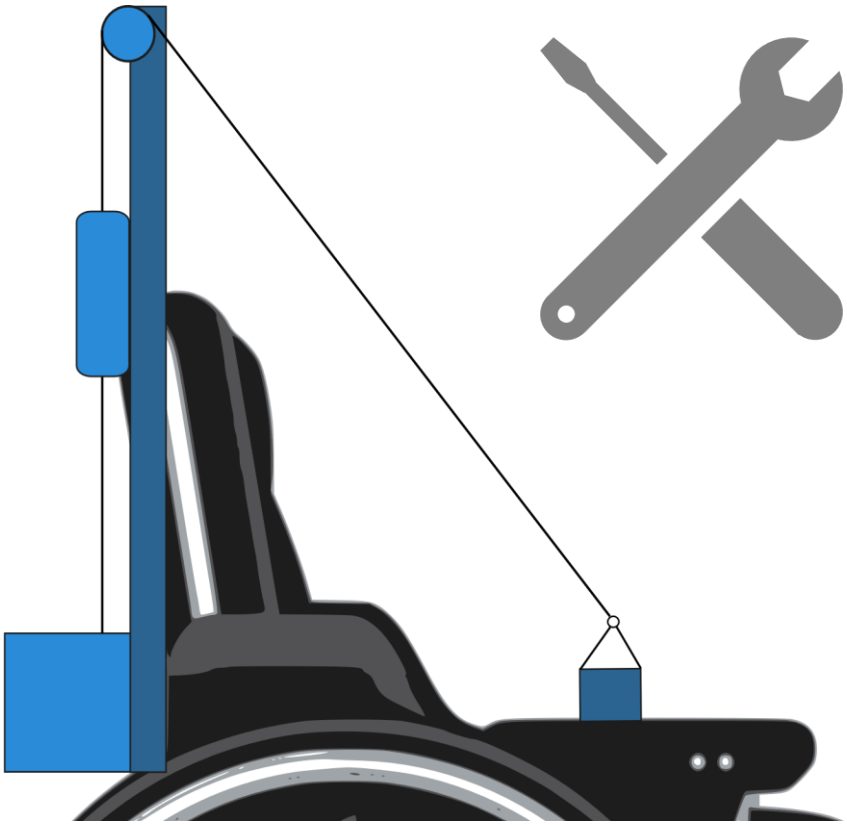
MiAssiSt

- Mike’s Assistive Strength -



Construction Manual

Preface

Within the scope of my master's thesis, I have met Mike. Mike was born with the neuromuscular disorder spinal muscular atrophy (SMA), which lead to a progressive decrease of his muscle strength over the years of his life. As his condition progressed to a point, where he lost function in all his limbs except the right arm and it became more and more exhausting for him to move said arm, he decided that he would need an assistive system which would support him in everyday activities such as eating, drinking or using computers.

Thus, together, we started developing the MiAssiSt – Mike's Assistive Strength. The MiAssiSt is a do-it-yourself device supporting elbow flexion and extension for users with decreased muscle strength in their upper arm. As passive and active compensation of the weight of the lower arm, the MiAssiSt supports the user in conducting various activities of daily living, giving the user parts of his independence back.

Mike currently uses the first version of his MiAssiSt on a daily basis at home. With his valuable feedback, we try to improve the MiAssiSt for further versions to be able to provide the optimal support not only for Mike but for anyone who might have similar needs as him. Thus, we decided to make our idea accessible and adaptable for everyone.

This manual guides you through manufacturing and customization of your own MiAssiSt. Please note that the MiAssiSt does not have a certificate. Thus, it is no medical device and manufacturing and usage is on your own risk.

If you have any feedback or possible ideas to further improve the MiAssiSt by yourself, please get in touch with us.

Best regards,

Jessica Gantenbein

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Contents

1. Introduction

The basic principle of the MiAssiSt is shown in the following Figure 1.

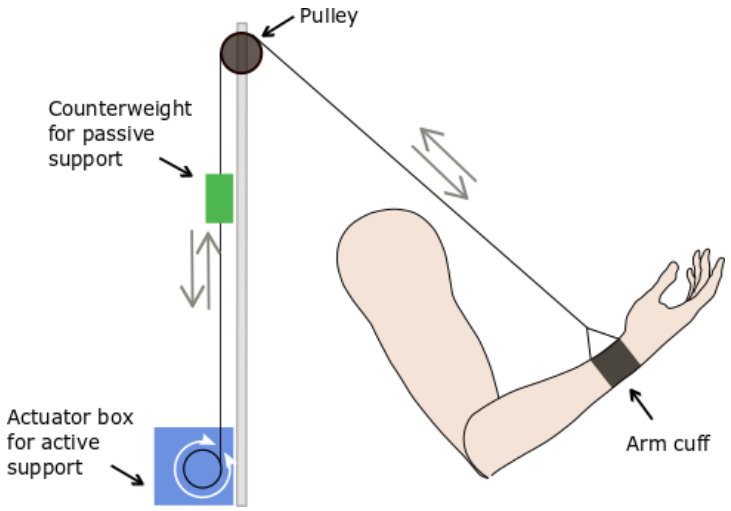

Figure 1: Schematic representation of the MiAssiSt including passive and active support components

1.1 Passive Support

The passive support consists of a counterweight, which steadily compensates a part of the weight of the lower arm. Thus, less muscle strength by the user is required to lift his lower arm. The weight of the counterweight is easily adjustable to the user's individual needs.

