N.E.A.T

No Effort Automated Transporter

User Guide

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1 Introduction

The No Effort Automated Transporter (N.E.A.T.) is an assistive relay robot designed to carry and deliver small items within a household setting. Its primary objective is to alleviate the difficulty or unease encountered by those with mobility issues when attempting to transport items, e.g. food, books, their laptop, as part of their everyday life. The robot may also be used by members of the general public. In this document you will find a complete guide on how to set up and run your N.E.A.T., including software and hardware details.

1.1 System Outline

- The app:
  - allows the user to move the robot using manual controls.
  - is used to cause the robot to start and later stop following the user.
  - allows the user to move the lift to various heights.
  - provides feedback to the user about issues the robot encounters.
  - can be used to control the robot via voice commands.
- The robot:
  - follows the user around their home by sensing the user's portable beacon.
  - uses sensors to avoid obstacles in its path while following the user.
  - receives manual commands from the app to move in 8 directions - forwards, backwards, left, right, diagonally forwards and backwards in left and right directions, and to rotate clockwise or anticlockwise.
  - has a lift with a non-slip tray atop it, which it uses to carry items up to 3 kilograms.
  - uses the lift to raise the tray to heights up to 91 centimeters.
  - sends feedback to the user via the app to inform them of issues, e.g. if the beacon is lost, if it is unable to avoid an obstacle.

2 Hardware

2.1 Equipment Included

Pre-built Robot Base (Lego™):

- Mecanum™ wheels x4
- Raspberry Pi with power bank x1
- Lego™ EV3 brick x1
- Lego™ NXT motors x4
- Lego™ Ultrasonic sensor x3
- Lego™ Infrared sensor x1

- Lego™ Infrared beacon (following controller) x1
- Lego™ connector Cables x 15 (11 required, 4 extra)
- Lego™ EV3 brick charger x1
- 12V battery pack, with 8 AA batteries

Pre-built Lift:

- Lift tray x2 (1 required, 1 extra)
- Pre-installed Lift motor x1
- Pre-installed lift PCB x1
- PCB connector cables x8
- 24V battery pack, with 16 AA batteries

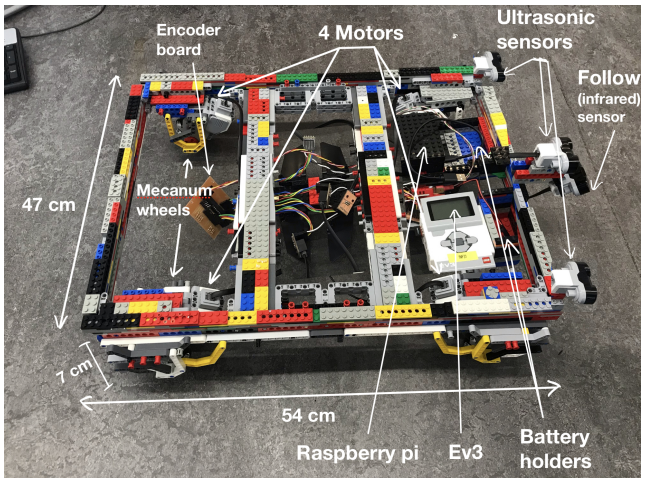

Figure 1: N.E.A.T. Base with labelled components

Figure 2: EV3 sensors connection table

2.2 Base

2.2.1 Overview

The dimensions of the N.E.A.T. robot base are 54cm by 47cm with its chassis at 7cm above the ground. It has four Mecanum™ wheels aligned on the diagonals of the base frame allowing the robot to move in eight directions and rotate. Each wheel is powered by an individual motor. The Raspberry Pi controls these motors directly, as well as the lift's motor. There are four sensors on the base: three ultrasonic sensors for object detection and avoidance and an infrared sensor for following. The EV3 brick is connected to the sensors via Lego connector cables and to the Raspberry Pi via USB cable. See *Figure 1* for more details.

