

Knee-Less Bipedal Robot: Design & Simulation in Webots

Note: This document is prepared by Subashish Datta. *Google Gemini* has helped a lot to get the used codes and procedures.

To add a Robot node to the Webots scene tree, follow these step-by-step instructions directly inside the Webots user interface:

Step 1: Open the Scene Tree View

On the left-hand side of your Webots window, you will see a hierarchical list of text nodes (such as `WorldInfo`, `Viewpoint`, `TexturedBackground`, etc.). This vertical list is the Scene Tree.

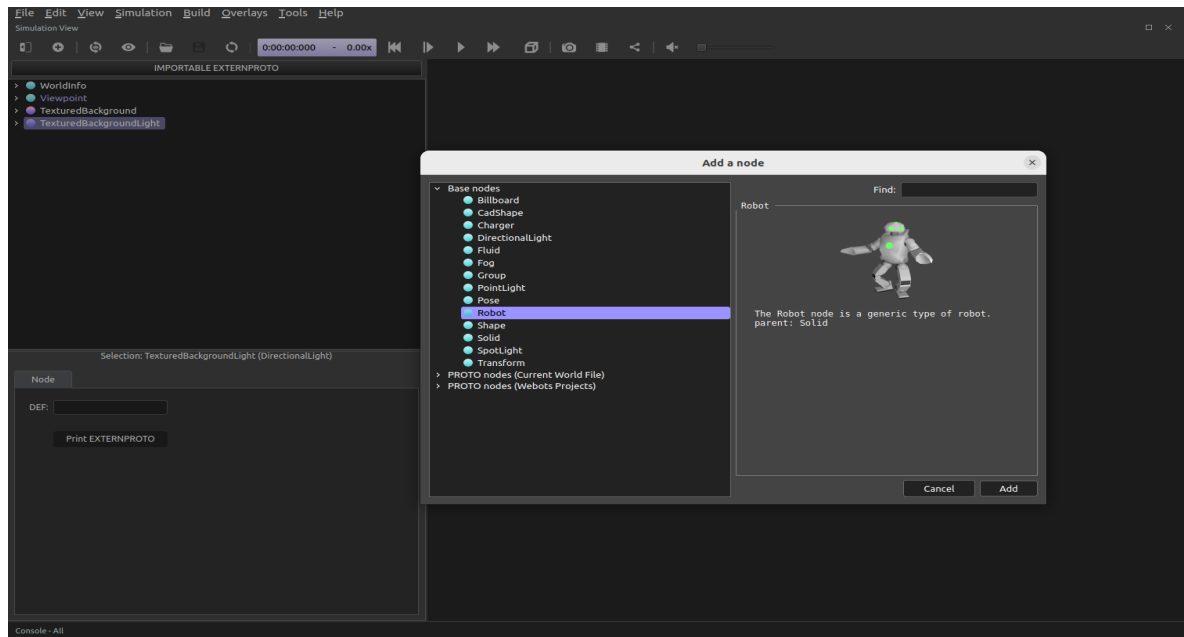
Step 2: Open the Node Selection Menu

1. Click on the very last node currently listed in the Scene Tree (for example, click on `TexturedBackground` or `Floor`).
2. Look at the toolbar directly above the Scene Tree list. Click the plus icon (`+`) (or press `Ctrl + Shift + A` on Windows/Linux, `Cmd + Shift + A` on Mac).
3. A new window titled "Add a node" will pop open in the center of your screen.

Step 3: Find and Insert the Robot Node

1. In the "Add a node" pop-up window, expand the category folder named Base nodes .
2. Scroll down alphabetically through the list until you find `Robot` .
3. Click on `Robot` to highlight it, and then click the Add button at the bottom right of the window.
4. In the Robot node, click on small right arrow, go to name, and give the name of robot as "bipedal_robot".

