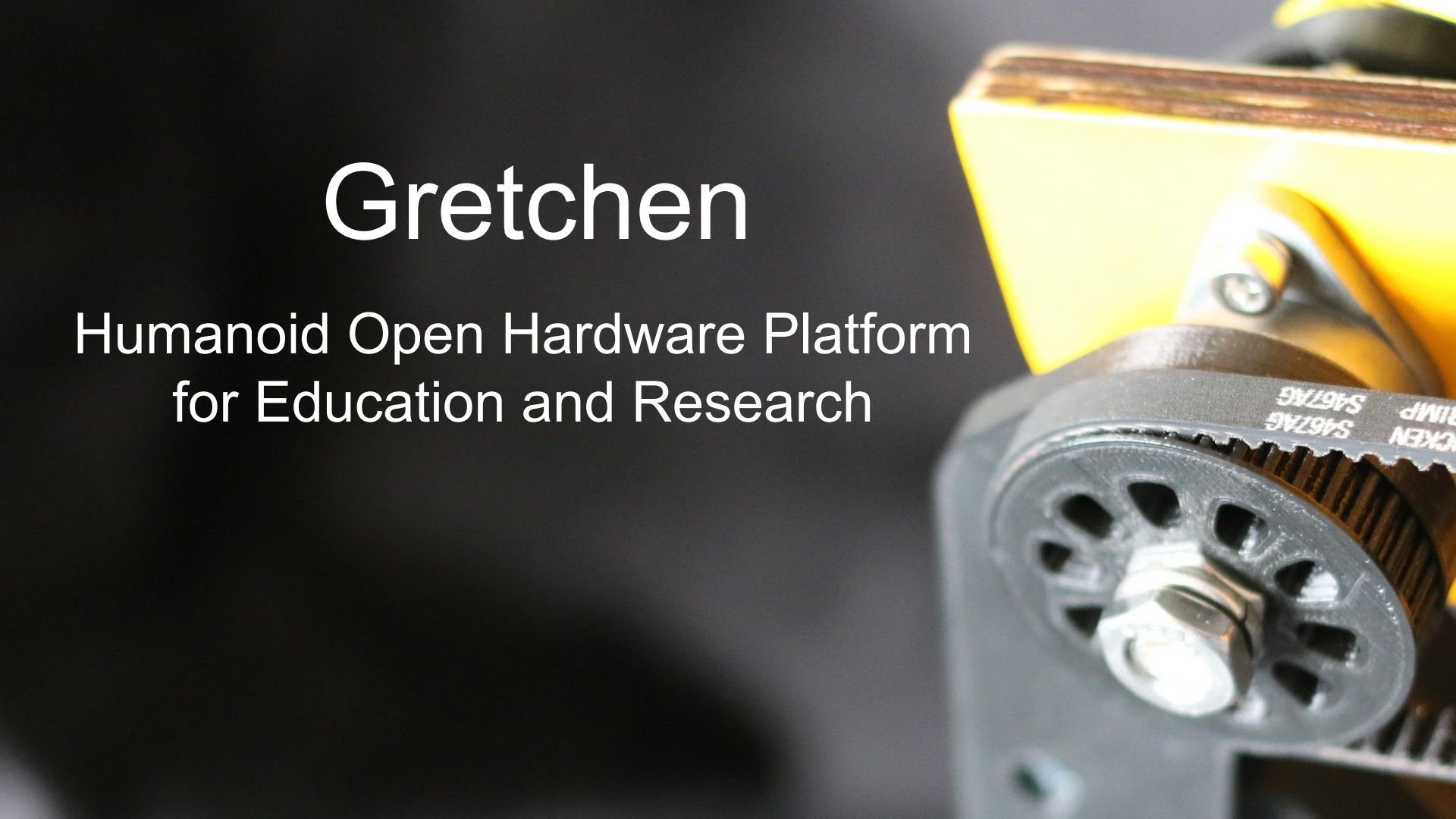
Gretchen

Humanoid Open Hardware Platform
for Education and Research



Intro

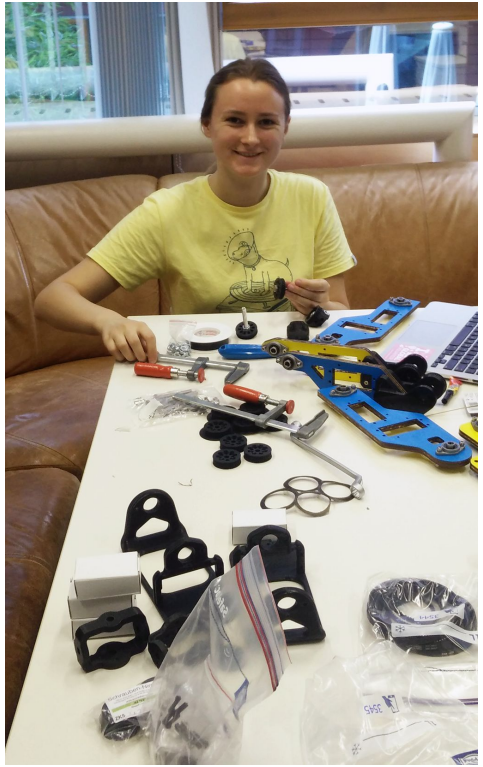
Gretchen

Sensorimotor boards

Intro

Presenters

Heinrich Mellmann



Anastasia Prisacaru

jetpack cognition lab

Matthias Kubisch

Berlin United

- RoboCup Team at the Humboldt-Universität zu Berlin
  https://naoth.de

- Participated in RoboCup since 1998 [SPL, S3D, 4LL, (HL KidSize)]
- Main focus on software

- Motivation:
  - want to build a robot in a sustainable way
  - want to collect experience with hardware

Berlin United at the RoboCup German Open 2019

Gretchen Project

- Aims
  - Good for education
    - Accessible (high level access)
    - Teaching materials
    - Documentation
    - Affordable
  - Good for research
    - Complex
    - Extensible
    - Access on different levels
  - Good for RoboCup (one day :)
    - Robust enough

- Approach
  - Modularity
  - Open source, open hardware
    - For as many components as possible
  - Accessible manufacturing methods
  - Community
    - Learn from other open platforms
    - Collaborate on components

- Current state
  - Prototype of Assembly kit
  - Documentation https://github.com/aibrainag/Gretchen
  - Used in seminar

Gretchen Project

AIBRAIN, INC
THE INTELLIGENT COMPANY

https://jetpack.cl

- Development
- Gretchen Kit
- Sponsoring

NaoTH
Berlin United

https://naoth.de

- Software
- Testing
- Teaching
- RoboCup

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- Hardware
- Low level software

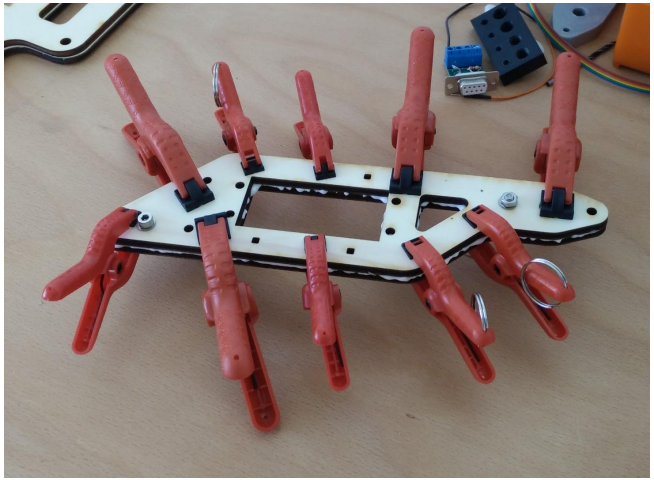
Gretchen

Gretchen Robot

- Goal: provide a low-cost and low-level access to bipedal robots
- Open Source and Open Hardware
  - github.com/aibrainag/gretchen
- Hight: 0.74m
- Weight: ~5kg
- 10 DOF
- Materials:
  - Wooden parts
  - 3D-printed parts
  - Bearings
  - Toothed belts
  - Servos and electronic components
- Bill of materials: 1400€