2.2.2 Raspberry Pi

The Raspberry Pi is encased in a black Lego compatible case attached to the base. It runs on a battery pack connected via its Micro USB power connector, which automatically powers up the Pi when it is connected; there is no power button. We then use an I2C cable on the GPIO pins of the Pi to connect a motor board, the central control board of the robot. It has 4 motors and an encoder board connected to it through I2C cables and a pack of 8 AA batteries in a holder connected through a DC cable. These together allow for the control and powering of the motors running the wheels.

2.2.3 EV3 and Sensors

The EV3 brick directly connects to four sensors *(see Figure 2)* and passes their data to the Raspberry Pi continuously.

The infrared sensor is located at the front of the robot, in the centre, and it is connected to port 2 on the EV3 brick. Its proximity measurement is approximately 50-70 cm and sensing range from the beacon is up to two meters.

There are three ultrasonic sensors placed on the robot base: one in the middle under the infrared sensor which is connected to port 3 on the EV3 brick, one in the front left corner, connecting to port 1 and one in the front right corner, connecting to port 4. The distance range of the ultrasonic sensors is between 1 and 250 cm with an accuracy of +/- 1 cm. EV3 also establishes a wired connection with the Raspberry Pi *(see Section 3.3.3 for details)*.

2.3 Lift

The N.E.A.T. robot is equipped with a scissor lift to enable the user to move items onto the transport platform with minimum effort. The lift can extend up to standard kitchen countertop height (91cm) [Parotas(2019)] with ease, using controls from within the app.

The scissor lift assembly is made up of three main parts; these are the motor and electronic control, the drive mechanism, and the platform. *See Figure 3*.

2.3.1 Motor and Electronic Control

The motor used on your N.E.A.T. robot was chosen such that it should be able to comfortably handle up to 3kg of weight. It uses custom designed circuitry to interface with the Raspberry Pi and control the direction of the motor. This means that the direction of the lift can be controlled through the app, whether it is manual control of the lift height or lifting to pre-set heights.

2.3.2 Drive System

The drive mechanism is a threaded rod, connected at one end to the motor. The threaded rod spins, which allows the threaded component connected to the bottom support shaft to move up and down the rod. The motor uses a 24V battery pack with 16 AA batteries to function.

2.3.3 Platform

The platform is attached to a scissor lift assembly, which allows the lift to reach the maximum height of 91cm while maintaining stability and strength.

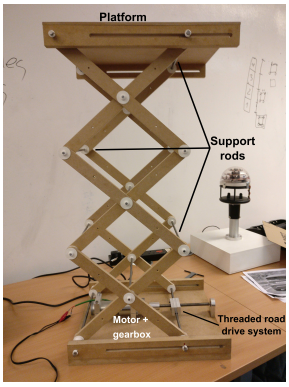

Figure 3: Completed lift at 75% extension, with labelled components

3 Setup Instructions

3.1 Basic robot setup

You should receive two separate components, a base and a lift, in the package of your N.E.A.T.

In order to start up your N.E.A.T., connect the Raspberry Pi to its power bank and press the ENTER button in the centre of the EV3 to switch on the EV3. You will see two LED lights start flashing to indicate the brick is waking up. To switch off after use, press the BACK button directly under the screen and to the left on the EV3 and select *Power Off* from the menu. Disconnect the Pi's power bank.

Once you have switched on your N.E.A.T., place the lift on the top of the base within the boundaries of the raised edges, and let the four corners of the lift fit into the preset grooves on the base. Make sure that the metal rod on the lift is in the same orientation as the sensors, i.e. facing forward, so that the lift doesn't exceed the boundary of the base. Failure to do so may cause potential damage to you and your belongings. Slightly adjust the position of the lift on the base until it is stable. We strongly recommend that you ensure the lift is securely in place, otherwise unexpected accidents may occur during usage.

