Nermo Robot

User Manual

Peer Lucas

This Manual and the Robot resources are available free of charge from:
https://github.com/Luchta/nermo_robot (Hardware)
https://github.com/Luchta/nermo_code (Code)
https://github.com/Luchta/nermo_simulation (Simulation)

Abstract

This manual serves to build, assamble and use the final version of the Neurorobotic mouse robot, also called Nermo. This biomimetic robot is modular and low-cost; it was created to mimic the locomotion of a rodents, and has the size of a common rat (Rattus Norvegicus). The robot is untethered, easy to use and simple to produce; it thus can be used as a universal research platform. It is based on tendon-driven actuation, which enables the implementation of a compliant leg and body design and thus enables adaptive and dynamic walking motions. Small biomimetic robots can be useful for behavioural/social studies in combination with animals, or for investigating new, efficient types of locomotion for exploration systems. Combined with digital twins, they are a useful tool to reduce the reality gap between simulation and the real world.

Key words

Rodent; mouse; rat; robot; locomotion; biomimetic; tendon-driven actuation; Nermo.

Table of Contents

List of Tables

List of Figures

1. Introduction

The present report details the evolution of the so-called Neurorobotic Mouse robot, and presents the main features of its latest release. The development of that robot was initiated in 2018 [1] with the view to become a general-purpose research robot for roboticists and neuroscientists alike. Over the last two years, four main successive versions [2] were built before finally obtaining the final version described herein. The minimal set of features for such a robot to be useful to all intended users [2] are:

- Flexible and functional backbones.
- Biologically relevant limbs with a small number of parts (for ease for build).
- A functional tail (for facilitating balance and locomotion).
- A sensory system sufficient to provide the robot with capabilities for autonomous navigation and decision-making.
- Tendon-driven actuation that mimics the biological musculoskeletal system of a rodent.

Additionally, the perquisites for this project where to create a low-cost and modular robot, in order to facilitate uptake of the device in the research community. These features were already realized with the last version of this robot [2]. The Final version presented herein features multiple improvements over previous iterations, especially ease of assembly and robustness to allow for a wider user group. Additionally, we created a digital twin of the robot (i.e. a simulated model, reproducing the characteristics of the real one with as much fidelity as possible) within the Neurorobotics Platform (NRP).

2. Parts List

Category	Item	Description	Quantity
Electronics			
	Raspberry Pi Zero W	Main Computer	1
	Micro SD memory card	Storage for RasPi	1
	Akku-Pack, Li-Polymer, 7,4 V 1000 mAh, 2, 25 C	Battery	1
	Nose Touch Button	Nose Touch Button	1
	1.0mm 1.0 SH Micro JST with 15cm Wire	Cable to connect Servos	17
	Cable to connect leg sensor PCB	Cable to connect leg sensor PCB	4
	0-200g Thin Film Pressure Sensor	Foot Pressure Sensor	4
	Micro USB Hub	USB Hub for Cameras	1
	U1-MWD	Camera in Head	2
	Modified PowerHD HD-DSM44	Motors	13
	Spine Adapter Board	Power and Motor control	2
	Leg Sensor Board	Angle and Pressure sensor	2
	4 Hole Wiring Board	Wiring Harness	2
	5 Hole Wiring Board	Wiring Harness	1
Mechanics			
	M2x8	Head Tilt Axis	1
	M2x6	Camera holder	1
	M2x14	Tail Mount	1
	M2 Stop-nut	Tail Mount	1
	M1x4	Leg-Wire Fixes	20
	M1*3	Leg-Wire Fixes	10
	M1x8	Hip Fix	8
	Magnet 4x4x4 mm	Leg Sensor Magnet	8
	M2,5*6,5	Distance holder for RasPi	4
	India rubber tape self-adhesive	Feet covering	1
	Perlon thread ø0,3 mm length 50 m	Tendons	1
3D Prints			22
	Body	Main Body of the Mouse	1
	Body Coil	Small Coils for Tendons	2
	Body Solarplexus	Holder for Battery and Raspi	1
	Head	Robot Head	1
	Head Camera mount	mount for all head components	1
	Head Neck	Connection Head-Body	1
	Hip	Servo Mount for all Legs	4
	Leg Coil	Coils for Leg tendons	4
	Leg Fore Left	Left Foreleg	1
	Leg Fore Right	Right Foreleg	1
	Leg Hind Left	Left Hindleg	1
	Leg Hind Right	Right Hindleg	1
	Leg Hind Linkage	Linkage for Hindlegs	2
	Tail	Tail	1

2.1 Custom Parts and Reusables

The Servo motors for this robot will have to be modified according to the servo modification manual in this repository. The parts needed for the modification are the following Table 1.

Item	Description	Quantity
PowerHD HD-DSM44	Servo	13
M1x12	Attach servo PCB	26
Custom servo PCB	New control board	13
Magnet 2x2x2 mm	Magnet for Hall sensor	13
Servo magnet holder	3D printed magnet holder	13

Table 1. List of parts for the 13 modified servos.

Additionally. some parts come with the original PowerHD HD-DSM44 servos, that will be used in the build as listed in Table 2.

Item	Description	Quantity
Servo Horn Cross	All Coils	6
Servo Horn Lever	Legs and Neck	5
Servo Horn Bar	Neck and Tail	2
Servo Horn Screw	Mount all Horns 1.6x3	13
Attachment Screw	Mount all Servos wood screw 1.6x6 (DIN 7981)	26

Table 2. All additional parts needed from the original PowerHD HD-DSM44 Servo packages.

3. Preparations

There are some preparations to be taken before the robot can be assembled.

3.1 Electronics

Additionally to the Servo PCBs there are two types of PCBs that will have to be assembled before the robot can be build. Those are the Spine Adapter Board and the Leg Sensor Board. For both boards the eagle files and assembly manuals can be found in the folder "/Electronics/Eagle/"

3.1.1 Servos

Before starting with the Robot's assembly, make sure that you have 13 assembled servos. The Manual on how to assemble the custom servos can be found in the same directory as this manual (Servo_Assembly.pdf) Figure 1 shows a overview of the assembly process.

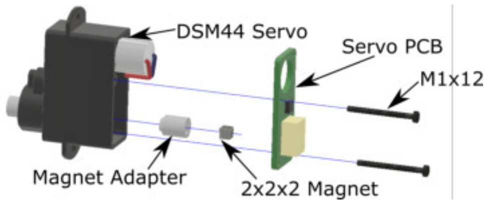


Fig. 1. Assembly of the custom Servos

3.1.2 Spine Adapter Board

The Spine Adapter board goes on top of the Raspberry Pi Zero and handles communication and power distribution in the robot. Additionally to the PCB there are some off the shelf parts, that are added to the board as shown in Figure 2.

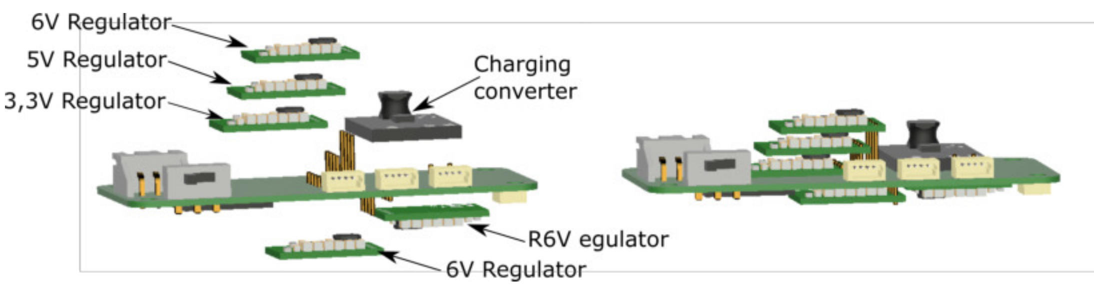


Fig. 2. Spine assembly board with all regulator and adapter boards.

3.1.3 Leg Sensor Board

The leg sensor boards have a hall sensor to measure the knee/elbow angles as well as a ADC to measure the ground pressure with the pressure sensors. To have less work later on you can solder wires already to the according pads (Figure 3).

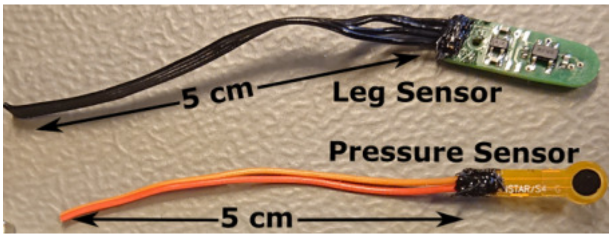


Fig. 3. Leg and pressure sensor prepared with wire.

3.1.4 USB Hub

To address the cameras in the Head, we used a simple USB-Hub. This Hub can be bought from Amazon or anywhere else. We only need the core pcb as shown in Figure 4. After Disassembly, the cameras and a USB cable can be soldered to the USB Hub as shown in Figure 5.

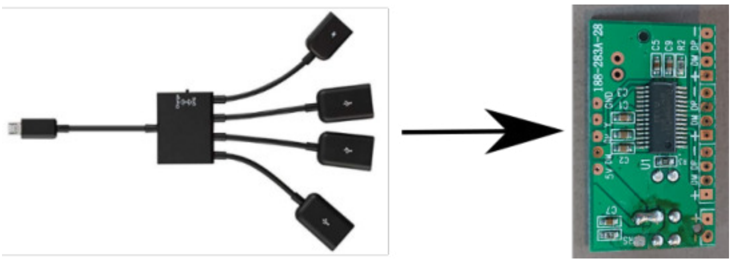


Fig. 4. Disassembly of the USB Hub.

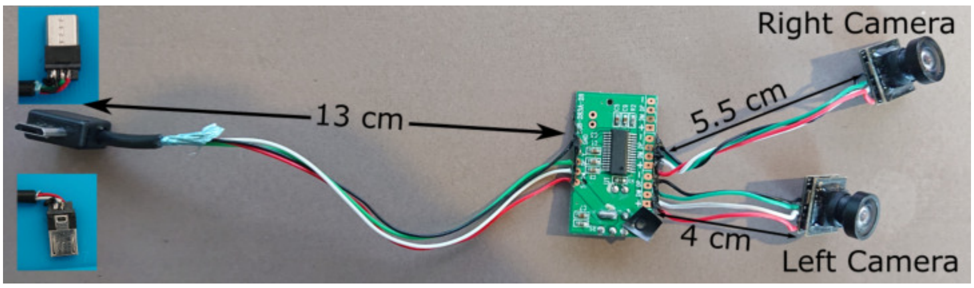


Fig. 5. Assembly of the USB Hub with the cameras.