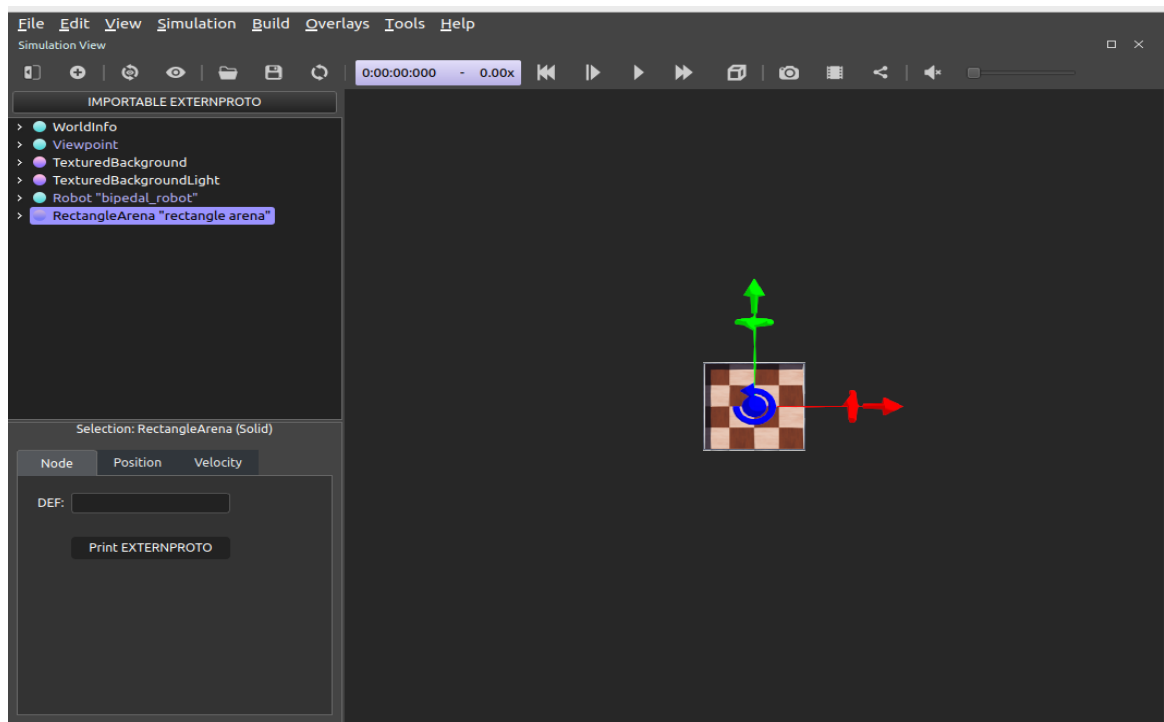
You will now see a new line labelled `Robot` "bipedal_robot" appear at the bottom of your Scene Tree on the left.



Step 4: Add the Ground / Floor (Crucial)

Before editing the robot, let's give it a surface to walk on:

1. Hold on the Robot node.
2. Click the plus icon () above the Scene Tree again.
3. Expand the PROTO nodes (Webots Projects) folder.
4. Expand objects → floors.
5. Select **Floor** or **RectangleArena** and click Add. You will see a rectangle floor in your screen.



Now that you have your Robot node and a Floor inside your Webots world, the next phase is building the physical body (the **Hip Box Chassis**) inside the Scene Tree.

We will configure the exact weights and dimensions we planned earlier (**120mm x 80mm x 80mm** with a heavy mass to simulate your Rhino motors).