3.2 Robot maintenance guidelines

- When N.E.A.T. is in idle mode i.e. turned on and ready to receive connection, you should place it in a flat, clean and dry location. You should also make sure that there aren't any obstacles in the robot's path.
- If you are not going to use N.E.A.T. in the next 6-8 hours, gently detach the EV3 brick, Raspberry Pi's power bank and motors' batteries from the base and charge them with the provided chargers respectively. You are strongly encouraged to charge them once you are finished using N.E.A.T. to protect battery lifespan.
- Clean the lift and base components with a moisturised wipe (take care that it's not too wet otherwise the electronic components may be damaged) regularly to avoid dust accumulating in the robot, in particular on the sensors and in the connection joints of the scissor lift.
- The wheels should be kept clean at all times to ensure that dust and debris do not impact the wheels' functionality, which can result in poor diagonal and rotational movements. Check there are no small items in between small inner wheels regularly (ideally after each use), as small objects may prevent Mecanum wheels from functioning correctly.

3.3 Advanced robot configuration

Ideally, the N.E.A.T. robot should be either shipped to you pre-configured or configured by our technical support staff on the day you receive the robot. Additionally, you can also do it on your own by carefully following the steps listed below.

3.3.1 Requirements

1. WiFi with SSID and password.
2. A visual display with HDMI (or VGA) cable.
3. A keyboard.

3.3.2 Configure wireless network for Raspberry Pi and set up the server

1. Detach the Raspberry Pi from the robot base, keeping the power bank connected.
2. Plug the HDMI cable of the monitor (use a HDMI-to-VGA adapter for monitor with VGA cable) and keyboard into Raspberry Pi. *(see Figure 4)*
3. Log in with user name *pi* and password *r00t*.
4. Enter the command **"sudo iwlist wlan0 scan"** into the console to scan for available wireless networks. Find your chosen network and keep a record of its ESSID.
5. Enter **"sudo raspi-config"** to the console *(see Figure 5)*. Select **Network options** from the menu and then **Wi-Fi**.
6. Enter the SSID and password of your chosen local network as prompted. (SSID is the ESSID displayed during the Wi-Fi scan.)
7. Return to the console and enter **"ifconfig"** to check if Raspberry Pi is connected. Repeat this step until the connection is established. If it still doesn't work, check if the SSID and password you entered are correct.

8. Once the Raspberry Pi is connected to your local network, keep a record of **"ifconfig"** command's outcome for later use. You can add more network details to Raspberry Pi via the command line. Check the official documentation for more details.

9. To allow Raspberry Pi to run the program automatically when the Pi boots, enter **"sudo nano /etc/rc.local"** to edit the file **rc.local** and add the new line: `python2 pi_server.py` before the last line of the file (`exit 0`). (See official documentation for more details). Save and exit the editor. Reboot Raspberry Pi by running **"sudo reboot"**.

10. Unplug the visual display and keyboard. Attach Raspberry Pi (and also power bank) back to the base frame.

Figure 4: Connect visual display and keyboard to Raspberry Pi

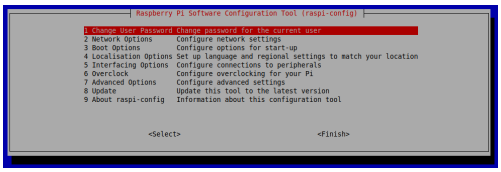

Figure 5: Raspberry Pi configuration menu

3.3.3 Configure Ethernet connection for EV3

1. Make sure the EV3 is fully charged. If not, charge it before proceeding to the next step.

2. Connect EV3 PC port to Raspberry Pi with the USB cable provided *(see Figure 6)*.

3. Turn on EV3 by pressing the ENTER button in the middle for several seconds till the light on EV3 blinks and wait for the main menu to appear.

4. Go to **Wireless and Networks**, select **All Network Connections**, and then select the **Wired connection** with the USB icon. Wait for the state change from **disconnected** to **online**.

