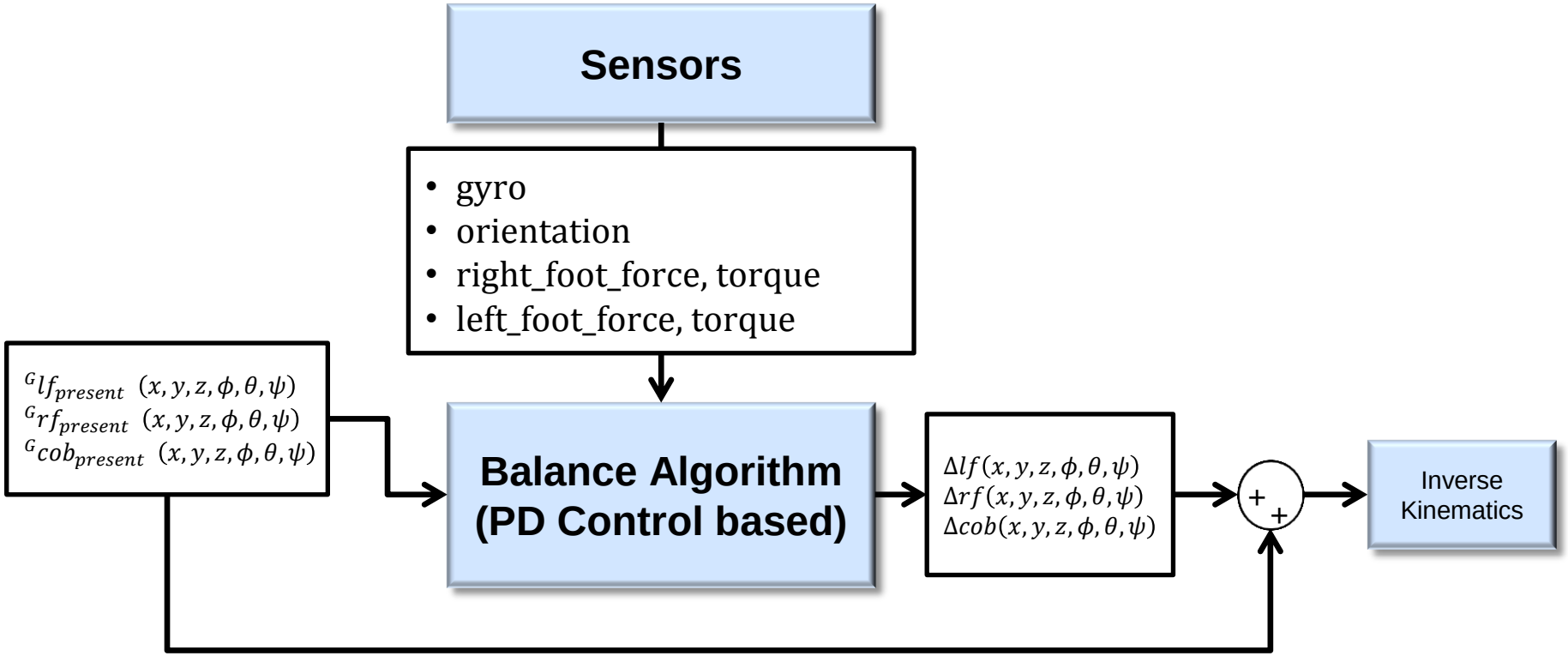
$^{G}lf_{present}\ (x, y, z, \phi, \theta, \psi)$
$^{G}rf_{present}\ (x, y, z, \phi, \theta, \psi)$
$^{G}cob_{present}\ (x, y, z, \phi, \theta, \psi)$

Balance Algorithm

Inverse Kinematics

3) Balance Algorithm

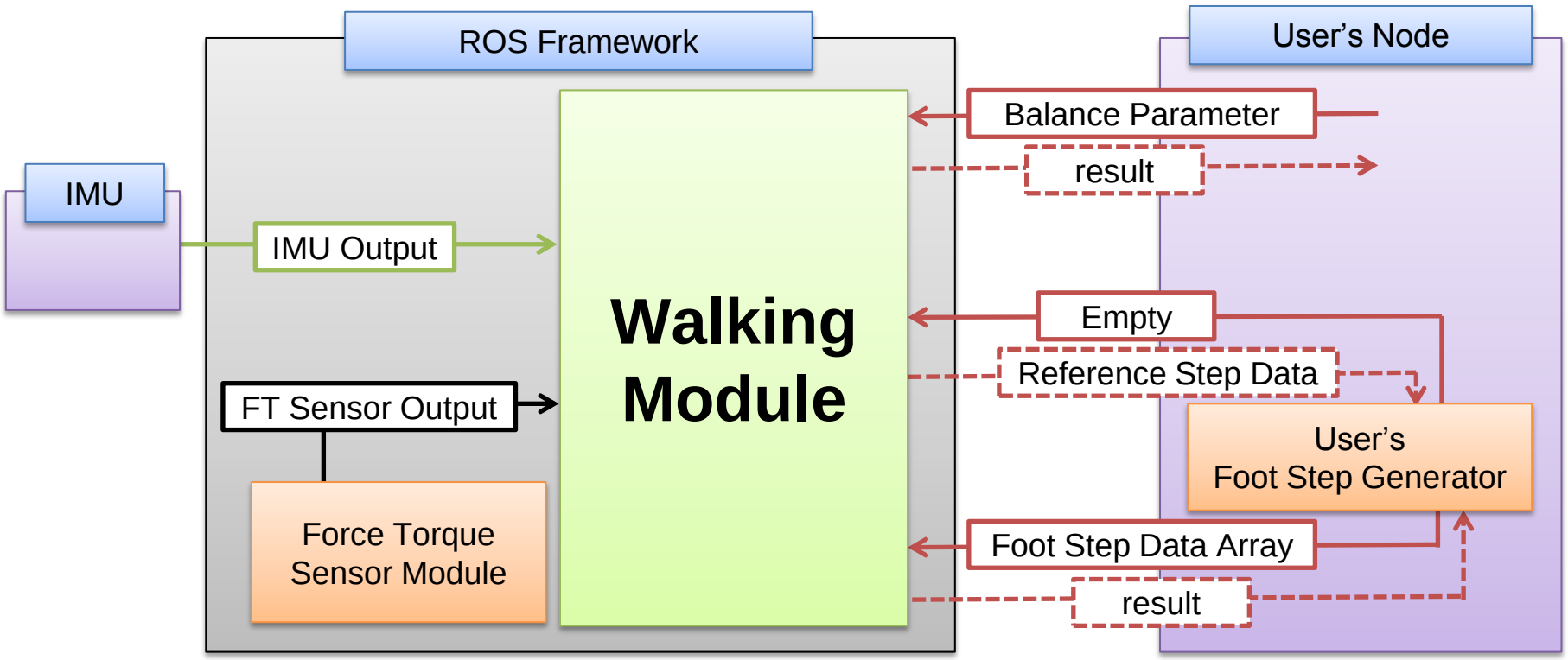
- The sensory feedback balance algorithm is used.
- The result of balance algorithm is ${}^{COB}T_{COB^*}$, ${}^{RF}T_{RF^*}$, ${}^{LF}T_{LF^*}$



