Devlopment of a weight-shifting based control scheme

BSc Colloquim

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Technical Aspects of Multimodal Systems

2019-12-10

1 Motivation

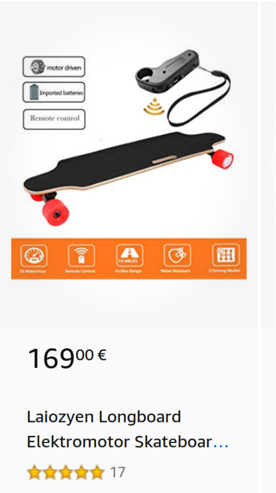
2 Planning
- Setting goals
- Definition of a control scheme

3 Hardware
- Microcontroller
- Sensors
- Electric longboard
- Assembly
- Breakout board and remote

4 Software
- Taking measurements
- Filtering
- Development tools and debugging features

What are electric longboards?

- longboards powered by an electric motor
  - usually at the rear axis
- Commercial products affordable
- Majority of products use remote controls
- Hands-free control is not adopted



https://www.amazon.de/Laiozyen-Longboard-Elektromotor-Skateboard-Fernbedienung/dp/B07VPTJ5SS

- Segway exist
  - controlled by shifting the operators weight

Idea

- Develop a hands-free control scheme for an electric longboard
- (optional) understand why similar products are not commercially available

Goals

- Evaluate required resources
- Develop proof-of-concept prototype
- Use practical experience to reevaluate
  - More filtering?
  - Bad response time?
  - Problems not anticipated

Control scheme

- Rough outline was part of the project idea.
- Adjustments based on practical experience

Priorities

- Safety by design (getting on the board)
- Intuitive for new users

Introduction: Loadcells

- Measure force
- Deformation causes change in electric resistance
- Requires signal amplification
- Robust

User position

- Wide stance
- Neutral postion
  - Equal weight distribution?
  - More weight on the rear foot?
- (optional) knees bent slightly (lower center of mass)

Acceleration

- Shifting bodyweight to the front
- Maintain stance to maintain current velocity
- Return to neutral position to roll out

Braking

- Shifting weight to the back
- Analogous to acceleration

Stepping on/off the board

on Stressing the rear first to engage brakes
slow controlled movement, avoiding load spike in the front

off Lift front foot of the board when stopped

Danger lifting rear foot causes acceleration

Reasoning

- Minimal set of motions
  - Intuitive, moderate learning curve
  - Avoiding misinterpreting the users wishes
- The users' inertia counteracts the desired action
- Requires a relative simple setup of sensors

3 Hardware
- Microcontroller
- Sensors
- Electric longboard
- Assembly
- Breakout board and remote

Bill of materials

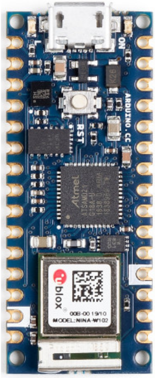
Product	Amount	Price
Electric longboard kit	1	340 €
Longboard deck	1	50 €
Load Cell 200kg (TAS606)	2	54 €
Arduino Nano 33 IoT	1	16 €
USB-powerbank	2	10 €
Total		≈ 470 €

The costs of 3D-printing, Soldering and the value of the signal amplifier are not listed.

Microcontroller: required taks

- Reading loadcells
- Control the longboard's motor
- Operate from battery power
- Use wireless communication
  - logging sensor data
  - update parameters on-the-fly

Arduino Nano 33 IoT



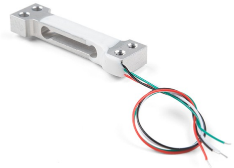
- 2 SPI-interfaces
- Surplus of digital pins
- Power via USB-battery
  - converting voltage from main battery too complex
- Analog pin with attached DAC
- WiFi-module on-board
- Small form factor
- IMU included on the board

Sources

https://store.arduino.cc/arduino-nano-33-iot

Loadcells

- Shape crucial for mounting
  - Stick
  - S-shape
  - “Hockey-puck”
- Capacity several human weights
  - ⇒ Dynamic load
- Amplifier required
  - using board developed by Bit-Bots



Sources:
https://www.exp-tech.de/en/sensors/load-cell/8978/mini-load-cell-500g-straight-bar-tal221

https://www.variohm.com/news-media/technical-blog-archive/what-is-an-s-type-load-cell-

