UNIVERSITY OF AGDER

Utilizing EVEr3: An instructional guide

Regarding safety measures and guidance
for powering up, connecting, powering down and charging the Halodi EVEr3 Robot
Eve is a continuously evolving platform and changes are committed daily. This paper has been updated summer 2021

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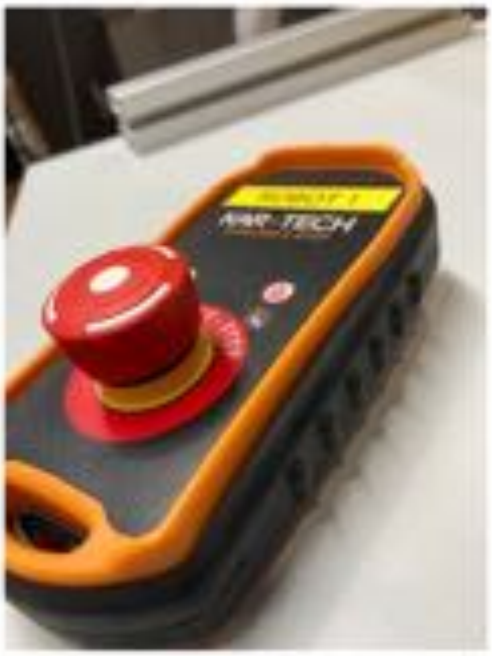
Workspace safety

At the time of writing this document, the robot is found inside the UiA Mechatronics lab, placed inside the safety cage. The space provided for the robot is small enough to obstruct its movement, therefore the robot has to be placed perpendicular to the frame it is hanged on. Practically, the robot has the same range of movement as a person. A additional check could be made by the person to ensure if there are any obstructions. The motors of the robot are not capable of producing enough torque to cause serious damage both to a person, environment or itself, but the plastics are fragile and are susceptible to fracture. The EVE weights approximately 80[kg] and should be handled accordingly.

Emergency Stops

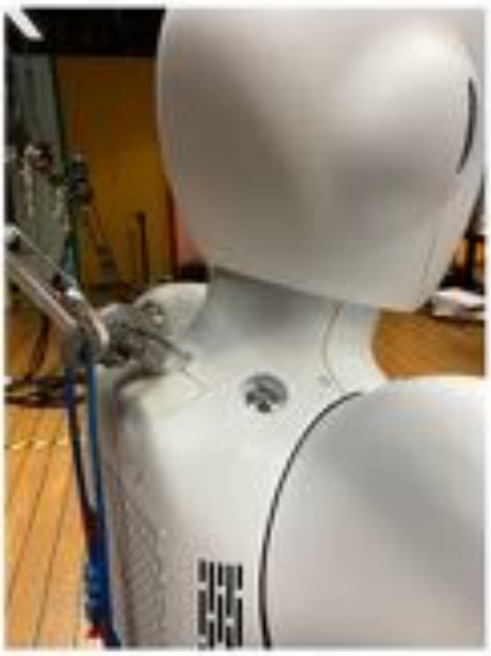
EVE has two emergency stops (E-stops). Each has two states:

- Enganged: The E-stop blocks EVE from powering its motors
- Disengaged: EVE is able to power its motors



Wireless E-Stop. Keep within 20 meters from the robot, ideally with a clear line of sight

- Engaged: The red button is pressed in
- Disengaged: The red button is popped up. The green light blinks.



Wired E-Stop. Estop installed on the back of the robot on the right hand side.

- Engaged: The button is pressed down.
- Disengaged: The button is up and flush with the ring

NOTE: When one of the E-stops is engaged (or both) then EVE will shut down. The robot utilizes backdrivable motors. When the power to the motors is cut via emergency stop, EVE will collapse to the ground. Make sure the robot is caught by the rope or by other means to minimize damage. If used for shutting down normally, follow the safety steps for shutting down EVE.

Computer recommendations for controlling simulated or real EVE

- Processor: Intel i5+ or Ryzen 5+, minimal 4 cores. Desktop class
- RAM: 32GB RAM (16GB would limit visualization duration)
- Hard Drive: SSD with 100GB free space
- Ethernet Port: 1GBit/s ethernet port available (dedicated to robot communication)
- Operating System: Ubuntu Linux 20.04 (64bit)
- Software: ROS2 Foxy