Walking Module

Walking Module

1) Overview



2) Topic and Service List

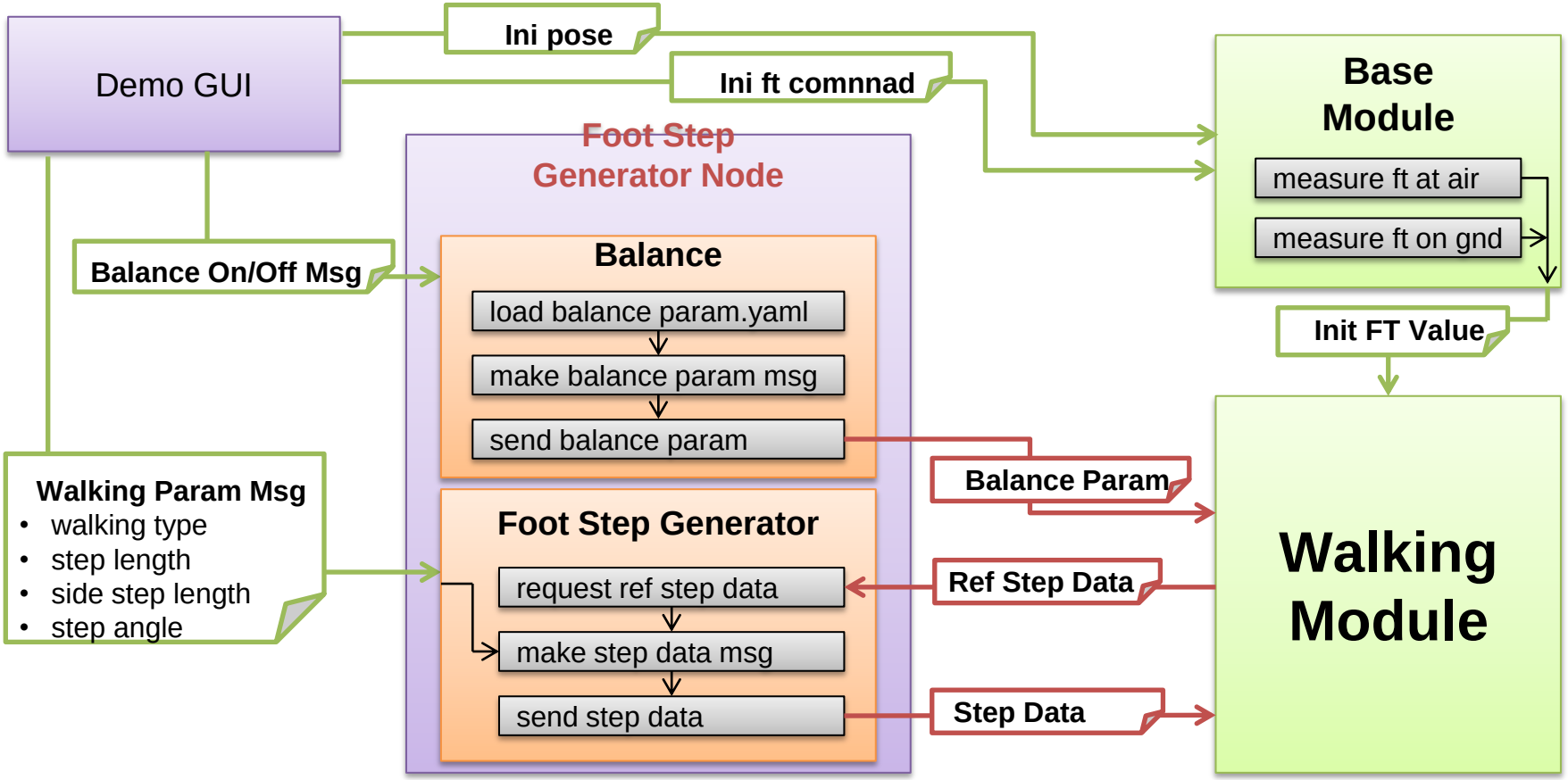
	Name		Description
Topic (Publish)	/robotis/walking/status_message		The status message from walking module
Service (Server)	/robotis/walking/get_reference_step_data	req	Empty
		res	Reference Step Data
	/robotis/walking/add_step_data	req	"Auto Start" and "Step Data Array"
		res	Processing Result for Request
	/robotis/walking/walking_start	req	Empty
		res	Processing Result for Request
	/robotis/walking/remove_existing_step_data	req	Empty
		res	Processing Result for Request
	/robotis/walking/set_balance_param	req	All of Desired Balancing Parameter
		res	Processing Result for Request
	/robotis/walking/is_running	req	Empty
		res	Running or Not

3) Example

- Overview
  - User can choose 6 kinds of step data. (forward/backward, leftward/rightward, turn left/right)
  - User can turn balance on or off.