Figure: Loadcell used in the current configuration, TAS606 with a capacity of 200Kg

Electric longboard

- Controlling motor with microcontroller should be possible
- Space beneath the board for the electronics
- Axes
  - Loadcells mounted using 3D-printed bracket

DIY Longboard Kit

- Modular Do-it-yourself-kit
  - access to internal components
- Longboard
  - Battery and electronics fit beaneath
  - Feet spread wide apart
- Clearance around the axes
- Technical data
  - **Speed** 35 kph
  - **Battery** 36V 10AH
  - **Range** up to 30km
  - **Weight** 8kg

Kit used http://www.diyeboard.com/10s5p-360wh-batteryescpower-truck-kit\
-dual-9052mm-hub-motors-p-598.html

Controlling the motor

Expectation

Connect the microcontroller directly to the “electric speed controller” of the board

- ESC not accessible
- Disassembling the remote controller is simple
- Emulate potentiometer with DAC of the microcontroller

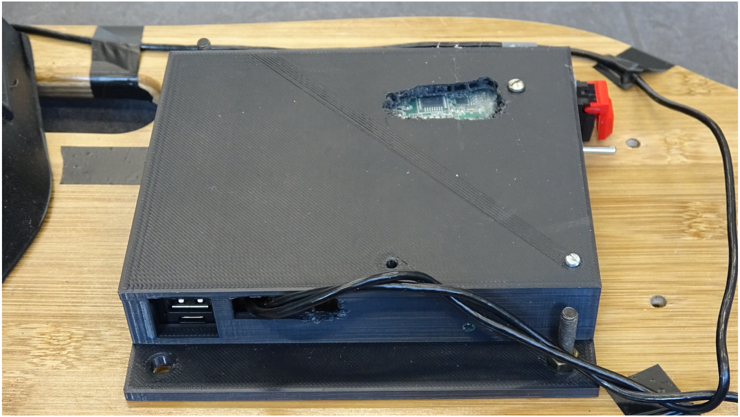


Figure: Eletronics box containing microcontroller, USB-battery, signal-amplifier and remote control

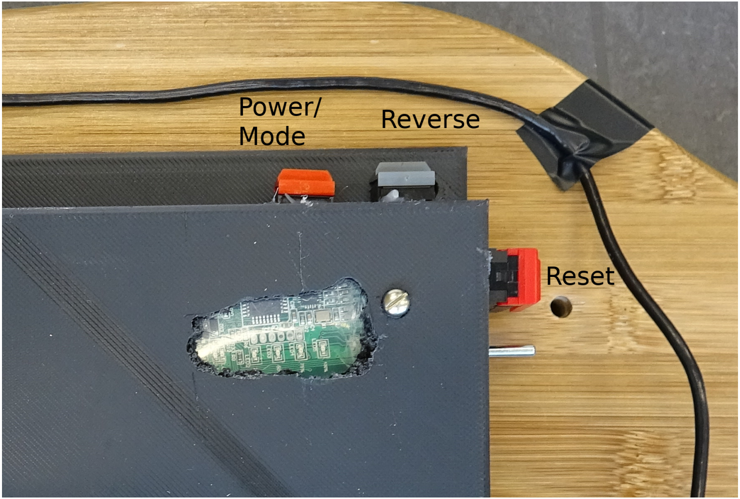
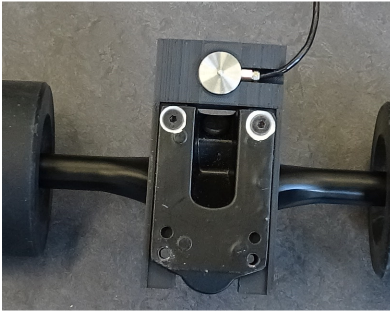
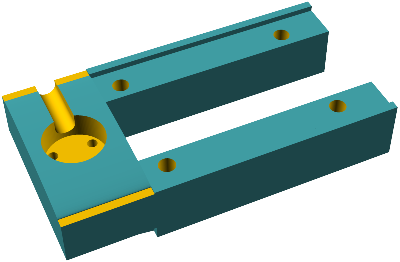
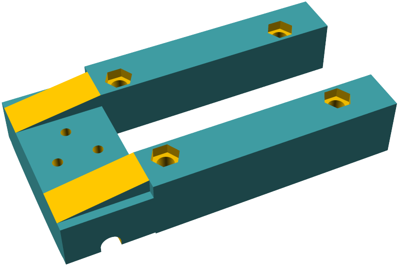