Steps to power up and connect to EVE

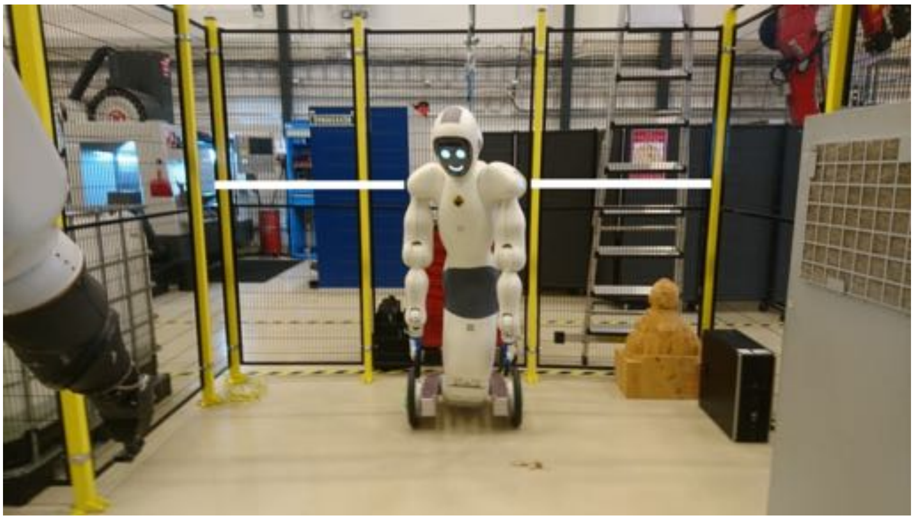
1. Use a screwdriver to remove the lid of the wireless E-stop and insert two AA batteries. The E-stop will blink green to show that it is connected. E-stop quickly uses up the charge in the batteries, when not in use, either remove the batteries or keep the E-stop engaged.

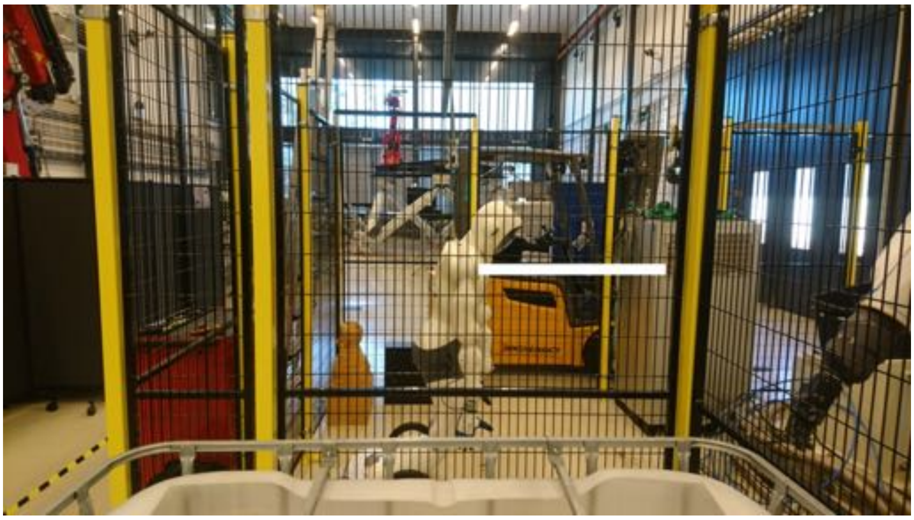
2. At the moment of summer 2021, Eve has been connected to a different network/router. Eve is connected to the router through a wireless internet connection. Add the PC you are using to the same network to access Eve. The D-Link router should be kept close to the robot and not displaced, because changing networks is complicated and requires change of IP's for both router and the robot.

3. *Outdated* Connect to the wireless network IoT, which is only accessible when the MAC address has been registered.
   Password IoT Network: EveRobot
   NOTE: In order to connect to the IoT access point, one must disconnect from all other UiA networks and delete credentials, and register one's MAC address with UiA Grimstad. Contact the IT department for registration.
   The MAC address can be found by:
   -typing *ifconfig* in the terminal and locating the address next to *ether*.
   -navigating in to network settings and selecting settings of current connection. It is found under *Hardware address*.