1.2 Active Support

The active support consists of a rotating actuator placed in the actuator box connected to a spool. If the command for the active upwards movement is given, the spool will be turned and the rope will be wound up. This pulls the connected counterweight downwards and thus the arm upwards. To move the arm back downwards, the rope will be unwound so that is it is not tensioned anymore and the counterweight may be pulled upwards.

If the MiAssiSt has lifted the arm to the maximum possible height, the movement will be stopped automatically as the counterweight then presses an emergency-stop placed on the top of the actuator box. In this position, only arm downwards movement may be initiated.

2. Safety Information

The MiAssiSt does not have a certificate!
Usage and manufacturing is on your own risk!

2.1 Usage

- The MiAssiSt should only be used as long as an other person remains within calling distance who may interfere in case of an emergency.
- The MiAssiSt is not completely waterproof and should therefore not be used in case of rain.
- Frequent manual checks of the functioning of the emergency-stop are recommended.
- Frequent manual checks of all ropes and knots are recommended. In case of signs of wear or tear, ropes and knots should be replaced.

2.2 Cables and Battery

- Moving, bending and straining of all cables should be avoided where possible.
- The battery is a rechargeable 7.2 V Nickel-metal hybrid battery. The battery should not be exposed to any kind of impacts.
- The battery should be connected as careful as possible. The cables to the connectors should be slightly supported during connection and disconnection.
- If one of the two cables slips out of the connector, it should be carefully put back in. If this is not possible, the active support is no longer useable and the blank metal end of the cable should be covered with insulating tape up until the repair.
- Conductive parts of two inversely polarized wires (e.g. the black and red cables of the battery) may never touch – risk of electrical shorts causing fire!
- If an electrical short of the battery happened, it should immediately be properly recycled and replaced.
- Further specific information concerning the correct and safe handling and charging of the battery are to be found on the user manual of the battery and its charger itself.

2.3 Soldering

- The tip of the soldering iron is very hot! Careful handling is required.
- The soldering iron should always be turned off when not in use.
- A useful guide to learn to solder safely and properly can be found here: https://www.makerspaces.com/how-to-solder/

3. Set-Up

3.1 Sub-Assemblies

The MiAssiSt consists of four sub-assemblies as shown in Figure 2.

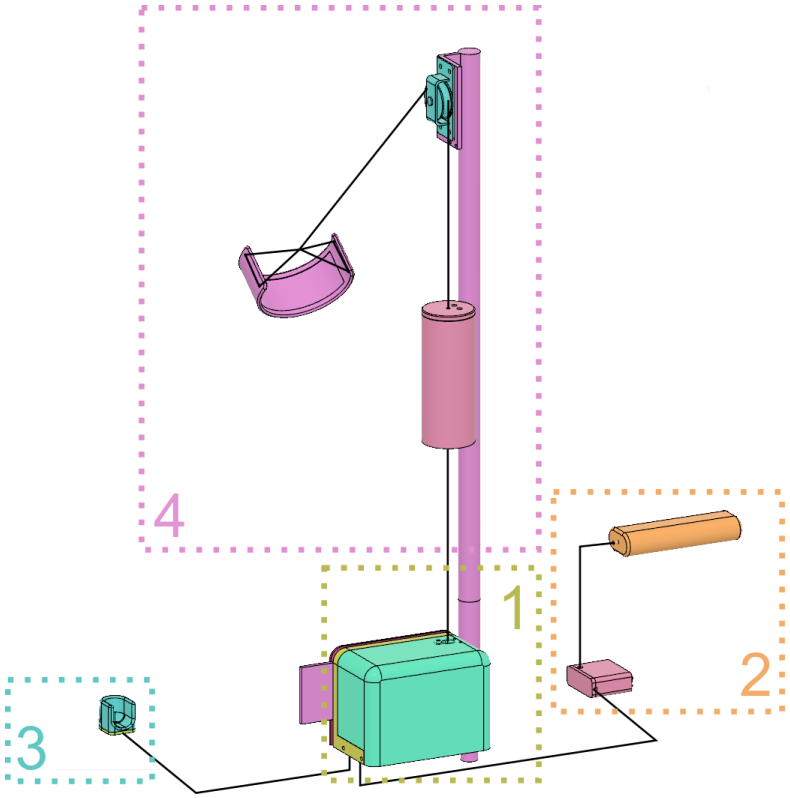

Figure 2: Basic Set-up consisting of four sub-assemblies: 1) Actuator box assembly, 2) power supply assembly 3) control interface assembly, 4) pole assembly

1) Actuator box assembly

The actuator box is the “heart” of the MiAssiSt. It consists of the actuator and the spool to wind up the rope as well as the majority of all the electronics and the emergency-switch all placed in a single box.