Figure: Buttons used to control the remote, charge the remote and reset the microcontroller

Assembly







Assembly

Breakout board and remote

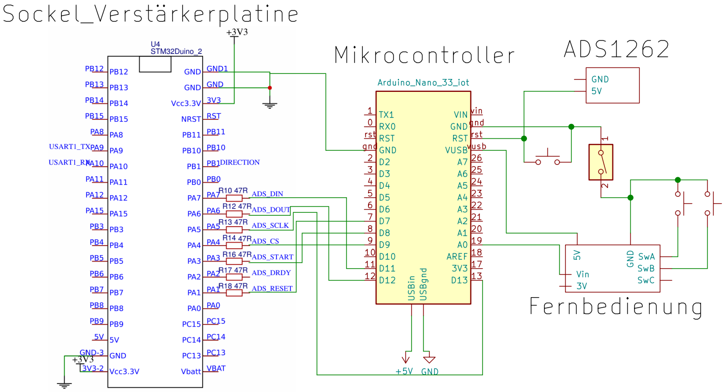


Figure: Schematic of electronic components

Breakout board and remote

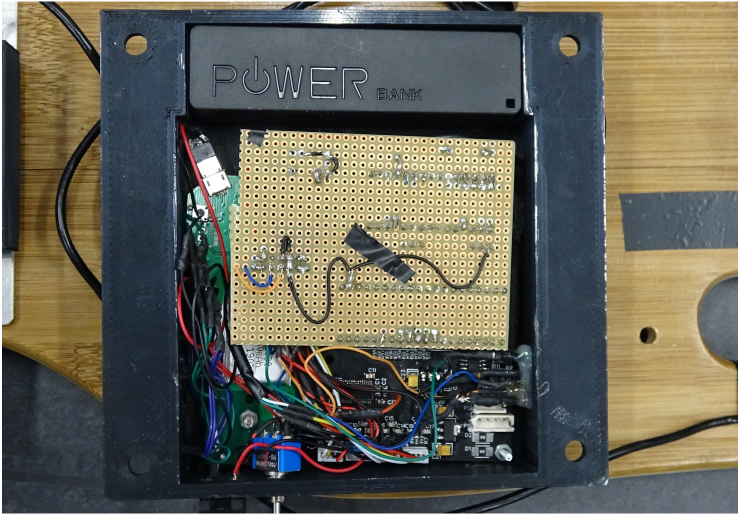


Figure: Electronic components packed in box

Breakout board and remote

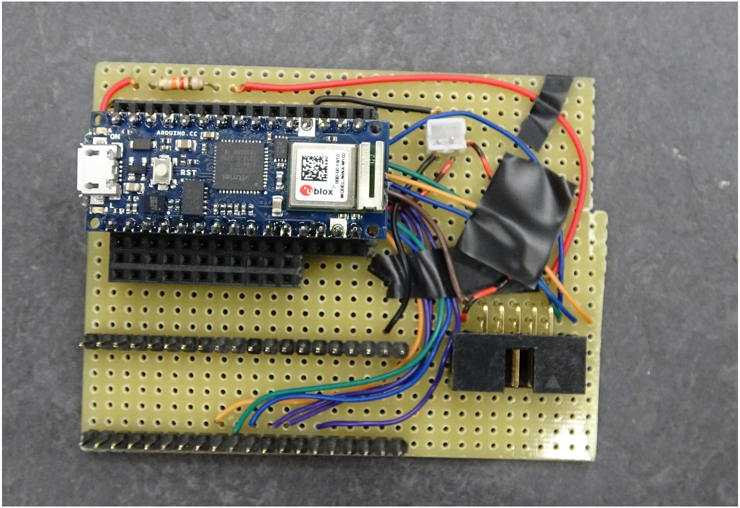


Figure: Breakout board connecting all components

Breakout board and remote

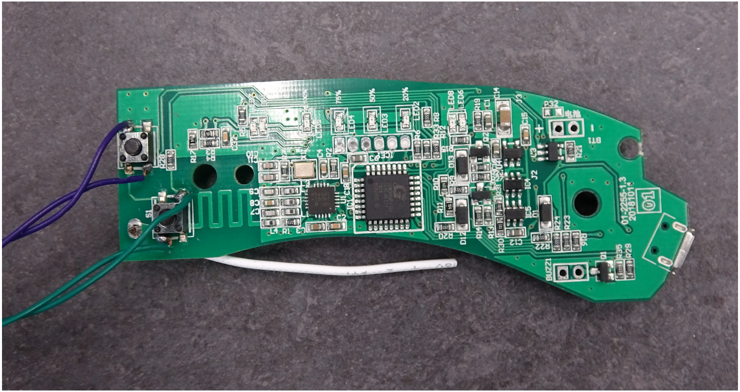


Figure: Remote controller with bypassed buttons

Reading the loadcells

- Signal amplifier required
- Communication using appropriate library, utilizing SPI

Performance bottleneck due to hardware properties

