UTRA Robosoccer

Robot Modeling for WeBots

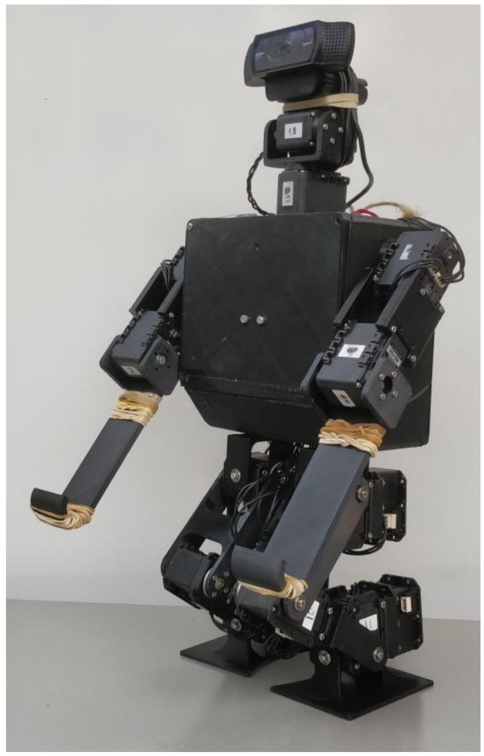
For HLVS 2022 Qualification

List of Changes/Revisions:

Date	Revision	Editor(s)	Changes
2021-04-23	0.1	Shahryar Rajabzadeh	First Draft - IMU Section
2021-04-23	0.2	Jonathan Spraggett	Added Actuator Section
2021-05-09	0.3	Shahryar Rajabzadeh	Changed the LUT unit for Gyro from deg/s to rad/s
2022-12-02	0.4	Jonathan Spraggett	Added a specs page, actuator table and camera section
2023-1-12	0.5	Jonathan Spraggett	Added Bez 2

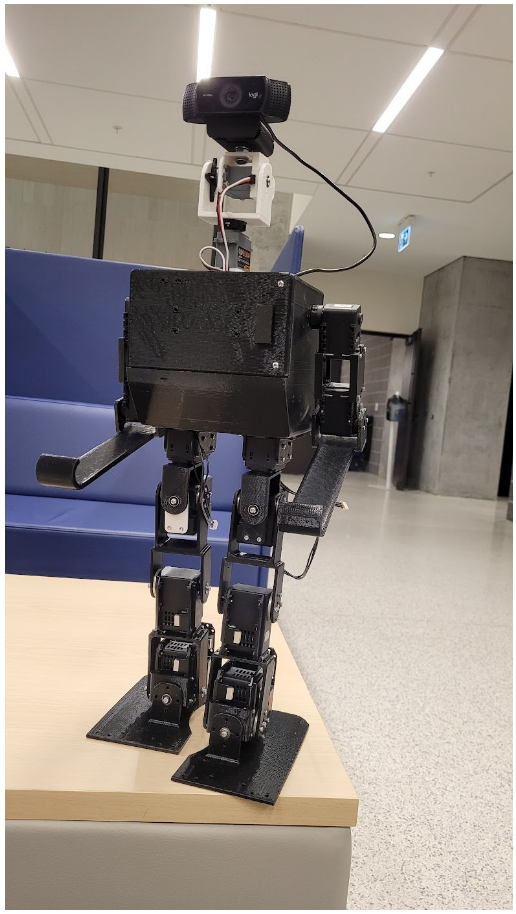
Proto Specification

BezRobocup



Name	Bez
Height	50cm
Weight	2.3kg
Walking Speed	12cm/s
Degrees of freedom and actuators	18 degrees of freedom total: 6 Dynamixel MX28 in each leg 2 Dynamixel MX28 in each arm 2 Dynamixel MX28 in the head
sensors	MPU6050 IMU Logitech C920 HD camera
Computing Units	Nvidia Jetson TX2 STM32F446RE

Bez2Robocup



Name	Bez 2
Height	60cm
Weight	4 kg
Walking Speed	12cm/s
Degrees of freedom and actuators	18 degrees of freedom total: 3 Dynamixel MX64 in each leg 3 Dynamixel xm430 in each leg 2 Dynamixel xc430 in each arm 2 Dynamixel xc430 in the head
sensors	MPU6050 IMU Logitech C920 HD camera
Computing Units	Nvidia Jetson TX2 STM32F446RE

Actuators

BezRobocup

We are planning to use MX28 motors from Dynamixel set at 14.8V with characteristics and positional sensor resolution found in the MX28 datasheet. We used the exact values from the sample actuators listed in robot modeling specification document v1.01 from RoboCup Humanoid League Organizing Committee.

Motor Type	Parameter	Variable Name	Value
MX28	Max Torque	mx28_max_torque	3.1
MX28	Max Velocity	mx28_max_velocity	7.02
MX28	Damping Constant	mx28_damping_constant	0.3086
MX28	Static Friction	mx28_static_friction	1.03
MX28	Backlash	mx28_backlash	0.01
MX28	Resolution	mx28_resolution	0.00153

Bez2Robocup

We are planning to use MX64, xm430, xc430 motors from Dynamixel set at 12.0V with characteristics and positional sensor resolution found in the MX64, xm430, xc430 datasheet. We used the exact values from the sample actuators listed in robot modeling specification document v1.01 from RoboCup Humanoid League Organizing Committee.