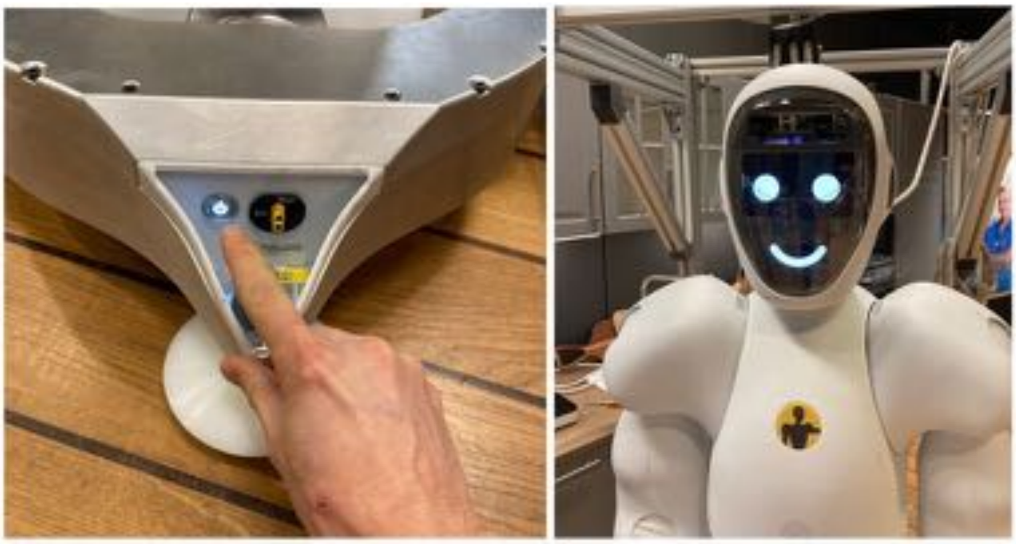
4. Make sure that the body of EVE is directly perpendicular to the wide side of the cage.

5. Make sure that workspace around EVE is clear to freely allow its movement (the size of the workspace must be above arm length forward and to the sides. In the following images the white lines represents the minimum required space).



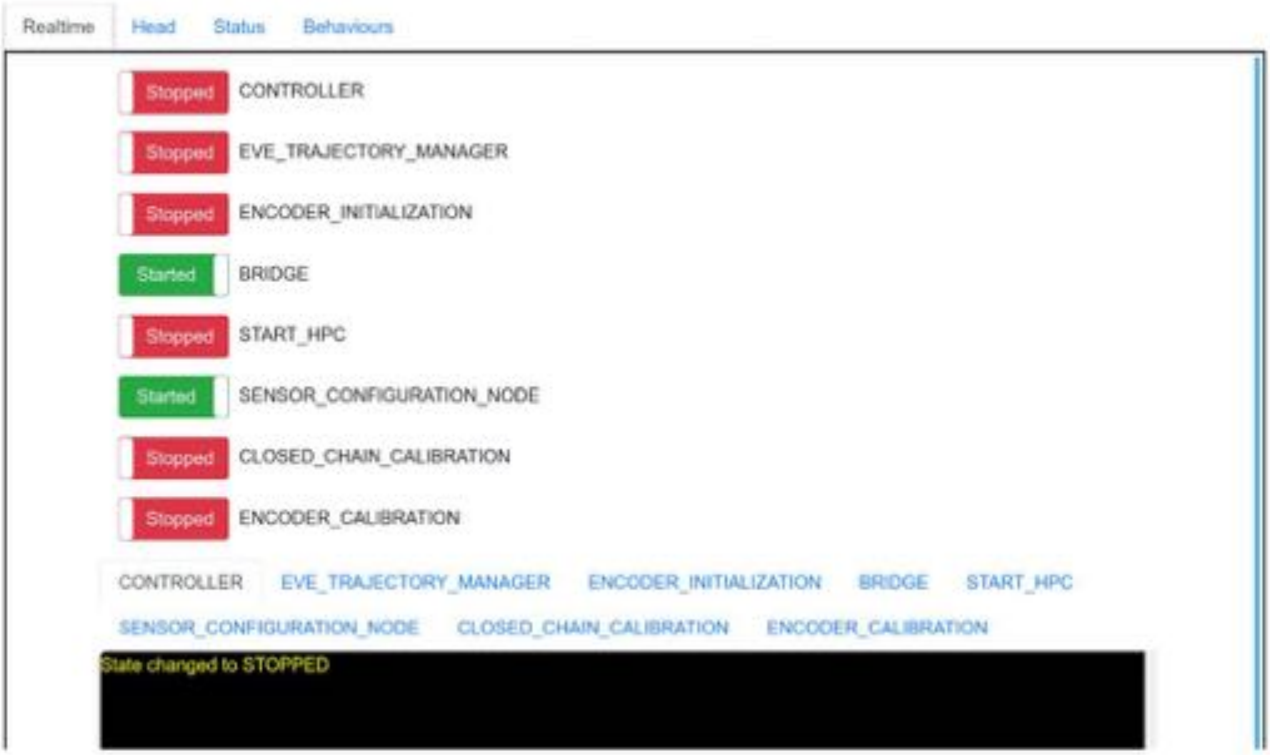


6. The further calibrations will involve EVE lifting its arms to sides and up. Watch out for the hands, they will forcefully close and open after the boot. Do not interfere.
7. Press the power button on the base. EVE will now boot, and when the booting is finished, the smiley face lights up on its face. This process will take several minutes.