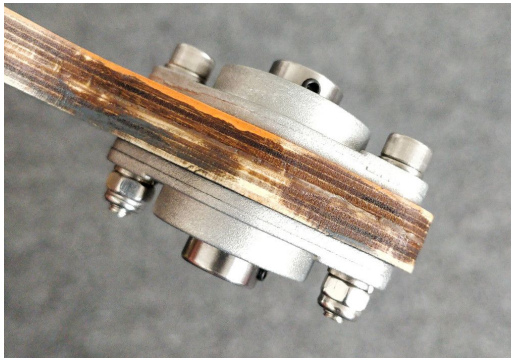
Wooden Body Parts

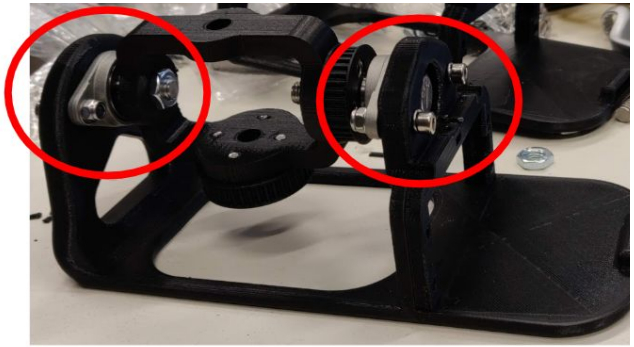
- Thighs, shanks and lower torso
- Plywood, 2x0.5mm thick
- Laser cutting, gluing, coloring and coating



Bearings

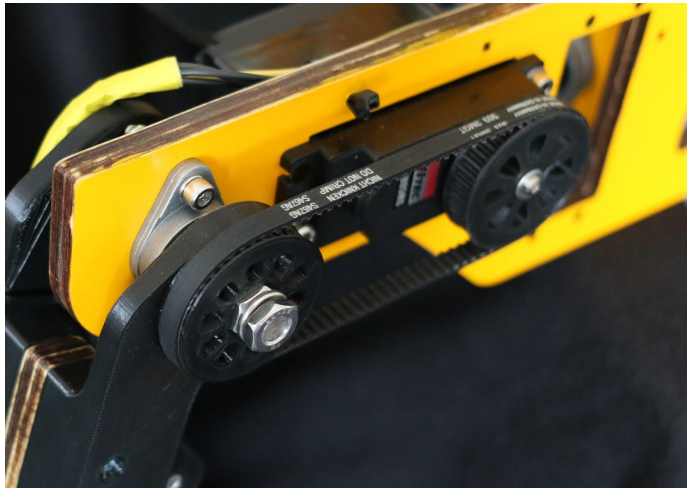
- Ensure a smooth connection between moving parts
- Connected in pairs on both sides
- Self-centered





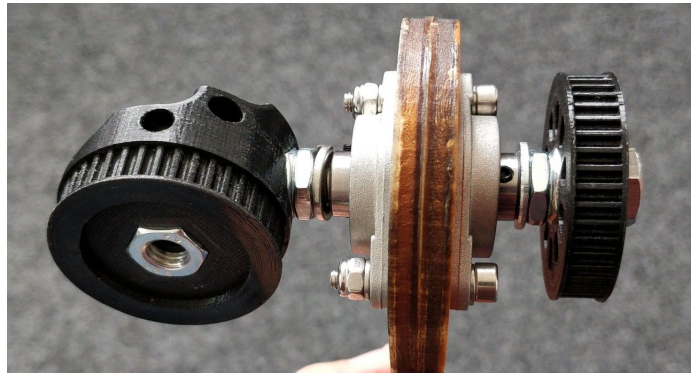
Toothed Belts

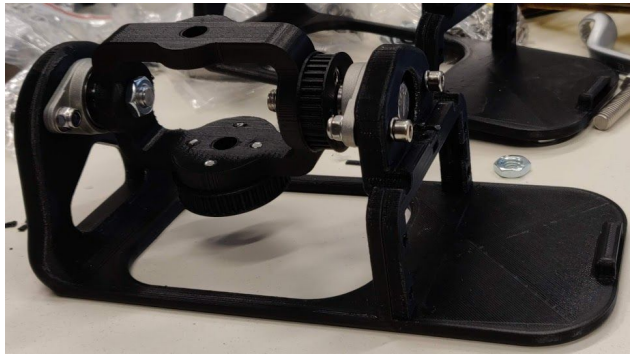
- Indirect transmission between the joints and the motors
- Run over matching toothed pulleys



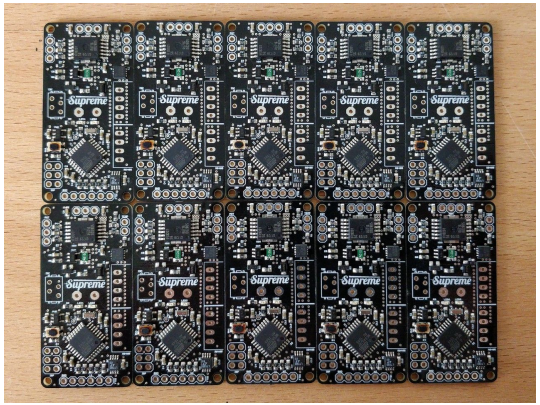
3D-Printed Parts

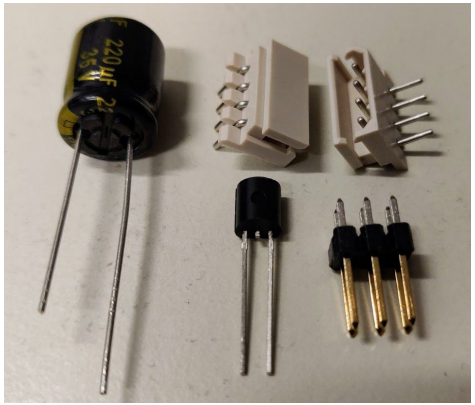
- Joints, feet, pulleys, motor covers
- Hip - pitch+roll due to the inner X/Y integrated pulley
- Knee - pitch
- Ankle - pitch+roll due to the cardan joint mechanism
- Feet - perfectly identical

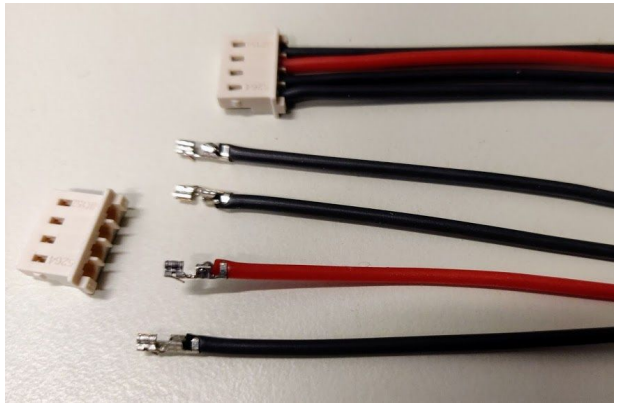




Servos and Electronic Components







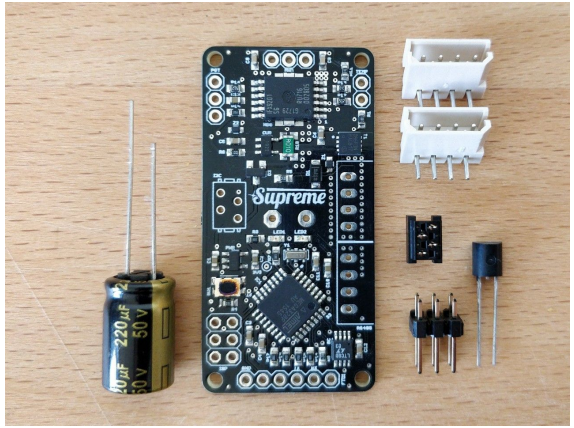
Servo

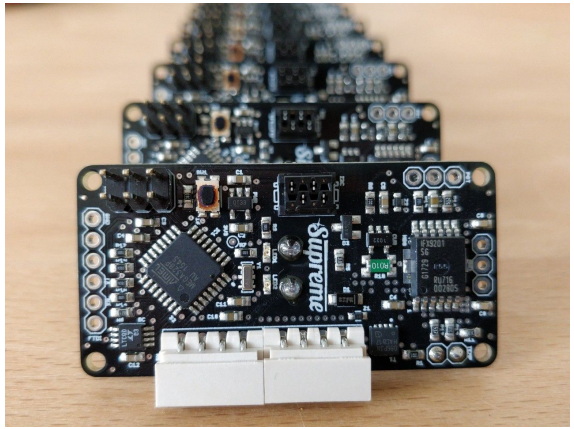
HS-805MG Mega Giant Scale, Metal Gear Servo:

- brushed DC motor
- a metal gear train
- a potentiometer
- an integrated circuit
- Microcontroller: RCD ht7004
- Speed: at 6 Volt - 0.14 sec /60 degrees (**71 rpm**)
- Stall torque: at 6 Volt - 24.7kg x cm (**2,4 Nm**)
- Weight: **197 g**
- Dimensions: **65,8 x 30,0 x 57,4 mm**
- Price: ~50€

Sensorimotor board

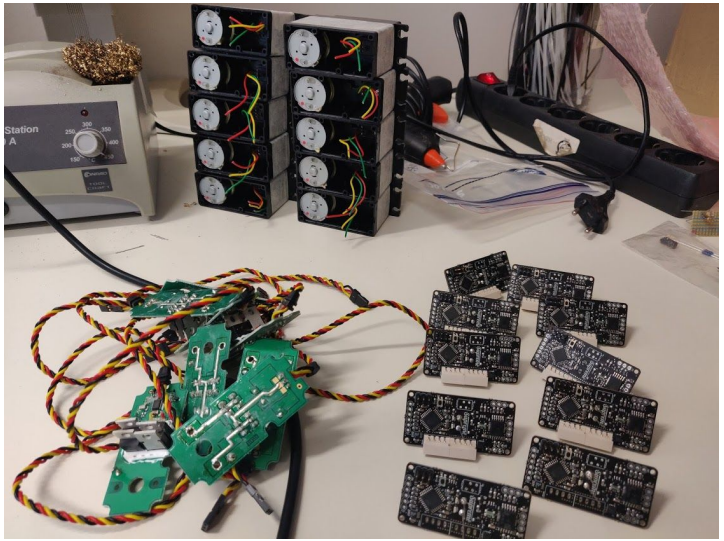
- Open Source
- Easily programmable microcontroller
  - ATmega328P 16MHz
- Voltage range 6V - 12V
  - At 12V -> higher torque
- Bus communication - RS485
- Sensory measurements
  - Current
  - Temperature
  - Position
  - Voltage
  - External measurements via I2C

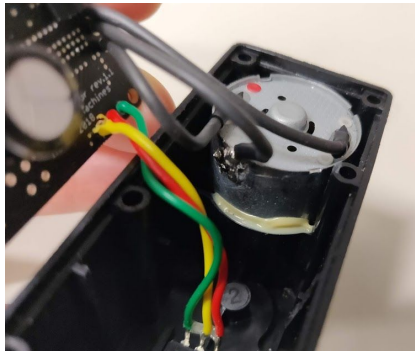


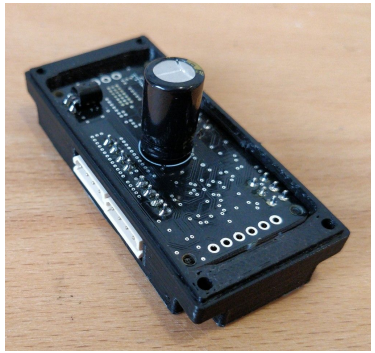


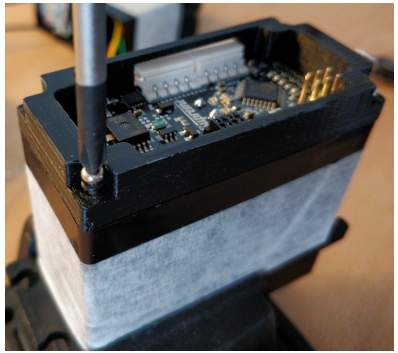
Changing the servo board

- Removing the old board
  - Keep the potentiometer wires
- Prepare the motor wires
- Solder cables to the new board
- Inserting the boards in the 3D-printed covers
- Mounting the 3D-printed motor pulleys



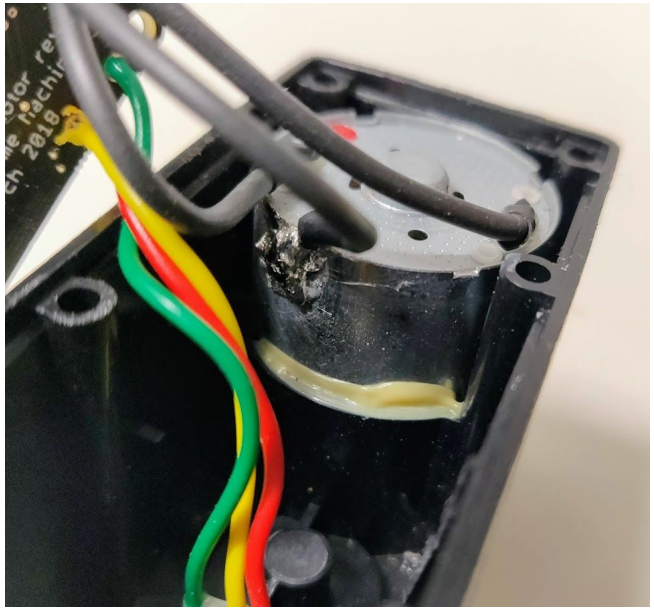


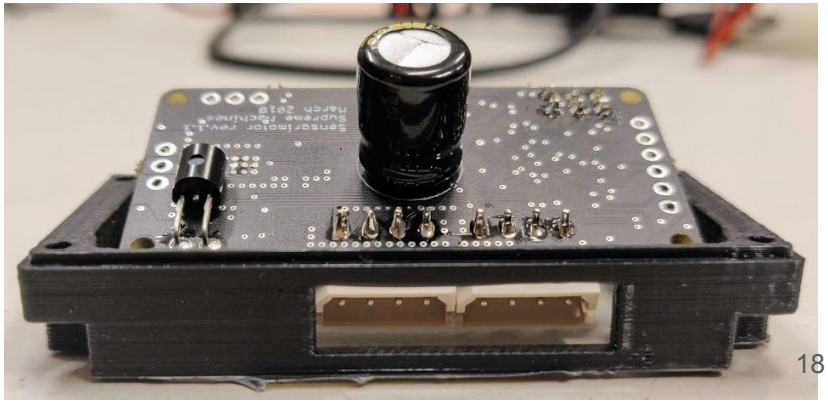




Challenges

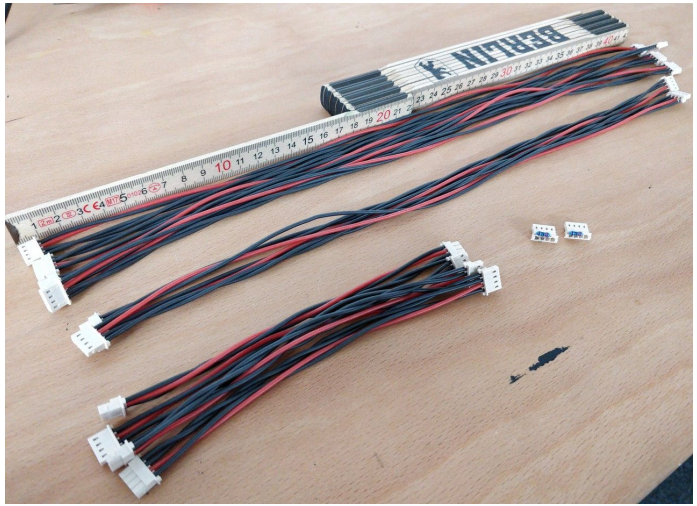
- Desoldered motor pin, which made the soldering of the motor wires much harder
  - Solution: gas torch and soldering fat
- shifted position of the side hole of the servo covers, due to the error of the 3D-printer
  - Solution: drilling the hole