3.1.5 Wire Harness

The following three wiring harnesses have to be build according to the specification in Figure 6

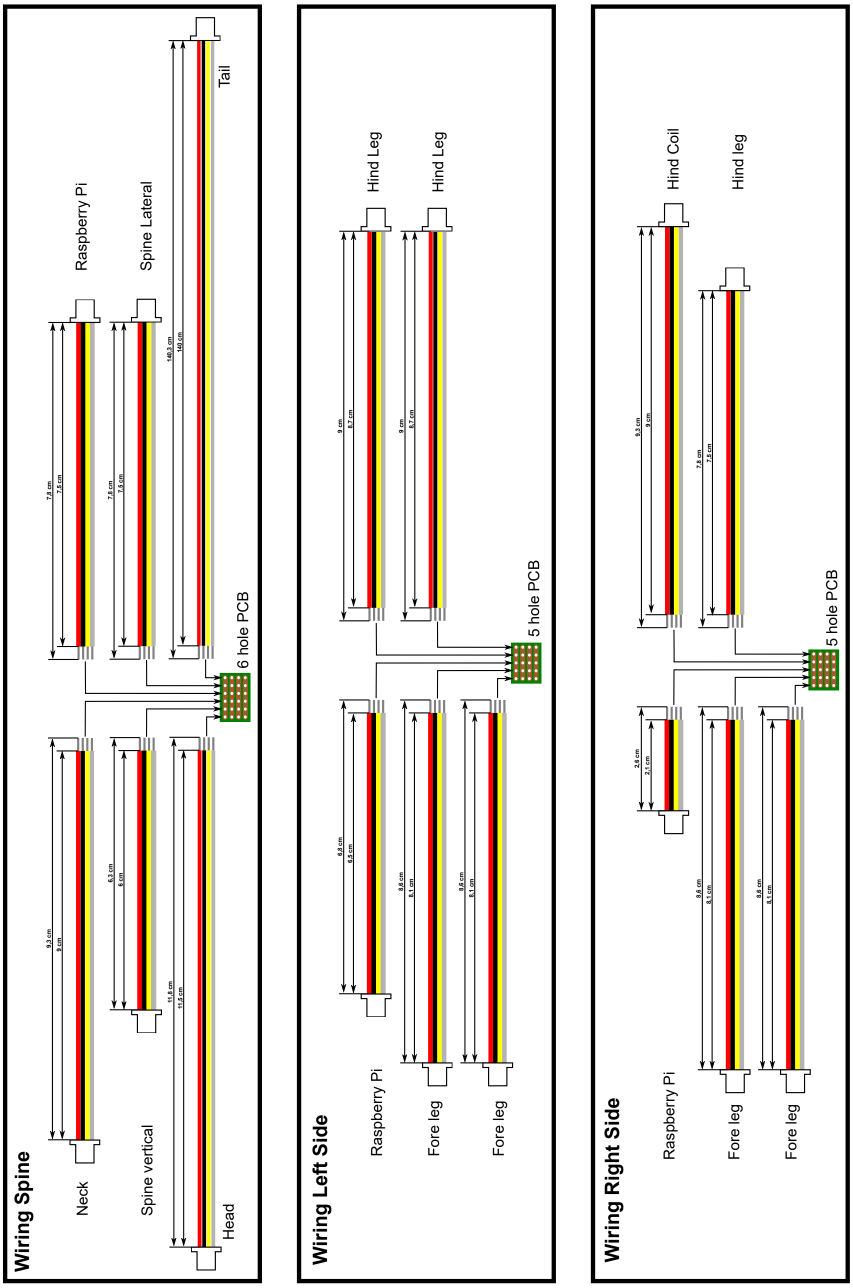


Fig. 6. Wire harness for connecting the 13 servos to the Spine Adapter Board.

3.2 Reworking printing parts

In order to be able to insert the wires to actuate the spine and tail, you will have to ensure, that the pathways are clear. The pathways are usually blocked slightly by residue of the Nylon powder used for 3D printing. This is most easily achieved by pushing a wire or a needle through the entire length of the respective pathway.
There are 5 Pathways to be cleared, three in the Body of the robot (Figure 7) and two in the Tail (Figure 8).

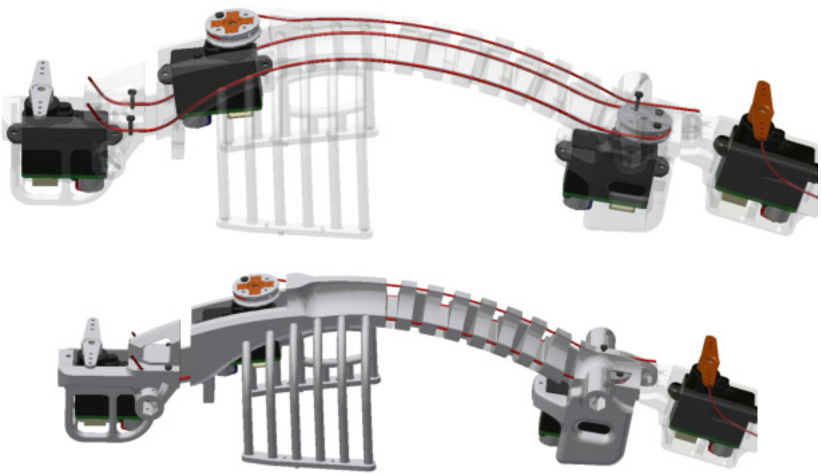


Fig. 7. Detail view of the wire pathways in the body of the robot in red. The pathways are symmetrical. Top: transparent body, Bottom: Solid body

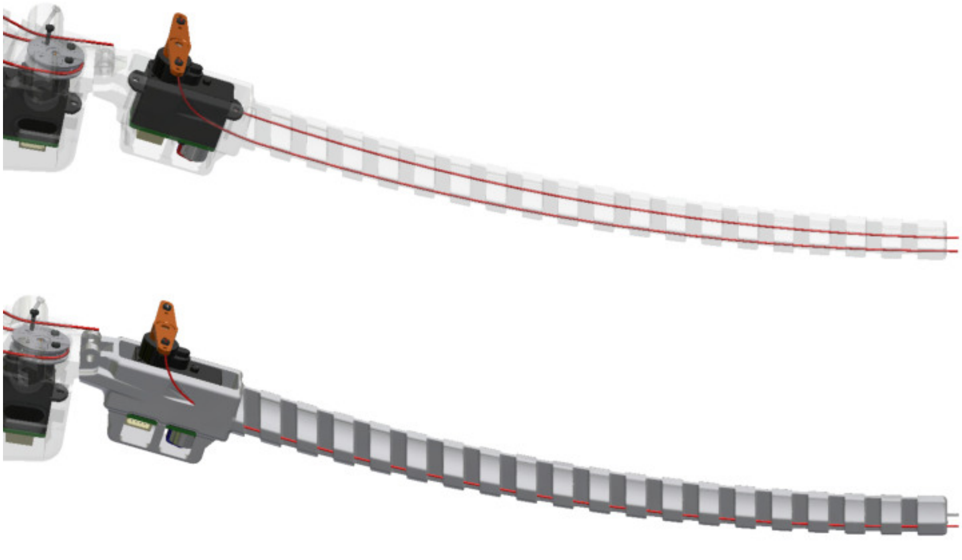


Fig. 8. Detail view of the wire pathways in the tail of the robot in red. The pathways are symmetrical. Top: transparent body, Bottom: Solid body

3.3 Coils

To attach the tendon coils to the servos, servo horns have to be attached to the 3D printed parts. This is best achieved by using Super glue, please ensure that the servo horns are fitted fully into the coils.

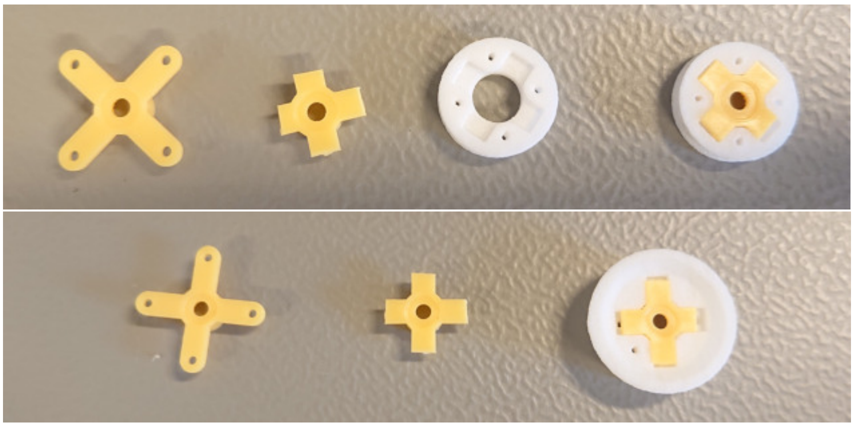


Fig. 9. Assembly of the tendon coils. Top: Body coil, Bottom: Leg coil

4. Components Assembly

The Robot can be separated into multiple Modules as shown in Figure 10. These modules will be assembled each on their own, until the full robot can be completed.

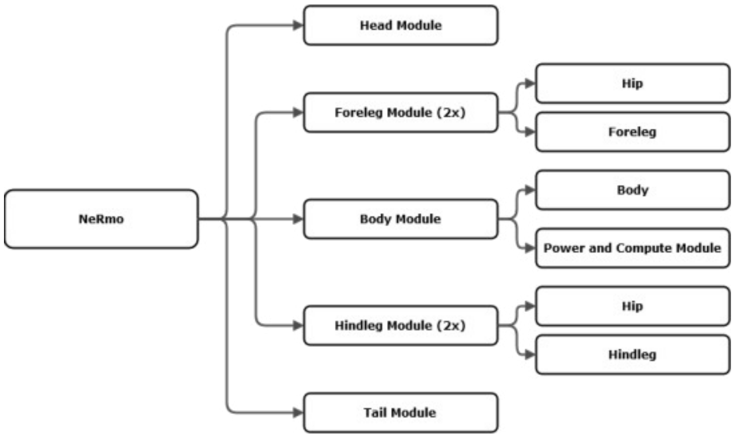


Fig. 10. NeRmo Module tree.

The modules can be seen in Figure 11 labelled on the actual Robot.

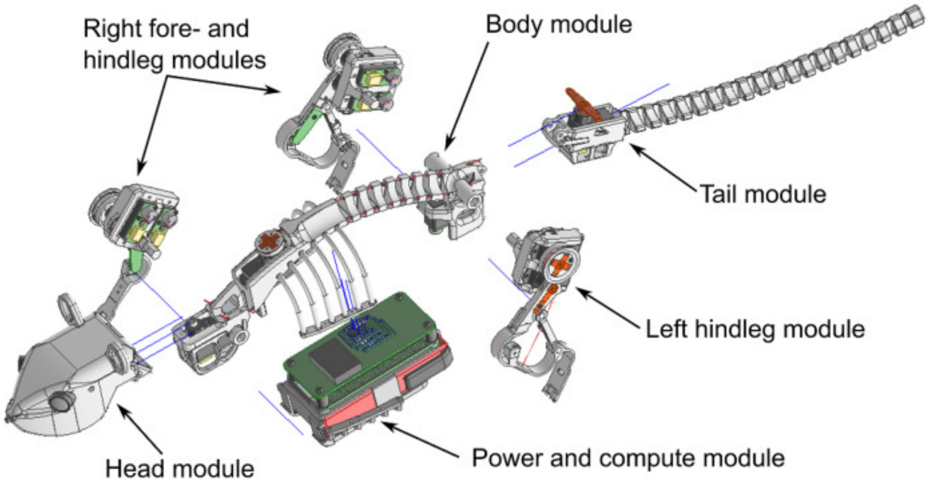


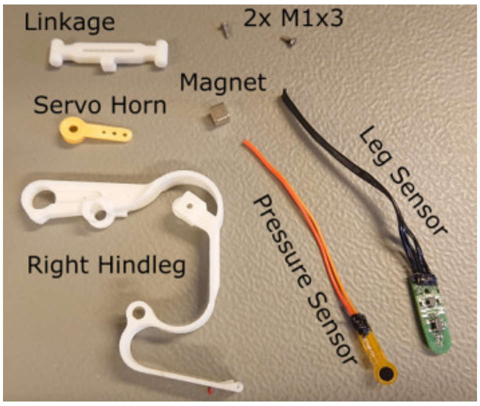
Fig. 11. Exploded view of the Robot, without the left foreleg.