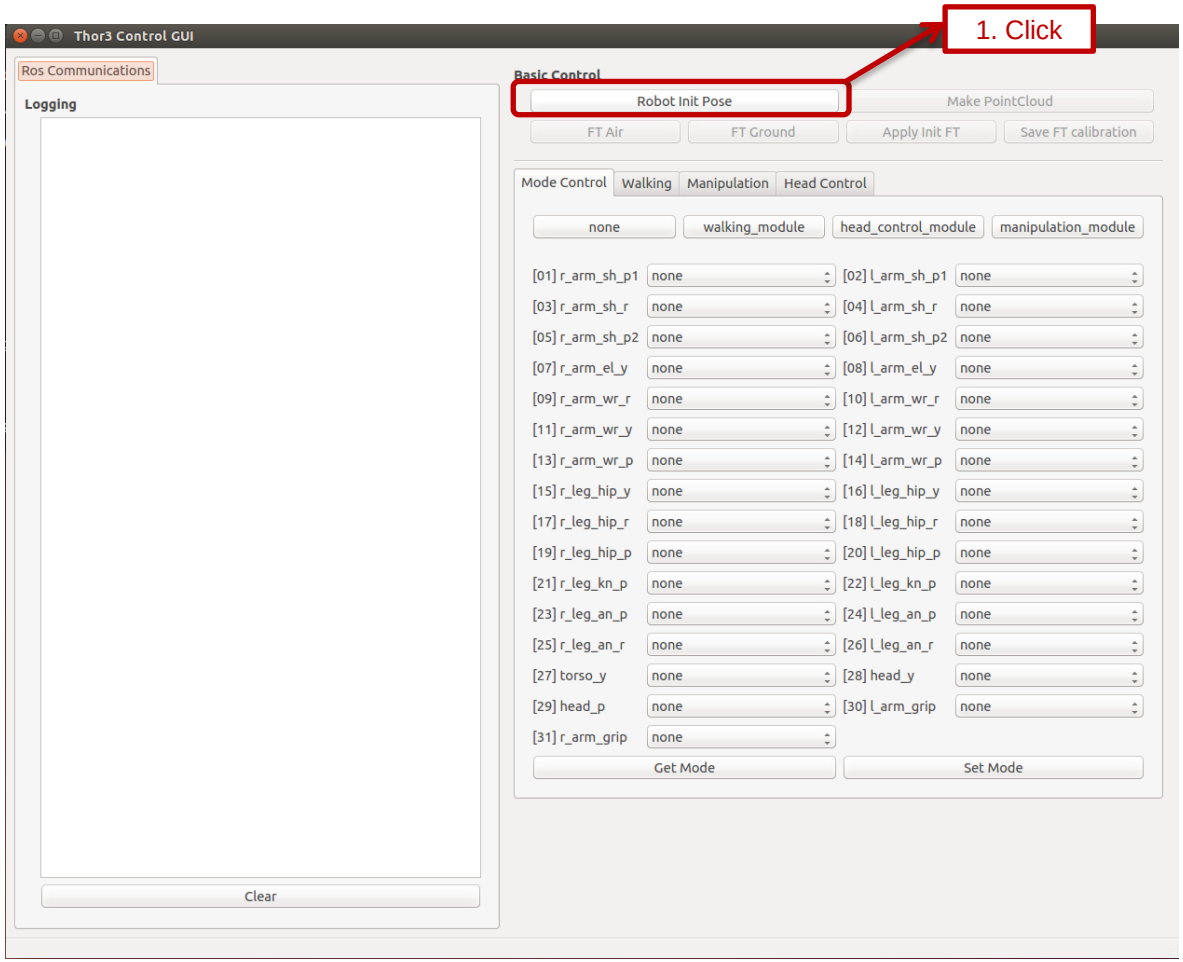
3) Example

- Overview



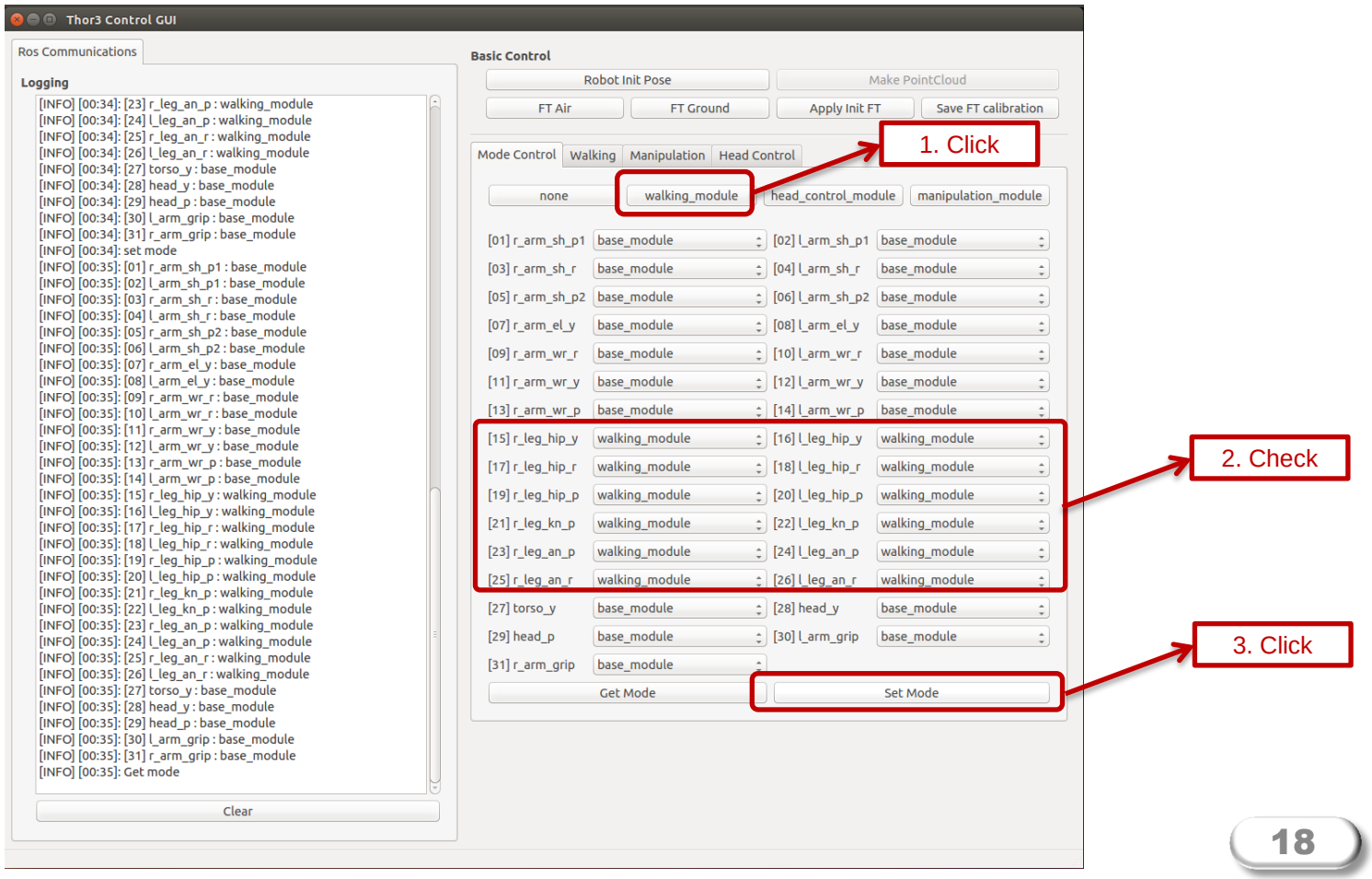
3) Example

- Initial Pose
  - Before using walking control, the robot should be moved to initial pose