2) Power supply assembly

The power supply assembly consists of the rechargeable battery as well as a mechanical toggle switch to turn the MiAssiSt on and off. The power supply assembly is connected to the actuator box via an AUX stereo jack.

3) Control interface assembly

The control interface of the MiAssiSt is a sensor that registers the input commands by the user for activation of the actuator. It is connected to the actuator box via an AUX stereo jack.

4) Pole assembly

This assembly consists of the pole attached to the wheelchair, a pulley that redirects the direction of the rope connecting the arm cuff and the counterweight.

3.2 Placement on Wheelchair

The MiAssiSt is placed on the user's wheelchair as exemplarily shown in Figure 3.

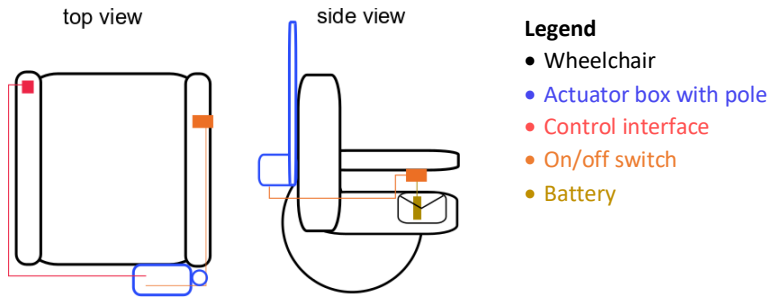

Figure 3: Exemplary placement of the MiAssiSts components on the user's wheelchair<

Please note that all the parts are designed for support of the right arm. For the left arm, the parts need to be mirrored accordingly.

Further, the connection of the pole and the box to the wheelchair is highly dependent on the wheelchair itself. Therefore, an individual solution has to be found.

3.3 List of Components

All components and tools needed to manufacture your own MiAssiSt are listed on the file "list-of-components_full.xlsx". The numbers after the components in the following manual refer to the numbers assigned in the file.

4. Preparation

4.1 Manufacturing Metallic Parts

To manufacture the metallic parts, solid metal working experience and equipment are necessary. If you do not have them, you should ask an experienced metal worker to manufacture them for you. For weight reasons, we decided to use aluminium for the parts, but any other metal should be fine as well.

4.2 Printing 3D Printed Parts

3D printing is a technique which allows quick and easy manufacturing of relatively complex structures. However, 3D printing requires a bit of practice and experience and the results may highly depend on the printer and the printer settings you are using.

If you have access to a 3D printer, please note that some printers are not able to print overhangs larger than a certain angle, usually around 45°. Some of the parts to be printed for the MiAssiSt do have such large overhangs. If your printer is not able to print them, you need to modify the models accordingly, e.g. by printing them in multiple pieces and glue them together afterwards as exemplary shown in Figure 4.

If you do now have access to a 3D printer, you can find a variety of 3D printing services online.

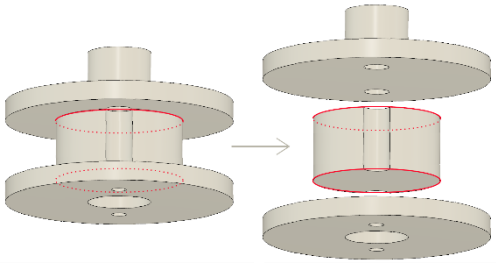

Figure 4: Example for cutting the spool model to avoid overhangs by printing in in three separate parts

4.3 Shopping Purchased Parts

The links attached in the components lists are mostly Swiss online shops. If you order from another country, we suggest to look for shops in your own country. If the exact same part is not available, usually other similar parts do work as well but do not forget to check the .step-files if all the sizes still fit and adjust them accordingly where necessary, i.e. increase the size of the hole if you want to use bigger screws. For some of the parts to be purchased, .step-files to scale are available.

4.4 Programming the Arduino

For the programming, you need your computer (4.04), your USB A-B cable (4.06) and the Arduino Uno (3.27).

1. Download the freeware Arduino IDE from https://www.arduino.cc/en/main/software
2. Open your preferred program “A_doubleclick.ino” or “B_singleclick.ino” in Arduino IDE. Their differences are explained in detail in the User Manual.
3. Plug in your Arduino to your computer using the USB A-B cable.
4. Go to “Tools > Board:” and choose “Arduino/Genuino Uno” as shown in Figure 5 left.
5. Go to “Tools > Port:” and choose “COM” as shown in Figure 5 middle. If multiple COMs are available, unplug the Arduino, check which COM-choice disappeared, plug it in again and choose the reappeared one.
6. Click on the upload button on the top left as shown in Figure 5 right.
7. If it says “Done uploading” on the bottom, your Arduino is all settled!