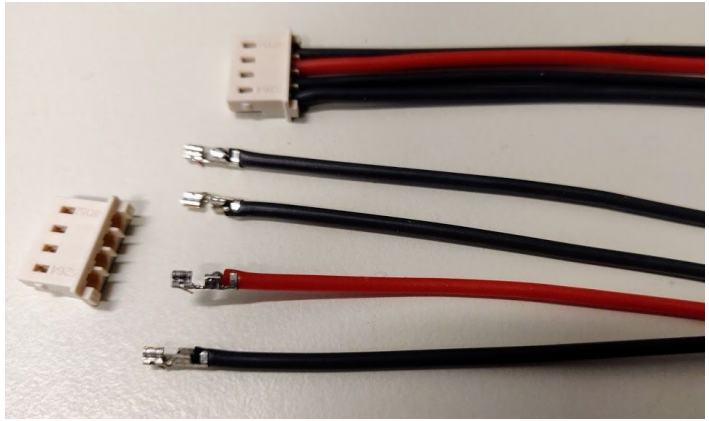




Confectioning the bus cables

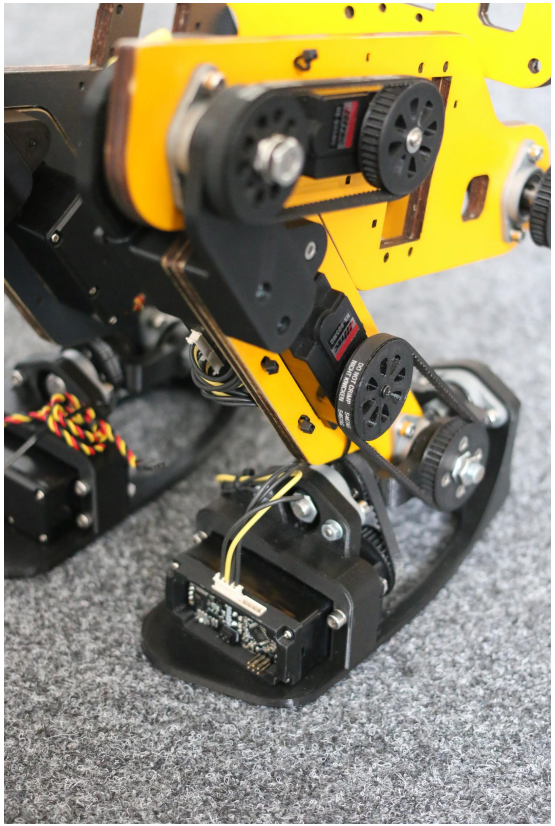
- Confectioning 9 cables:
  - each cable: 3 black and 1 red wire (power)
  - twist the cables pairwise
- Silicon wires
- Flexible
- Heat resistant

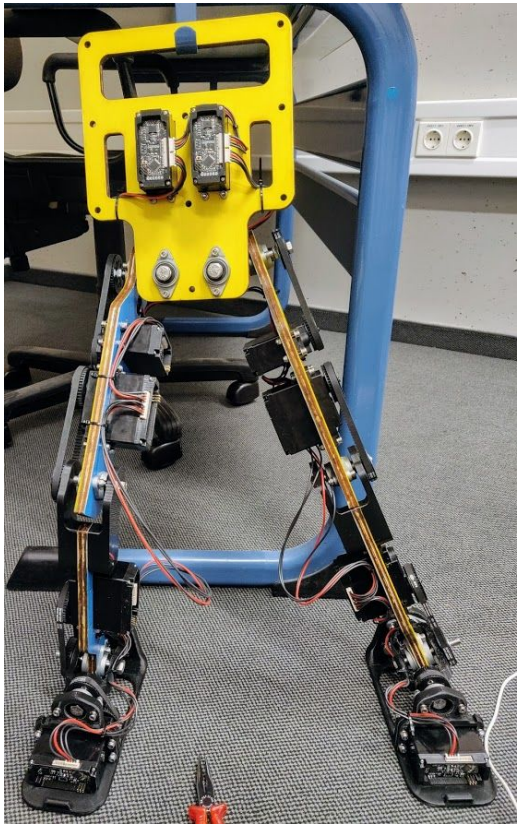




Final assembly

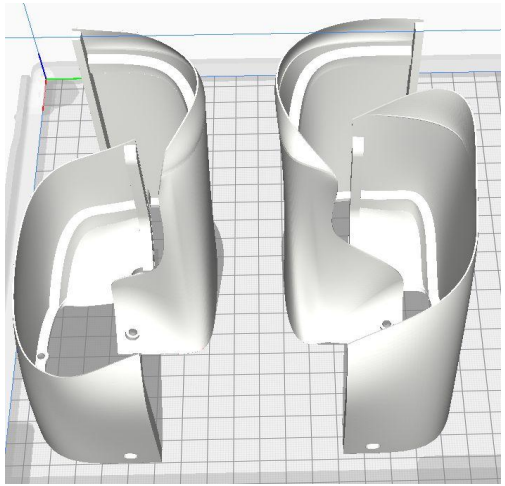
- Putting everything together
  - Mounting the motors
  - Mounting the toothed belts
  - Connecting and tightening the bus cables

