NUGUS PROTO SPECIFICATION

GENERAL SPECIFICATIONS	
Height (cm)	90
Weight (kg)	7.5
Walking Speed (cm/s)	20

THE UNIVERSITY OF NEWCASTLE (AUSTRALIA)

DEGREES OF FREEDOM	
Legs (each)	6
Arms (each)	3
Neck	2
Total	**20**

NUgus Robot.

MOTORS AND SENSORS	
Dynamixel MX-106R Servo	x12
Dynamixel MX-64AR Servo	x6
FLIR BlackFly S BFS-U3-13Y3C-C	x2
3-axis Gyroscope	x1
3-axis Accelerometer	x1

1 Accelerometer & Gyroscope PROTO Implementation

The Webots program, provides users with a range of sensor nodes that can be modified to the needs of the user. Two of these sensors, the accelerometer and gyroscope, are used within the NUbots 'NUGUS' PROTO model. Both these simulated devices have been modeled to represent the 'lis331dlh' and 'L3G4200D' devices respectively, to a satisfactory level of accuracy [1][2].

1.0.1 Sensor Parameter Values

There are various modifiable parameters for both devices that have been adjusted accordingly by the team. The following listed values are those currently implemented:

1. Accelerometer Parameters
   - X-axis: TRUE
   - Y-axis: TRUE
   - Z-axis: TRUE
   - Resolution: 0.01916
   - LUT: Defined in 1.3
2. Gyroscope Parameters
   - X-axis: TRUE
   - Y-axis: TRUE
   - Z-axis: TRUE
   - Resolution: 0.0042621
   - LUT: Defined in 1.3

1.1 Process & Justification

The following sections will discuss the process, reasons and assumptions the team made thought development.

1.1.1 Gyroscope & Accelerometer Axis states

As within the physical robot, the NUgus uses 3-axis gyroscope and accelerometer sensors. Hence all three axis have been declared TRUE.

1.1.2 Gyroscope & Accelerometer Resolution Parameter

In-order to closely represent the physical device, the 'Resolution' value has been chosen according to the 12 bit return value of the sensors.

Accelerometer $: resolution = \frac{78.48}{4095} \approx 0.01916$

Gyroscope $: resolution = \frac{17.4533}{4095} \approx 0.0042621$

1.1.3 Look Up Table for Accelerometer

As defined within the Webots documentation, A lookup table (LUT) indicates how the values measured by Webots must be mapped to Return values returned by the sensor. The noise on the return value is computed according to a Gaussian random number distribution whose range is calculated as a percent of the Return Value (RV).

Return Value Range The team has decided that a sensing range of +/-4g will be satisfactory. The RV selected is a 1-1 mapping between input to RV in $[m/s^2]$, with a DC offset of 100. The offset is added due to the numerical limitation on LUT's (https://cyberbotics.com/doc/reference/distancesensor), such that the output range will be from 60.76 to 139.24 $[m/s^2]$. In addition to this, a range of 60.76 to 139.24 allows for more sensible noise values around measurements of 0 $[m/s^2]$.

Noise Values From the datasheet, the stddev of the noise is 218 $[\frac{\mu g}{\sqrt{Hz}}]$, and assuming a sampling rate of 400Hz is approximately 0.04276 $[m/s^2]$. By calculating the max and minimum RV noise percantage values, a constant standard deviation is achieved, since WeBots linearly interpolates the sttdev over the range.

$$Noise\ Min = \frac{0.04276}{-39.24 + 100} \approx 0.000704 \tag{1}$$

$$Noise\ Max = \frac{0.04276}{+39.24 + 100} \approx 0.000307 \tag{2}$$

1.1.4 Look Up Table for Gyroscope

Return Value Range The team has decided that a sensing range of +/-500 dps will be satisfactory. The RV selected is a 1-1 mapping between input to RV in $[rad/s]$, with a DC offset of 100. The offset is added due to the numerical limitation on LUT's (https://cyberbotics.com/doc/reference/distancesensor), such that the output range will be from 91.238 to 108.762 $[rad/s]$. In addition to this, a range of 60.76 to 139.24 allows for more sensible noise values around measurements of 0 $[rad/s]$.