Step 5: Build the Hip Box

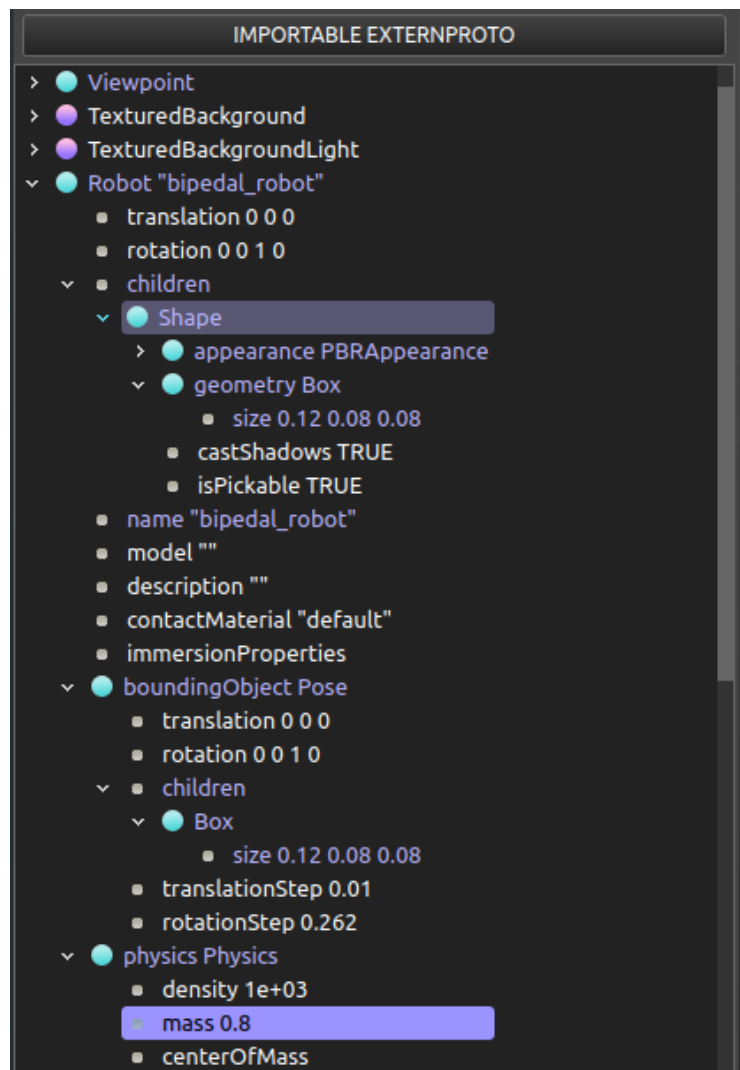
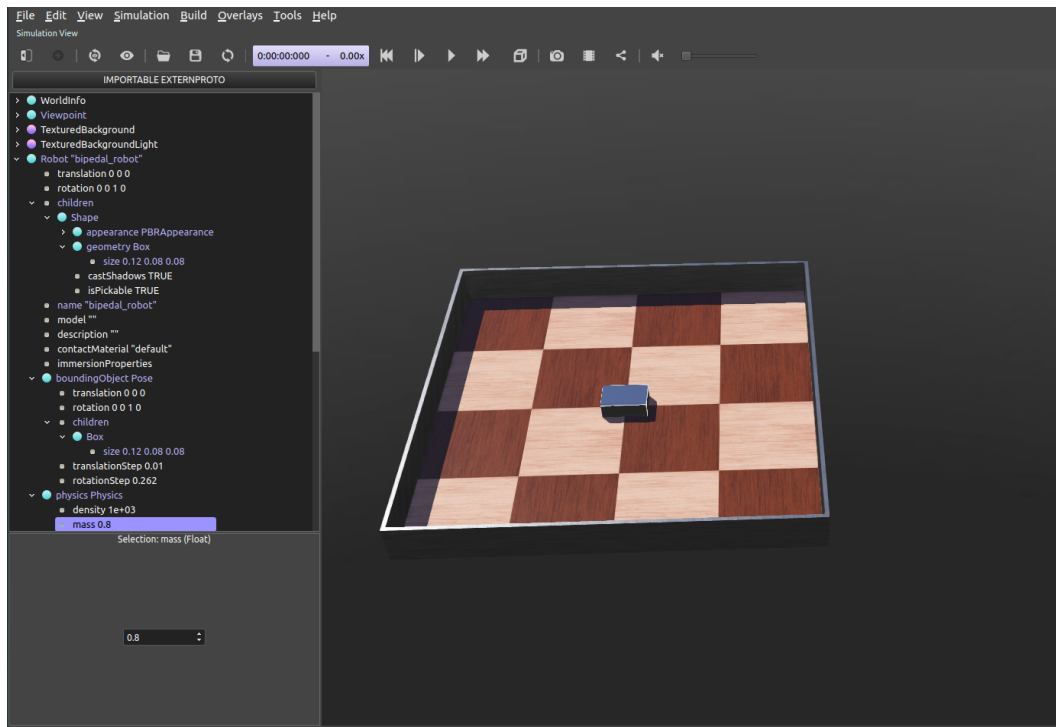
Follow these clicks carefully in your left-side Scene Tree panel to define the main body:

1. Locate your **Robot** node and click the small triangle arrow next to it to expand its internal options.
2. Click on the **children** field under the Robot node, then click the **+** (**Add a Node**) icon at the top of the panel.
3. In the pop-up window, expand **Base nodes** and choose **Shape**, then click **Add**.
4. Expand this new Shape node:
 - Click on **appearance** → click **+** → expand **Base nodes** → select **PBRAppearance** → click **Add**. (Under baseColor, you can change this to any colour you like, such as blue or grey).
 - Click on **geometry** → click **+** → expand **Base nodes** → select **Box** → click **Add**.
5. Expand the **Box** node and click on its **size** field. Change the three values to match our hip box dimensions in meters:
 - **X: 0.12** (120 mm wide)
 - **Y: 0.08** (80 mm deep)
 - **Z: 0.08** (80 mm tall)
6. You can now see a small box sitting on the floor in your screen.