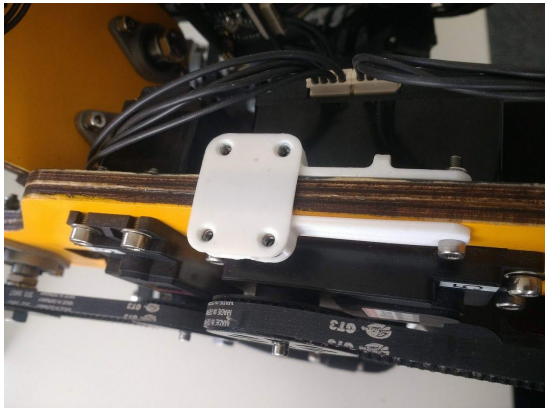




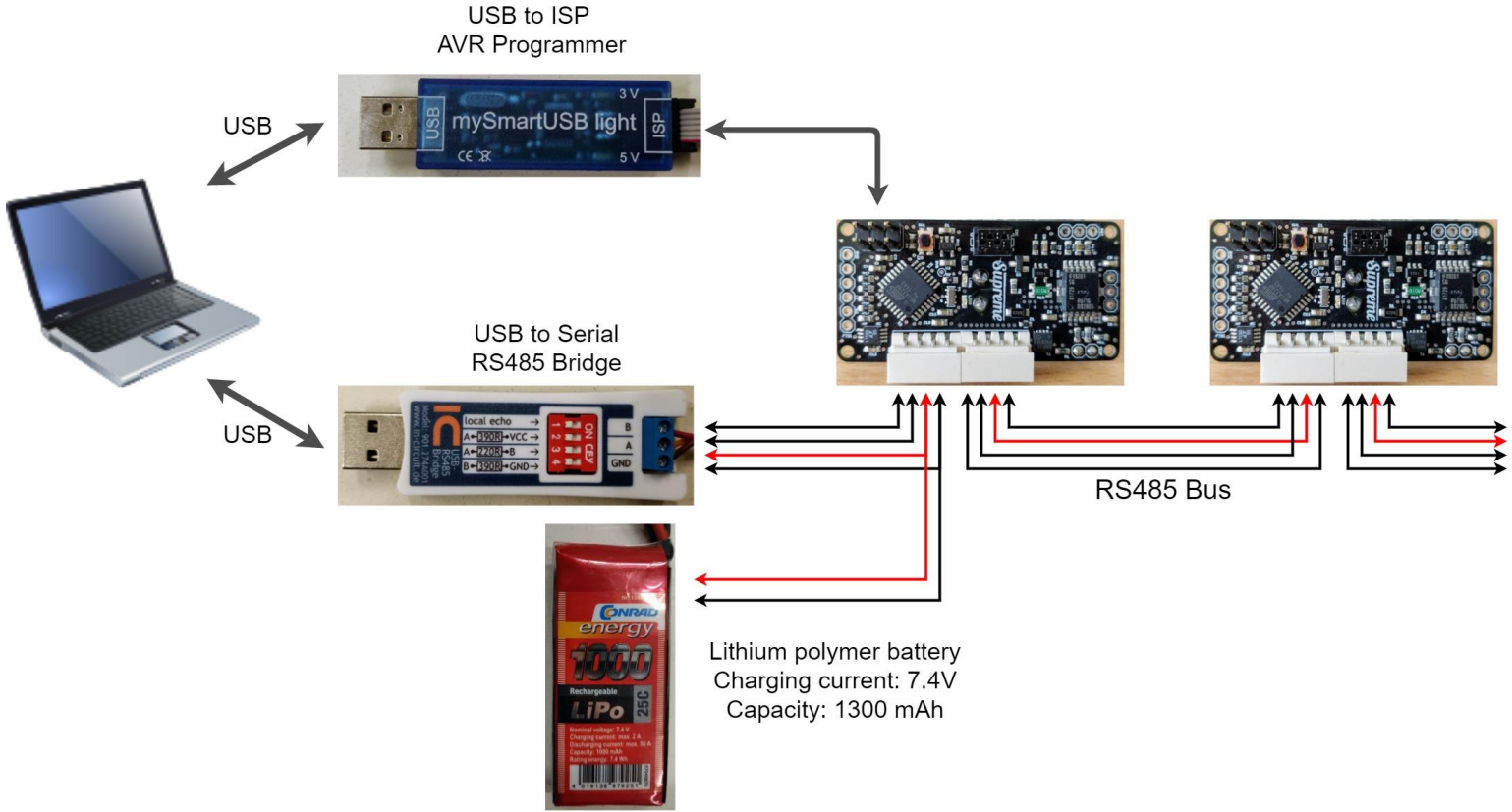
Shells

- ToughPLA (Ultimaker)
- Lightweight protection
- Easy to (un)mount for maintenance