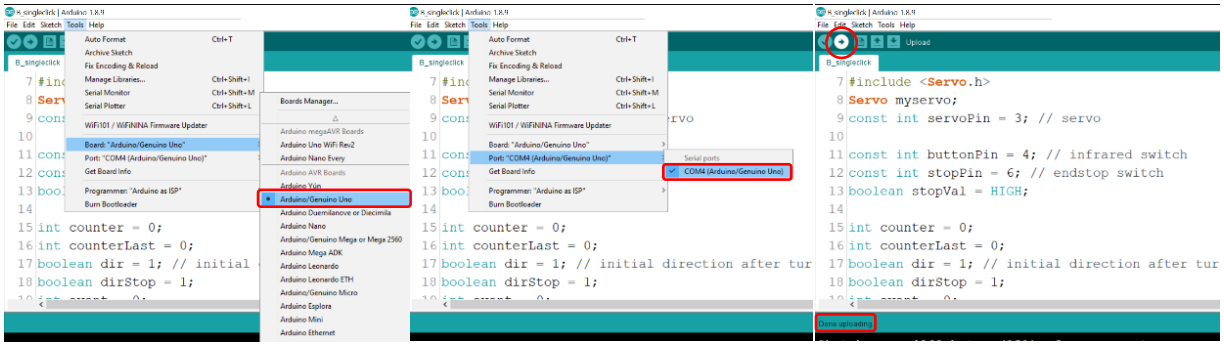

Figure 5: Programming the Arduino, left: Choosing "Board", middle: choosing "Port", right: uploading and uploading successful

5. Pre-Assembling

5.1 Actuator Box Assembly

For this assembly, the following components are needed:

Metallic:	1.02 / 1.03
3D printed:	2.01 / 2.02 / 2.03 / 2.04 / 2.05
Purchased:	3.02 (~1 m) / 3.03 / 3.04 / 3.05 (2) / 3.06 (5) / 3.08 (7) / 3.13 / 3.14 / 3.15 / 3.17 / 3.19 / 3.20 (1) / 3.27 / 3.28 / 3.29 / 3.30 / 3.31 / 3.41
Tools:	4.01 / 4.02 / 4.05

Assembling of electronic parts

1. Prepare all components
2. Solder the pin headers (3.15) onto the protoshield (3.28) as marked on Figure 6 so that it can be plugged directly onto the Arduino Uno (3.27).

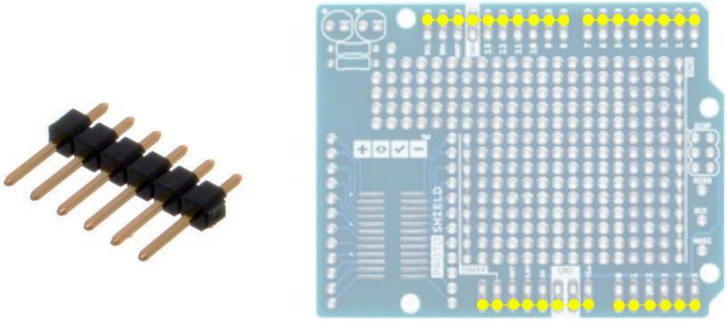

Figure 6: Left: Six pin headers (photo: commons.wikimedia.org), Right: Protoshield with the locations to solder the 32 pin headers marked in yellow.

3. Solder all the parts (linear voltage regulator (3.29), capacitor 0.15 µF (3.30), capacitor 22 µF (3.31) and various jumper wires female (3.13) and male (3.14)) onto the protoshield according to the following Figure 7. Make sure to solder the poles to the AUX stereo connector (3.17) and DC barrel connectors (3.19) correctly (i.e. centre positive, outer shell ground, and if available, signal in-between). Please note, that the actual solder points may be shifted arbitrarily on the protoshield, as long as the correct points stay connected.

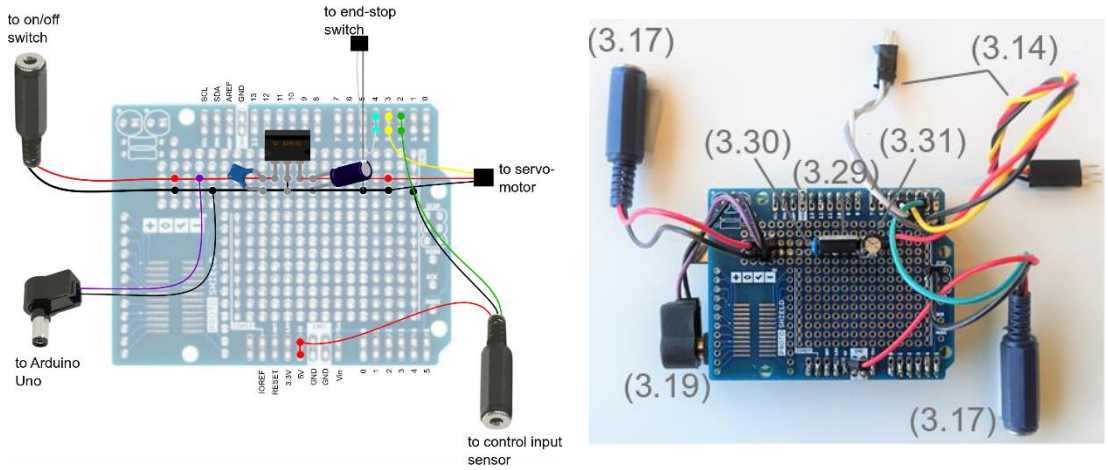

Figure 7: Left: Schematic protoshield with the locations to solder the electronic components and wires to and the loose cables and their respective connectors. Thick points mark the soldering locations. Right: Photo of actual soldered protoshield with numbers of used components.