```
int32_t sensor_read_front() {
  delayMicroseconds(DELAY_ADC_READ);

  adc.readADC1(pos_pin[PIN_LOAD_CELL_FRONT],
  neg_pin[PIN_LOAD_CELL_FRONT]);

  delayMicroseconds(DELAY_ADC_READ);

  return adc.readADC1(pos_pin[PIN_LOAD_CELL_FRONT],
  neg_pin[PIN_LOAD_CELL_FRONT]);
}
```

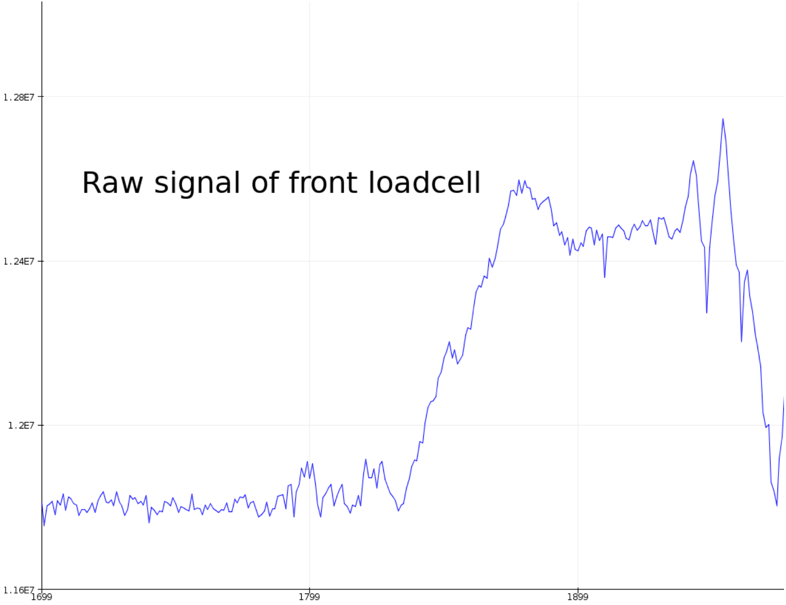
Problems

- Front and rear sensors react differently to stress
  - Sum not constant
- Measurements not guaranteed to be linear

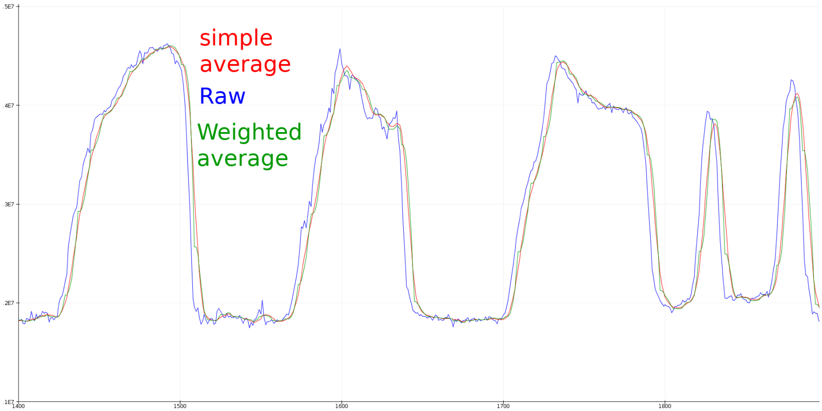
Mean value

- Raw signal contains noise
  - Electric interference
  - Vibrations
- Smoothing creates additional delay
  - acceptable history length?
- Tradeoff between responsiveness and smoothness of the signal