Step 6: Give the Hip Box Physical Weight (Mass)

Without physics properties, Webots treats your robot like a ghost—it won't experience gravity or interact with the world.

1. Come out from Children node. Look back up at the main **Robot** node fields and locate **boundingObject**.
2. Click boundingObject → click **+** → expand **Base nodes** → select **Box** → click **Add**.
3. Give this box the exact same size as hip-box was created: **X: 0.12, Y: 0.08, Z: 0.08**. (*This tells the physics engine the shape used for collisions*).
4. Locate the **physics** field under the main Robot node.
5. Click physics → click **+** → expand **Base nodes** → select **Physics** → click **Add**.
6. Expand this new Physics node, click on **mass**, and change it to **0.80** (This simulates the heavy 800-gram payload of your two Rhino motors and Arduino Mega box).



Step 7: Raise the Robot Above the Floor

Right now, your hip box is embedded halfway into the floor because it spawned at ground zero (0, 0, 0). Let's lift it up so we have room to attach the 200mm legs later.

1. Under the main **Robot** node, click on the **translation** field.
2. Change the third value (**Z-axis** in Webots default orientation, or **Y-axis** depending on your world settings - look at the 3D axis widget at the bottom right of your screen) to raise it up.
3. Set the vertical height value to **0.3** (300 mm off the floor).

You should now see a solid rectangular block floating perfectly in the air above your floor grid.

Now that your hip box is floating in the air, we are going to add the **HingeJoints**. In Webots, a HingeJoint represents a motor shaft. We will attach two heavy-duty **Rhino RMCS-2257 motors** to the left and right sides of the chassis.

Step 8: Add the Left Hip Motor, Leg and Foot

1. In the Scene Tree, expand your **Robot** node and click on the **children** field.
2. Click the **+** (**Add a Node**) icon.
3. Expand **Base nodes**, select **HingeJoint**, and click **Add**.
4. Expand this new HingeJoint node. You will see three critical fields: jointParameters, device, and endPoint.

We configure them one by one:

A. Set the Pivot Location (jointParameters)

We need to shift this motor axis to the far **left edge** of your 120mm hip box.

1. Click on **jointParameters** → click **+** → select **HingeJointParameters** → click **Add**.
2. Expand HingeJointParameters and set:

anchor: X: -0.06 (hip_box_size/2), **Y: 0, Z: 0**

Axis: [1 0 0]

B. Name the Motor Device (device)

1. Click on **device** → click **+** → expand **Base nodes** → select **RotationalMotor** → click **Add**.
2. Expand RotationalMotor and look for the **name** field.
3. Double-click it and type exactly: **"left_hip_motor"** (see in scene that the name is in double quotes).

C. Left Leg Addition

1. You are in the **Children** Node of main node **Robot**. Inside Children, you have created a **Hinge Joint** node. Inside Hinge Joint, you will be seeing: **Joint Parameters, Device** and **endpoint**.
2. Go to now **endPoint** -> **click +** -> expand **Base nodes** -> Add a **Solid** node (this is the leg).
3. Expand this **Solid** and set DEF: LEFT_LEG.

D. Add Geometry to Left Leg Solid

1. Under **endpoint DEF LEFT_LEG Solid > children > click +** and add a **Shape** node.
2. Expand **Shape** node and
 - Click on **appearance** -> + -> expand **Base nodes** -> select **PBRAppearance** -> click **Add**
 - Click on **geometry** -> + -> expand **Base nodes** -> select **Cylinder** -> click **Add**. Go to **geometry Cylinder** and set **height: 0.15 radius 0.01**. [This is left leg shape]

You will be seeing a cylinder in the middle of the box. This needs to be positioned appropriately to serve as a left leg. You can fix it as follows:

- Goto **endpoint DEF LEFT_LEG Solid**, set **translation: [-0.06 0 -0.075]** (X= - length of box/2; Y=0; Z= - leg length/2) and **rotation: [1 0 0 0]** (angle 0). You will be now seeing the left leg is attached at the left side of Hip-Box. These parameters need to be adjusted. Usually, in Webot, the axis colours are as follows: **X: Blue, Y: Green and Z: Red**. Then depending upon the position of these shapes, one needs to adjust these axis parameters (particularly, translation component) to place the components at appropriate locations.