For this manual, we will start with the Leg modules and work ourselves on to the full robot.

4.1 Hindleg

Needed Parts:

Item	Quantity
Leg Hind Left/Right (3D-Print)	1
Leg Hind Linkage (3D-Print)	1
M1x4 (Screw)	2
Servo Horn (Servo Parts)	1
Leg Sensor PCB with Wire	1
Pressure Sensor PCB with Wire	1
4x4x4 mm Magnet	1
small piece rubber tape	1



The process is the same for the left and the right Hindleg. All mounting holes are included in the 3D print, you might have to clean up the holes but you will not need to drill new holes for mounting. If you drill new holes you are placing the component wrong.

A First screw the Servo Horn in place.

B Push the Magnet into the provided Space in the Knee. WARNING! Make sure, that the separation line of the magnet poles is as indicated on the picture or the sensor will not work.

C Screw the Leg Sensor in the provided place on the other side of the Leg. Make sure that the Hall sensor is facing the Magnet.

C,D Thread the Pressure sensor cables through the hole in the foot (1), the guide on the ankle (2) and the guide on the Linkage (3) up to the Leg Sensor.

E Solder the pressure Sensor to the Leg sensor and add the rubber tape to the sole of the Foot.

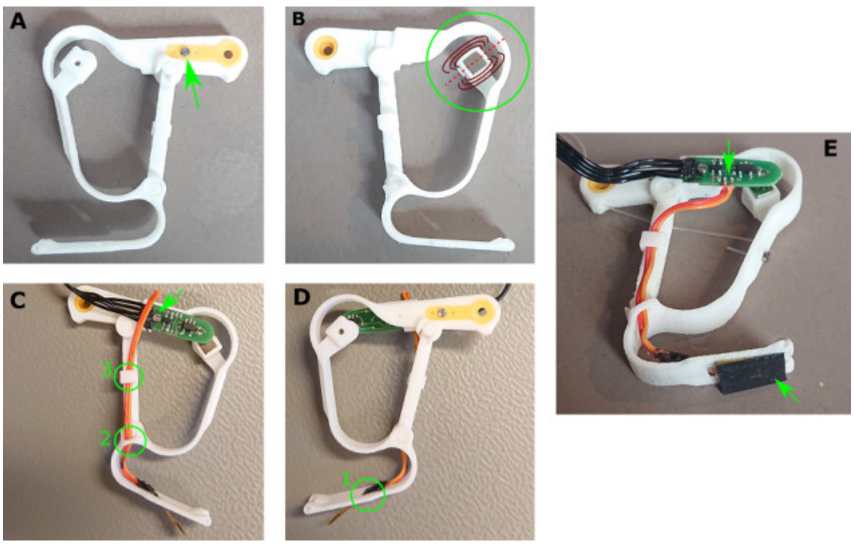


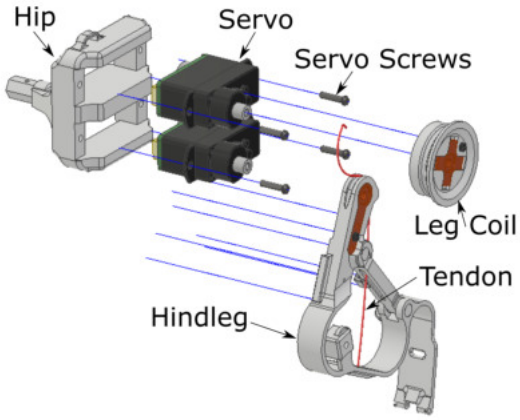
Fig. 12. Assembly Process for the Hindlegs.

4.2 Hindleg Module

The Hindleg Module combines the Hindleg with the Hip, the Servos and the Coil for the Leg Tendon. The Stringing of the Tendons itself will be handled in its own section later on.

Needed Parts:

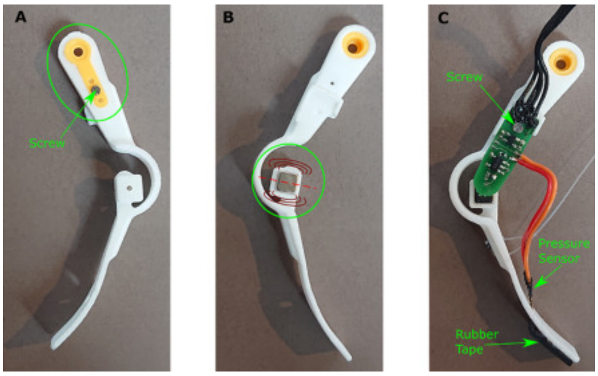
Item	Quantity
Hindleg Left/Right	1
Hip (3D-Print)	1
Leg Coil (3D-Print)	1
Servo Horn Cross (Servo Parts)	1
Servos (ID 0)	1
Servos (ID 1)	1
Servo mount screws (Servo Parts)	4



4.3 Foreleg

Needed Parts:

Item	Quantity
Leg Fore Left/Right (3D-Print)	1
M1x4 (Screw)	2
Servo Horn (Servo Parts)	1
Leg Sensor PCB with Wire	1
Pressure Sensor PCB with Wire	1
4x4x4 mm Magnet	1
small piece rubber tape	1



The process is the same for the left and the right Foreleg. All mounting holes are included in the 3D print, you might have to clean up the holes but you will not need to drill new holes for mounting. If you drill new holes you are placing the component wrong.

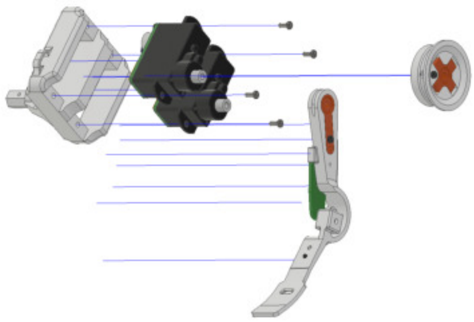
- A First screw the Servo Horn in place.
- B Push the Magnet into the provided Space in the Knee. WARNING! Make sure, that the separation line of the magnet poles is as indicated on the picture or the sensor will not work.
- C Screw the Leg Sensor in the provided place on the other side of the Leg. Make sure that the Hall sensor is facing the Magnet.
- C Thread the Pressure sensor cables through the hole in the foot.
- C Solder the pressure Sensor to the Leg sensor and add the rubber tape to the sole of the Foot.

4.4 Foreleg Module

The Foreleg Module combines the Foreleg with the Hip, the Servos and the Coil for the Leg Tendon. The Stringing of the Tendons itself will be handled in its own section later on.

Needed Parts:

Item	Quantity
Foreleg Left/Right	1
Hip (3D-Print)	1
Leg Coil (3D-Print)	1
Servos (ID 2)	1
Servos (ID 3)	1
Servo-horn Cross (Servo Parts)	1
Servo mount screws (Servo Parts)	4



4.5 Soldering Leg Modules

The lead wires to the leg sensor board of all leg modules have to be soldered to the servo, closest to the leg. The schematic and the resulting connection is shown in Figure 13. Make sure to thread the cables through the guide on the hip to avoid any stress on the soldering connections during motions. You can also fix the cables to the PCBs with silicon or glue.

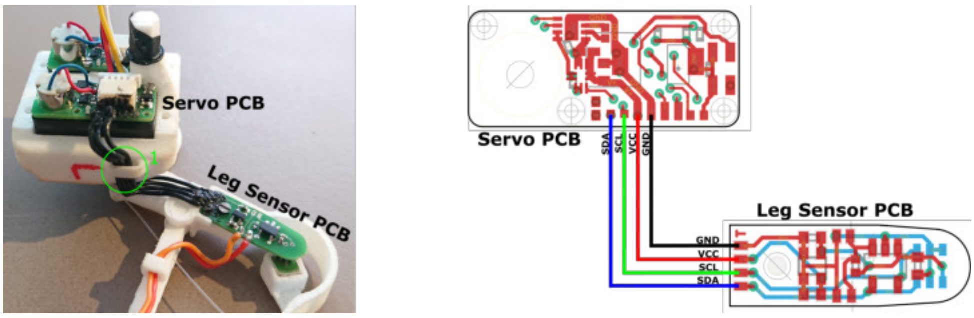


Fig. 13. Soldering of the leg modules with schematic.

4.6 Body Module

Item	Quantity
Body (3D-Print)	1
Body coil (Preparations)	2
Servo (ID 0,1,3)	3
M1x3 (Screw)	3
M1x4 (Screw)	3
Servo mount screw (Servo Part)	6
Servo-horn bar (Servo Part)	1

The Body module is the base structure to which every module will be attached. It houses the actuators for the Neck, the stretching of and the left/right movement of the spine. The Parts are shown in Figure 14. The Later Flex Servo can not be inserted directly, but has to be slided in from the front before moving it upwards in the final resting position as shown in Figure 15.

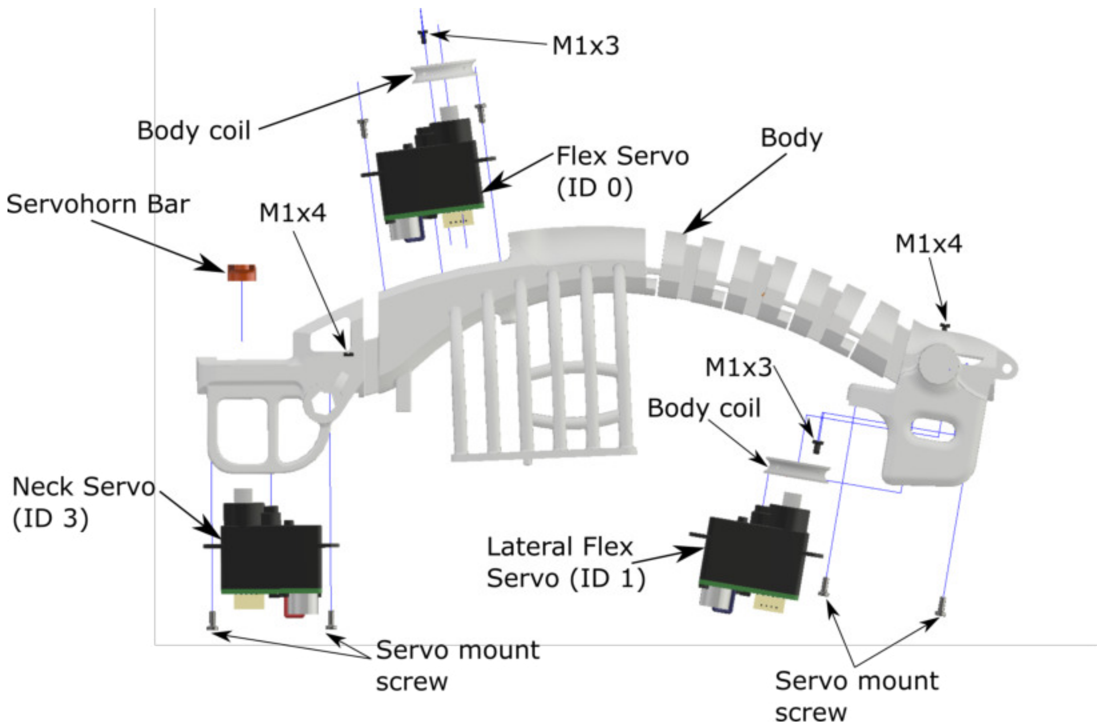


Fig. 14. Assembly of the Body module.

Fig. 15. Assembled Body module with transparent Body.