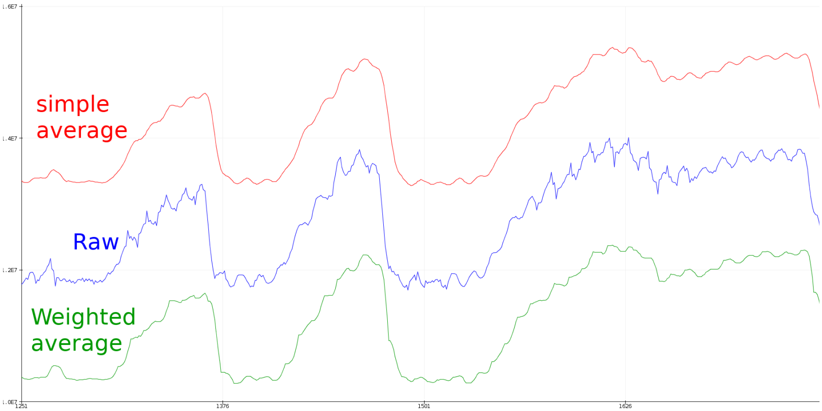
Filtering


Raw signal of front loadcell
1.28E7
1.24E7
1.2E7
1.16E7
1699
1799
1899

Filtering


simple average
Raw
Weighted average
.5E7
.4E7
.3E7
.2E7
.1E7
1400
1500
1600
1700
1800

Filtering

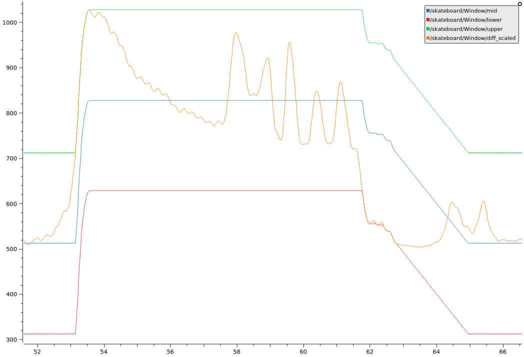

simple average
Raw
Weighted average
1.6E7
1.4E7
1.2E7
1.0E7
1251
1376
1501
1626

Preprocessing the datapoints

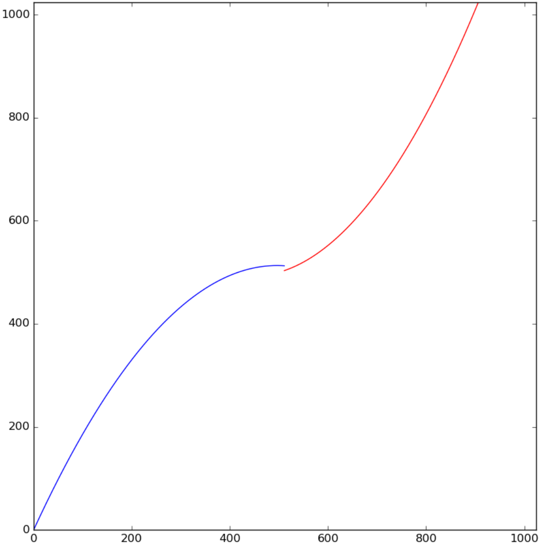
- Difference signal is generated from smoothed data
- Motor control requires values from 0 to 1023 (10 bits)
  - $\Rightarrow$ Assumptions about the users' weight

Window mechanism

- Filters oscillation caused by users' inertia
- Problems while braking/accelerating



Resulting 10 bit difference signal fed into response curve function



Controlling the motor

- Preprocessed response written out using analog pin with DAC

Serial communication with Arduino IDE

- Wired
- Print values at any point
- Fastest debugging

ROS

- Wireless
- Recording
  - Comparison between different configurations
  - Analyzing phenomena only occurring while in movement
- High burden to implement

rqt-reconfigure

- Update variables on the microcontroller without flashing
- Optimization
  - Curve
  - User weight threshold
  - Window size

Thank you for your attention!

[1] *Arduino Nano 33 IOT, technische Informationen.* URL: https://store.arduino.cc/arduino-nano-33-iot (visited on 10/10/2019).

[2] *Electric longboard as commercial product, example: Laiozyen Longboard Elektromotor Skateboard E Skateboard.* URL: https://www.amazon.de/Laiozyen-Longboard-Elektromotor-Skateboard-Fernbedienung/dp/B07VPTJ5SS (visited on 10/10/2019).