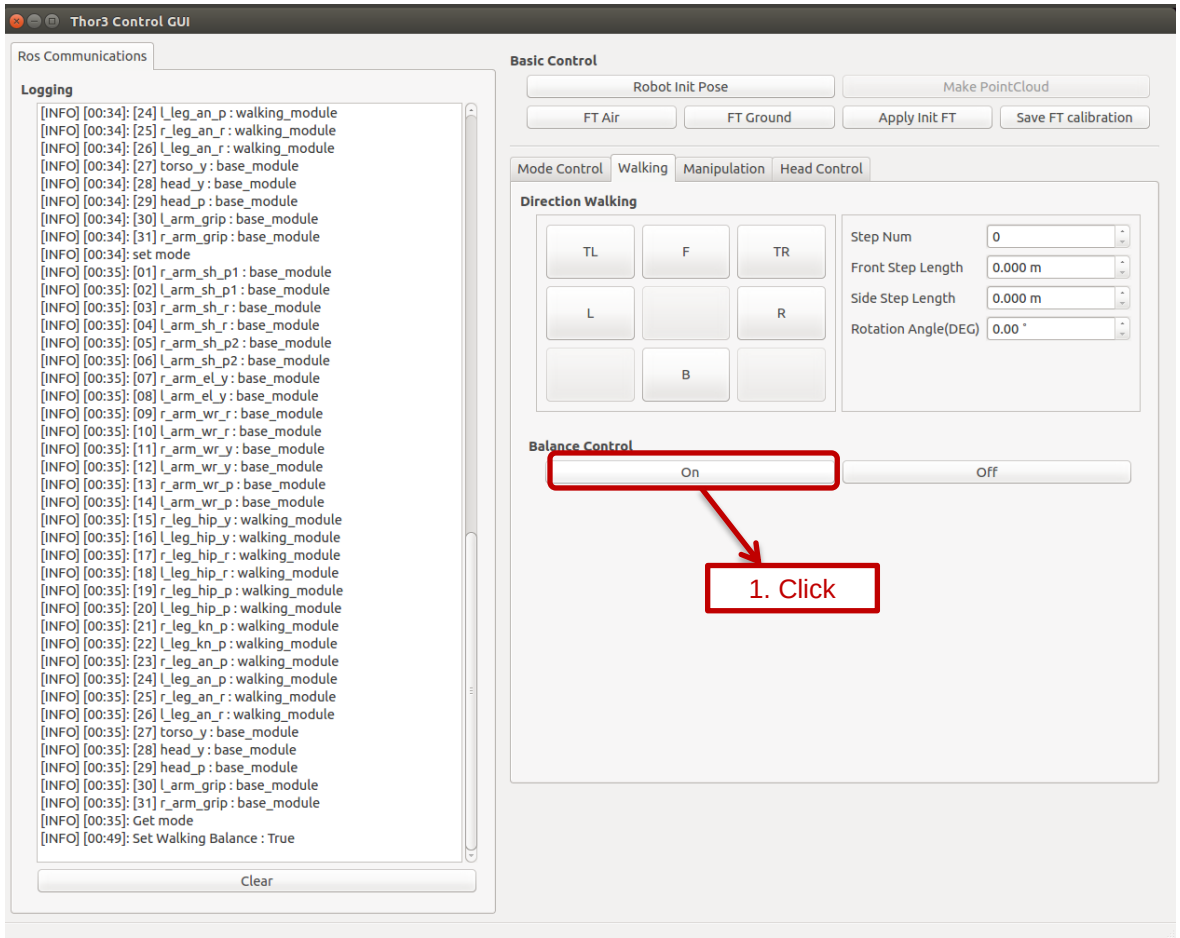
3) Example

- Set Mode
  - After move to initial pose, the motion mode of leg joints is changed to “walking control mode”.