4.7 Power and Compute Module

Item	Quantity
Body Solarplexus (3D-Print)	1
Spine Adapter board	1
Raspberry Pi Zero WH	1
M2.5x4 (Screw)	4
M2.5x6.5 Distancer	4
1000 mAh 7.4 V Battery	1
Wireless charging coil	1
Epoxy glue	1

If you want to have the wireless charging feature for the robot, you will have to attach the charging coil to the Solarplexus as shown in Figure 16. First insert the Charging Board into the slot at the front of the Solarplexus (A), then you can bend the coil on to fit into the bottom of the Solarplexus and glue it in place with the Epoxy (B). Finally add the Protective shield that comes with the charger into the battery compartment.

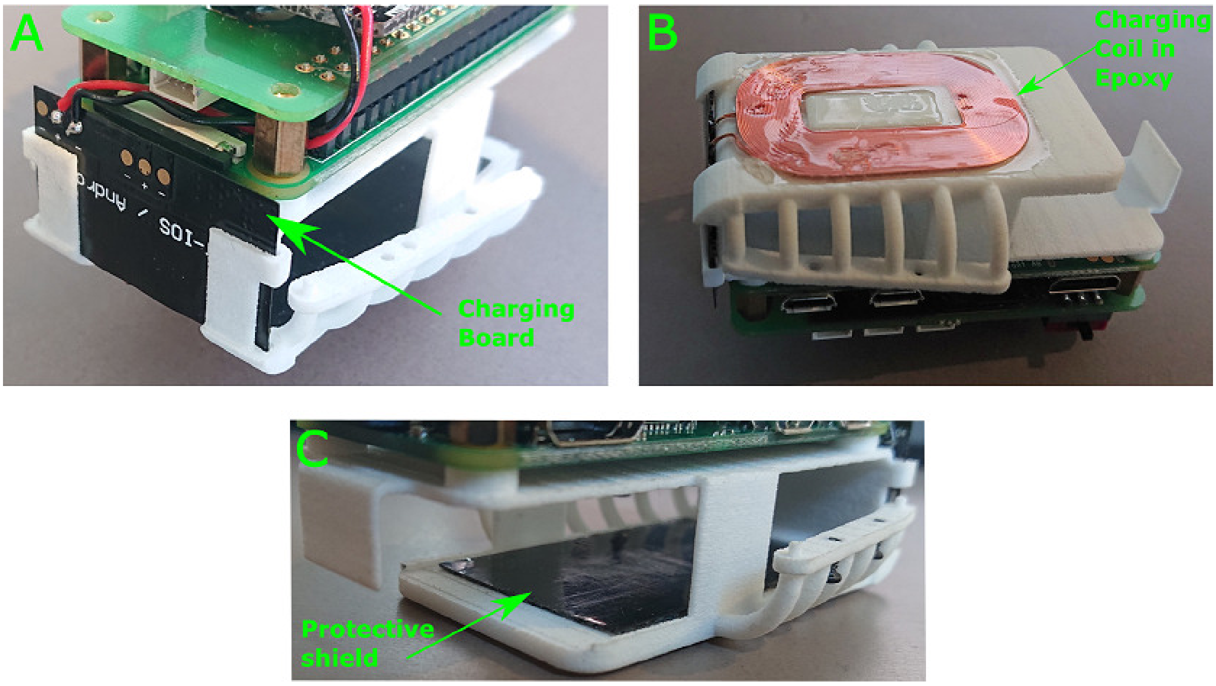


Fig. 16. Assembly of the charging coil to the Power and Compute Module.

Then you can attach the Raspberry Pi and the Spine Adapter board on top of the Solarplexus using the distancers and the screws as shown in Figure 17. Finally to attach the charger to the Spine adapter board, solder a wire from the charging board to the converter board on the Spine Adapter board as shown in Figure 18.

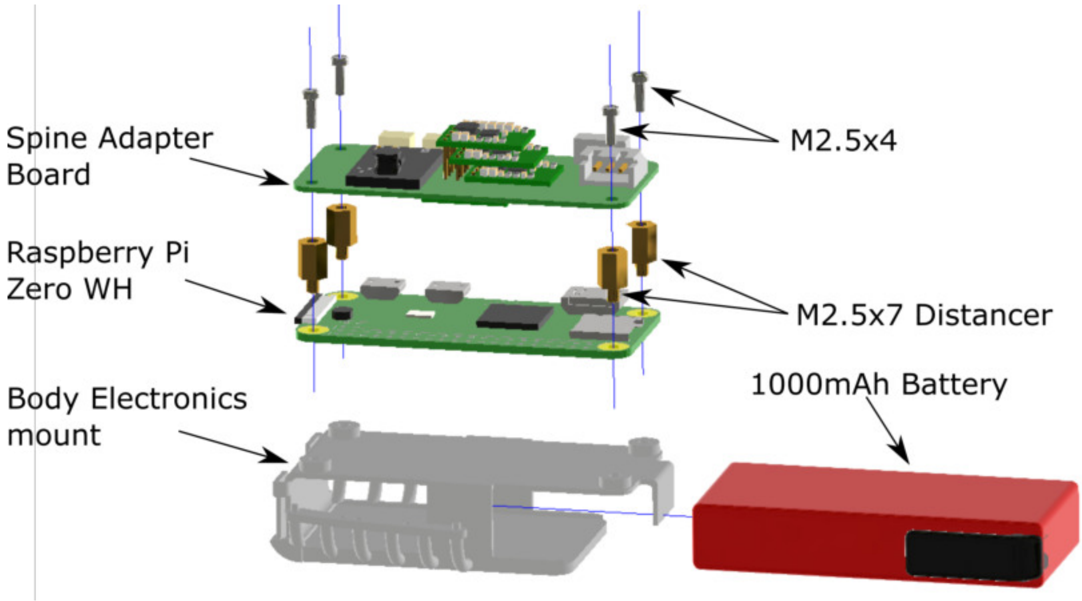


Fig. 17. Assembly of the Power and Compute Module.

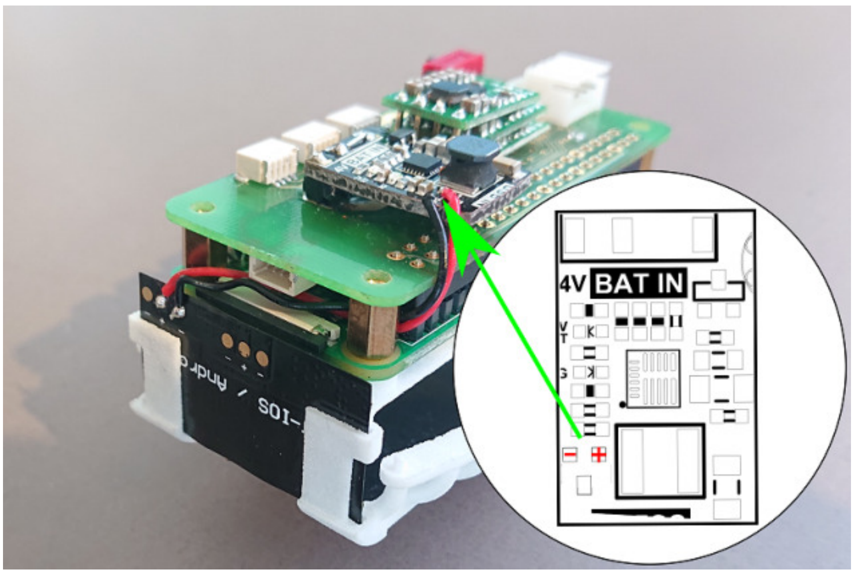


Fig. 18. Connection of the charging board and the Spine Adapter board.

4.8 Tail

Item	Quantity
Tail (3D-Print)	1
Servo (ID 2)	1
M1x3 (Screw)	2
M1x2 (Screw)	2
Servo mount screw (Servo Part)	2
Servo-horn screw (Servo Part)	1

For the tail, only one motor has to be attached in the according cage, including the servo horn and some screws needed for stringing later on, see Figure 19. The Stringing of the Tendons itself will be handled in its own section later on.

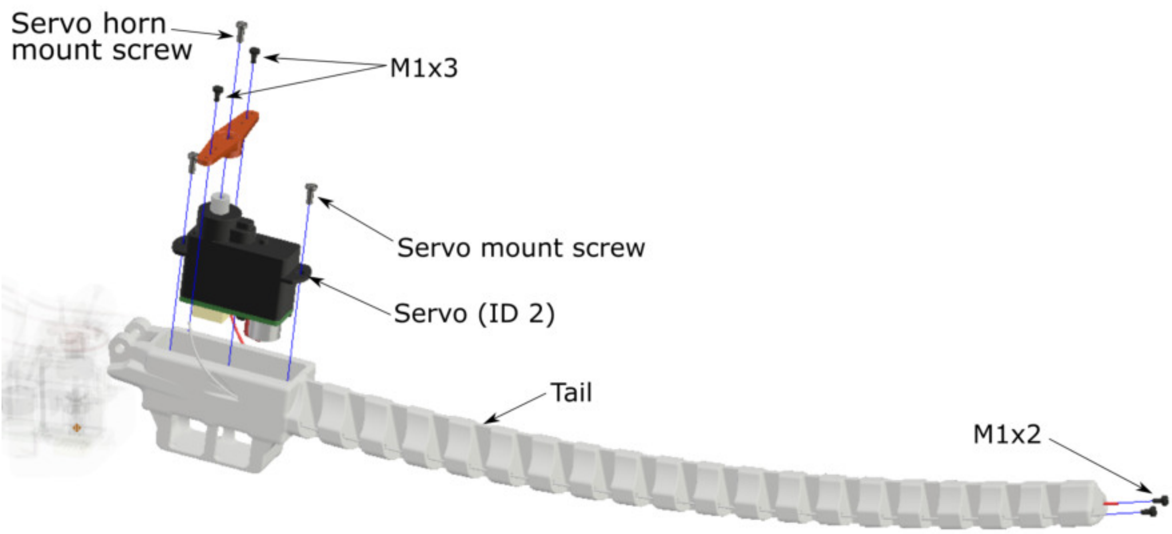


Fig. 19. Assembly of the Tail Module

4.9 Head

Item	Quantity
Head (3D-Print)	1
Head Neck (3D-Print)	1
Head C mount (3D-Print)	1
Camera	2
USB Hub	1
Nose Button (39-138 BLK)	1
Touch Sensor (TTP223)	1
Servo (ID 4)	1
Servo mount screw (Servo Part)	2
Servo-horn (Servo Part)	1
Servo-horn Bar (Servo Part)	1
Servo-horn screw (Servo Part)	1
M1x3	3
M1x4	2
M2x8	1
M2x6	1

The Head is the most complex part of the robot to build. It consists of many parts and needs multiple steps to complete. before building the head, make sure, that you have done the preparations for the USB-cameras and the USB-Hub.