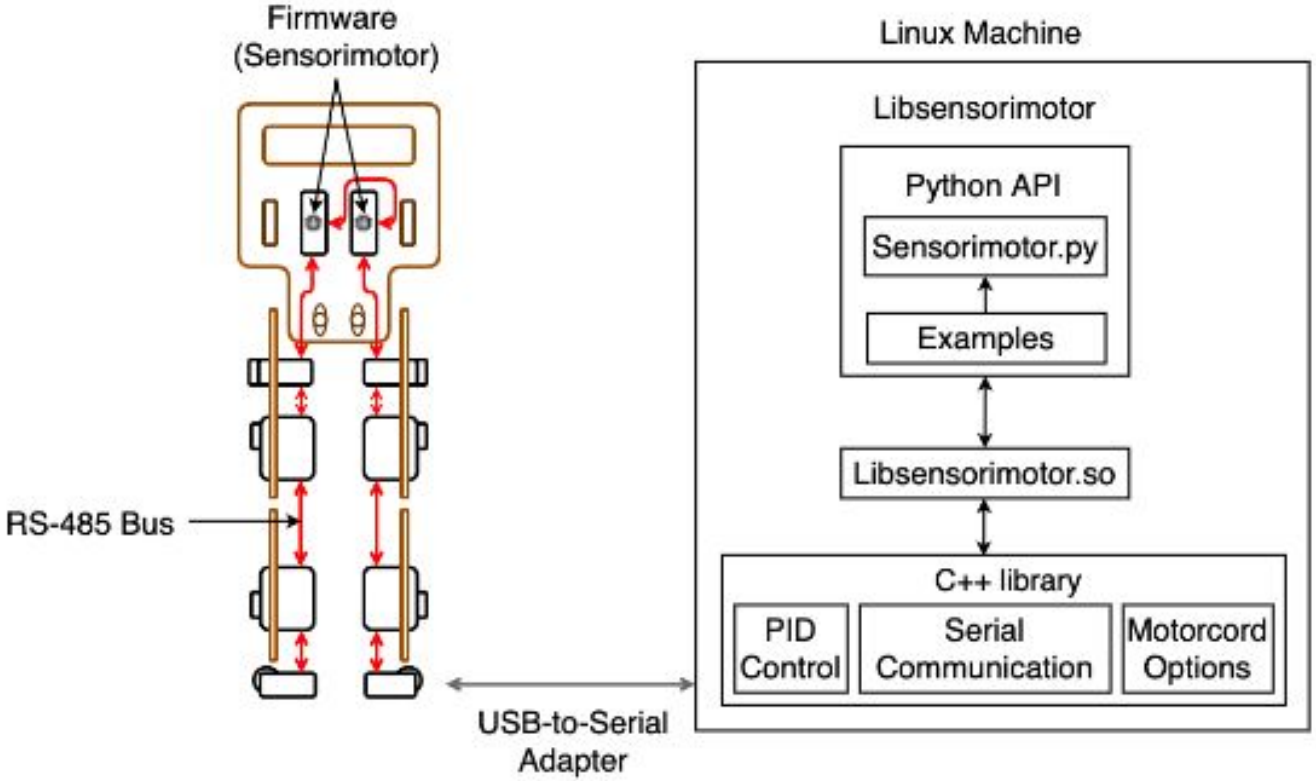




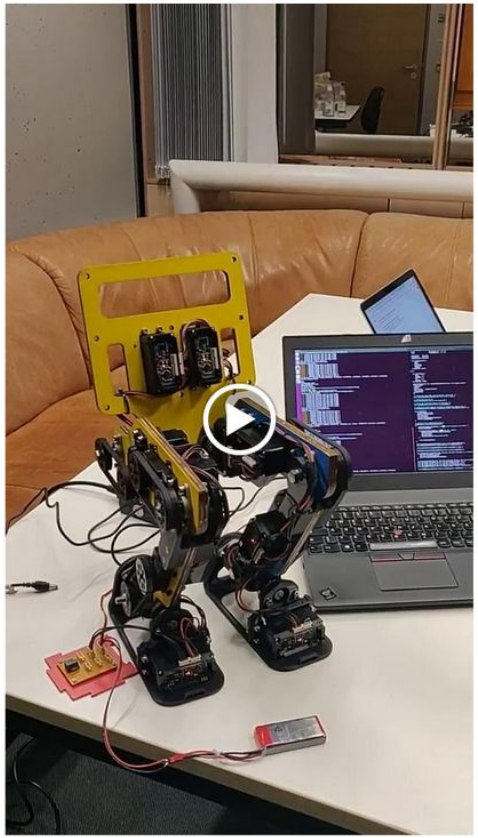
Communication between servos and PC



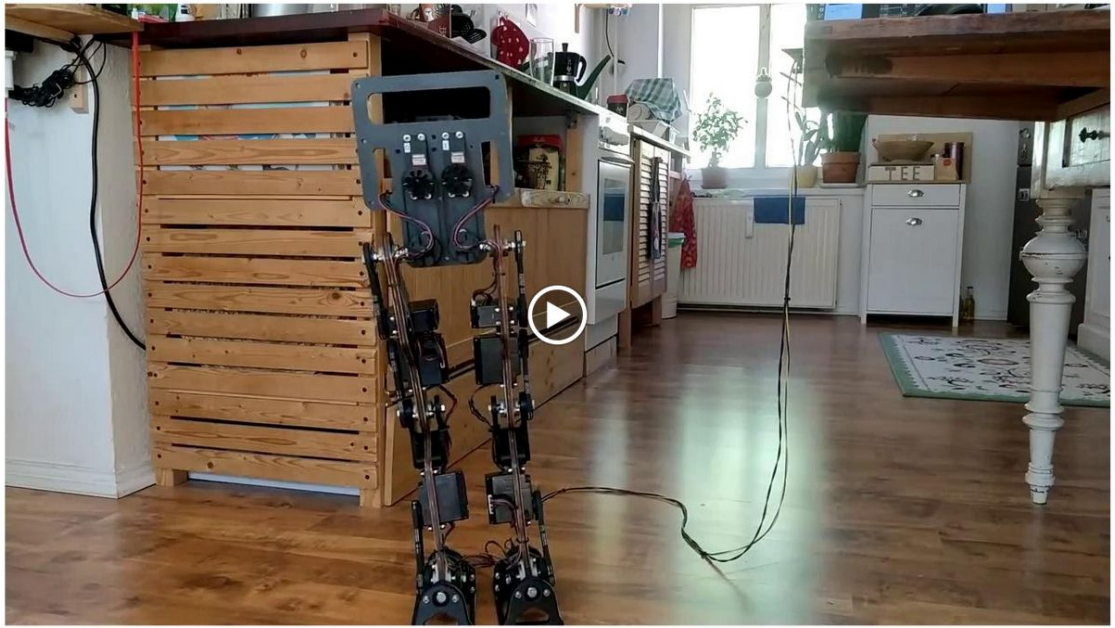
Software Overview



Stand Up Demo & First Steps



https://youtu.be/Sa2bKjIAHFQ

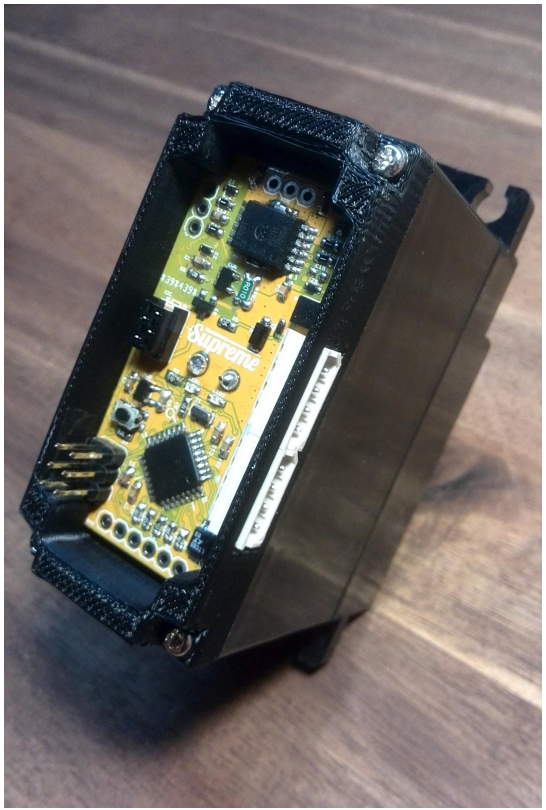


https://youtu.be/ubMeLkMhT9Y

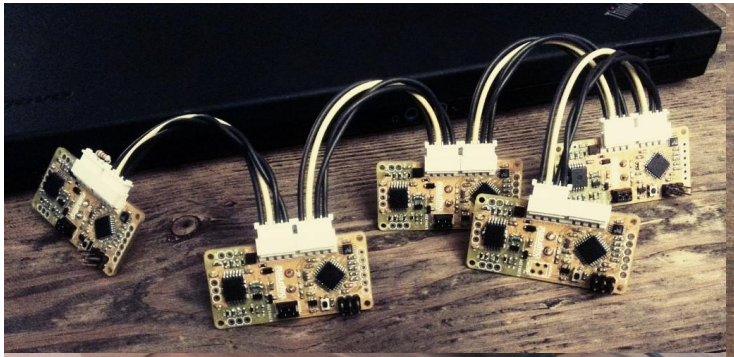
Sensorimotor boards

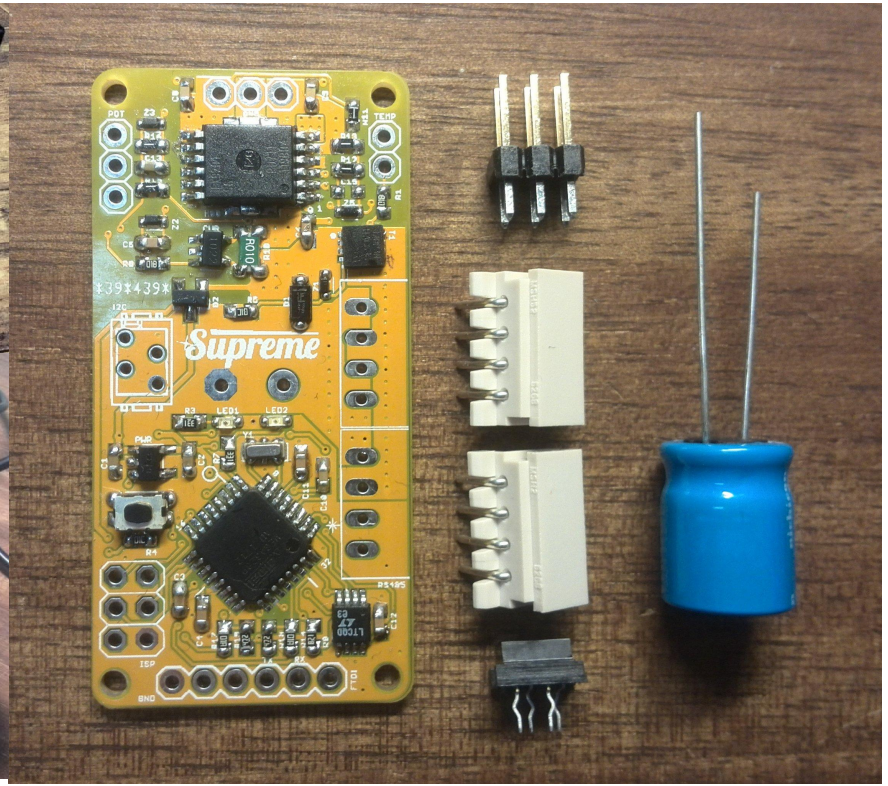
What is the Sensorimotor project about?

- open-source robot servo drive
- free hardware design and free software
- hackable firmware
- allow for modular robots (robust rs485 bus communication)
- motor brand agnostic, any DC motor up to 6A,12V
- low-cost smart servo capabilities
- self-assembly to further reduce cost
- Initial motivation: building a fourlegged-robot