5. Ethernet connection between EV3 and Raspberry Pi should be established automatically. If not, manually select **Connect**. You can also check the **Connect automatically** box for automatic connection in the future. *See Figure 7 for details.*

6. Go back to main menu and click on **file manager**. Find the file **ev3_client.py** and press ENTER to run the program. Manually running the program is only required once after configuring EV3. Later the program will be automatically invoked once EV3 is turned on.

Figure 6: Wired connection between EV3 brick to Raspberry Pi

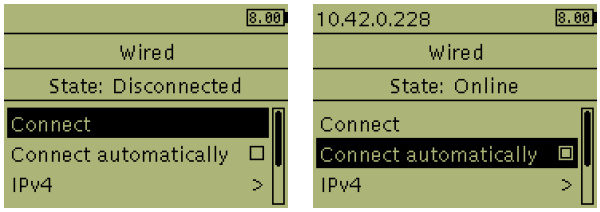

Figure 7: EV3 wired Ethernet connection settings menu

3.4 Mobile App

To run the N.E.A.T. Android app, you will need a mobile phone with Android 7.0 or above and 5 MB of free storage space. The app has been specially designed to adhere to W3C Accessibility Guidelines and is compatible with all screen readers and other accessibility features found in most smartphones. Once you have downloaded the app, the only further setup is to connect your phone to the correct Wi-Fi network.

3.4.1 Set up network connection

1. Open system settings and then go to Wi-Fi connection.

2. Make sure your local network is open for wireless connection. Connect to the same network as the Raspberry Pi i.e. the Wi-Fi with same SSID.

3. If your robot is self-configured, the first time you open the app, you will be prompted to enter the IP address of your N.E.A.T. Check the output of Raspberry Pi's 8 **"ifconfig"** command and enter the ipV4 address separated by three dots. You are ready to connect to your N.E.A.T.

4 Usage Instructions

4.1 Bring the robot to your current location

When you want your N.E.A.T. to carry an item for you, start by opening the app installed on your mobile phone. Make sure the robot is turned on *(see Section 3.1 for details)* and placed upright without any obstacles blocking its path.

The welcome page containing the logo for N.E.A.T. asks for your permission to connect to the robot *(see Figure 9)*. Click on **connect** and wait a moment for the robot to awaken from idle mode. Then, the connection between the robot and your mobile phone will be established. You will be presented with the main menu with four buttons displayed, *as shown in Figure 9*. If the robot is nearby and you wish for it to follow you to the location you plan to transport an item from, follow the instructions in Section 4.3. Otherwise, use the manual controls to direct the robot to the desired location, following the guidance in the second part of Section 4.4.