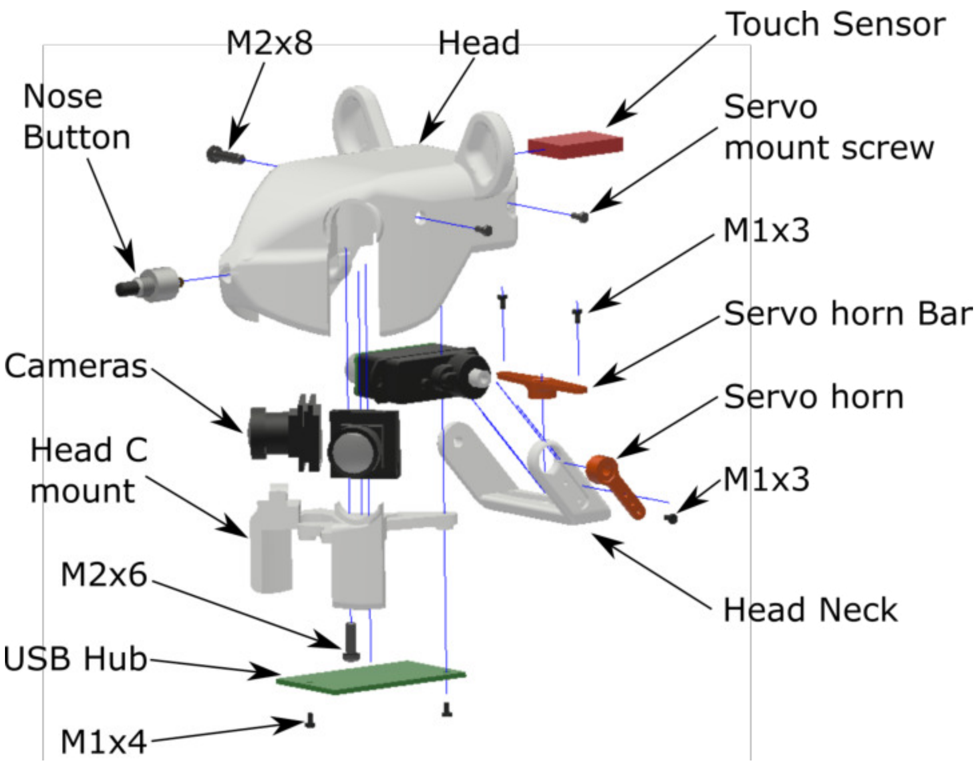


Fig. 20. Head Module components

The first step is the assembly of the sensors into the head. The schematic is shown in the right of Figure 21. First attach wires to the touch sensor and thread the wires through the cable channel in the top of the head, while pushing the sensor in its compartment. Then you can screw the nose button into the respective place in the head and connect all wires according to the schematic plans. The wire to the Spine Adapter Board should be 13 cm long.

The following Figure 22 shows the remaining step by step assembly of the head module. The steps are as follows:

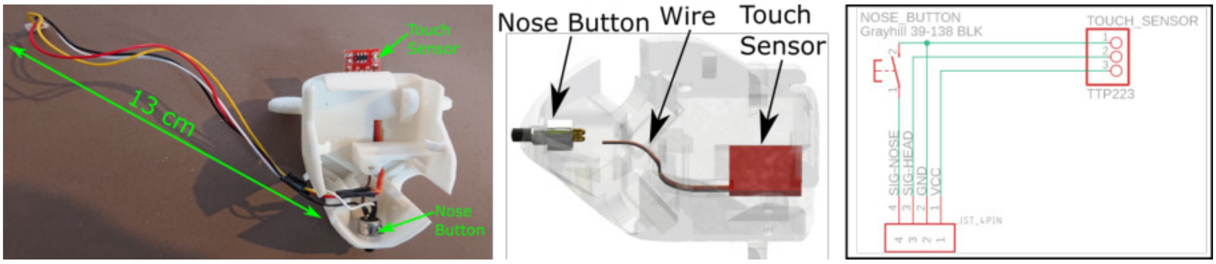


Fig. 21. Assembly and schematic of the Head Sensors.

A Assemble the Neck with all servo horns as shown in Figure 20 and attach it to the head servo (ID 4). Make sure the motor is set to its centre (0800) position.

B Insert the servo with the neck into the head and secure it with the servo mount screws.

C Insert the two cameras into the two the according recesses. Be careful not to break off the lens from the sensor. The camera with the longer lead wire is the right eye of the head (when facing forward).

D Insert the Head C mount to secure the cameras. Ensure that all camera wires can go unobstructed. And secure it with a M2x6 Screw.

E Attach the USB Hub atop of the Head C mount, make sure, that the camera wires from the right camera are running over the PCB. Then secure it with two M1x3 screws.

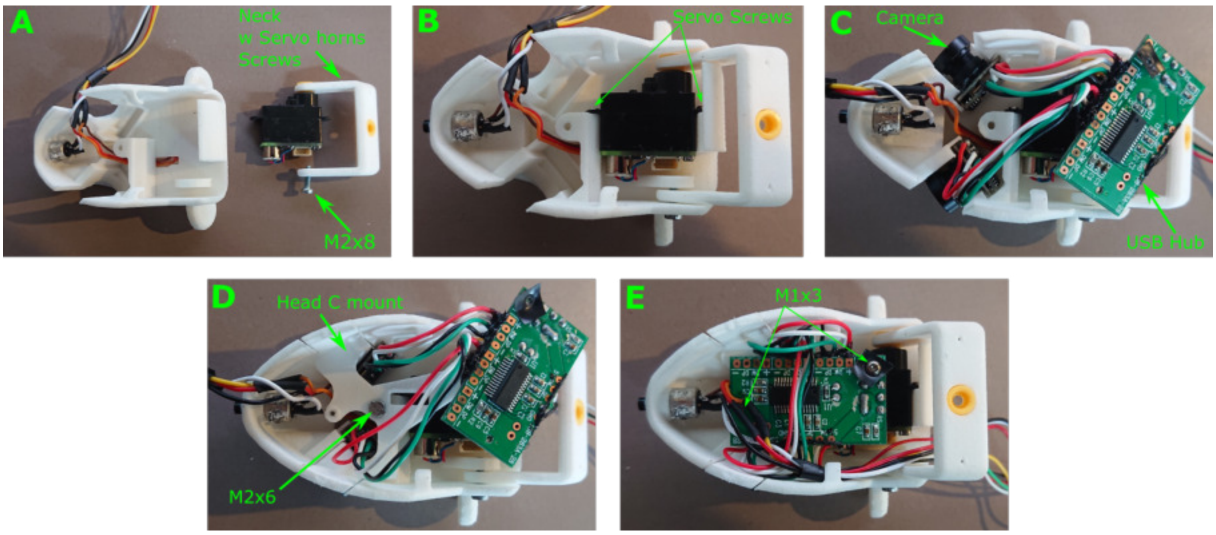


Fig. 22. Assembly of the Head steps A-E.

5. Whole Robot Assembly

Item	Quantity
Body Module	1
Hindleg Module Left	1
Hindleg Module Right	1
Foreleg Module Left	1
Tail Module	1
Power and Compute Module	1
Head Module	1
Wiring Harnesses	3

With all sub modules assembled, we can no start to assemble the complete robot.

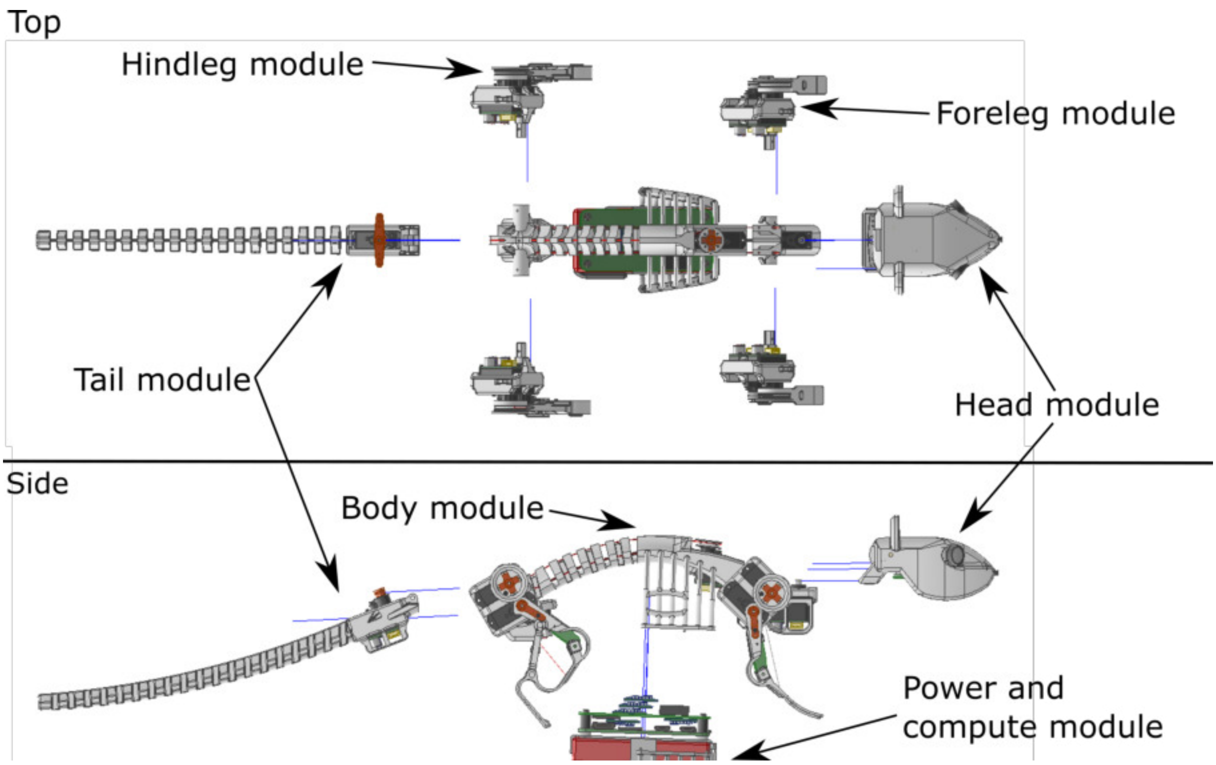


Fig. 23. Assembly of all sub modules to the complete Nermo Robot.

5.1 Stringing

For inserting the robot tendons, please make sure, that all motors are set to zero, especially the spine motors. For tendons we use nylon wire with a 0,3 mm diameter and a max force of 4 kg. The tendons are fixed with screws, but can be glued into place when the final setup of the robot is completed.

5.1.1 Foreleg

To string the foreleg tendon first attach the tendon on the leg as shown in the middle bottom on Figure 24 with a M1x3 screw. Then thread the tendon onto the coil as shown in the figure through the hole in the coil. The tenon can then be tightened fixed with a M1x4 screw.

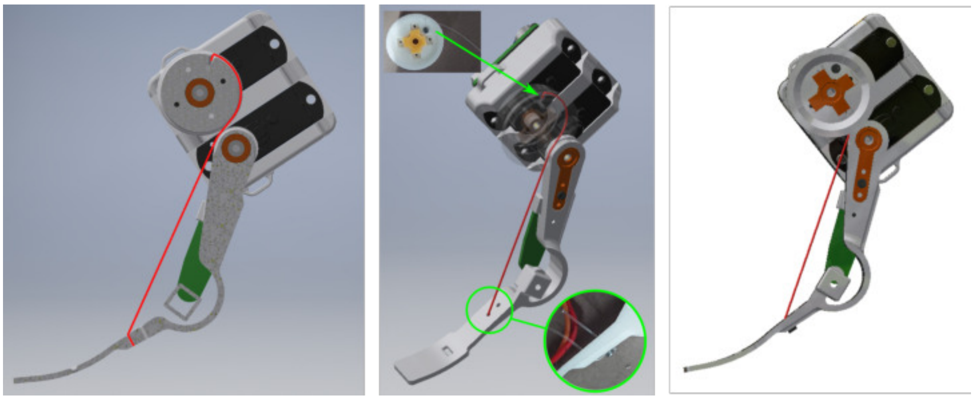


Fig. 24. Stringing of the foreleg.

5.1.2 Hindleg

To string the hindleg tendon first attach the tendon on the shin of the leg as shown in the middle bottom on Figure 25 with a M1x3 screw. Then thread the tendon through the linkage (2) and the hole on the top of the leg (1) and onto the coil as shown in the figure. The tendon can then be tightened through the hole in the coil and fixed with a M1x4 screw.