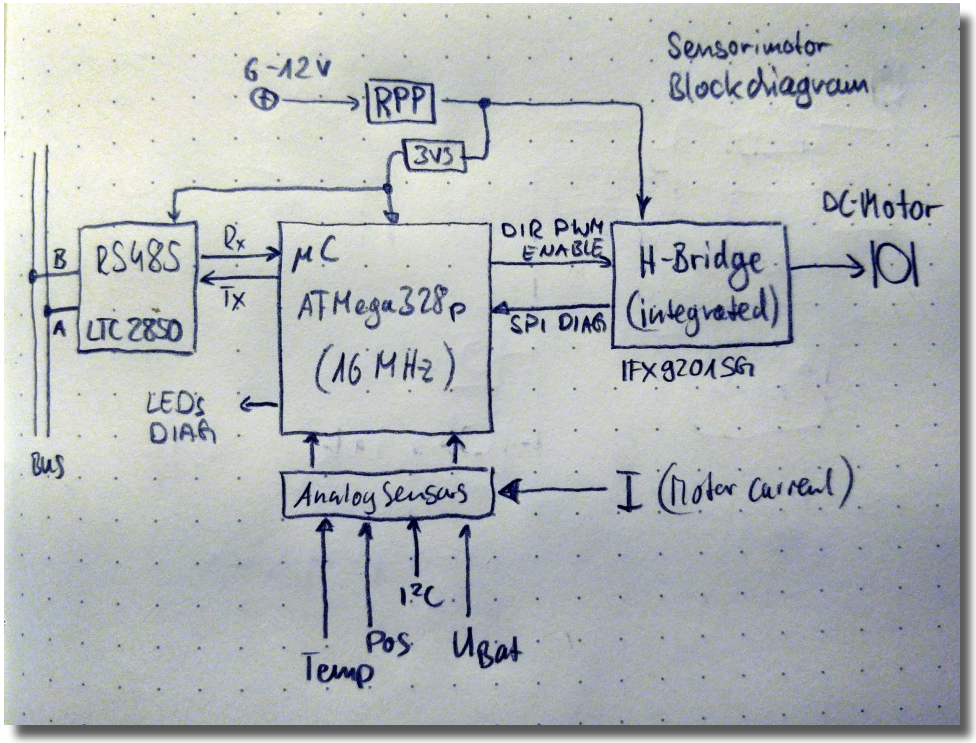
Sensorimotor



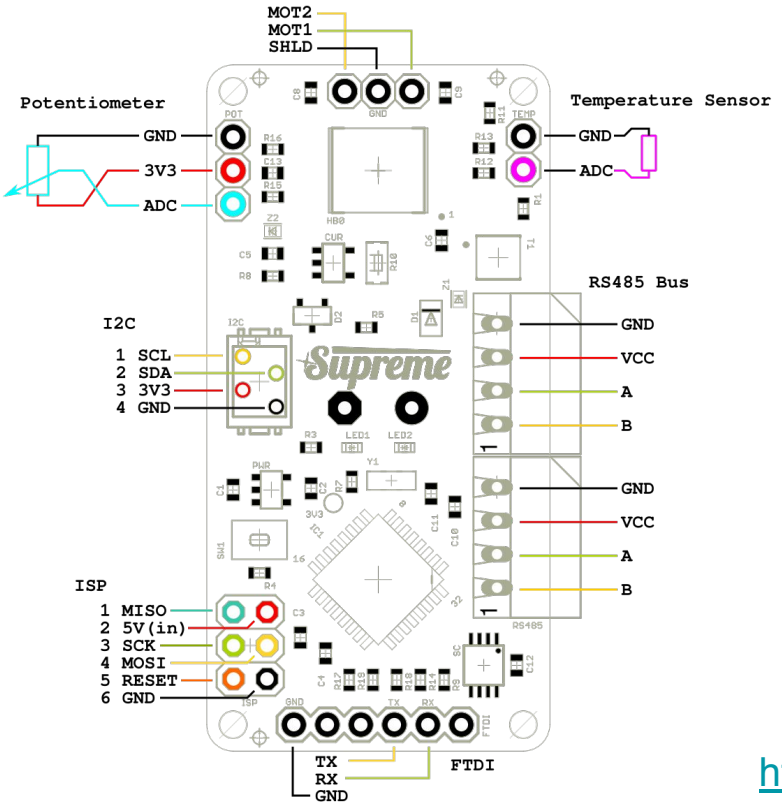


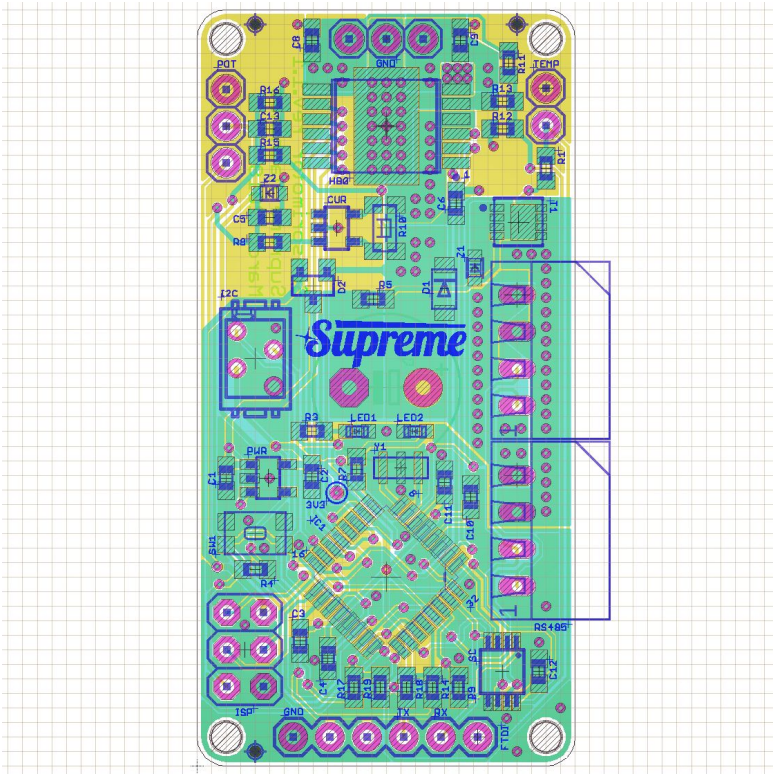
Sensorimotor: Technical Details / Schematics

- µC: ATmega328p
- RS485 bus, 1 MBaud, 256 units max.
- 6 A integrated H-bridge (IFX9201SG)
- position, velocity, current, voltage and temperature sensing
- additional sensors possible via I²C
- lean client/server com protocol
- 6–12 V(DC) supply voltage range



Sensorimotor: Schematics

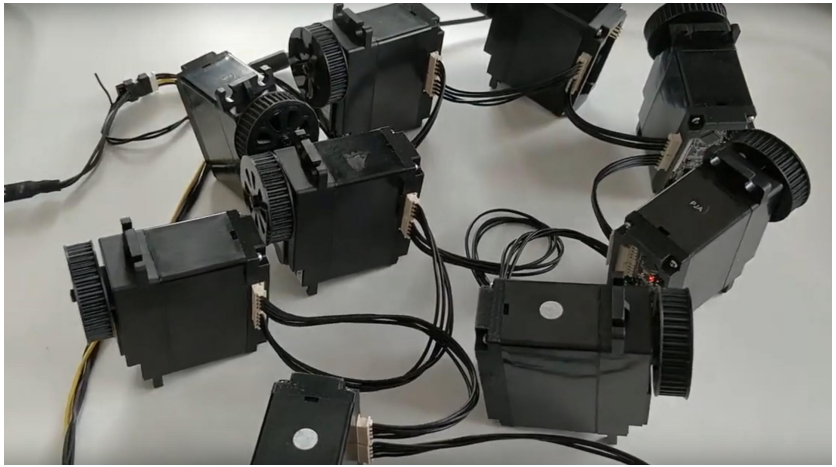




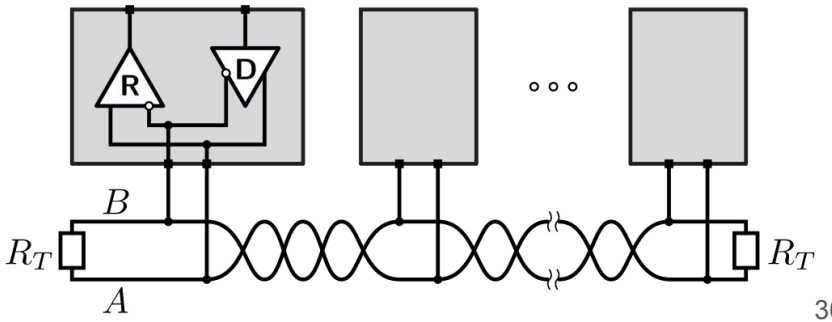
https://github.com/suprememachines/sensorimotor

RS485 bus communication

- multiple-tap differential bus
- inherent noise rejection
- speed: 1 MBd, limited by µC
- for wires > 1-2m, termination resistors recommended to reduce reflections
- simple custom protocol

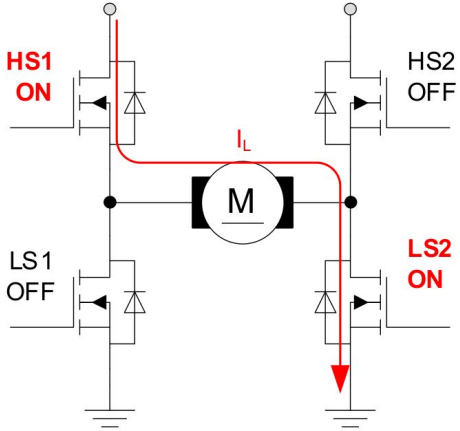


UX0 Motor Request from Host to Sensorimotor			
00	1111.1111	Sync 0	0xFF
01	1111.1111	Sync 1	0xFF
02	1011.000D	Request ID	0xB0, 0xB1, D:DIR
03	0xxx.xxxx	Motor ID	IDs 0..127
04	xxxx.xxxx	Voltage	simple 8bit PWM
05	cccc.cccc	Checksum	~sum_i(byte_i) + 1