8. If the smiley face does not show up after several minutes, and you encounter a different output on the screen than usual, then do a power cycle (press the power button on the base to turn off, wait 10[s] and try again). Ping the backpack computer if unsure about it powering up.
   Ping `192.168.0.30`

9. Open your web browser (recommended: Firefox) and open the "robot launcher" at: `http://192.168.0.30/`. You will be greeted with the launcher. If there is any issues connecting to the backpack computer, an alternative is possible. Connect to the head computer through `http://192.168.0.20:8080/`. You will be able to launch the robot without access to the backpack computer.:

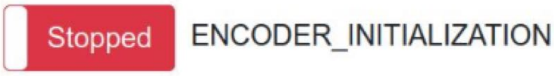


Stopped CONTROLLER
Stopped EVE_TRAJECTORY_MANAGER
Stopped ENCODER_INITIALIZATION
Started BRIDGE
Stopped START_HPC
Started SENSOR_CONFIGURATION_NODE
Stopped CLOSED_CHAIN_CALIBRATION
Stopped ENCODER_CALIBRATION

```
State changed to STOPPED
```

10. After power up, it is necessary to run encoder initialization. EVE will move its arms sideways and up, so make sure there is space around EVE. Be sure to place Eve's base and the body on the same axis, otherwise the skewed body position will give wrong readings under encoder initialization. It results in auto-balance and other failures inside the controller.

11. Make sure both E-stops are disengaged. Press the red button next to "ENCODER_INITIALIZATION" to start the initialization process.



Stopped ENCODER_INITIALIZATION

12. Once the initialization procedure is done, the "ENCODER_INITIALIZATION" state will switch back to "Stopped" automatically.

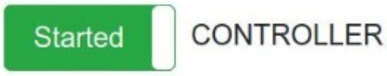
13. It is possible to fail the encoder initialization process by obstructing the robot arms. Check the logs at the web launcher by selecting ENCODER INITIALIZATION in case of irregularities.

Starting the controller

14. To start the controller properly, the process requires at least two people. One will assist robot to move itself to the default stance, and the other will operate the terminal.

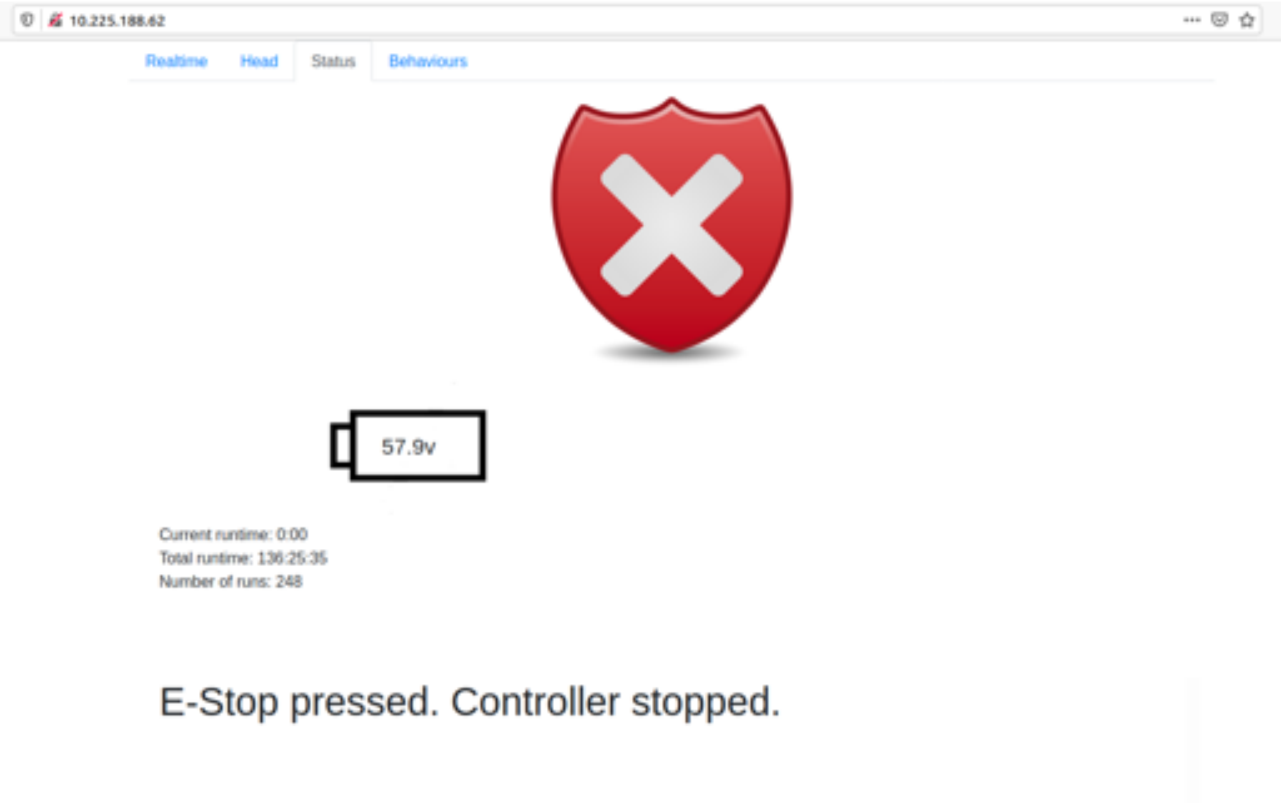
15. Make sure EVE is free to move. Engange the wired E-stop, but keep the wireless E-stop disengaged. We want EVE to start when we disengage the wired E-stop.