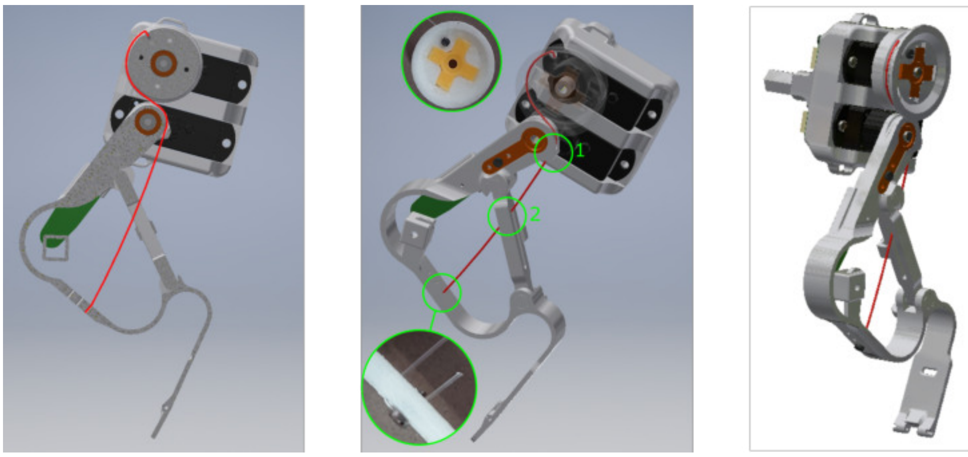


Fig. 25. Stringing of the hindleg.

5.1.3 Body Module

For the left and right lateral tendons prepare two tendons with about 20 cm length and remove the lateral flex servo from the body module. First attach the two tendons on the coil of the lateral flex servo as shown in Figure 26 on the right side. Take care, that the left tendon is attached to the right screw and the right tendon to the left screw to ensure the tendons can moved enough distance later on. The next step is to thread both tendons along their respective pathways until they are at the very front of the body module. You can then reinsert the lateral flex servo into the body module. Finally tighten the strings and fix them at the front with two M1x4 screws.

For the spine flex tendon prepare a 15 cm piece of tendon. Then attach the tendon to the coil at the servo as shown

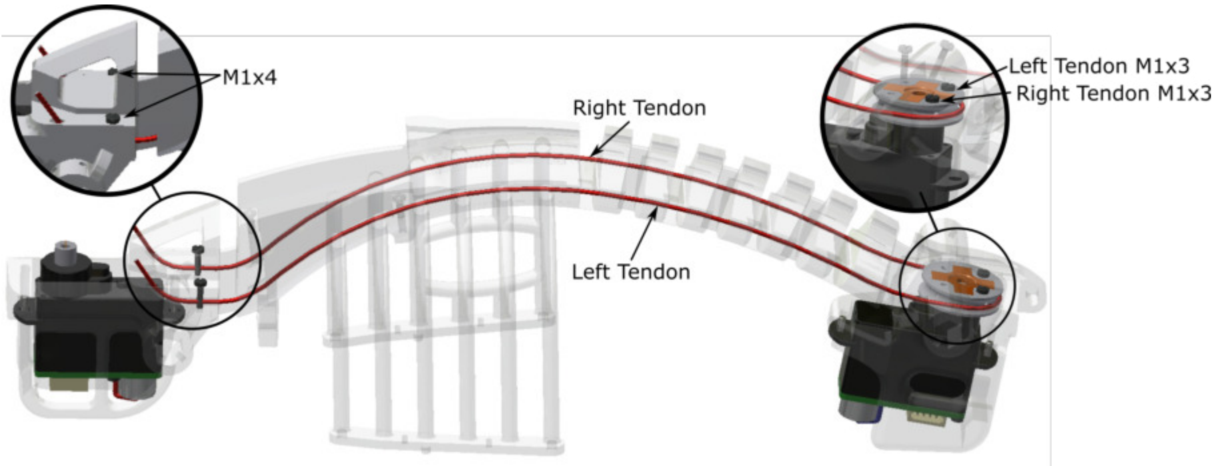


Fig. 26. Stringing of the lateral tendon on the body module.

in Figure 27. then thread the tendon through to the back of the module, tighten the string and fix it with a M1x4 screw.

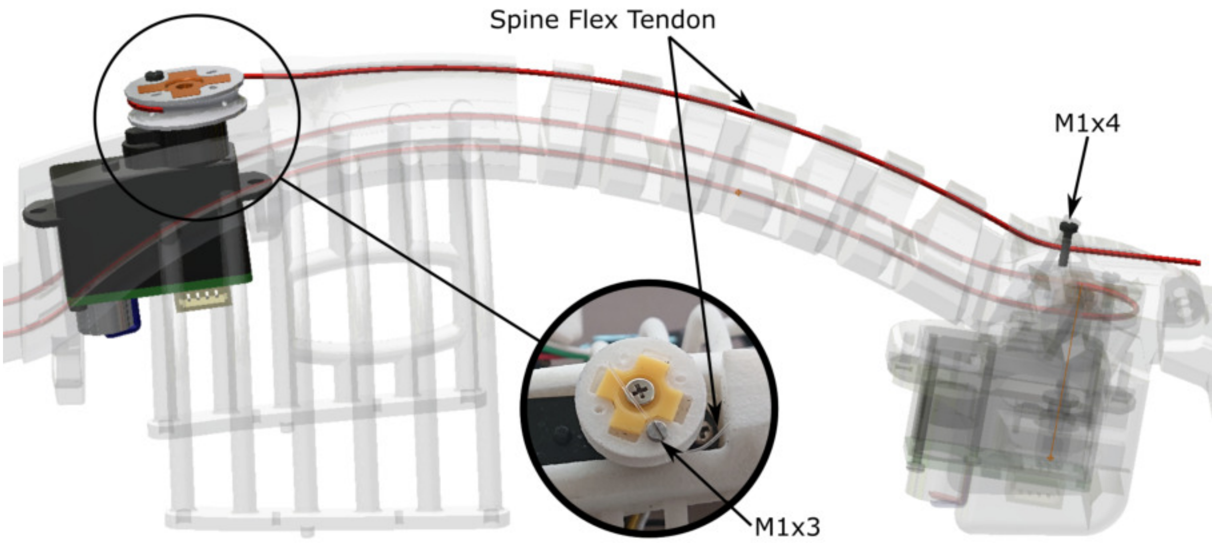


Fig. 27. Stringing of the flex tendon on top of the body module.

5.1.4 Tail Module

For the tail module prepare two pieces of wire of about 30 cm length. Thread the two pieces through their respective pathways as shown in Figure 28. On the end of the tail, attach the the tendons with two M1x2 screws. On the servo side of the tail, thread the tendons through the holes of the servo horn, tighten the strings and fix them with two M1x3 screws.

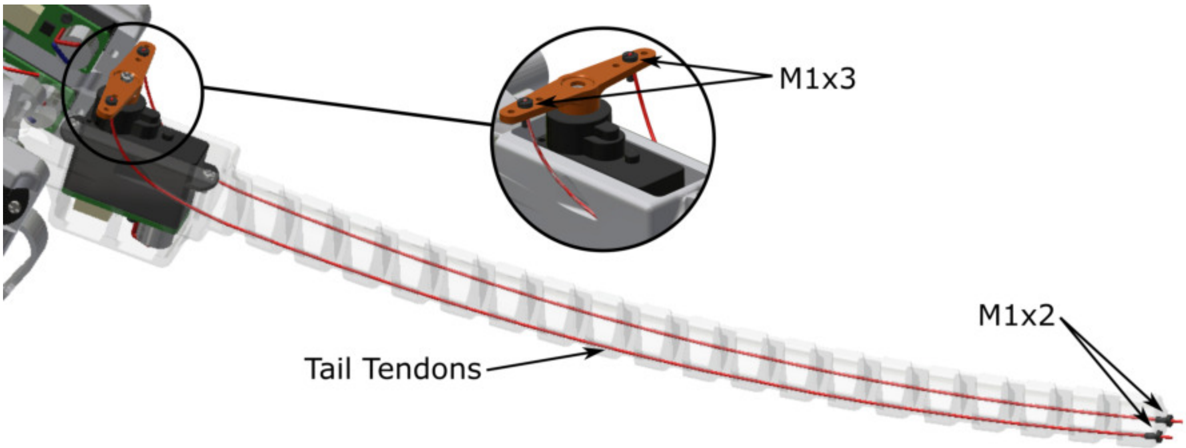


Fig. 28. Stringing of the foreleg.

5.2 Centre-line Assembly

The centre line of the robot consists of the body module together with the tail and the head modules. You will need a M2x11 screw with a Stop-nut and one of the servo horn screws form the servos.

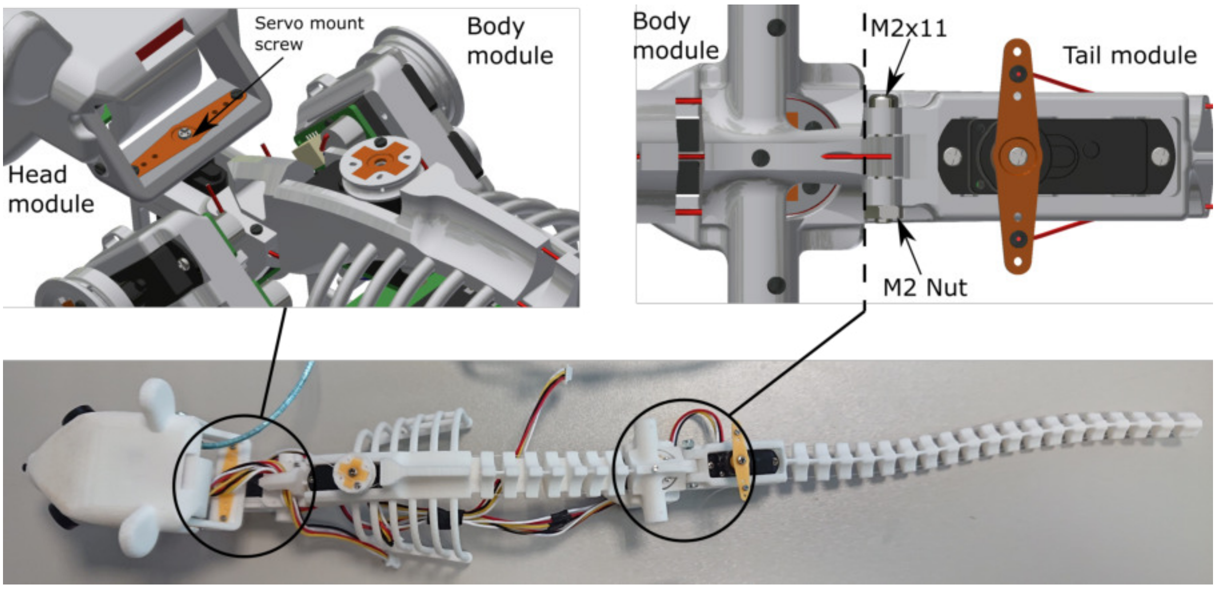


Fig. 29. Assembly of the centre line of the robot.

5.3 Wiring

The Wiring of the servos should be quite clear based on the plan from Figure 6. What is to be taken into account is to remove one of the servos of the leg modules for attaching the wire, as the mounting is in the way of pluging the connector in in the assembled module (Figure 30).