E. Add Geometry to Left Leg Foot

- Again go to **endpoint DEF LEFT_LEG Solid > children > click +** and add a **Solid** node. Give the name as “**LEFT FOOT**” (click on name and then change it).
- In the **Solid LEFT_FOOT** node, go to **Children**, add a **Shape** node.
- Expand **Shape** node and
 - Click on **appearance** -> + -> expand **Base nodes** -> select **PBRAppearance** -> click **Add**

- Click on **geometry** -> + -> expand **Base nodes** → select **Box** → click **Add**. Go to **geometry Box** and set **size: [0.08 0.12 0.01]**. [This is left foot shape and its dimension]

Again you may see the foot is sitting in the middle of leg. Now we need to bring this to appropriate location similar to the leg part we did.

- Under the **Solid LEFT_FOOT** node, set **translation: [0 0 -0.075]** (X=0; Y=0; Z= - leg length/2) and **rotation: [1 0 0 0]** (angle 0). You will be now seeing the foot is attached at the end of left leg.

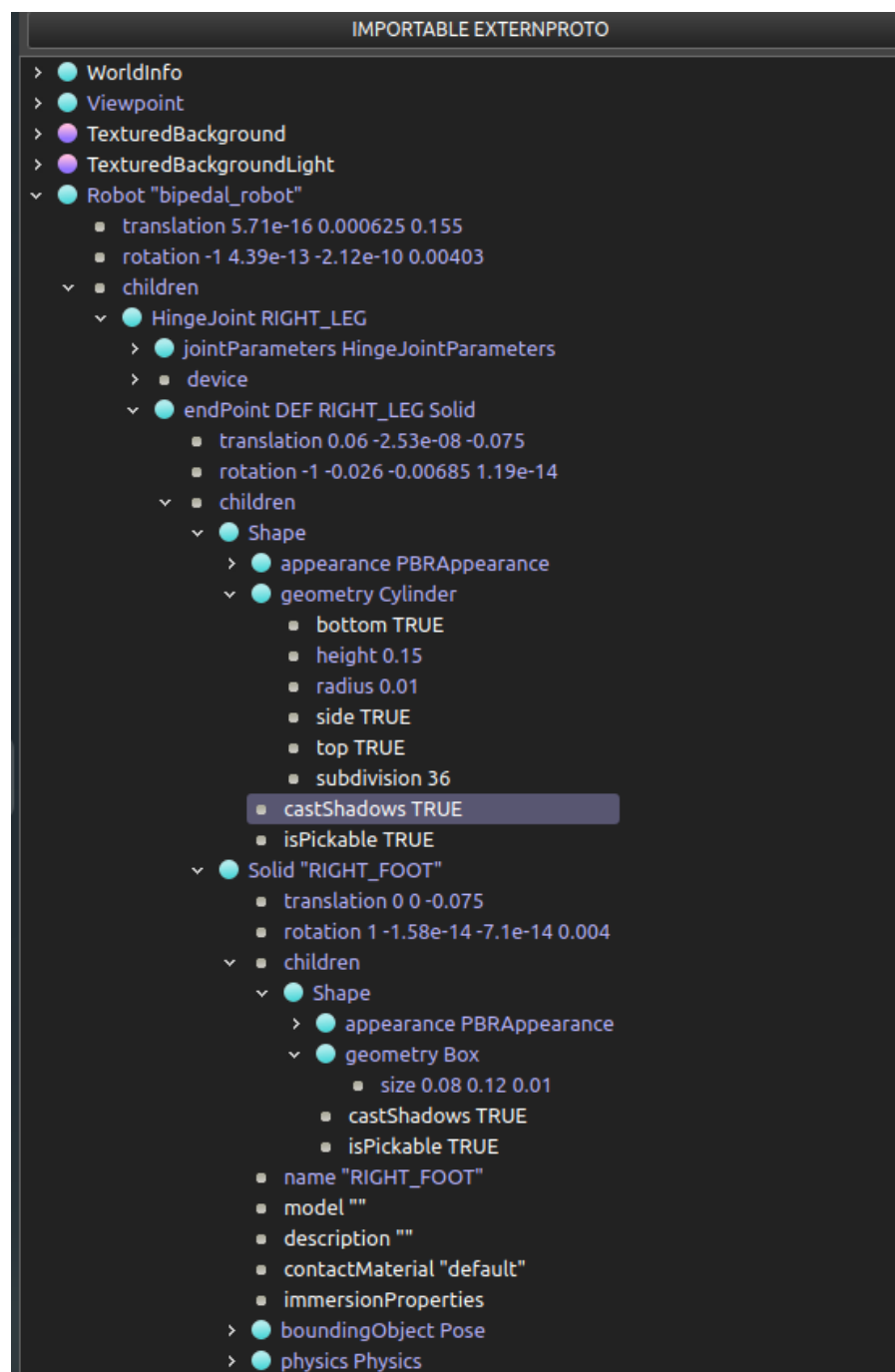
The left side scene tree will be looking now as follows (excluding the RIGHT_LEG):