Noise Values From the datasheet, the stddev of the noise is 0.03 $[\frac{DPS}{\sqrt{Hz}}]$, and assuming a sampling rate of 400Hz is approximately 0.0105 $[rad/s]$. By calculating the max and minimum RV noise percantage values, a constant standard deviation is achieved, since WeBots linearly interpolates the sttdev over the range.

$$Noise\ Min = \frac{0.0105}{-8.762 + 100} \approx 0.0001151 \tag{3}$$

$$Noise\ Max = \frac{0.0105}{8.762 + 100} \approx 0.000096541 \tag{4}$$

1.2 Modeling Assumptions

Various assumptions were made throughout the modelling process.

1. Assumed that both devices will sample at a frequency of 400Hz
2. Assumed that average noise is equal for all return values

1.3 LUT's

Table 1: Accelerometer LUT

Measured Value $[m/s^2]$	**Return Value** $[m/s^2]$	**Noise (%)**
-39.24	60.76	0.000704
39.24	139.24	0.000307

Table 2: Gyroscope LUT

Measured Value $[rad/s]$	**Return Value** $[rad/s]$	**Noise (%)**
-8.72665	91.238	0.0001151
8.72665	108.72	0.000096541

2 Motor Implementation

The arms and head of the NUgus robot use Dynamixel MX64AR servos, with two in each shoulder, one in each elbow, and two in the neck. The legs use Dynamixel MX106 servos, with two in each ankle, three in each hip, and one in each knee.

2.0.1 Actuators

All the active joints were implemented using the HingeJointWithBacklash. The backlash parameter provided in the Dynamixel datasheet is 0.33° which is approximately 0.0058 [rad]. However, due to the limitations on modelling small values of backlash the minimum value of 0.01 [rad] was chosen.

2.0.2 Actuator & Joint Parameters

Parameters for the Dynamixel motors were provided in the model specifications document by the TC for voltages of 12v and 14.8v. The values for 14.8v were chosen as the NUgus robot operates at around 14v.

Motor Type	**Parameter**	**Variable Name**	**Value**
MX106	maxTorque	MX106-torque	10.00
MX106	maxVelocity	MX106-vel	5.76
MX106	dampingConstant	MX106-damping	1.23
MX106	staticFriction	MX106-friction	2.55
MX64	maxTorque	MX64-torque	7.30
MX64	maxVelocity	MX64-vel	8.17
MX64	dampingConstant	MX64-damping	0.65
MX64	staticFriction	MX64-friction	1.73

2.0.3 Motor Position Sensors

The Dynamixel motors use a 12 bit rotary encoder. For each motor a PositionSensor is used with a resolution of 0.0015 as specified in the model specifications document.

3 Camera Implementation

The camera was based on the FLIR BlackFly S BFS-U3-13Y3C-C camera [3] with the Lensation BF10M19828S118C lens [4]. Due to the lack of spherical lens support in Webots, we set the lens as close to the real lens while having a rectilinear projection. There are two cameras in each robot.

The **field of view** has been reduced to $\frac{\pi}{2}$ since the rectilinear lens cannot support a field of view of more than $\frac{2\pi}{3}$ and values between these had an undesirable zoom effect.

The **width** and **height** have been set to 640px and 480px respectively. This is lower than the physical camera specifications of 1280px and 1024px respectively because of bandwidth limitations.

Noise has been set to 1e-9 and motion blur to 10, as these seemed to be reasonable values for the camera due to its high frame rate.

Since we are using rectilinear projection due to the lack of true spherical projection, the **spherical** field and lens parameters and are set to their defaults.

The lens of the real camera has a fixed focus, so we leave the **focus** parameter as its default values. The focal length is set to 1.98mm, as specified in the lens datasheet.

References

[1] STMicroElectronocs: MEMS digital output motion sensor ultra low-power high performance 3-axes "nano" accelerometer,
https://www.st.com/resource/en/datasheet/cd00213470.pdf

[2] STMicroElectronics: L3G4200D: three axis digital output gyroscope,
https://www.elecrow.com/download/L3G4200_AN3393.pdf

[3] FLIR: BlackFly S BFS-U3-13Y3C-C: Camera
http://softwareservices.flir.com/BFS-U3-13Y3/latest/Model/spec.html

[4] Lensation: Lensagon BF10M19828S118C: S-Mount lens
https://www.lensation.de/pdf/BF10M19828S118C.pdf