Motor Type	Parameter	Variable Name	Value
MX64	Max Torque	mx64_max_torque	6.0
MX64	Max Velocity	mx64_max_velocity	6.6
MX64	Damping Constant	mx64_damping_constant	0.66
MX64	Static Friction	mx64_static_friction	1.42
MX64	Backlash	mx64_backlash	0.01
XM430-W350	Resolution	mx64_resolution	0.00153
XM430-W350	Max Torque	xm430_max_torque	4.1
XM430-W350	Max Velocity	xm430_max_velocity	4.82
XM430-W350	Damping Constant	xm430_damping_constant	0.721165
XM430-W350	Static Friction	xm430_static_friction	0.777
XM430-W350	Backlash	xm430_backlash	0.01
XM430-W350	Resolution	xm430_resolution	0.00153
XC430-W240	Max Torque	xc430_max_torque	1.9
XC430-W240	Max Velocity	xc430_max_velocity	7.33
XC430-W240	Damping Constant	xc430_damping_constant	0.159155
XC430-W240	Static Friction	xc430_static_friction	0.80667
XC430-W240	Backlash	xc430_backlash	0.01
XC430-W240	Resolution	xc430_resolution	0.00153

IMU Sensor

We are planning to use the LSM6DSOX IMU from STMicroelectonics. The sensor is set to be operated in high-performance mode and sampled at 104Hz.

Noise Modeling

We considered the noise inherent to the IMU and modeled the drift-due-to-temperature effect as a random variable obeying normal distribution. We also assumed that the sensor is calibrated to offset the zero-level bias by taking measurements of the sensor at still condition and we did not include its effect within our webots modeling.

Accelerometer

Sensor Range and Raw Output

The sensor is set to measure from -2g to 2g linear accelerations in each axis. The raw output of the sensor is 16 bits represented in 2's complement, the same scheme used to store signed integers in the C/C++ language variables. (Refer to pages 10, 72-73 of the IMU datasheet)

Noise Components

Inherent Noise

The accelerometer's noise density (An) is 70 (micro-g / √Hz) for the sensor reading range we defined earlier. A sample rate of 104Hz is considered as it is the closest sample rate to our control-loop frequency. If sampled at 104 Hz, we will have ±700 (micro-g) noise. (Refer to page 10 of the IMU datasheet)

Temperature Noise

The IMU datasheet reports the LA_OffDr, the coefficient for the temperature drift as ±0.1 (mili-g / C). Considering a temperature difference of 40 degrees (assuming operating range of 10C - 50C), we will have ±4 (mili-g) variation in the sensor readings. To overestimate the noise, the value of 4 mg is used as the std-dev of the gyro sensor readings. This value is 0.2% of the ±2 (g), the boundaries of the sensor readings.

Combined Noise

Without knowing about the internals of the sensor, we assumed the two components of noise are independent from one another. Therefore the combined noise standard deviation would be 4.06. This value is 0.203% wrt to the sensor reading boundaries.

Gyro

Sensor Range and Raw Output

The sensor is set to measure from -500 (deg / s) to 500 (deg / s) angular velocities in each axis. The raw output of the sensor is 16 bits represented in 2's complement, the same scheme used to store signed integers in the C/C++ language variables. (Refer to pages 10, 70-71 of the IMU datasheet)

Noise Components

Inherent Noise

The gyro's noise density (Rn) is rated at 3.8 ((mili-deg / s) / √Hz). A sample rate of 104Hz is considered as it is the closest sample rate to our control-loop frequency. If sampled at 104 Hz, we will have 0.039 (deg / s) noise. (Refer to page 10 of the IMU datasheet)

Temperature Noise

The IMU datasheet reports the G_OffDr, the coefficient for the temperature drift as ±0.01 ((deg / s) / C). Considering a temperature difference of 40 degrees (assuming operating range of 10C - 50C), we will have ±0.4 (deg / s) variation in the sensor readings. To overestimate the noise, the value of 0.4 deg/s is used as the std-dev of the gyro sensor readings. This value is 0.8% of the ±500 (deg / s), the boundaries of the sensor readings.

Combined Noise

Without knowing about the internals of the sensor, we assumed the two components of noise are independent from one another. Therefore the combined noise standard deviation would be 0.402. This value is 0.804% wrt to the sensor reading boundaries.

LUTs for Webots

Using g = 9.81(m/s^2), the following are the look-up tables (LUTs) for the gyro and accelerometer:

[
-19.62 -32768 0.00203
19.62 32767 0.00203
]

And for the Gyro:
500 deg/s is converted to 8.7266 rad/s(Refer to Gyro for Webots)
[
-8.7266 -32768 0.00698
8.7266 32767 0.00698
]

Refer to the LUT API for Webots to understand the placement of each number. Note that the resolution field for both Gyro and Accelerometer should be set to 1 to reflect the digitized nature of these sensors. (Refer to Accelerometer and Gyro API for Webots)

Camera

We are planning to use the Logitech C920 HD camera. The field of view has been set to 1.39626 rad. The width and height have been set to 640 and 480 respectively. The noise is set to 0.007000. Near has been set to 0.2 and far as 10. (Refer to Logitech C920 HD camera Datasheet)

References

MX28 & MX64 specs for WeBots:
https://cdn.robocup.org/hl/wp/2021/04/v-hsc_model_specification_v1.01.pdf

XM430-W350 specs for WeBots: https://emanual.robotis.com/docs/en/dxl/x/xm430-w350/

XC430-W240 specs for WeBots: https://emanual.robotis.com/docs/en/dxl/x/xc430-w240/

IMU Sensor's datasheet from: https://www.st.com/en/mems-and-sensors/lsm6dsox.html

Accelerometer API for Webots: https://cyberbotics.com/doc/reference/accelerometer

Gyro API for Webots: https://cyberbotics.com/doc/reference/gyro

LUT API Guide for Webots: https://cyberbotics.com/doc/reference/distancesensor#lookup-table

Logitech C920 HD camera Datasheet:
https://www.logitech.com/content/dam/logitech/en_gb/video-collaboration/pdf/c920e-datasheet.pdf