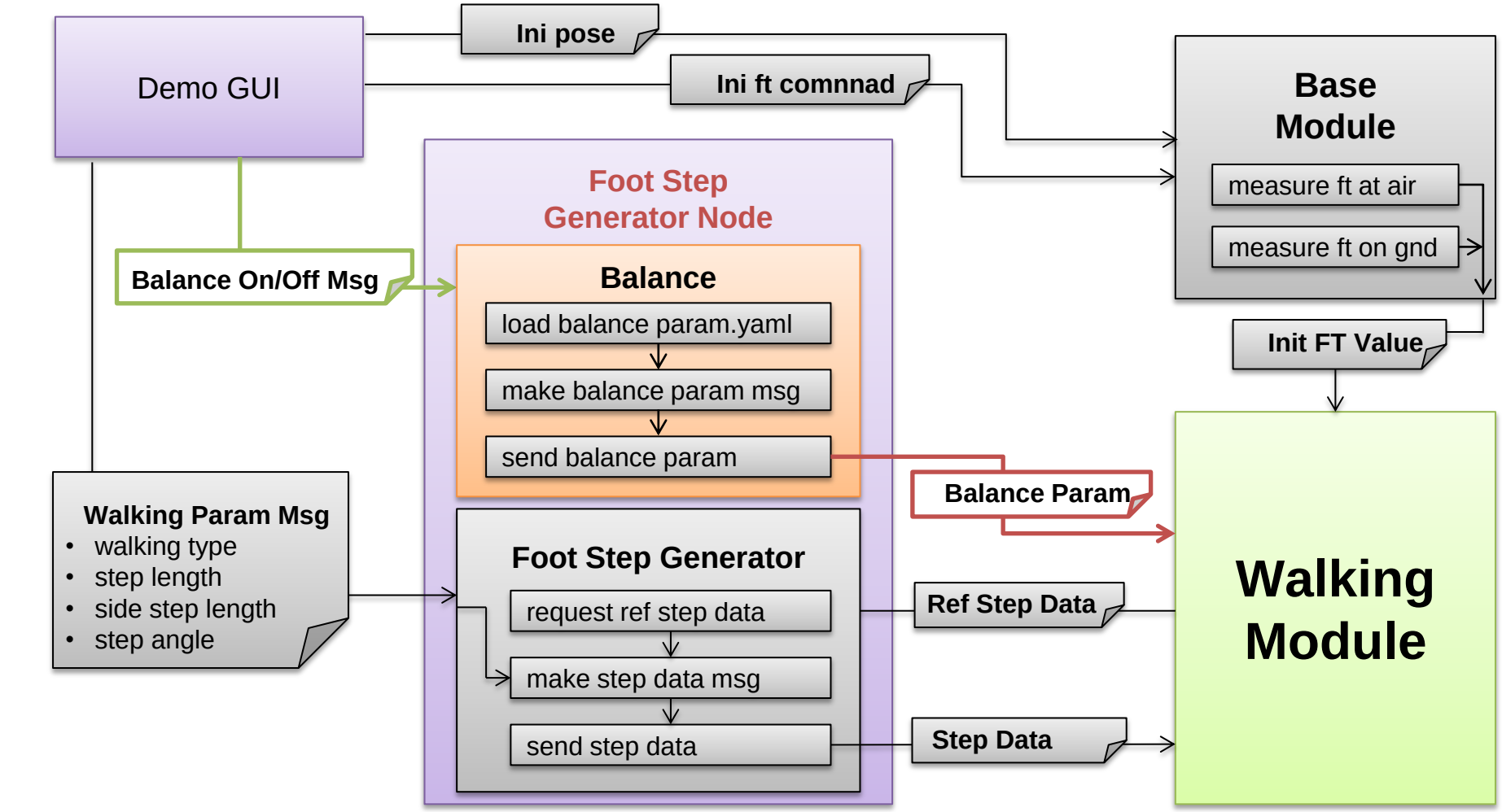


3) Example

- Balance On/Off



Walking Module



3) Example

- Balance On/Off

/robotis/walking/set_balance_param			
	Variable Type	Variable Name	Description
Request	`BalanceParam`	`balance_param`	All of parameter for balancing algorithm
Result	`int32`	`result`	The processing result of "balance_param" 0x00 : There is no error. 0x02 : The walking module is not enable. 0x20 : Previous request is not finished 0x40 : The time constant is zero or negative.

3) Example

- Balance On/Off – Balance Parameter for Floor Condition

in KINDRED : Carpet

```
####### cob_offset #######
cob_x_offset_m : -0.01
cob_y_offset_m :  0.0

####### FeedForward #####
hip_roll_swap_angle_rad : 0.008 # 0.0174532925 rad =  1 deg

########## Gain ########
#by gyro
gyro_gain : 0.8

#by imu
foot_roll_angle_gain  : -1.0
foot_pitch_angle_gain : -1.0

#by ft sensor
foot_x_force_gain      :  0.1
foot_y_force_gain      :  0.1
foot_z_force_gain      : -0.02
foot_roll_torque_gain  :  0.002
foot_pitch_torque_gain :  0.0015

########## TIME CONSTANT ##########
#by imu
foot_roll_angle_time_constant  : 0.1
foot_pitch_angle_time_constant : 0.1

#by ft
foot_x_force_time_constant      : 0.2
foot_y_force_time_constant      : 0.2
foot_z_force_time_constant      : 0.2
foot_roll_torque_time_constant  : 0.2
foot_pitch_torque_time_constant : 0.2
```