There are 2 places where the central spine wiring will have to be threaded through, at the neck the wiring coming

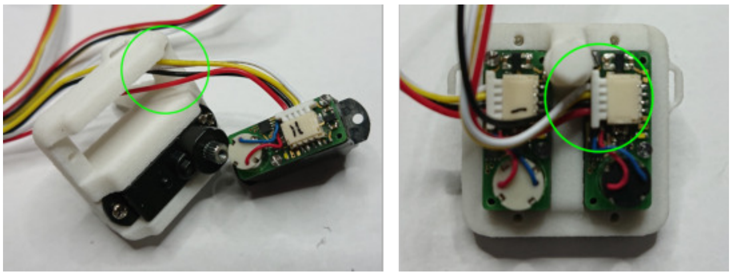


Fig. 30. Attaching the Wiring harness to the leg modules

from the head can be threaded through the hole in the body module as shown in the enlarged picture in Figure 31. At the tail, the wires can be attached or threaded through at the side of the flex servo.

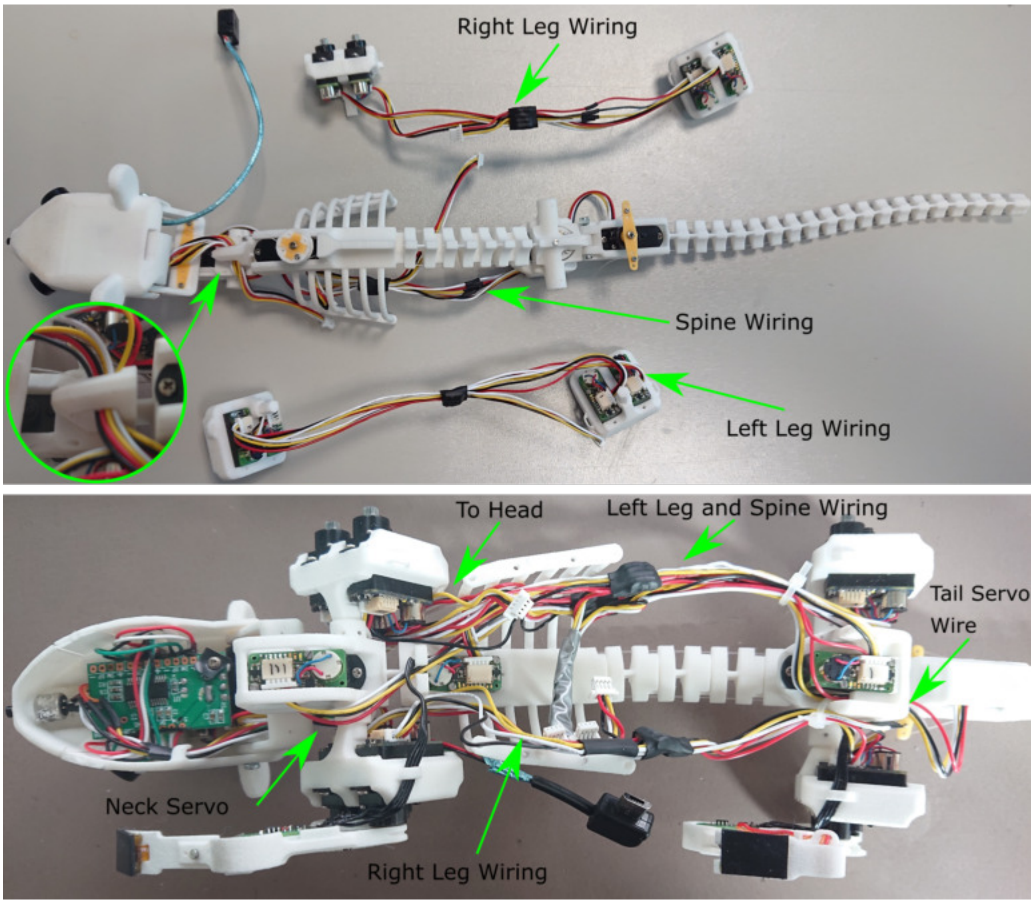


Fig. 31. Attached Wire harnesses to the Spine, and both Leg sides.

When all three wiring harnesses are attached to the servos you can attach the Leg modules to the body module as shown in Figure 23. The wires are then to be organized as shown in Figure 31.
Finally you can insert the power and compute module. The plugs are to be attached as shown in Figure 32. The module is to be inserted from the bottom as shown in Figure 23. For securing the module to the body four M1x3 screws can be used as shown in Figure 33.

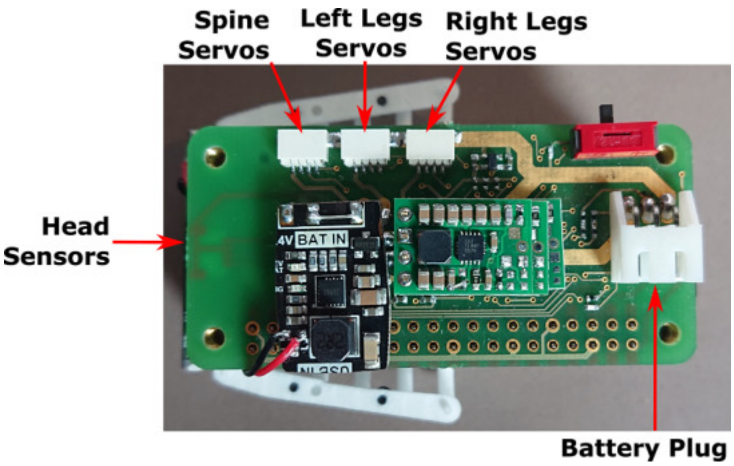


Fig. 32. Power and compute module connectors.

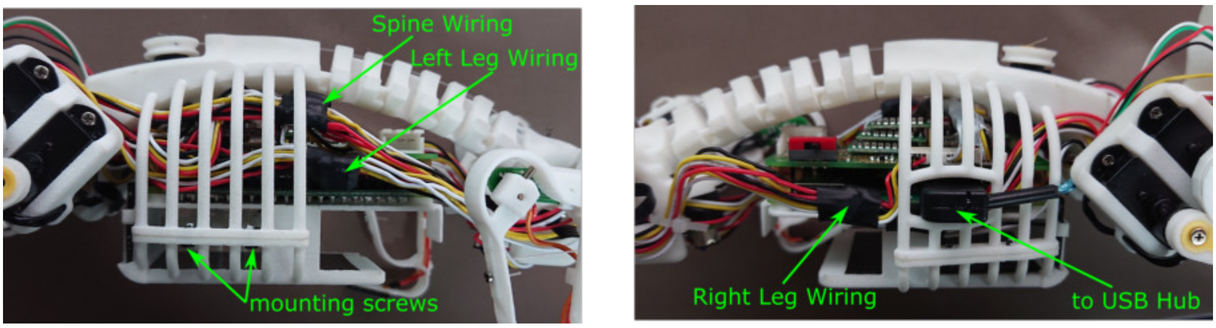


Fig. 33. Power and compute module attached to the body module with connected usb plug.

6. First Setup

Before using the robot, the control environment as well as all joints have to be setup. With building the custom servos and the spine adapter board, you should also have added the newest firmware to those parts. If not, please do so now.

6.1 Connection Protocols

When using the pre-installed sd image, the robot is setup to connect to the following wireless network in Table 3. To connect you can open an ssh connection to the user pi@<IP address> . The Robot infrastructure uses

SSID	LOSTLITTLEROBOT
Pasword	********

Table 3. WIFI setup for the robot

mostly single wire UART connections for the servos and normal UART between the Raspberry Pi and the Spine Adapter. The settings for the connection can be taken from Table 4. To connect to the spine or the servos from a computer you can use a UART adapter with TeraTerm or similar software. To program the chips we used the STM32CubeProgrammer.

Connection	Setting	Baud	Setting	Connection
RPI-Spine	Control	1000000	8E1	UART
Spine-Servo	Control	1000000	8E1	Single Wire UART
All	Programm	57600	8E1	UART

Table 4. Connection settings for the UART connections.

6.2 Servo Programming

The used programming software is the STM32CubeProgrammer. To connect to the Spine or the Servo you will need a USB to UART adapter. Additionally for the servos, you will need a special wire setup in order to talk via the single wire UART and programm via usual UART, according to the schematics in Figure 34. To set a already

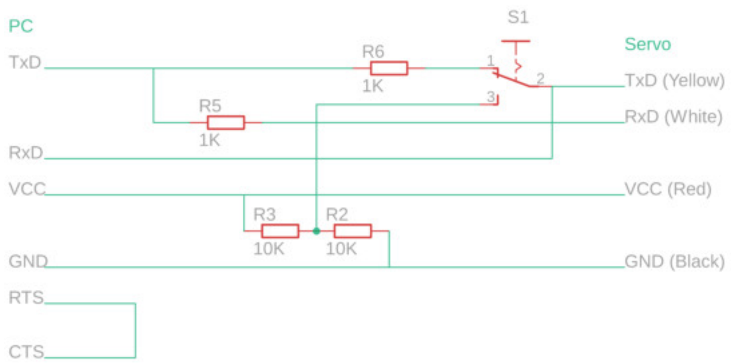


Fig. 34. programming cable to connect to the servos.

programmed servo into programming mode, connect to the motor and start the bootlaoader mode. Then disconnect the terminal program from the servo (NOT the Cable!) and start the flashing with the CubeProgrammer, same goes for the Spine Adapter. When the servos are connected to the Spine adapter, all servos can be programmed simultaneously by connecting to the spine and selecting the respective mode as explained in subsection 7.4, then again disconnect the terminal software and start the programming.

6.3 Raspberry Pi setup

The raspberry Pi runs with raspian, a operating system provided by the Raspberry Pi Foundation. Either you have the already installed the available sd image on an sd card or you can setup the raspi from scratch. For the later please refer to the setup documentation here: https://www.raspberrypi.org/documentation/.

6.4 Control software setup

To run the basic control script please clone this repository: https://github.com/Luchta/nermo_code and follow the Readme instructions to compile the code. You will have to create a build folder and use "cmake .." and "make" to compile the code. Additionally you can some helper scripts form https://github.com/Luchta/nermo_scripts and compile with the same steps as the nermo code repository.

6.5 Leg setup

When using the robot for the first time, make sure, that all the legs are in the correct starting positions. The servos on the central line of the robot should all be setup correctly, as the servos have been set to their centre position during assembly. If that has not been done, you will also have to reset the servo horns on those servos. For the legs, first remove all legs and coils from the servos. Then, power on the robot and start the control software. Hit "i" which sets all motors to an initial position. Then attach the lags as shown in Figure 35, make sure that the left and right side are correctly aligned. Finally make sure, that all joints are aligned as in Figure 35. For the Coils, make sure the strings are tensed without actuating the knee/elbow.