4. Your protoshield is ready to be plugged onto the Arduino Uno as shown in Figure 8. Do not forget to plug the DC barrel connector (bottom left) into the DC-input connector of the Arduino.

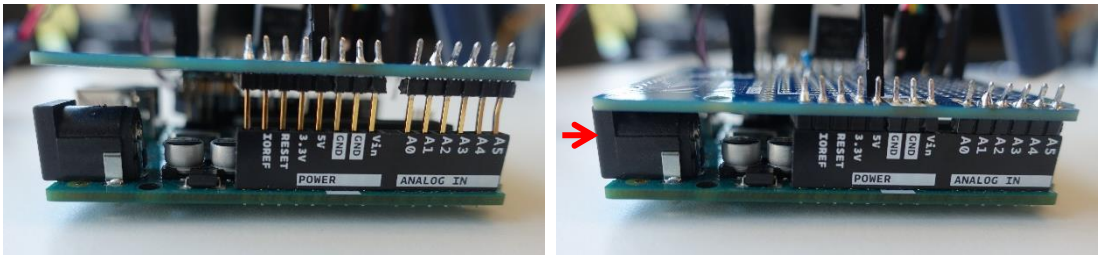

Figure 8: Left: Protoshield about to be plugged into the Arduino via the pin headers, right: Protoshield plugged into the Arduino. The DC barrel connector should be plugged into the input connector indicated by the red arrow.

Assembling of mechanical parts

The full assembly of the actuator box and the included components are shown in Figure 9.

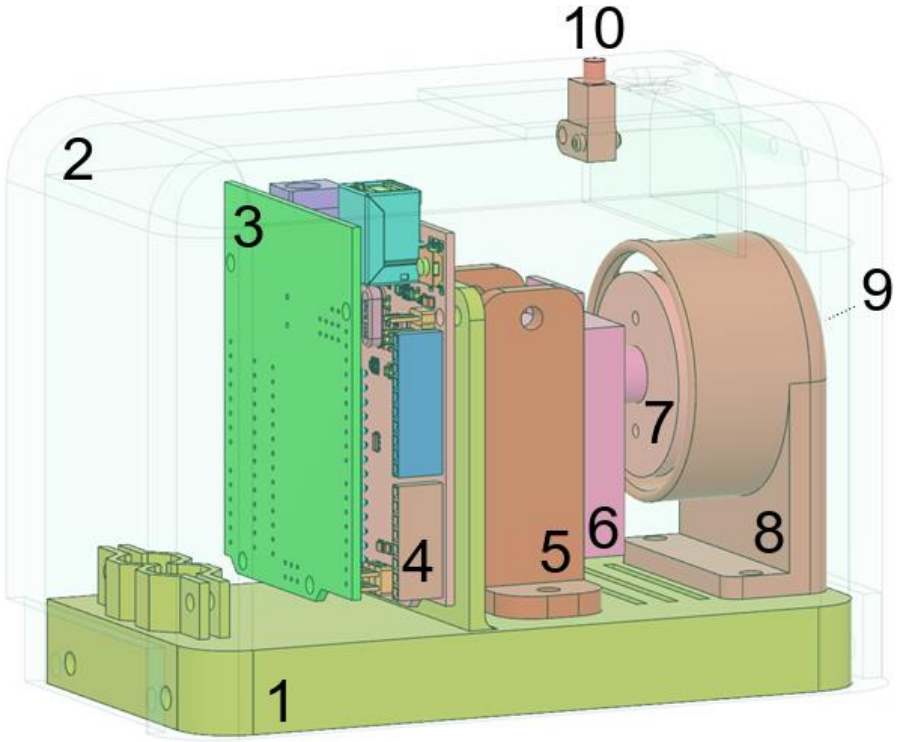

Figure 9: Assembly of actuator box. 1) box base, 2) box lid (transparent), 3) protoshield (wires and electrical components not shown), 4) Arduino Uno, 5) servo holder, 6) servo, 7) spool, 8) spool holder, 9) bearing (not visible inside spool holder), 10) end-stop switch

1. Prepare all components
2. Screw the spool holder (2.05) on the plastic attachment of the continuous rotation servo (3.03) using two M1.5x10mm screws (3.05). You may need to drill the holes from the plastic attachment a bit larger.
3. Fix the end of the rope (3.02) using one of the holes in the spool holder (2.03) and wind around 1m of rope around the spool. Attach a small carbine (3.20) at the end of the rope.
4. Clamp servo/spool into the servo holder (2.03) using a long M4x30mm screw (3.08) and make sure it sits very tight in there.
5. Place bearing (3.04) in the spool holder (2.05).

6. Press the front part of the spool into the inner ring of the bearing as shown in Figure 10. Guide the carbine through the hole of the spool holder.

