Hubo+ Operating Instructions

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1 Connecting to the Robot

Hubo is controlled by an internal "body computer" (PC1) and, optionally, a second internal "head computer" (PC2). To operate the robot, use remote desktop (or a similar program) to access the internal computers via a local router. The robots are currently configured to connect to the router metHubo with the following settings:

Robot	username	password	Wireless IP	Wired IP
Hubo+ 1 PC1	hubo	1234	192.168.0.51	192.168.0.11
Hubo+ 2 PC1	hubo2	1234	192.168.0.52	192.168.0.12
Hubo+ 3 PC1	hubo2	1234	192.168.0.53	192.168.0.13
Hubo+ 4 PC1	hubo	1234	192.168.0.54	192.168.0.14
Hubo+ 5 PC1	hubo	1234	192.168.0.55	192.168.0.15
Hubo+ 6 PC1	hubo	1234	192.168.0.56	192.168.0.16

2 Robot Setup

2.1 Power On

1. Put a battery in the robot (calibration was done with the weight of the battery present)
2. Plug in and turn on power supply
3. Turn off the E-stop (allow power)
4. Turn on Hubo via toggle switch on back. This switch is under a small PCB next to the switch labeled SENSOR.
5. Turn on body computer via toggle switch labeled PC1
6. Remote desktop into PC1 using the information in Section 1

2.2 Run Code and Get to Home Position

1. Open My Computer → C: → Rainbow → Rainbow.dsw
   - **Rainbow** and **Rainbow GUI** should be visible in the left panel. If not, make sure you are using the file view tab.
   - It is recommended to create a backup of the current version of the Rainbow folder before making significant changes.
2. Build Rainbow (the RTX side of the program)
   - Right click on **Rainbow** in the left menu and choose Build (Section Only).
   - Make sure the output has no errors.

- If the output says Debug instead of Release, select Rainbow-RTSS win32 Release from Build → Set Active Configuration, then build again.

3. Build Rainbow GUI (the Windows and GUI side of the program)
   - Right click on **Rainbow GUI** in the left menu and choose Build.
   - Make sure the output has no errors.
   - If the output says Debug instead of Release, or if the Rainbow-GUI code is not the active project, select Rainbow-GUI win32 Release from Build → Set Active Configuration, then build again.
4. Turn on sensors and motors via remote (button 2) or switches in back (labeled SENSOR and ON).
5. Click ! to start the program
   - This starts the windows side of the program
6. Turn on RTX (button RTX on)
   - The RTX message window will pop up and indicate that RTX has successfully turned on
   - RTX is the Windows Real Time Extension, which ensures motor commands are received in real time.
   - Wait 3-4 seconds before continuing
7. Load the parameters from the motor controller boards (button Load Param)
   - Make sure they all say ok. You may get errors if you load parameters too soon after starting RTX or if you forgot to turn the motors on.
8. Make sure the robot is close to its home position
   - arms and legs should be straight and perpendicular to the floor.
   - Feet should be parallel to the floor.
9. Turn on the FETS (button FET on).
   - Motors will now be "sticky" or hard to move
10. Enable control of the motors via the motor controllers (button CTRL ON)
    - The main portion of the GUI will now have more tabs and buttons to use
    - Check that the motors are locked into position.
11. Initialize the robot's joints to their home position (button All Init Pos)
    - Robot will find joint limits by moving its motors until they find a limit switch or the end of their motion range. The joints then go into their totally straight home position (all joints are at 0 degrees in this position).
    - Make sure the status of all joints is ok: home search results under the Hubo2 Upper Status and Hubo2 Lower Status tabs must all be 6.
    - Controller boards will flash the status (hopefully 6) and then resume blinking. If they don't start blinking, shut off the motors and restart this process.
    - Only do this if the home position is already set up correctly. The home position usually needs to be redone only if the robot has an accident or appears to be misaligned.

2.3 Go to Walk Ready Position

1. Go to the Walking and Demo Tab
2. Click the Range on button
   - This enables joint limitations to (help) prevent the robot from damaging itself
3. Click the Walk Ready button
   - The robot will go into a crouch, this is the "Walk Ready" position.

2.4 Go to stored ZMP Position

1. Click ZMP Init Pos.
   - The robot will load stored ZMP data and move to the saved position.
   - This date is saved after the robot has successfully balanced itself on a flat surface. This data can be loaded and re-used until the robot appears to no longer be balancing.