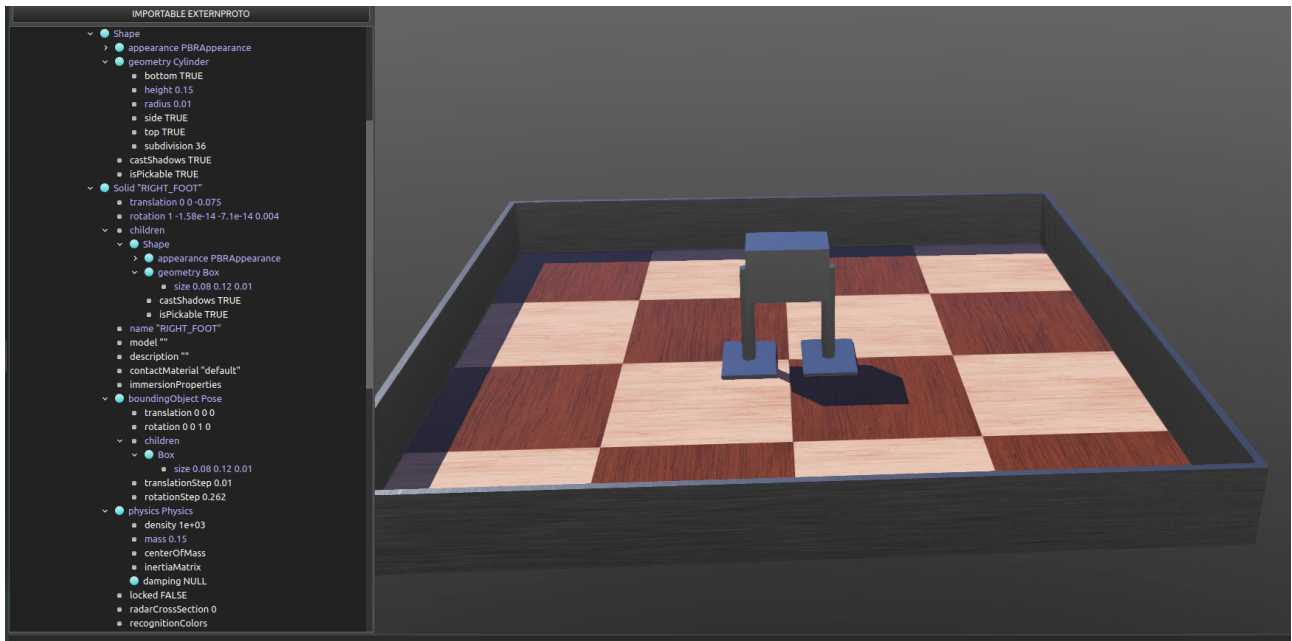


Step 9: Add the Right Hip Motor

Now we will do the exact same thing for the right leg that we did for left leg and left foot by changing the following parameter:

- In the **endpoint DEF RIGHT_LEG Solid > children > DEF_LEG_POSE**, set **translation: [0.06 0 -0.075]** (X= length of box/2; Y=0; Z= - leg length/2) and **rotation: [1 0 0 0]** (angle 0). You will be seeing the Scene tree as follows.





This is the Knee-less bipedal robot you would be seeing in your screen after adding left, right legs and feet.