in ROBOTIS :Hard Floor

```
####### cob_offset #######
cob_x_offset_m : -0.01
cob_y_offset_m :  0.0

####### FeedForward #####
hip_roll_swap_angle_rad : 0.008

########## Gain ########
#by gyro
gyro_gain : 0.5

#by imu
foot_roll_angle_gain  : -1.0
foot_pitch_angle_gain : -1.0

#by ft sensor
foot_x_force_gain      :  0.1
foot_y_force_gain      :  0.1
foot_z_force_gain      : -0.02
foot_roll_torque_gain  :  0.002
foot_pitch_torque_gain :  0.0015

########## TIME CONSTANT ##########
#by imu
foot_roll_angle_time_constant  : 0.2
foot_pitch_angle_time_constant : 0.2

#by ft
foot_x_force_time_constant      : 0.2
foot_y_force_time_constant      : 0.2
foot_z_force_time_constant      : 0.2
foot_roll_torque_time_constant  : 0.2
foot_pitch_torque_time_constant : 0.2
```

Walking Module

3) Example

- Balance On/Off – Balance Parameter for Floor Condition

in KINDRED : carpet

```
####### cob_offset #######
cob_x_offset_m : -0.01
cob_y_offset_m :  0.0

####### FeedForward #####
hip_roll_swap_angle_rad : 0.008 # 0.0174532925 rad =  1 deg

########## Gain ########
#by gyro
gyro_gain : 0.8

#by imu
foot_roll_angle_gain  : -1.0
foot_pitch_angle_gain : -1.0

#by ft sensor
foot_x_force_gain       :  0.1
foot_y_force_gain       :  0.1
foot_z_force_gain       : -0.02
foot_roll_torque_gain   :  0.002
foot_pitch_torque_gain  :  0.0015

########## TIME CONSTANT ##########
#by imu
foot_roll_angle_time_constant  : 0.1
foot_pitch_angle_time_constant : 0.1

#by ft
foot_x_force_time_constant       : 0.2
foot_y_force_time_constant       : 0.2
foot_z_force_time_constant       : 0.2
foot_roll_torque_time_constant   : 0.2
foot_pitch_torque_time_constant  : 0.2
```

in ROBOTIS :Hard Floor

```
####### cob_offset #######
cob_x_offset_m : -0.01
cob_y_offset_m :  0.0

####### FeedForward #####
hip_roll_swap_angle_rad : 0.008

########## Gain ########
#by gyro
gyro_gain : 0.5

#by imu
foot_roll_angle_gain  : -1.0
foot_pitch_angle_gain : -1.0

#by ft sensor
foot_x_force_gain       :  0.1
foot_y_force_gain       :  0.1
foot_z_force_gain       : -0.02
foot_roll_torque_gain   :  0.002
foot_pitch_torque_gain  :  0.0015

########## TIME CONSTANT ##########
#by imu
foot_roll_angle_time_constant  : 0.2
foot_pitch_angle_time_constant : 0.2

#by ft
foot_x_force_time_constant       : 0.2
foot_y_force_time_constant       : 0.2
foot_z_force_time_constant       : 0.2
foot_roll_torque_time_constant   : 0.2
foot_pitch_torque_time_constant  : 0.2
```