2.5 Sensor Setup

1. While the robot is suspended in the air, press the FT nulling button under the sensor tab.
   - The robot MUST be in the air.
   - Values for L and R My, Mx, and Fz should be close to 0.
   - This initializes the Force Torque sensors to zero (no force when in the air).
2. Lower robot onto the floor or level surface you will be using.
3. Click on FT Angle Zero
   - This sets the accelerometer angles in the ankles to 0
   - R and L Roll and Pitch should be almost 0
4. Click on IMU Nulling
   - This zeros the inertial measurement unit
   - IMU roll should be about 0, if it's not, then the floor is not level (do not walk if the values are close to 1). If the floor is level, you need to recheck the home position (Section 4.1)

3 Robot Shutdown

1. Raise the robot back into the air
2. Put the robot back in Home position (click Goto Home under the Walking & Demo tab)
3. Turn the motor controllers off (button Ctrl Off)
4. Turn off RTX (button RTX Off)
5. Exit the program
6. Power off the sensors and motors (remote button 1 or the OFF switch on the robot's back)
7. Shut down the computer (run shutdown -t 0)
8. End the remote desktop session
9. Power down the robot

4 Calibrating the Robot

As the robot is used it will slowly become uncalibrated, which can cause problems with walking and balancing. Accidents resulting in damage to the robot (such as a fall) or transporting the robot can cause the robot to lose calibration more quickly.

4.1 Set the Home Position

After an accident, shipping, or if the robot doesn't seem to be walking properly you need to check the home position. The home position is where all joint angles are set to 0 degrees. Change parameters on the GUI (Initialize tab) to move joints to correct home position.

1. Remove the front chest plate, the thigh and calf shells, and the shells covering the front of the ankle and hip roll motors.
2. Follow all steps in section 2.1 and section 2.2
   - If there is no previous set home position (or it is dangerous to the robot) stop after step 10 in section 2.2. You will need to use the Hubo-i to set the new home position.
3. Turn off the robot's ankles (ankle off button in the Walking & Demo tab)
4. Lower the robot onto a level plate. To prevent moments on the ankles, raise the robot back into the air slightly before lowering it again.
5. Fix the hip yaw
   - The front of the metal connectors above the hip roll motors (front of robot) should line up horizontally. Line up a straightedge along the metal surface and make sure there are no gaps between the metal and ruler (caused by the legs being rotated the legs aren't turned out or in.
   - If there is a gap, change the home position for the incorrect joint by following step 9.
6. Fix the knee pitch (both sides)
   - Tilt the robot by its unlocked ankles and use the laser leveler to line up the center of the ankle pitch and hip pitch joints from the side (right or left leg). You may need to (temporarily) move the arm out of the way by changing the shoulder pitch (follow step 9, then return the arm to its original position before saving the new home position in step 10).
   - Check to see that the center of the knee pitch motor lines up with the ankle and hip pitch motors. If it does not, change the angle of the knee so that the three joints are lined up by following step 9.
   - Repeat these steps for the other leg.
7. Fix the hip roll
   - From the front of the robot, use the laser leveler to make sure the ankle motor and hip roll motor are directly in line with each other.
   - If one of the legs does not line up, change the hip pitch for that leg by following step 9.
8. Fix the hip pitch
   - Using the laser level, line up the center of the ankle, knee, and hip pitch motors. Check that the line from the laser leveler is parallel to the vertical gaps in the torso shell casing.
   - If needed, adjust the hip pitch (step 9).
   - Check that the other leg is directly beside the first. Use a straightedge, it should make contact with both sides of both legs when lined up horizontally across the front of the legs. (e.g.. there should be no gap due to one leg being further back). Check at the front of the ankle roll motor.

- If needed, adjust the hip pitch of the second leg (step 9).