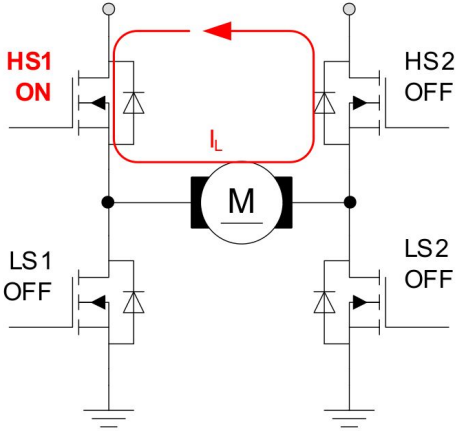
Motor Control Hardware Details

- Integrated H-bridge IFX9201SG
- 6A
- SPI-interface
- Freewheeling Mode



DIR=1, PWM=1

Forward



DIR=1, PWM=0

Freewheeling Through HS 2 Body Diode (Forward)

Firmware

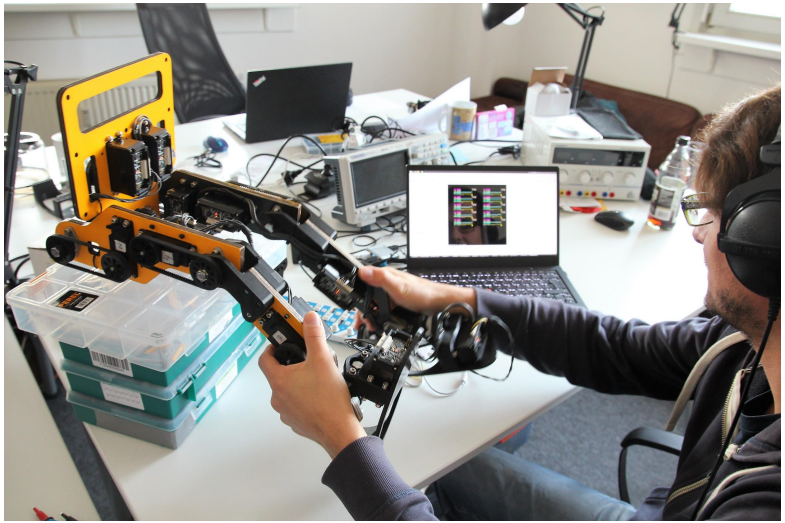
- 1 KHz internal loop
- 100 Hz communication loop (10 boards)
- Faster com with fewer boards in bus
- C++11 / xpcc-framework (now: MODM[1])
- Scons build system
- Servo-PWM control
- *What's next*: integrate PID, position and velocity control, CSL[2], torque control

```
92    »   systemClock::enable();¬
93    ¬
94    »   /* setup LEDs */¬
95    »   led::yellow::setOutput();¬
96    »   led::red::setOutput();¬
97    ¬
98    »   /* setup motor h-bridge */¬
99    »   motor::VSO::setOutput();¬
100   »   motor::DIR::setOutput();¬
101   »   motor::PWM::setOutput();¬
102   »   motor::DIS::setOutput();¬
103   ¬
104   »   /* connect and setup uart */¬
105   »   D0::setInput(Gpio::InputType::PullUp);¬
106   »   D0::connect(Uart0::Rx);¬
107   »   D1::connect(Uart0::Tx);¬
108   »   Uart0::initialize<systemClock, Uart0::Baudrate::MBps1>();
```

[1] https://modm.io/
[2] CSL: Cognitive Sensorimotor Loops (M.Hild et al.)

LibSensorimotor

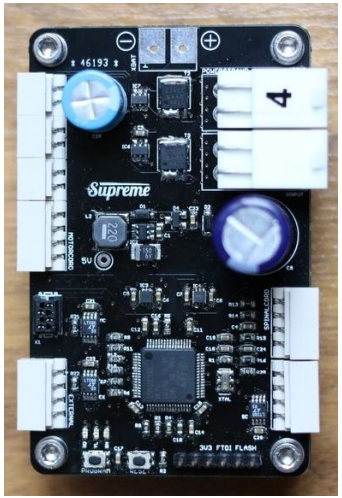
- Simple C++/Python library for controlling sensorimotors via Linux computers (e.g. PC or Raspberry PI)
- Supports various control modes
- Embedded Library Version under development



https://github.com/suprememachines/libsensorimotor

Other projects using Sensorimotor

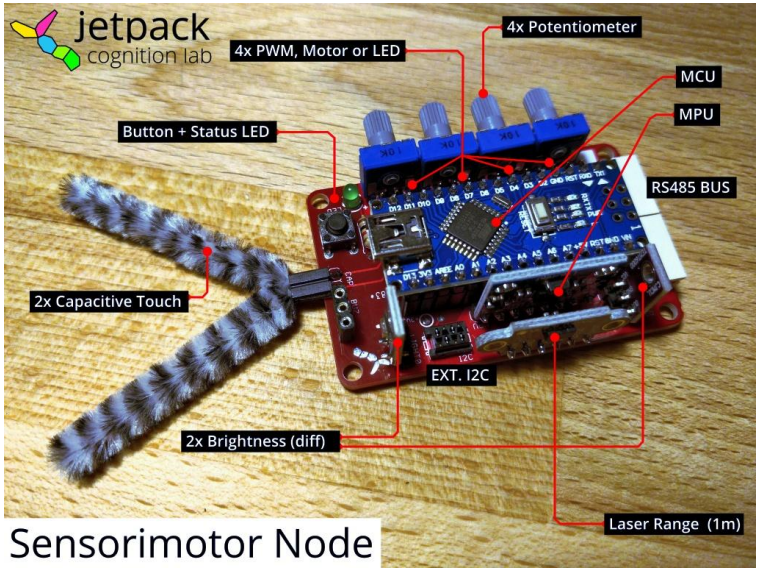
Flatcat



Hannah

Sensorimotor: Ongoing and Future Developments

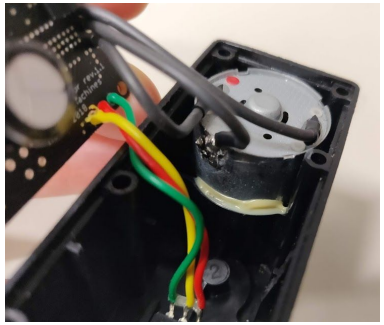
- Hardware Revision 1.2 (coming soon) with:
  - smaller footprint, easier to solder
  - pre-assembled temperature sensor
  - robust mounting holes
- LibSensorimotor for Arduino and STM32
- Derivative Versions:
  - *Node*, an RS485/Arduino based daughter board for motor control and sensor capture (prototype)
  - *Kiwi*, a micro-servo version (wip)
  - *Cargo*, a brushless heavy load version (wip)

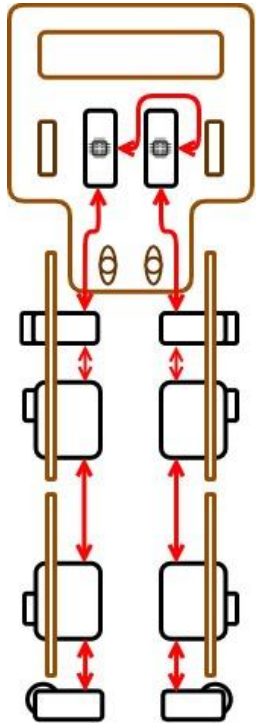


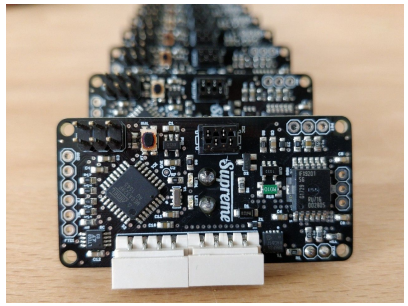
Sensorimotor Node

Stay tuned: https://jetpack.cl

Thank you for listening!







https://naoth.de

https://github.com/aibrainag/Gretchen

Ressources

- Gretchen related repositories
  https://github.com/Gretchen

- Berlin United
  https://naoth.de
- Jetpack Cognition Lab
  https://jetpack.cl
- AIBrain
  https://github.com/aibrainag