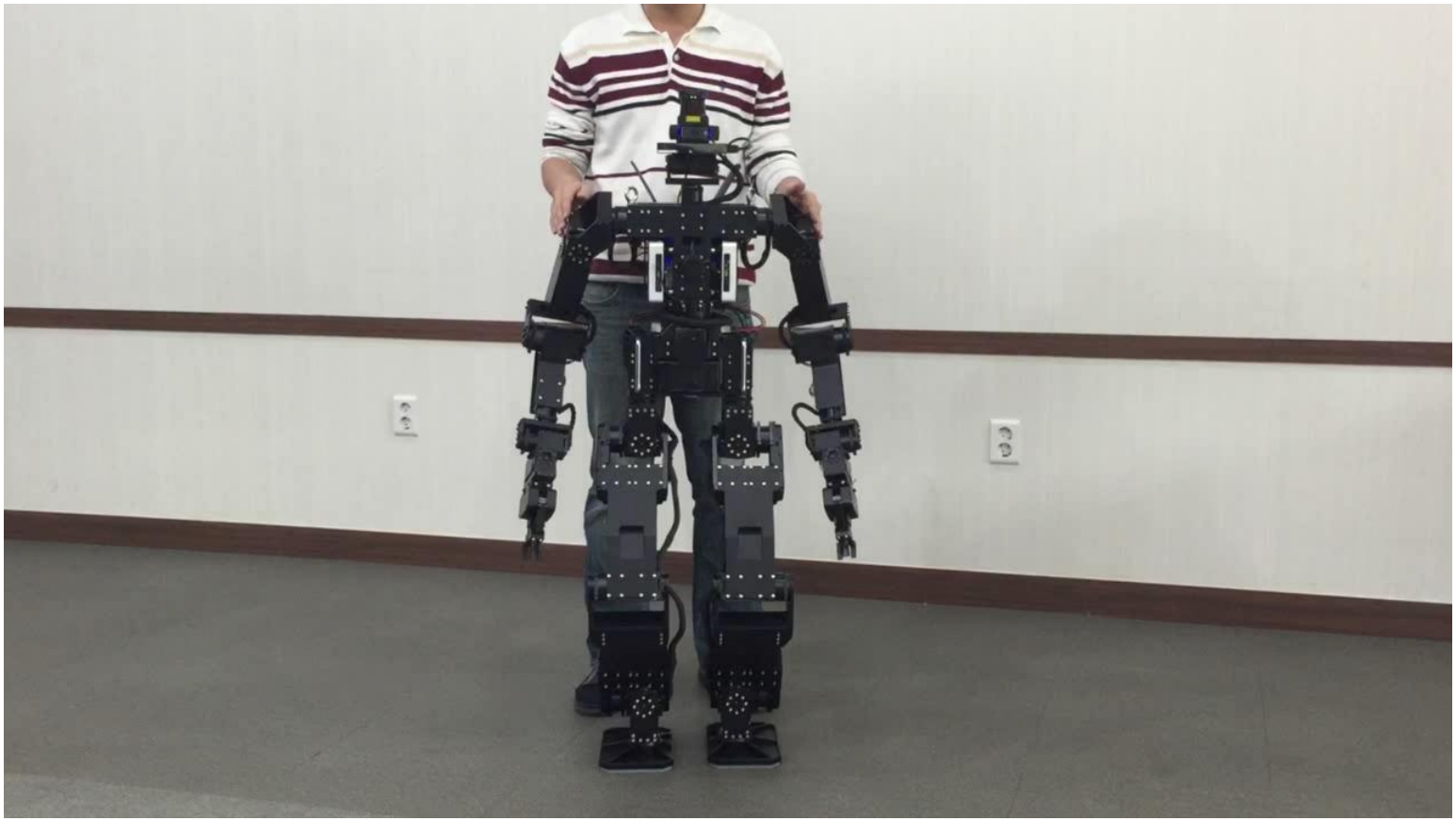
3) Example

- Balance On/Off – Balance Parameter

```
####### cob_offset #######
cob_x_offset_m : -0.01
cob_y_offset_m :  0.0

####### FeedForward #####
hip_roll_swap_angle_rad : 0.008 # 0.0174532925 rad =  1 deg

########## Gain ########
#by gyro
gyro_gain : 0.8

#by imu
foot_roll_angle_gain  : -1.0
foot_pitch_angle_gain : -1.0

#by ft sensor
foot_x_force_gain      :  0.1
foot_y_force_gain      :  0.1
foot_z_force_gain      : -0.02
foot_roll_torque_gain  :  0.002
foot_pitch_torque_gain :  0.0015

########## TIME CONSTANT ##########
#by imu
foot_roll_angle_time_constant  : 0.1
foot_pitch_angle_time_constant : 0.1

#by ft
foot_x_force_time_constant      : 0.2
foot_y_force_time_constant      : 0.2
foot_z_force_time_constant      : 0.2
foot_roll_torque_time_constant  : 0.2
foot_pitch_torque_time_constant : 0.2
```

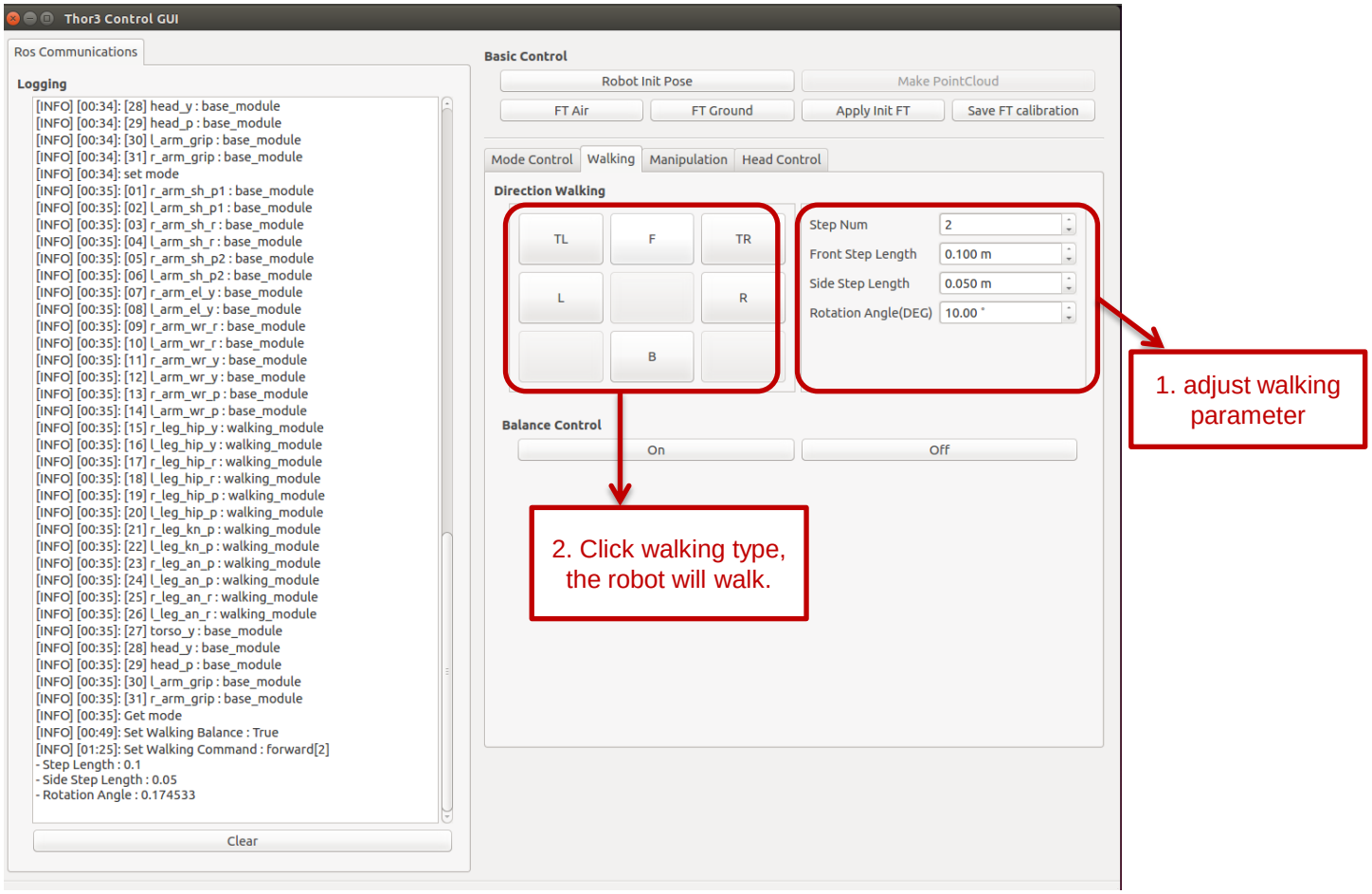
If user wants to turn off the balance algorithm,
these gains should be zero.