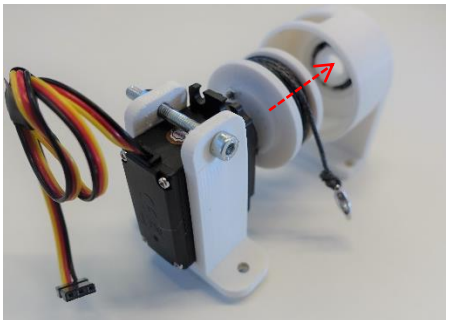

Figure 10: Servo and spool about to be pressed into the bearing placed in the spool holder. Arrow indicates direction of assembly.

7. Attach the whole assembly on the box floor (2.01) using four M4x30mm screws and nuts.
8. Fix the Arduino (without the protoshield) to the vertical wall using two M2x10mm screws and nuts (3.06).
9. Plug the protoshield into the Arduino.
10. Clamp the two AUX stereo connectors female in the hexagonal holder using two M2x10mm screws and nuts (3.06) and make sure they sit very tight in there and do not move if you plug a male connector in or out. Your assembly should now look similar to Figure 12.

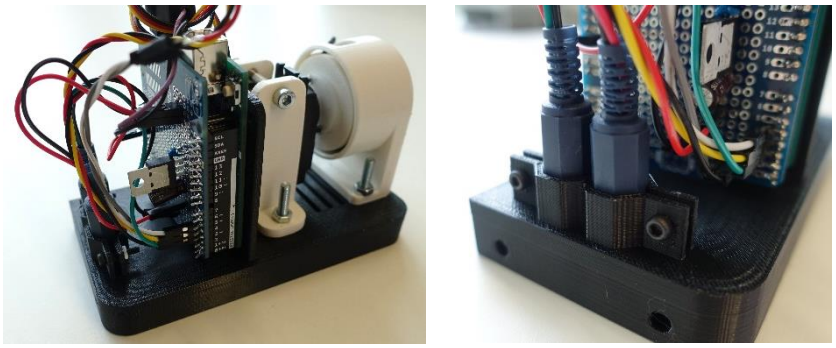

Figure 12: Actuator box assembly without lid (left) with detail on clamping of AUX female connectors (right).

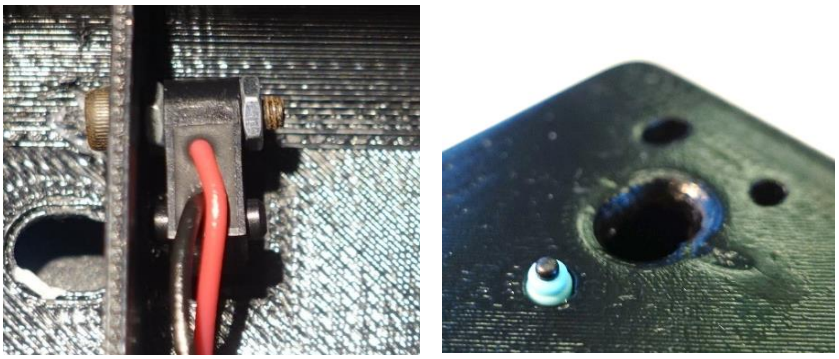

Figure 11: Fixation of the emergency-stop switch from inside (left) and outside (right) the actuator box.

11. Solder two jumper wire female (3.13) to the ends of the wires from the end-stop switch (2.23)
12. Fix the end-stop switch to the box lid (2.01) using one M2x10mm screw and two nuts (3.06) as shown on Figure 11, left. This might require a bit of patience and thin fingers… Make sure to guide the top of the switch through the hole in the lid appropriately so that it may be pressed from the outside as shown on Figure 11, right. Prevent the switch from wobbling using tape (3.41) if necessary.

13. Connect the cables of the servo and of the end-stop switch to the respective corresponding cables from the protoshield.
14. Place the box lid on the box floor assembly, guide the rope with the carbine from the spool through the hole in the lid and fix the lid using two M4x30mm screws and nuts (3.08) on the backside of the assembly. Make sure to fix the carbine somehow to avoid that it slips back into the box.
15. Your actuator box is ready!

Note: Optionally, for aesthetic reasons and to make the actuator box a bit more water repellent, we recommend to spray paint the box, lid (2.01).

5.2 Power Supply Assembly

For this assembly, the following components are needed:

Metallic:	none
3D printed:	2.06 / 2.07
Purchased:	3.07 (2) / 3.12 / 3.14 (2) / 3.16 / 3.18 (1) / 3.21 / 3.22 / 3.25 / 3.26 / 3.32 / 3.33
Tools:	4.01 / 4.02 / 4.05 / 4.08

Assembling

1. Prepare all components
2. Solder the 2-pole-cable (3.12), the 1-pole-wire (3.14), the switch (3.25), the LED (3.33) and the resistor (3.32) together according to the following scheme in Figure 13. Caution: LEDs are poled. Always solder the longer leg to the positive pole.

