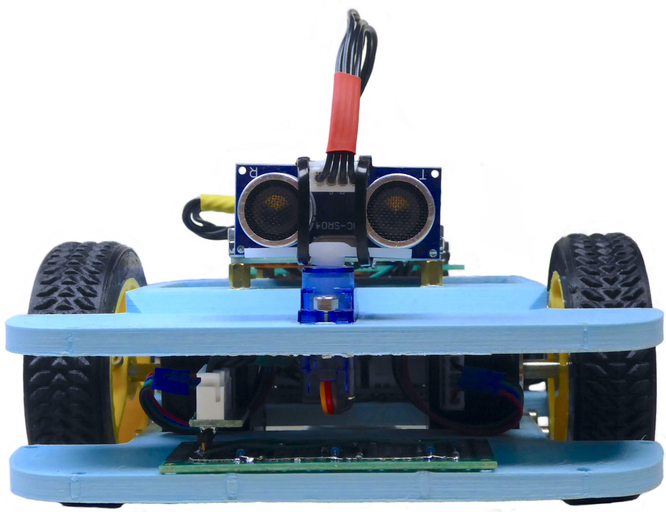
Prototyping a robotics plattform

in three different stages.



A project by Emil Altmann in 2023

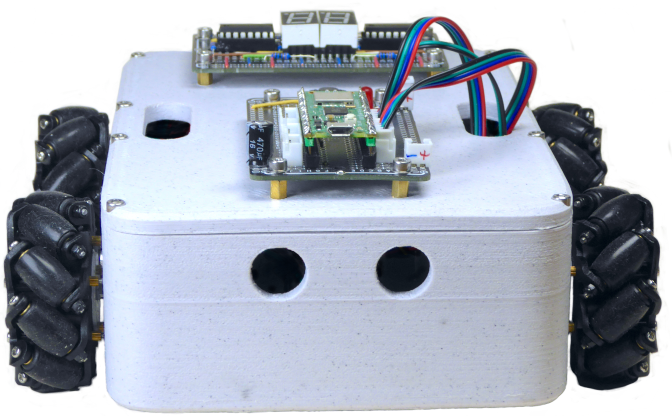
Prototyping a robotics plattform:

This project was motivated as a preparation for my diploma project. In three prototype testbeds, I tested different mechanical, electrical and programming ideas. This was done in an iterative progression. But most concepts where only done ones, because they failed or they exceeded their goals.

Many of the 3D prints were altered after creation, but I tried to keep the 3D models up to date with each alteration.

The whole project is published and documented on GitHub:

https://github.com/EmilAltmann/prototyping-a-robotics-plattforms.git



The first testbed:

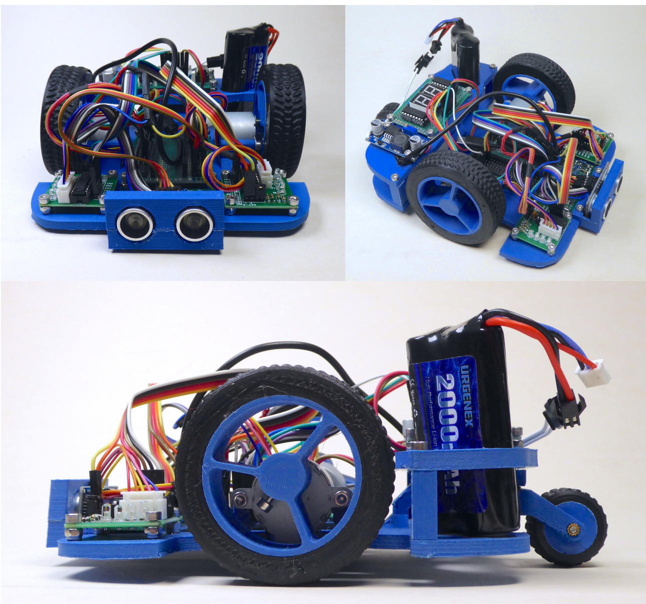
In the first prototype I used the raspberry pi pico w for my first time. So I really just tried around with the different software and hardware features of the rp2040 micro controller unit (mcu). The biggest feature I tested with tis testbed was the driving of the 28byj-48 stepper motors. Which were previously slow and computational heavy to drive with something like an arduino. Like expected, the programmable input output (pio) hardware of the mcu was really good at doing the bit banging for the steppers. But sadly the top speed and torque of the motor was just too slow and weak. Moreover I tested the use of the pio for shifting data out to an 74HC595 8bit serial in parallel out shift register. This was very nice, because I could run the communication at 100kBit/s which equates to over 3000 fps on a 4-by-7-segment display. Another big hurtle was the integrated bluetooth chip on the raspberry pi pico w. On release the mcu just had the support for wifi connectivity, but in the summer of 2023 the application programming interface (api) for the wireless chip was extended to allow a somewhat easy bluetooth communication. Sadly all of the released examples and most of the programs on the internet used higher communication protocols. But I wanted a bluetooth classic communication, with which you can send serial information like with the usb connection to an arduino. Luckily I found one example released by BlueKitchen which I could edit for my use case. The last thing I tested where the TRCT5000 infrared sensors for the detection and following of a black line. Those worked ok at first, but after lowering the pull down resistor from 10k Ohm to 5k7 Ohm, I had a full 12 bit swing from black to white which was wonderful.