- *With the above procedure, we have added a flat-foot to the robots. This may make robot difficult to walk. Hence, to improve performance, we a slightly different shape to the foot, that is, the middle is flat, but the outer side is a bit curved (not in the forward and backward motion direction).*

To achieve this type of design, following steps need to be considered:

1. Expand Solid (LEFT_FOOT).
1. Clear boundingObject so it reads NULL.
2. Select boundingObject, click + **(Add)**, choose **Group**, and click **Add**.
3. Under your new Group, select **children**, click + **(Add)**, choose **Box**, and click **Add**.
Expand Box and set size to: **[0.07 0.08. 0.01]** (X: 0.07, Y: 0.08, h Z: 0.01).

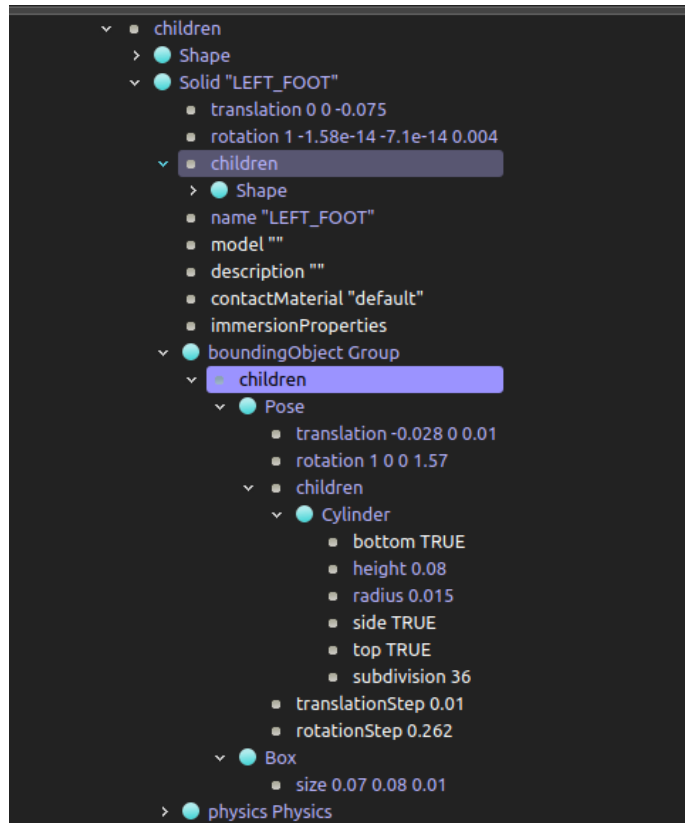
Add the Left Curved Edge (Lateral Roller)

4. Under **Group** > **children**, click + **(Add)**, choose **Pose**, and click **Add**. Goto **Children** > Add a **Cylinder** node. Set cylinder **hight: 0.08** and **radius: 0.015**.

5. Goto the Pose node, and set

- **translation:** **-0.028 0 0** (*Shifts to the left edge, some tuning may be required here*)
- **rotation:** **1 0 0 1.5708** (*Lays the cylinder flat along the Z-axis*)

6. Perform similar to the **Right foot** (make translation -ve to +ve)



Step 10: Adding Controller for Simulation

Add Position Sensors in Webots Scene Tree

Before running the script, Webots needs to know that position sensors exist on the hip joints.

1. Expand Robot > children > HingeJoint (LEFT_LEG) > device.
2. Click + (Add Node) and select **PositionSensor**.
3. Set its **name** field to **left_hip_sensor**.
4. Expand Robot > children > HingeJoint (RIGHT_LEG) > device.
5. Click + (Add Node) and select **PositionSensor**.
6. Set its **name** field to **right_hip_sensor**.

(Also verify that your RotationalMotor nodes under device are named left_hip_motor and right_hip_motor).

Create a New Controller Script in Webots

1. Go to **myproject** folder, and then **controller** folder. Create a folder with name **biped_walking**. With the same name (biped_walking) create a Text file and save in this biped_walking folder with an extension .py, that is, **biped_walking.py**. Copy and paste in this Text file the python code given to you, and then save.
2. In the Scene Tree, click on the root **Robot** node.
3. Scroll down to the **controller** field (it currently says <generic> or void).
4. Click on **controller**, press **Select**, and choose **biped_walking** folder from the list.

Run the Simulation

5. Make sure HingeJointParameters > minStop is set to **-0.8** and maxStop is set to **0.8** (so joints are no longer GUI-locked at 0).
6. Save the world (**Ctrl + S**).
7. Reload the world (**Ctrl + Shift + R**).
8. Press **Play**.