Figure 8: EV3 infrared following beacon

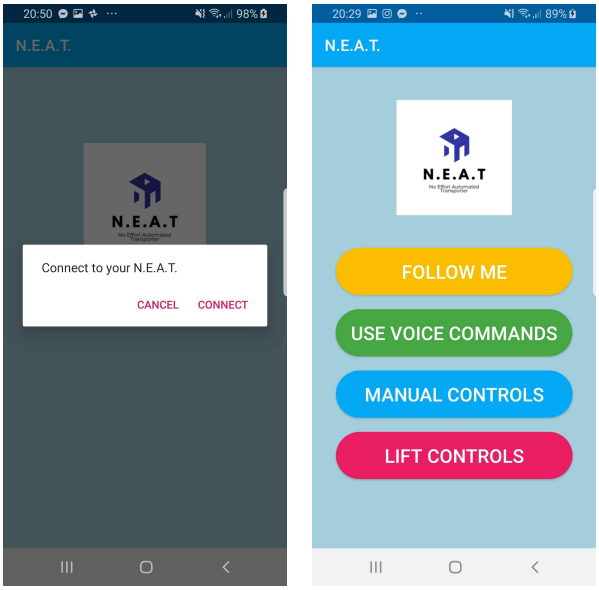

Figure 9: **Left:** Connection pop-up **Right:** N.E.A.T. main menu

4.2 Adjust lift to place your items

Click on **Lift Controls**, the last button in the main menu and you will see the lift control options, *as in Figure 10*. Here you can adjust the height of the lift to allow you to place your items on the tray with minimal effort. The tray can reach up to 91cm above the ground which accommodates the height of a standard kitchen countertop or dining table (76cm) [Parotas(2019)]. Make sure the item is placed securely on the tray, preferably in the centre.

In order for N.E.A.T. to locate and follow you while you are walking to your destination, please take the portable infrared beacon *(shown in Figure 8)* from the robot (you should find it attached to the tray).

Then click on the "go back" arrow at the bottom of the app screen to navigate back to the main menu. Once you select a movement option, the lift will automatically lower to the base height before carrying out any movement. For the safety of the robot lift and your items, the robot will not move if the lift is not at its base height.

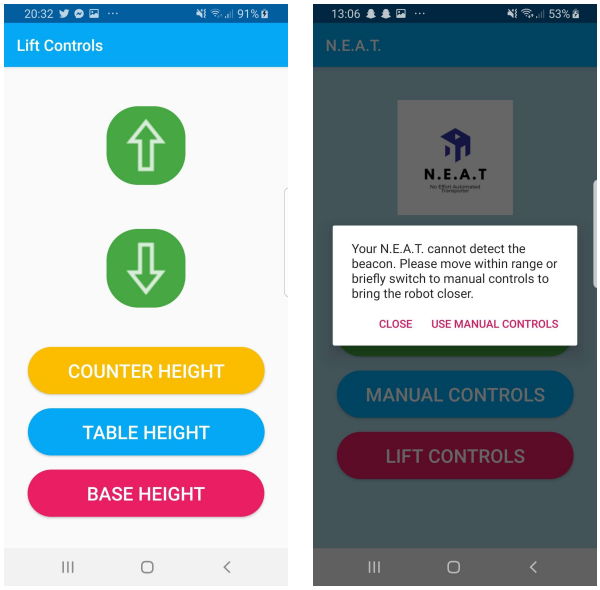

Figure 10: **Left:** Lift controls interface **Right:** Error pop up

4.3 Walk to your destination with N.E.A.T. following you

Click on the **follow me** button, the first button on the main menu. You will notice that the button now shows **stop following** with a red background. You should observe that all the robot's sensors are on and additionally the green LED light on the infrared beacon is flashing, indicating that the beacon is active. Hold the beacon with the signal emitting end i.e. the dark black part of the beacon, pointing to the robot. Hold the top right button on the beacon while walking. You should notice that N.E.A.T. is following you approximately one or two steps behind.

The robot will automatically avoid obstacles while following you, so feel free to move to your destination as normal. If the robot cannot figure out how to move around an obstacles or it is too far away from you and has lost the signal from the beacon, you will receive an alert from your app, *as seen in Figure 10*. In the case of a difficult obstacle,

you have the option to briefly switch to manual control to guide the robot around it, or you can opt to remove the obstacle or use the beacon to guide the robot to avoid it. In the case of a lost beacon, you can simply move closer to the robot, or opt to briefly use manual control to bring the robot closer to you.

Ideally the robot should continuously move at approximately the same speed as you, neither falling too far behind nor clipping at your heels. If either is the case, it means N.E.A.T.'s default moving speed doesn't fit with your walking pace. You can customize the speed to improve your user experience by clicking on the settings icon on the top right of the main menu and changing the speed from the default 90 to any whole number between 80 and 100. It may require trying a few different options to figure out the most appropriate speed for you. We suggest a change of approximately 5 each time so that you are able to adapt to the change in speed.

Once you have reached your destination, click on the **stop following** button and it should revert to the **follow me** button.