16. Go to the “robot launcher” and start the “Controller”.



17. The controller will now start, this will take about 30-60 seconds.

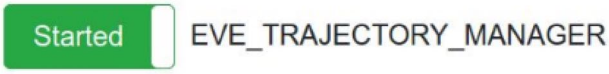
18. When you see the image below or when Eve informs you through a speaker, the controller has started. It will not start the motors and raise EVE up until the E-stop is disengaged (do not disengage yet).



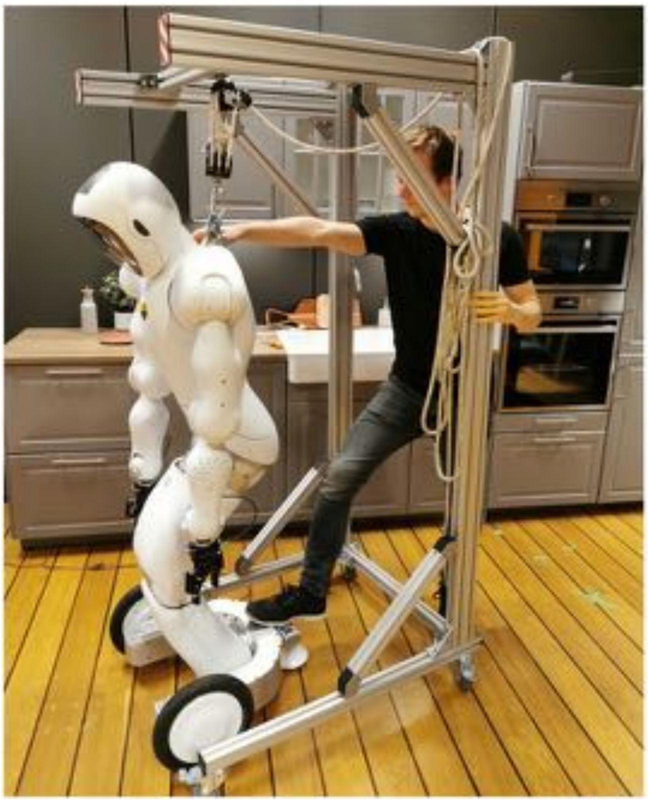
Current runtime: 0:00
Total runtime: 136:25:35
Number of runs: 248

E-Stop pressed. Controller stopped.

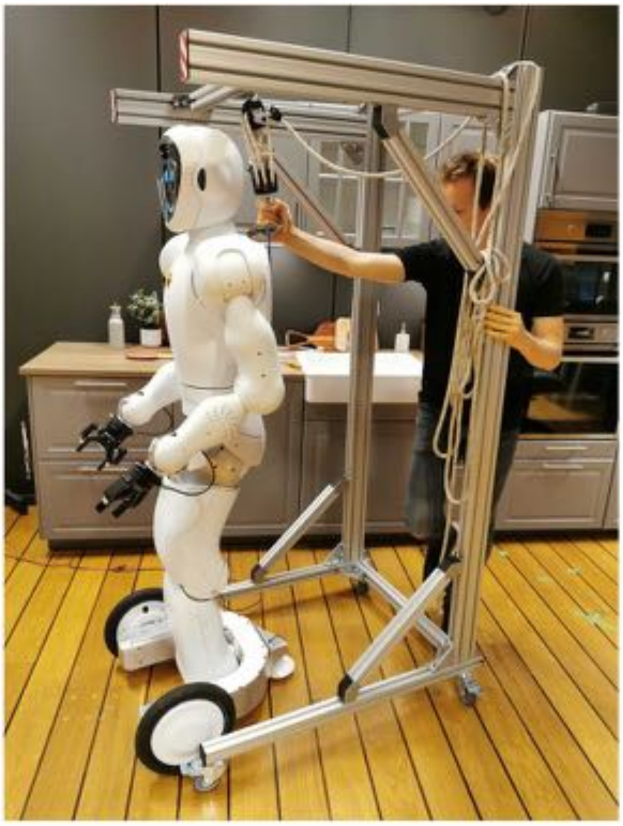
19. After the controller has started, navigate away from the "Status" tab and into to the "Realtime" tab and start the "Trajectory manager" (when not using the realtime API)