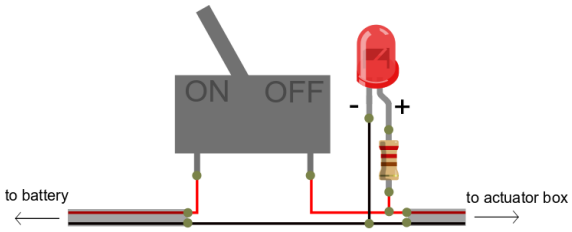

Figure 13: Soldering scheme for power supply assembly

3. Solder the Tamiya-connector female (3.16) to the two poles of the “to battery” cable according to the following Figure 14. Chose the length of the cable sufficiently long so that the battery connected to it may be placed in a backpack or pocket while the switch is placed under the armrest of the supported arm as shown in Figure 3.
4. Solder the AUX-jack male (3.18) to the two poles of the “to actuator box” cable according to the following Figure 15 (remember: center positive, outer shell ground). Chose the length of the cable sufficiently long so that the actuator box connected to it may be placed on the back of the wheelchair on the side of the supported arm as shown in Figure 3.

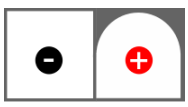

Figure 14: Correct soldering of poles on a Tamiya connector

Figure 15: Correct soldering of poles on an AUX-jack

5. Place switch and LED in the corresponding holes in the switch-holder lid (2.06), fix the switch using the switch cap (3.26) and close the assembly using the switch-holder base (2.07) using two M3x10mm screws (3.07).
6. Now your power supply assembly should look similar to Figure 16 and is ready to be connected to the battery and plugged into the actuator box!

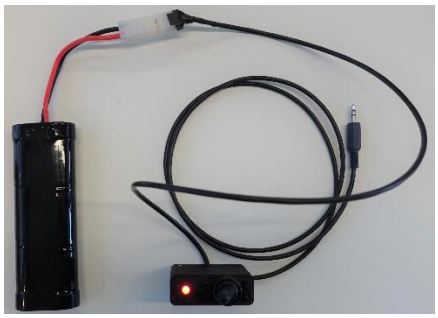

Figure 16: Finished power-supply assembly.

Optional check-up:

After having the AUX-jack plugged into the actuator box, you can check the voltage flow for all electric paths using a voltmeter (4.08). Paths coming from the battery should have around 7V, paths after the voltage regulator, going to and coming from the Arduino Uno and going to the servomotor should have around 5V.

5.3 Control Interface Assembly

For the control interface, a variety of different input controls with different advantages and disadvantages can be chosen, see Table 1 below. The control should be chosen depending on the user's capabilities and preferences.

Table 1: Example of different possible input devices with their respective advantages and disadvantages.

Input Device	Advantages	Disadvantages
IR-distance sensor	- No pressing force required - Small	- Sensitive to bright sunlight - Has to be placed in an open housing
Capacitive touch sensor	- No pressing force required - Can be placed in a closed housing	- Sensitive to other electric surroundings
Reed magnetic sensor	- No pressing force required - Can be placed in a closed housing - Not sensitive to surroundings	- Requires small magnet to be placed on fingertip
Push-button	- Not sensitive to surroundings	- Pressing force required

Since it is the most complicated one, in the following, the assembly for the IR-distance sensor is explained.

For this assembly, the following components are needed:

Metallic:	none
3D printed:	2.10 / 2.11 / 2.12 / 2.13
Purchased:	3.05 (2) / 3.06 (2) / 3.07 (2) / 3.10 / 3.11 / 3.18 (1) / 3.23
Tools:	4.01 / 4.02 / 4.05

Assembling

1. Carefully detach the infrared (IR) emitter/receiver from the ground plate of the sensor (3.23) . This can be done for example by bending it gently back and forth until the four connectors break.

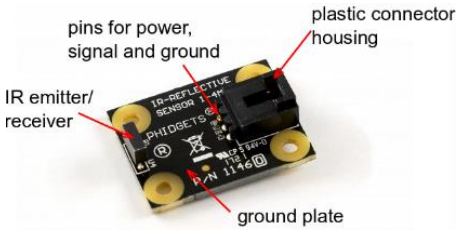

Figure 17: IR Reflective Sensor by Phidgets Inc. (photo: www.phidgets.com)

2. Use a four-pole cable (3.10) to reconnect the IR emitter/receiver to the ground plate. Be careful to resolder the four pins in the correct order back together as they were attached to the ground place – the two circles on the IR emitter/receiver should look outwards. The length of the cable should be long enough that the IR emitter/receiver can be placed below the user's index finger on the armrest and the ground plate somewhere safely below the armrest.
3. Pull the plastic housing for the connector gently from the power/signal/ground pins.
4. Solder a three-pole cable (3.11) to the three pins. The length of the cable should be long enough that the end of the cable may be plugged into the actuator box, see Figure 3.
5. Solder the end of the cable to an AUX connector male (3.18) (remember: centre positive, outer shell ground, signal in-between).
6. If the ground place now looks similar to Figure 18, place the plate between the sensorbox, lid (2.12) and the sensorbox, base (2.13) and fix them together using two M2x10mm (3.06) screws.