4.4 Alternatively switch to manual control mode for dedicated control

If you find the robot stops at an undesirable position or, as mentioned above, encounters obstacles it cannot avoid while following you, you can switch to manual control mode to move the robot by yourself. If the issue is an obstacle the robot cannot successfully avoid, the option to switch to manual control will be shown in the alert message. However, if the robot is still in following mode, click on the **stop following** button to stop auto-movement before proceeding to manual control.

Select **manual controls** on the main menu and you will see the manual control panel page, *visible in Figure 11*. There are 10 buttons in this control panel corresponding to moving forward, backward, right, left, diagonally left-forward, right-forward, left-backward and right-backward, as well as clockwise and anti-clockwise rotation. Hold the button to move the robot and release the button to stop. Once you are satisfied with the robot's location, click on the arrow in the bottom right corner of the screen to return to the main menu.

4.5 Finish the service

Once the robot arrives at your destination and has ceased movement, you can adjust the height of the lift by following the instructions in Section 4.2, and move your items from the tray on the robot to your desired location. Remember to attach the infrared beacon back on to the robot. You can now keep the robot in place, ready to follow you to your next destination, or use the manual controls to move it to a desired safe spot. Close the app on your mobile phone and it will automatically disconnect from N.E.A.T. The robot will now switch back to idle mode, waiting for your next use.

4.6 Use voice commands to control your N.E.A.T.

For the convenience of users with visual or mobility impairments, there is also the option to control your N.E.A.T. using voice commands. In order to do so, connect your app to the N.E.A.T. as in Section 4.1. When the main menu appears, select the button labelled **use voice commands**. A new screen will open with a microphone icon, ready to receive voice commands *(see Figure 11)*. You can now control the lift and robot movement using spoken commands. Once your command has been recognised, the app will respond with a success tone and the command will be shown on the screen. If the app doesn't recognise a command, it will respond with an error tone and display a message requesting that you try again.

1. In order to control the lift, start by saying **"lift controls"**. Follow this simply by saying **"raise"** and **"lower"** to change the height of the lift (the lift will move in preset increments so you may need to repeat the command to reach the correct height). Once you have the lift at the desired height, say **"close lift"**.

2. To allow the robot to start following you, use the command **"follow me"** and use the beacon as in Section 4.3. Once you have reached your destination, say **"stop following"** to stop your N.E.A.T.

3. To use manual controls, start by saying **"manual controls"**. Follow this by saying any of the 10 available directions: **"forward", "backward", "left", "right", "left-forward", "right-forward", "left-backward", "right-backward", "clockwise", "anti-clockwise"**. In order to stop the movement in that direction, simply say **"stop"**. Once you have the robot at the desired position, say **"close manual"**.