9. Change joint's home position
    - Raise the robot into the air
    - Go to the Initialize tab
    - Select the joint to change from the drop-down list labeled "Joint:" (e.g. right shoulder pitch is RSP)
    - Enter the number of degrees to move the joint in the "Offset Pos(deg):" box (usually less than 2). All joints follow the right hand rule for Hubo's global coordinate system.
    - Click the button Go Offset Pos. and the robot will move to the new position. The box for the moved joint will change to reflect the current offset from the old home position.
    - The robot can now be lowered onto the plate to check the joint's new position or move on to a new joint
10. Save the new home position
    - Select a joint that was changed from the Joint dropdown menu
    - Click the Save Offset button
    - Repeat for each joint that has been changed
    - Select the first joint again from the Joint dropdown menu
    - Press the Encoder Zero button (this will reset the offsets for all joints on that encoder to read as zero).
11. Set the Ankles' Home Position
    - Plug in and turn on the Hubo-i
    - Hold the robot so that the center of the ankle, knee, and hip joints line up (side view of robot).
    - Make sure the roll of the robot is ok by placing a level on the case for the lower front chest.
    - Check the current encoder value (E:) on the Hubo-i for ankle pitch on one side.
    - Go to the home position settings menu, and add this value to the current stored home position value
    - Repeat this for pitch and roll on both ankles.

4.2 Set the ZMP Values

The Zero Moment Pole (ZMP) position is used to ensure the robot is balanced. On a level surface, the robot shifts its position slightly until its center of mass is directly below it. This position can be saved and loaded again later as long as the robot does not become uncalibrated.

1. Follow all steps in sections 2.1- 2.3 and 2.5 (skipping section 2.4) using a balance plate whenever the robot is on the ground.
2. Go to the Walking and Demo Tab
3. Click on ZMP init start
    - This will find the center of mass.
    - It uses IMU and FT, so these need to already be set up.
    - Check that the robot's body is actually aligned and straight.
    - Robot will move back and forth slightly, should not move side to side much at all.
4. Check the values in the sensor tab

- ZMP x and y should be almsot 0
- R and L My and Mx should be about 0
- R and L Fz should be equal
- IMU roll and pitch should be 0

5. Go back to Walking and Demo tab and click ZMP init stop
6. To save the position so it can be used later, click the ZMP init save button. Now this new position will be loaded when ZMP Init Pos. is pressed.

5 Demonstrations and Running Code

5.1 Handshake

Don't use this right now. If things aren't exactly right, or the person tries to shake the robot's hand too soon, it could start to spasm.

1. Initial Setup: You have to run C - Grasping first. For some reason this allows the hands to grasp afterwards.
   (a) Select C-Grasping from the third drop-down menu under the Demos section
   (b) Press the Grasp Pos button. Robot will extend its right arm.
   (c) Press Grasp On. Robot will close its hand.
   (d) Press Grasp Off. Robot will open its hand fully.
   (e) Press Init Pos (formerly the Grasp Pos button). Robot will lower its arm.
2. Handshaking.
   (a) Select Handshaking from the third drop-down menu under the Demos section
   (b) Press the Grasp Pos button. Robot will extend its right arm.
   (c) Have someone hold the robot's hand to shake it.
   (d) Press Grasp On. Robot will close its hand.
   (e) Press Start. Robot will move its arm when the person shakes its hand.
   (f) Press Grasp Off. Robot will open its hand fully.
   (g) Press Init Pos (formerly the Grasp Pos button). Robot will lower its arm.

Notes: Do NOT press buttons out of order. Just don't do it, the robot could begin to shake or a motor could fail and make an awful noise.

5.2 Walking: random thoughts

When lowering the robot onto an unlevel surface (not the balance plate), lower it quickly to the ground. Lowering it slowly can allow the robot to hit the floor multiple times, causing sensor values to change several times.

To walk, set the step count (eg 3 steps). The button walking set will save changes made to parameters (must click this every time, even if no changes were made) and GO! will have the robot walk. Hubo will not use ZMP balancing while walking, only for 3 seconds to "adjust" after it has finished walking.

Set step count to -1 to keep walking until stop is pressed. For walking forward, start with small step sizes (.05m) but .1m, maybe .15m should be safe.

Sway is important for walking, a too large or too small value will make the robot walk strangely. Smaller sway to walk fast, but changes with step size. The start sway value multiplies the sway for the first step and stop sway value multiplies the sway for the last step.

6 Misc. Notes

- The battery doesn't charge when Hubo is plugged in, it needs to be removed to charge.
- Remote: button 1 turns off the sensors and motors, button 2 turns them on.
- Robot needs at about 52 (or more) volts to run properly. The minimum is 48V.