Goals for the first testbed:

- Are the 28byj-48 stepper motors suitable for driving? - Which speeds and torques are achievable?
- Does a bluetooth classic serial communication work easily with a raspberry pi pico w?
- Are the TRCT5000 infrared sensors usable, without a comparator or amplifier, for driving?
- Is a PIO state machine applicable for sending serial data to an 74HC595 shift register?

CONCLUSIONS:

- The driving of the steppers is OK, but sadly the torque and speed is suboptimal at best.
- The bluetooth and wireless chip of the raspberry pi pico w is good but very complex.
- The TRCT5000 work good. Maybe they could be a little bit more narrow.
- The PIO is a good workhorse for serial communication to a shift register.



The second testbed:

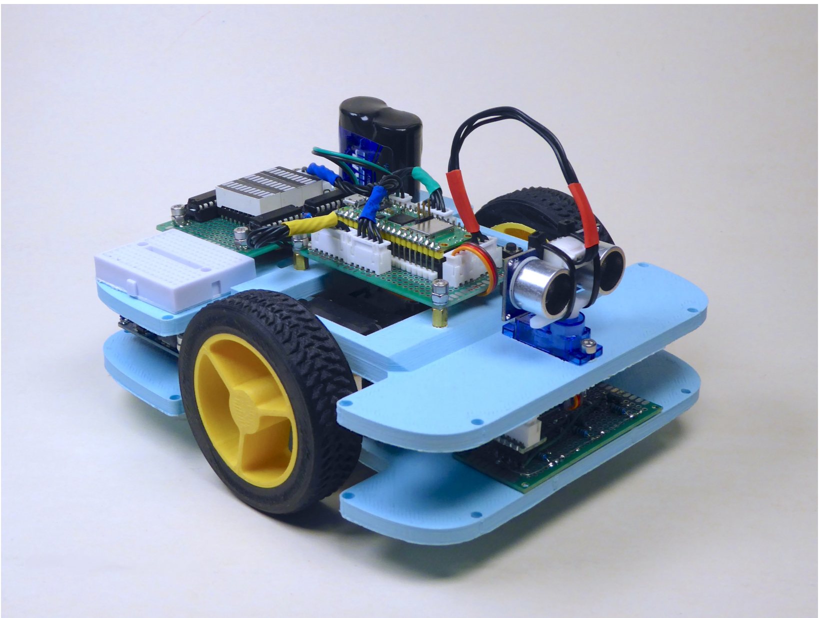
The second prototype started out as a great success, but sadly ended its live as the GND rail was “boosted“ up to 14.4V. However the prototype showed, that the NEMA17 steppers are good for driving, except for the whine they created with the a4988 drivers. I started off with a 23mm pancake motor, which was a little to weak at high rpm for a two wheel robot, but with full size NEMA17 the robot was very snappy at 14.4V. Moreover the bar graph display is a nice visual, but in my opinion not so useful for communication, as the seven segment display. As for the mishap I inserted the stepper drivers by accident with a one pin offset, this resulted that the H-bridge of the drivers was reversed powered and the motor VCC was shorted to the common GND. Sadly neither the electronic nor the hardware fuse of the battery cut the power and the low impedance of the Li-Ion battery pack gave all the silicon the rest. Luckily I socketed all active components so I could replace them after checking all the passive ones. But I sadly had to pass a test drive on the track of the university field of intelligent embedded systems.

Goals for the second testbed:

- Can we use polulu StepStick drivers and pancake NEMA17 steppers for driving?
- How does a bar graph display look for showing the line follower readings?
- Can the hardware PWM be used for tolerable RC servo signals?

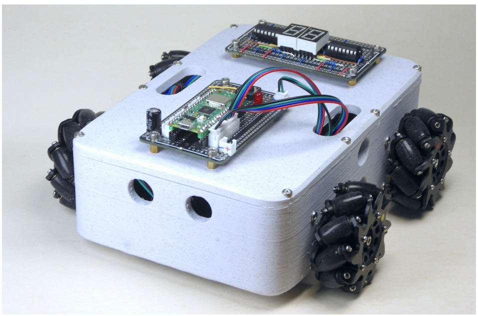
CONCLUSIONS:

- The NEMA17 are a bit too weak at 8.4V, but else OK.
- The bar graph display is an absolute rats nest of wires.
- The hardware PWM and servos are a match.