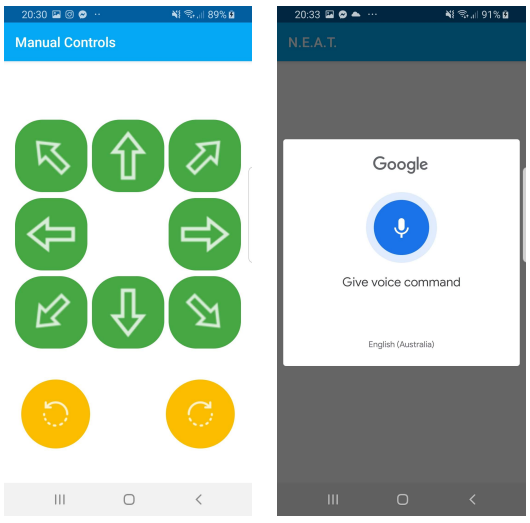

Figure 11: **Left**: Manual control interface **Right**: Voice command screen

5 Troubleshooting Guidelines

Problems	Possible Causes	Solution
ROBOT BASE		
Robot not waking up from idle mode	Raspberry Pi battery low	Remove, charge the external battery pack, then place back
	EV3 brick battery low	Remove, charge the EV3 brick using its charger, and place back
	Loose cable connection to RPi battery pack	Ensure the cables are connected securely
	Charging cable broken (Micro USB to USB)	Replace the cable
Slow robot movement	Loose cable connection to RPi battery pack	Ensure the cables are connected securely or replace them
	RPi battery low	Recharge/replace the 8 batteries connected to the RPi
	Load exceeds recommended value (3kg)	Remove some items from the platform
Inaccurate robot movement	Dirt/obstruction in the wheels	Clean the rubber part of the wheel using a wet cloth and remove any small object in the wheels
	Mecanum wheels are not orientated correctly	Rearrange the wheels so that the treads are pointing towards the centre of the base
	Mecanum wheel motors are not plugged into their correct sockets	Rearrange the motor cables according to Section 2.2
	RPi battery low	Recharge/replace the 8 batteries connected to the RPi
	Load exceeds recommended value	Remove some items from the platform
Robot does not start following	Connection lost between phone and robot	Follow the steps in Section 3 to re-configure robot's and mobile phone's WiFi connection
	Robot or beacon battery low/dead	Recharge/replace batteries
Base damaged	Likely due to a drop or several robot collisions	Contact the manufacturer
APP		
"EV3 power low" message displayed on the app	EV3 brick battery low	Remove, charge the EV3 brick using its charger, and place back
App shows "beacon not detected"	Activate button is not pressed while moving	Hold the top right button on the beacon pressed for it to send signal to sensor
	Beacon out of range/sight	Move within range of the infrared sensor/ensure the beacon is visible to the robot
	Beacon has no power	Change its battery
App shows "network connection error"	Mobile phone and robot are not connected to the same WiFi	Follow the steps in Section 3 to re-configure robot's and mobile phone's WiFi connection
App shows "EV3 brick disconnected"	EV3 brick and Raspberry Pi are not connected	Replug or replace the USB cable between EV3 brick and Raspberry Pi
App shows "xxx sensor is not working"	Faulty sensor	Replace sensor
	Faulty cable	Replace cable
App doesn't recognise voice command	Command not from list of recognised commands	Use one of the commands given in Section 4.6
	Too much background noise	Bring the phone closer to you and minimise background noise where possible
LIFT		
Lift can't raise platform	Low battery or load is too heavy	Replace the lift batteries. If the problem persists, remove some items from the platform.
Lift motor doesn't run	Low battery or H-bridge circuit fault	Replace the lift batteries. If the problem persists, replace the H-bridge circuit
	Broken lift motor	Replace the motor
Lift doesn't move in the correct direction	H-bridge circuit fault	Replace the H-bridge circuit
Lift doesn't fully retract	Obstruction between the lift and base	Clear obstruction
Lift is leaning to one side	Support rods are under too much stress	Check all support rods are intact and correctly positioned.
Lift is jammed /Not smooth	Drive shaft has debris impacting it	First clean the driveshaft, then apply lubricant
RASPBERRY PI		
Black screen when connecting Raspberry Pi to visual display	Input signal from Raspberry Pi is not detected	Reboot Raspberry Pi with the display plugged in
Cannot connect Raspberry Pi to WiFi	Outside range of WiFi i.e. weak signal	Troubleshoot network
	Wireless network connection not enabled on Raspberry Pi	Go to "raspi-config" setting menu, turn on network connection
EV3		
ev3_client.py fails with connection error	Wrong IP address for connection between EV3 and Raspberry Pi	SSH into EV3 from the Raspberry Pi and update the server IP address to match the Raspberry Pi's IP address

If there's any problem you couldn't solve based on this user guide, please contact us at our website.

References

[Parotas(2019)] Parotas. Standard table and chair heights. *parotas.com*, 2019. URL `http://www.parotas.com/en/standard-table-chair-heights-guide/`.