20. The robot is not physically capable of moving itself in to the required position. Failure of keeping the pelvic region above the base will lead to rapid heating of the ankle and increased fan noise. It will therefore require physical interference. Place yourself behind the robot. Use the foot to hold the base and drag the robot by the rope/hook to position it. The pelvic region has to be right over the wheeled base as shown in the pictures. Do not touch the red button on the hook! It will disconnect it from the robot.



21. Disengage the wired E-stop and prepare to adjust the robot. It will now start the stand-prep state and switch in to the balancing state. Help the robot to properly balance itself by holding on the hook. The robot has to *click* in to its place. If you don't hear or feel a click, push the robot gently around.



Secure Remote Connection

Connect to the backpack-computer on EVE by establishing a secure remote connection from your Linux shell:

```
ssh halodi@192.162.0.30
```

Password: halodi

NOTE: When you are connecting via SSH for the first time, the terminal will ask you to continue connecting. Type yes to continue.

Connect to the head-computer the same way:

```
ssh root@192.162.0.20
```

Password: halodi

Starting ROS2 Node

- Source EVE workspace in your terminal:
  ```
  source ∼/eve_ws/install/setup.bash
  ```
  or
  ```
  cd ∼/eve_ws
  . install/local_setup.bash
  ```

- Run example code to test the connection
  Syntax: ros2 run Package-name Node-name
  Examples:
  ```
  ros2 run eve-ros2-examples wave_right_hand
  ros2 run eve-ros2-examples go_to_default
  ```

- If one wants to run self made packages, one has to transfer them to the computer of EVE via Secure Copy. Open a new terminal and type the following in your local computer and then type the given password in the last step when prompted. If you don't specify a desired directory, the file or package will be copied to the home directory of the computer of EVE.
  For package/folder transfer, type in the command below. For the local directory, include the package folder in the path.
  ```
  scp -r ∼/local_directory halodi@10.225.188.62:∼/eve_ws/src
  ```
  For file transfer:
  ```
  scp ∼/local_directory/file.filetype halodi@10.225.188.62:∼/eve_ws/src/desired_directory
  ```

- Navigate to the ∼/eve_ws directory

- Run colcon build –packages-select package_name to build the package

- Source the workspace with . install/setup.bash

How to use the controller

- The examples of what and how Eve can do is provided in the official Halodi Github https://github.com/Halodi/eve-ros2-examples

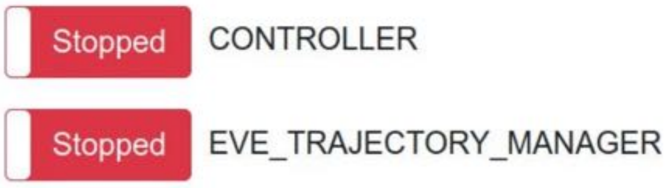
- There is 2 possible ways to send the command to arms, a joint space and a task space command.

- Joint space command requires inputting specified joint angles in to each joint to trigger a movement. The command can be stacked in to a queue and is possible to send it to every joint, excluding the up to the pelvic region. The movement execution speed depends on the time difference from between each command. The safe operation angles are found inside the urdf file in the github `https://github.com/Halodi/halodi-robot-models/blob/main/eve_r3_description/urdf/eve_r3.urdf`. The robot is accepts and moves joints once per command.

- Task space command takes Cartesian coordinates and frame as a command. X-Y-Z coordinates as meters and angles as quaternions. It is also possible to queue up the commands, but Eve only starts executing the movement once per arm. It proves moving some tasks like moving a box with hands difficult, since there will be a lag between each arm command. Only safety feature found is the collision prevention between wrist joints. When inputting invalid coordinates in to the controller, the robot will try to move arms to the position and possibly failing.
- At the moment, Eve does not have a driving controller, only simple drive commands. You choose only linear and angular speed in meters per second to move the base. The robot also uses wheels to balance itself, making position based driving difficult. The controller itself have a 100ms timeout period and will stop if new command is not issues.
- Pelvis can only be moved using task space commands. Since the auto-balancing is operated one level lower than arm movement, balance is always prioritized. The pelvis can move in all directions and try to keep base as steady as possible.
- Hands can only be closed or opened. There are several inputs, such as amount of hand closed, speed and torque, but it seems only amount is controllable.
- Eve published topics at a 500Hz frequency. When writing the script with a subscriber, use best-effort Quality of service to catch the messages from the topic.