The third testbed:

The third testbed was created around the concept of mecanum wheels, which are special wheels which allow omni directional driving. Furthermore I wanted to test if four pancake NEMA17 driven by tmc2208 stepper drivers feel strong and fast enough for driving. The size and proportion of the robot where chosen by the constrain, that the 14.4V tool battery should be placed under the back of the robot. Moreover the length should be smaller than 20cm so I could print the two parted chassis directly on my 3D printer. The printing was one of the first really big prints with my ultimaker 2 and a 0.8mm high flow nozzle. The speed and stability of the print were exceptional, but you can see clearly the 10 000+ hours of printing the ultimaker did in its live. The tmc2208 stepper drivers are comparable in strength and speed to the a4988, but in StealthChop mode you only can hear the motors when changing directions and starting up or stopping. The whine isn't hearable any more which is very nice. Moreover I had a hiccup while designing the case of the robot, because I put the two holes for the ultrasonic module at the front at the wrong distance to each other. Furthermore I realized that the mecanum wheels have to much play in their movement, so sadly they behave not nice enough for autonomous driving. Another thing about the mecanum wheels is that they are very poor on even slightly uneven undergrounds. If one wheel looses contact to the surface the robot can move irregularly or even slide away.

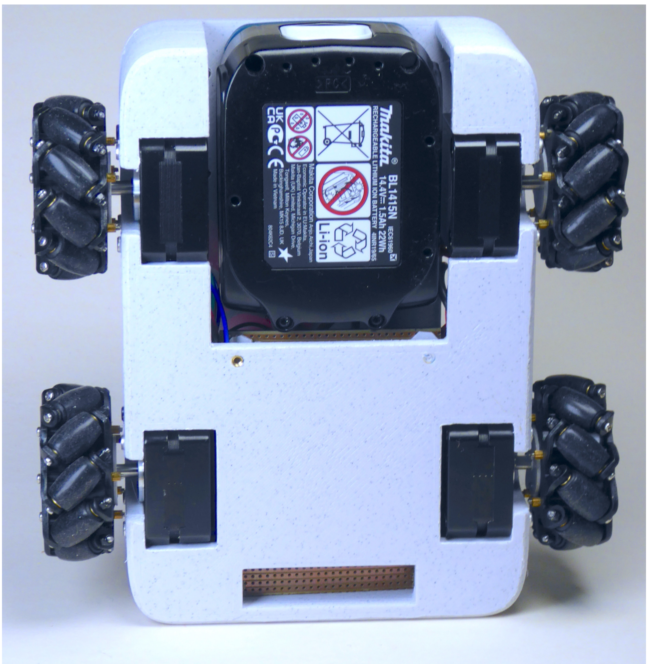


Goals for the third testbed:

- Is a four wheel drive with mecanum wheels and NEMA17 pancake motor possible?
- Can a 14.4V Li-ion power tool battery be used?
- Are tmc2208 faster, stronger and quieter than the a4988 stepper drivers?

CONCLUSIONS

- four NEMA17 pancake steppers are well suited for driving, but the mecanum wheels are dependent of a perfectly even surface.
- The 14.4V Li-ion power tool battery is very convenient and safe, so from now on I will always use these batteries for my robotic projects.
- tmc2208 stepper drivers are a nice replacement. The only problem I had was that I didn't connect the enable pin to GND which wasn't necessary for the a4988 drivers.



Essence for the diploma robot:

WHAT THE ROBOT SHOULD DO:

- driving
- bluetooth communication
- line detecting
- find its orientation and position
- range detecting
- be interactive
- **not** breaking and easy to repair

WHAT THE ROBOT SHOULD HAVE:

- differential steering
- three infrared line sensors
- IMU
- pan (and tilt) gimbal with TOF or ultrasonic sensor
- LED lights/displays/bars
- power tool battery

WHAT THE ROBOT COULD HAVE:

- stereo vision cameras
- LiDAR
- RFID
- Camera
- mecanum wheels
- tracked propulsion
- color sensors for line detection
- GNSS
- grabber (2 axis manipulator)
- bumper sensors

WHAT ARE THE DESIGN RULES OF THE ROBOT:

- be modular / hot swappable components
- only use “of the shelf components“
- easy and fast to 3D print
- no irreversible connections / fasteners / assembles
- minimal diversity of components
- only rugged connectors
- PCBs should be doable in Perma-Proto Board layouts

LIMITATIONS AND NO GOES:

- pink
- not lager than 200 x 300 x 100 mm
- being to loud
- having to disassemble something else to get to an issue
- rats nest of wires

CONCLUSIONS FOR THE TOP AND BOTTOM BAYS:

- 60 x 90mm due to the PCBs at 51x81mm
- Height 20mm
- open at front and top

CONCLUSIONS FOR THE MOTOR BAY:

- height full
- depth 30mm and length 160mm