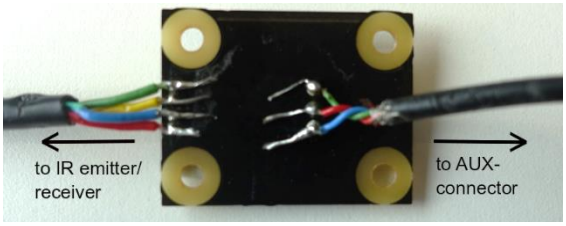

Figure 18: Ground place of IR sensor after soldering cables to IR emitter/receiver and to the AUX-connector

7. Place the IR emitter/receiver in the fingerpad, lid (2.10) so that the two circles can be seen from the top.
8. Close the fingerpad using the fingerpad, base (2.11) and fix it by screwing in two M1.5x10mm (3.05) screws from below. The IR emitter/receiver should now not be able to move inside the fingerpad anymore.

9. Now your control interface assembly should look similar to Figure 19 and is ready to be plugged into the actuator box!

Figure 19: Finished control interface assembly

Note: Most of the other sensors available consist only of three (power, ground, signal) or even only two (power, ground) pins. These can be connected analogously to step 5 to an AUX connector male and plugged into the actuator box without any further adaptions.

5.4 Pole Assembly

For this assembly, the following components are needed:

Metallic:	1.01 / 1.04
3D printed:	2.08 / 2.08 / 2.14
Purchased:	3.01 / 3.02 (~2m) / 3.08 (4) / 3.20 (3) / 3.36 / 3.38 / 3.39 / 3.37 / 3.40
Tools:	4.01 / 4.03 / 4.05

Assembling

1. Prepare all components.
2. Attach pulley (3.01) to pole (1.01) using four M4x30mm screws and nuts (3.08).
3. Put the pole into the connection to the wheelchair (1.04) and secure it with the cotter (3.36) through the hole.
4. Guide ropes (3.02) through the holes in the arm cuff (2.14) and place a ring or a carbine (3.20) in the middle.
5. Sew a comfortable padded cushion ~size 130mmx40mm out of the breathable fabric (3.38) and stuff it with the padding material (3.40).
6. Attach the cushion in the arm cuff (2.14) with Velcro (3.39). Now your arm cuff should look similar to Figure 20.

Figure 20: Finished armcuff with padded cushion

7. Prepare a rope of length around 150cm with a small carbine on both ends. Make sure that the knots are loose enough that the length of the rope may be adapted according to the user's needs (as explained in the User Manual) afterwards.
8. Limit the elongation of the spring (3.37) as shown in Figure 21. The elongated spring must be shorter than the total height of the counterweight.

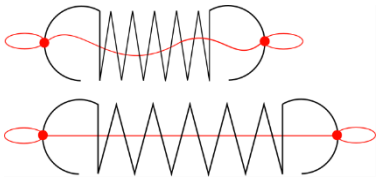

Figure 21: Limiting the elongation of a spring by guiding a rope with the desired maximum spring length inside the spring and fixing it on both ends.

6. Final Assembling

For the final assembly, the following components are needed in addition to the four previously assembled sub-assemblies.

Metallic:	1.02 / 1.03
3D printed:	none
Purchased:	3.09 (4) / 3.08 (4) / 3.30 (1) / 3.34 / 3.35
Tools:	4.05

Assembling

1. Attach the pole/connection to wheelchair assembly to the wheelchair. For that, an individual solution suiting the user's wheelchair has to be found.
2. Stick four M6x30mm screws (3.09) through the holes of the fixation front (1.02). Then place the actuator box in the fixation and fix it using two M4x30mm screws and nuts on each side.
3. Place the fixation/box assembly in front of the connection to the wheelchair (1.04), place the fixation of box, back (1.03) behind the connection to wheelchair through the four screws and fix it using four 6mm nuts.
4. Connect the spring to the rope coming from the actuator box using the carbine already attached to the rope.
5. Guide the spring through the large hole of the counterweight.
6. Fill the counterweight with lead granule (3.35).
7. Guide loop at the top of the spring through the hole in the lid of the counterweight and secure it using a small ring or carbine (3.20)
8. Close the counterweight by turning the lid.
9. Attach the prepared rope with the carbines to the counterweight, guide it along the pulley and attach the carbine on the other end to the small ring at the arm cuff. Caution: If the arm is not placed in the arm cuff, place the counterweight carefully on the actuator box instead of letting it fall on it.
10. Guide the wire strings (3.34) through the two holes on the left side of the actuator box (if you use guitar strings, you can use the small knobs on one end to avoid them slipping out of the hole. Otherwise you need to fix the strings by yourself). Afterwards, guide them through the two holes in the counterweight and attach them on the top of the pole. These strings prevent the counterweight from tangling around.

11. Plug in the AUX-jack of power supply assembly to the actuator box, guide the cable along the armrest, fix it using cable ties or tape and place the on/off switch below the arm rest using Velcro or tape.
12. Plug in AUX-jack of control interface assembly to the actuator box, guide the cable along the back of the wheelchair and the armrest of the unsupported arm and place the sensor on the arm rest at the approximate position of the user's index finger using Velcro or tape.
13. Plug in the battery, switch on the on/off switch and your MiAssiSt is ready to use!

Figure 22: MiAssiSt mounted to the wheelchair of a user