3) Example

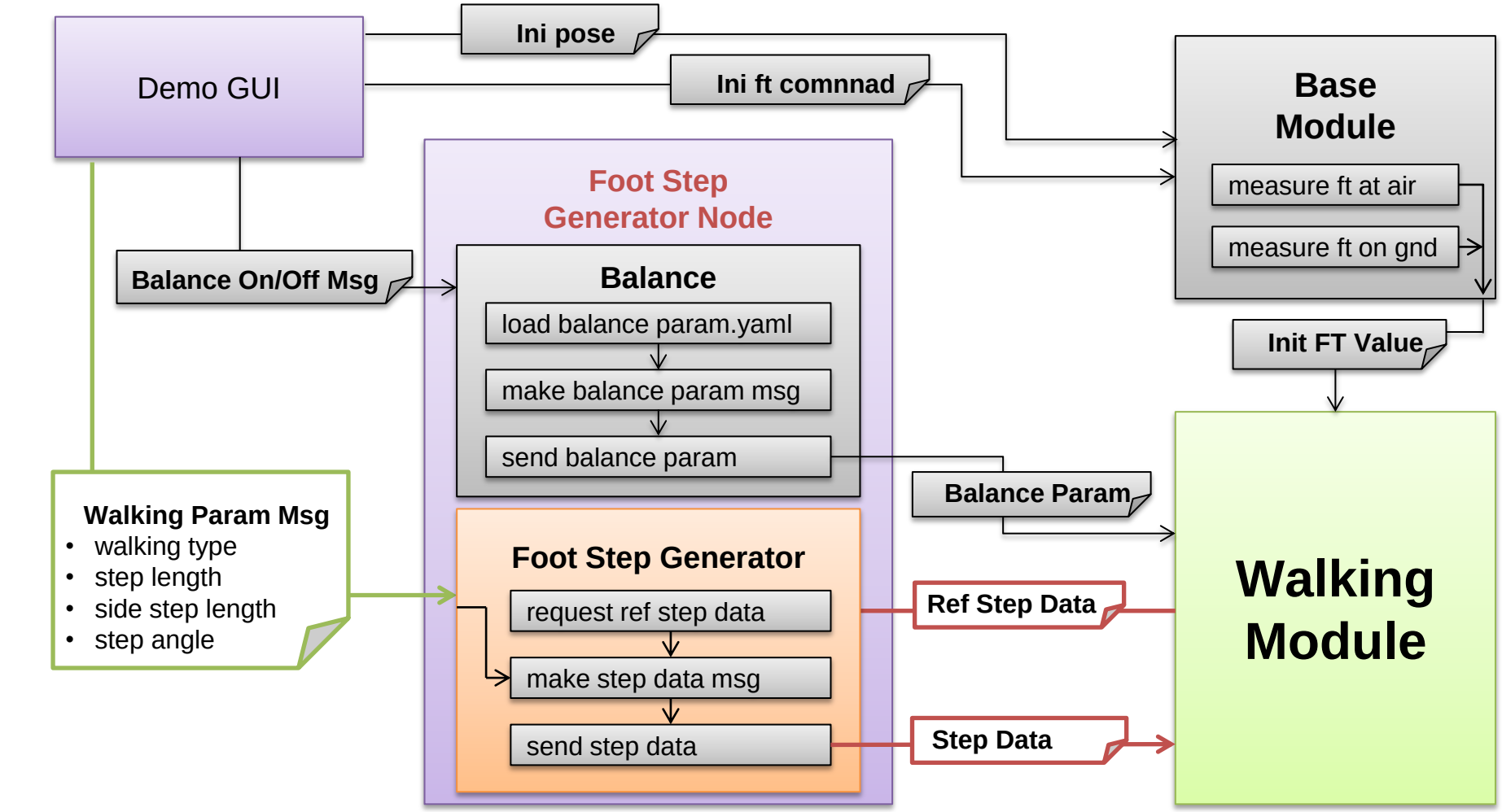


3) Example

- Add step data to walking module



Walking Module



3) Example

- Add step data to walking module

/robotis/walking/add_step_data			
	Variable Type	Variable Name	Description
Request	bool	auto_start	If "auto_start" is true, the robot will start walking automatically.
	bool	remove_existing_step_data	if "remove_existing_step_data" is true, all of the previous added step data are removed.
	StepData[]	step_data_array	step data array of user specified
Result	int32	result	The processing result of "add_step_data" 0x00 : There is no error. 0x02 : The walking module is not enable. 0x04 : There is some problem in step time data. 0x08 : There is some problem in step position data. 0x400 : The robot is walking now.

3) Example

- Add step data to walking module - StepData

```
#### Step Position Data
## MovingFootFlag
# LFootMove = 1;
# RFootMove = 2;
# NFootMove = 3;
int16       moving_foot

### Unit [meter, rad]
float32     foot_z_swap
float32     body_z_swap
float32     torso_yaw_angle_rad
PoseXYZRPY  left_foot_pose
PoseXYZRPY  right_foot_pose
PoseZRPY    body_pose
```

```
#### StepTimeData
## WalkingStateFlag
# InWalkingStarting = 0;
# InWalking         = 1;
# InWalkingEnding   = 2;
int16   walking_state

## Unit [sec]
float32 abs_step_time

# dsp_ratio >= 0.0 && dsp_ratio < 1.0
# recommand value is 0.2
float32 dsp_ratio
```

3) Example