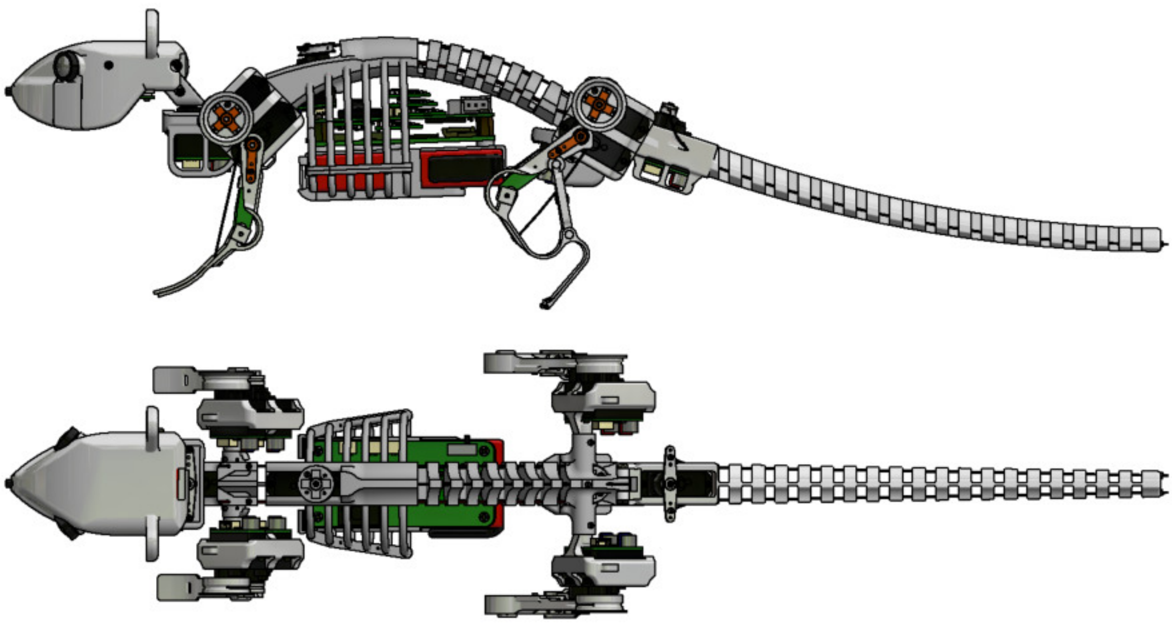


Fig. 35. Initial setup position of the robot.

7. Usage

The following chapter will introduce the reader to the usage of the robot. Starting with a Overview of the robot's setup. Then an explanation on how to charge the robot followed by how to connect to the robot and how to control it.

7.1 Overview

Figure 36 shows an overview of the robot's control system. As can be seen, there are three main UART lines that daisy chain the servos into left, right and spine motors. Nose and head touch sensors are directly connected to the spine adapter board, the cameras are connected to the raspberry pi via a USB hub. All other sensors are connected via the servos. The Battery is directly connected to the Spine Adapter board. The spine Adapter also carries an IMU additionally to the charging electronics and the power regulators. The connection between the Spine adapter and the Raspberry Pi is also done via UART.

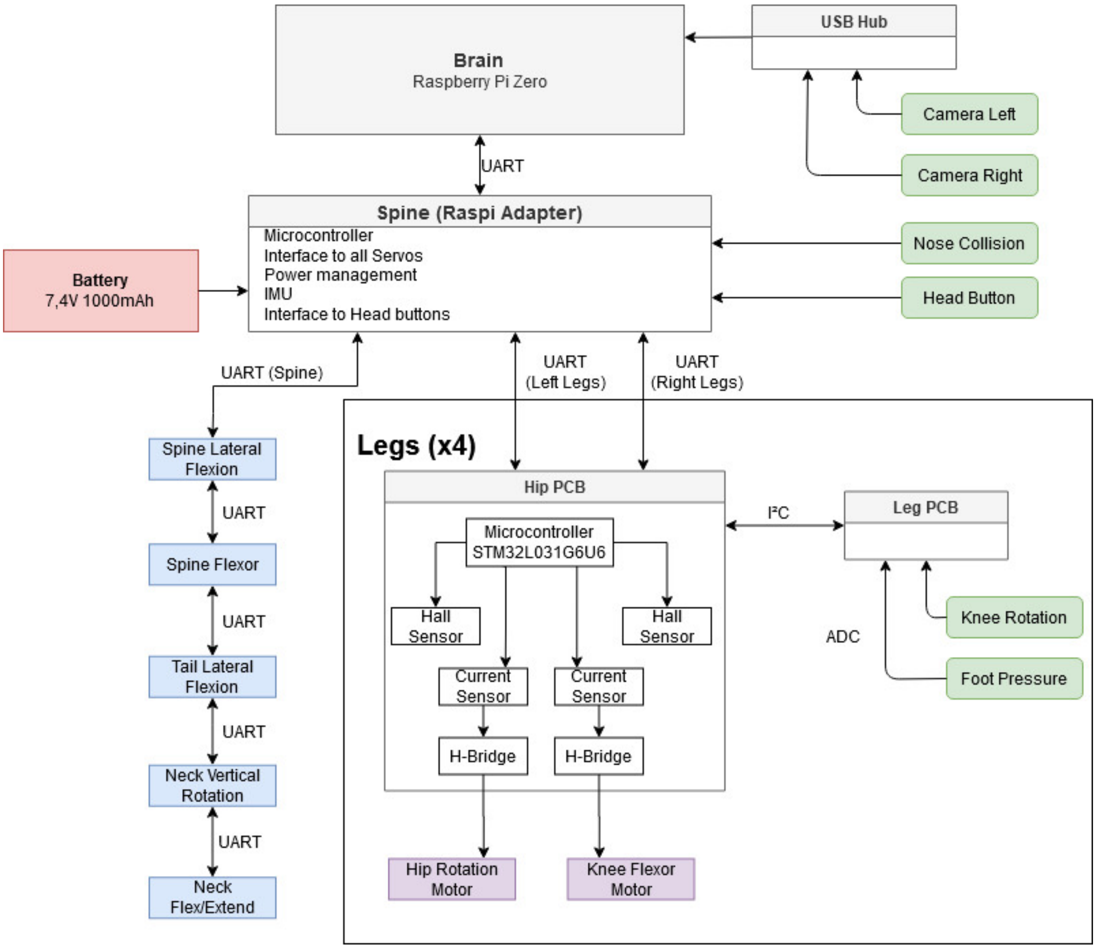


Fig. 36. Electrical setup of the robot.

7.2 Charging

The robot can be charged via the wireless charging coil as shown in Figure 37 on the bottom using any QI-standard charging platform. The charging can be done with the robot switched on or off. As the wireless charger on the robot does not balance the LiPo battery, it is recommended to charge the battery directly with a standard LiPo charger for 2 celled batteries.

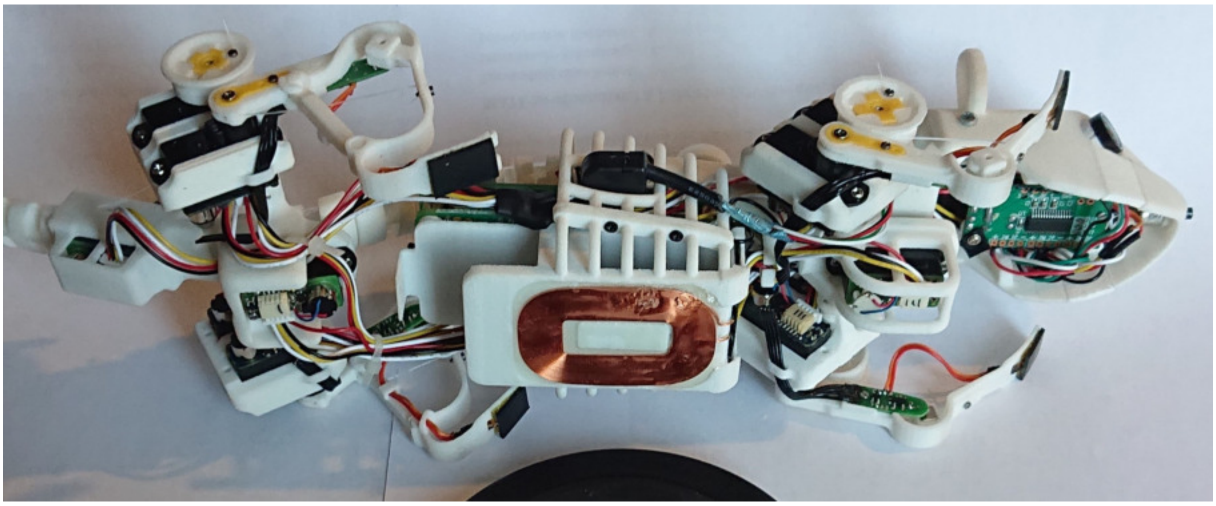


Fig. 37. charging coil of the robot.

7.3 Communication

When everything is set up, you can communicate with the servos or the spine adapter board from the Raspberry Pi using minicom https://help.ubuntu.com/community/Minicom. The settings are as shown in subsection 6.1. To view the programming possibilities on the spine type ":??" and you will prompted by a function overview. To talk to one of the servos you will have to know the UART line and the ID of the servo. The UART lines are "0" for the left side, "1" for the right side and "2" for the center line motors including the head. The motor IDs go from 0-3 for the left and right side and 0-4 for the centre line. So calling the info promt for the head motor would be ":24??". The IDs are listed in detail in Table 5.

Line	ID	Servo
0		
	00	Right Hind Coil
	01	Right Hind Leg
	02	Right Fore Coil
	03	Right Fore Leg
1		
	10	Left Hind Coil
	11	Left Hind Leg
	12	Left Fore Coil
	13	Left Fore Leg
2		
	20	Flex Spine
	21	Lateral Flex Spine
	22	Tail
	23	Neck Servo
	24	Head Servo

Table 5. Servo IDs on the robot.

7.4 Control

You can start the control software form the github with "./SimpleMaus". You will be presented with the following greeting:

```
****************************************
Welcome to the NRP_Mouse Control Software
****************************************
You have the following Options:
Control:---------------------------
s: Stop Motors
h: Hold program
q: Quit program
+: Increase Speed
-: Decrease Speed
Walking:---------------------------
i: Initialize pose
w: Walk forward Trott
a: Walk right the more the often you press
d: Walk left the more the often you press
b: Walk forward Bound
n: Walk forward Bound2
Sitting:---------------------------
y: Sit up
f: Press both paws up
t: Lift both paws up
e: Lift left paw
r: Lift right paw
x: Sit down
Files:-----------------------------
o: Read motion data from motion.txt
l: Playback data once
k: Playback data repeatedly
p: Print position data to file
```

As you can see the options are separated into Control, Walking, Sitting and Files. For control:
"s" disables the motors by deactivating H-Bridge on the Motor PCB. "h" holds the program immediately. "q" quits the program and returns to the terminal. For walking:
"i" sets the robot to it's initial pose. "w" sets the robot to a forward walking motion. "a/d" activate the lateral flex servo in the spine to move the robot left or right. The Bounding gaits are experimental. For Sitting:
The sitting pose is experimental and the robot can not sit up by itself. after pushing "y" it can be manually brought into a sitting position. from there the paws can be moved according to the remaining options. Files:
Motion files can be read and played back on the robot. To read a motion file it has to be called "motion.txt" and located in a sub folder "motions" as is in the git repository. "o" reads the data from the file. "l" plays the file once, "k" plays the file in an infinite loop. "p" saves to data from the last motion into a file.

Acknowledgments

Thanks to everyone who helped with this project.

Publications

The following publications have been published about the different NeRmo robots [1], [2], [3].

[1] Lucas P, Florian Walter AK (2018) Design of a biomimetic rodent robot (Technische Universitaet Muenchen, Institut fuer Informatik), TUM-I1873. https://doi.org/10.14459/2018md1464578

[2] Lucas P, Oota S, Conradt J, Knoll A (2019) Development of the neurorobotic mouse. *Proceedings IEEE International Conference on Cyborgs and Bionic Systems* (Munich, Germany), , p 6.

[3] Lucas P, Morin FO, Conradt J, Knoll A (2020) Neurorobotic mouse (nermo) v4.1 (Technische Universitaet Muenchen, Institut fuer Informatik), TUM-I2081. https://doi.org/10.14459/2020md1540519