Steps for shutting down EVE

1. If the arms have been actuated during the interaction: Program them to go back to the starting neutral position, so that there is no unnecessary stress on the parts of EVE when powering down:
   ros2 run eve-ros2-examples go_to_default
2. To end the SSH connection, there are severeal methods. Some of them are: 1) press [Ctrl]+[d], 2) type exit, 3) type ∼. (tilde dot).
3. Make sure the support harness has little to no slack in it, and help it go back to un-powered position. EVE will fall down and needs to be caught by the harness.
4. Press one of the E-stop buttons (wired or wireless). EVE will collapse and be caught by the rope.
5. Stop the controller in the “robot launcher” (this will stop the on-board log).



6. Press the power button on the base of the robot to turn it completely off.

7. Use a screwdriver to remove the back lid of the wireless E-stop and remove the two AA batteries to avoid unnecessary power consumption.

Troubleshooting

- Before launching a script on Eve, **ALWAYS** test it on the simulator. It provides a safe environment for testing and finding software/hardware breaking issues.

- The default values for the PID controller are
Kp: 50
Kd: 9.9
Damping ratio 0.7
To relax the arm of Eve, set the PID values to zero. To tense up the arms, increase the Kp values carefully. Changing the PID values too much leads to controller failure. Remember to reset the PID values to default before moving the arms, because the first command will use old PID values. To reset it, send a command without any angle or coordinate.

- When the robot is trying to move its joints outside the range of motion, the controller will often increase the feedback values to move it. While it is not possible to see it on the screen, you can observe the robot itself. The usual signs of the failure occurs when the fans start rotating at from minimal to maximum speed, clicking noise or joints trying to move to the position and failing. The consequences of failing to prevent the failure leads to volatile behaviour. The motors will behave randomly resulting in arm flaying and jerking of the base, possibly injuring a person or itself.

- Be sure to start the encoder initialization correctly. If the initialization is done when the robot is hanging skewed, restart the process. Otherwise the controller will reference wrong values and fail in auto-balancing. Sometimes it also effects joints leading to volatile behaviour.

- Sometimes, Eve does not catches published messages from the ROS2 script. The bug occurs randomly and requires the terminal operator to kill and start the publisher node again.

- Several robot topics are published in 500Hz frequency. To be able to catch the messages from these topic, use Best-effort QoS setting. Based on the experience from using C++, writing a more complicated script result in segmentation error. The processing speed in not high enough to efficiently capture published messages and result in a empty message leading to software crashes.

- Due to outdated design, the wifi card of the backpack computer is fitted loosely. Sudden jerk under operations damaged the port leading to losing the connection to the network. A makeshift solution was implemented. The wifi card is strapped and glued to the port, but could fail anytime. In case of losing

access to the backpack computer, connect to the head computer using ssh and then ssh to the backpack computer. Both computer are connected through a thunderbolt cable and can be access using ssh.
Head IP : `root@172.16.0.1`
Password : halodi

Backpack IP : `halodi@172.16.0.2`
Password : halodi

- On the case of accidentally running
  Sudo apt update
  or on change of some files, the website interface could become unresponsive. To fix this issues, reinstall the launcher using files found in Halodi github `https://github.com/Halodi/halodi-controller/blob/main/UPGRADE_FIRMWARE.md`. Careful to not update anything else since Eve is running on a outdated operating system Ubuntu 18.04.

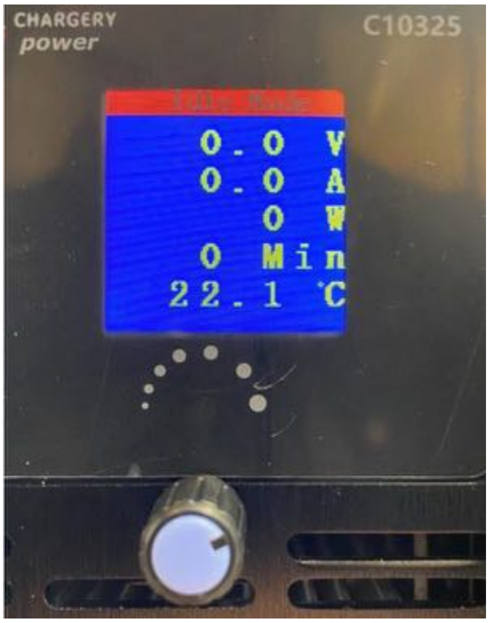
Charging EVE

Warnings:

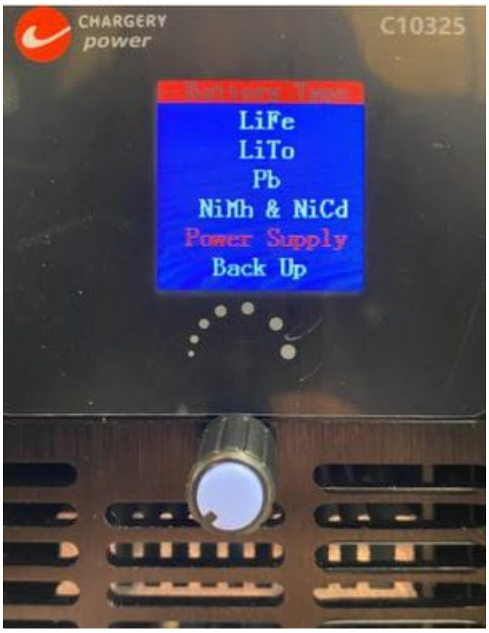
- **Turning the knob while it is charging will change the output voltage to an undesired voltage. Do not turn the knob while charging.**
- **EVE should only be charged when it is not powered. When it is powered, it draws a current. If that current is such that charge current minus consumption current is less than 1A, the charge port will close and the charger must be disconnected and reconnected to create a rising edge for the charge detection of the Battery Management System (BMS).**

Steps to charge EVE:

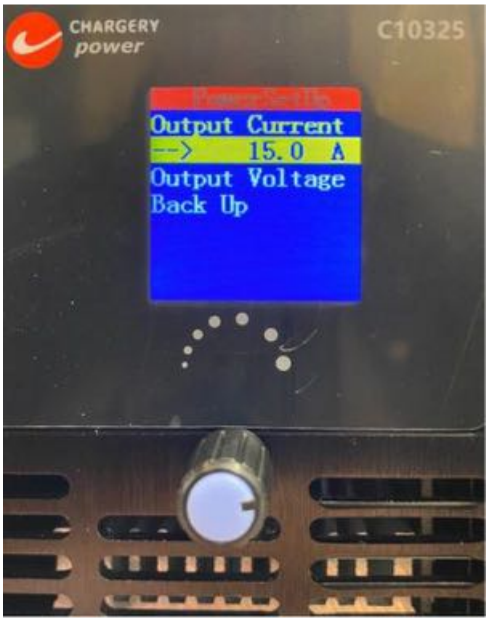
1. Connect Chargery C10325 to a power outlet
2. Connect the female XT60 charge port on EVE to Chargery's male XT60 output
3. When you see the screen in the image below: Press the knob once to get to the "battery type" menu



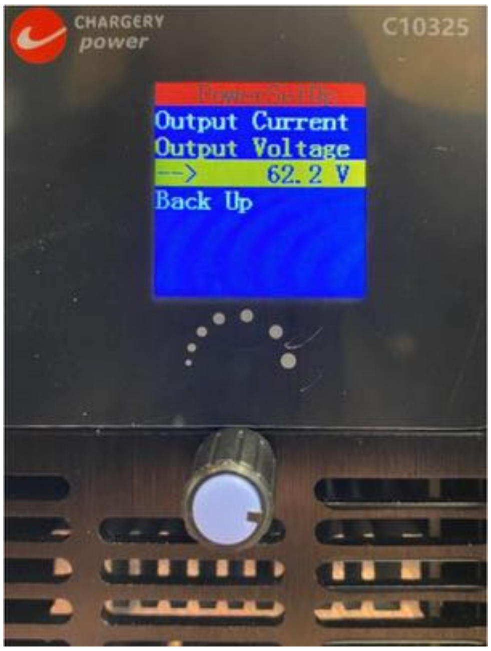
4. Turn the knob to navigate down to "Power supply" like in the image below and press the knob once to enter "PowerSetUp"



5. Turn the knob to navigate down to "Output Current". Set the output current to the desired value and press the knob. EVE supports charging with 1A to 15A. This is only a choice of charging time, so 15A will be the shortest and 1A is the longest charging time.



6. Turn the knob down to "Output Voltage" and press it. Turn the knob and adjust the voltage to 62.2V. Press the knob to set the value.



7. Press and hold the knob for 3 seconds until the charger starts delivering power. The BMS will close the charge port when the charge current is less than 1A.
8. The current will drop when the battery is fully charged. Press the knob to turn off the charger. The screen will then display the startup menu like below. Disconnect the power outlet and remove the charging wire.