Robot arm

Svavar Konráðsson

HÁSKÓLI ÍSLANDS
IÐNAÐARVERKFRÆÐI-, VÉLAVERKFRÆÐI- OG TÖLVUNARFRÆÐIDEILD

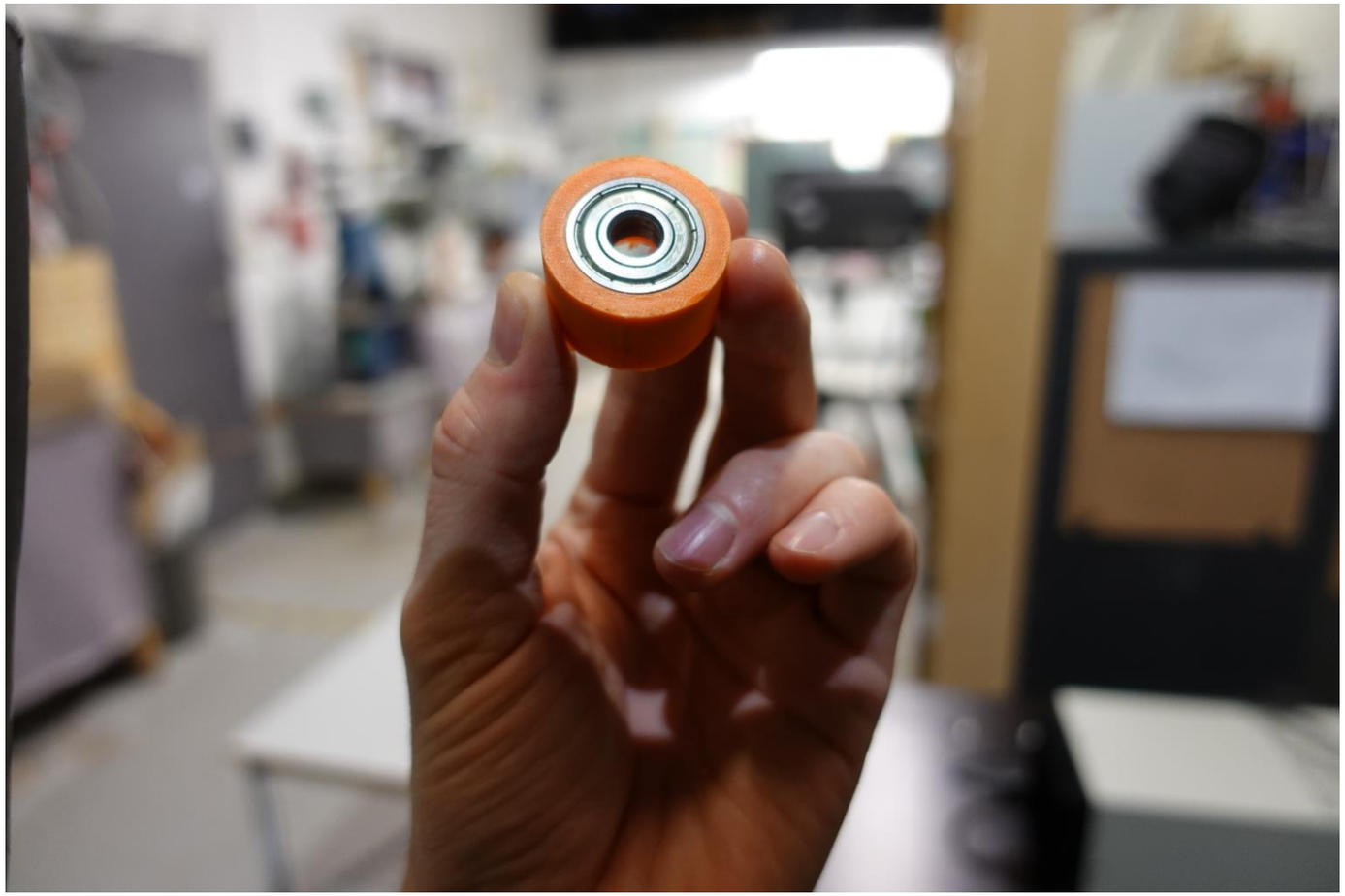
Project goals

- Robotic arm with 3 DOF
- Smooth and repeatable motion
- End effector always parallel to ground, until actuated (to pick up wine glass and pour)
- Create motion assembly before building

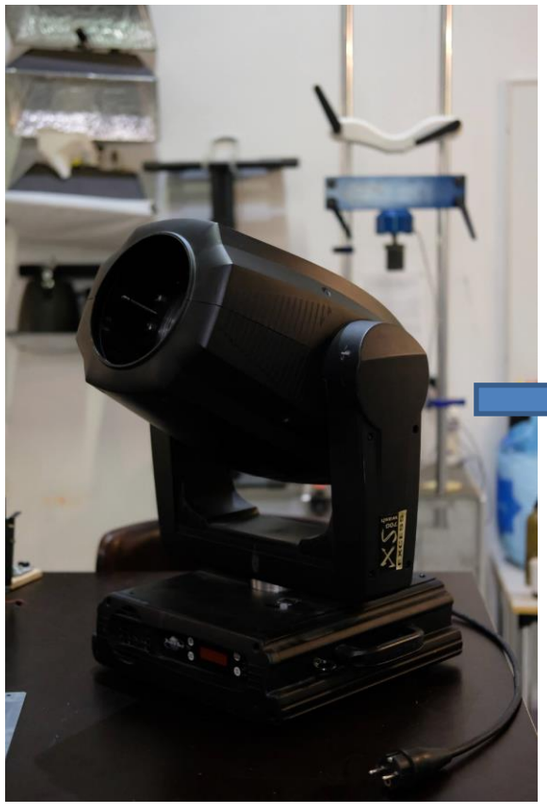
Practicalities

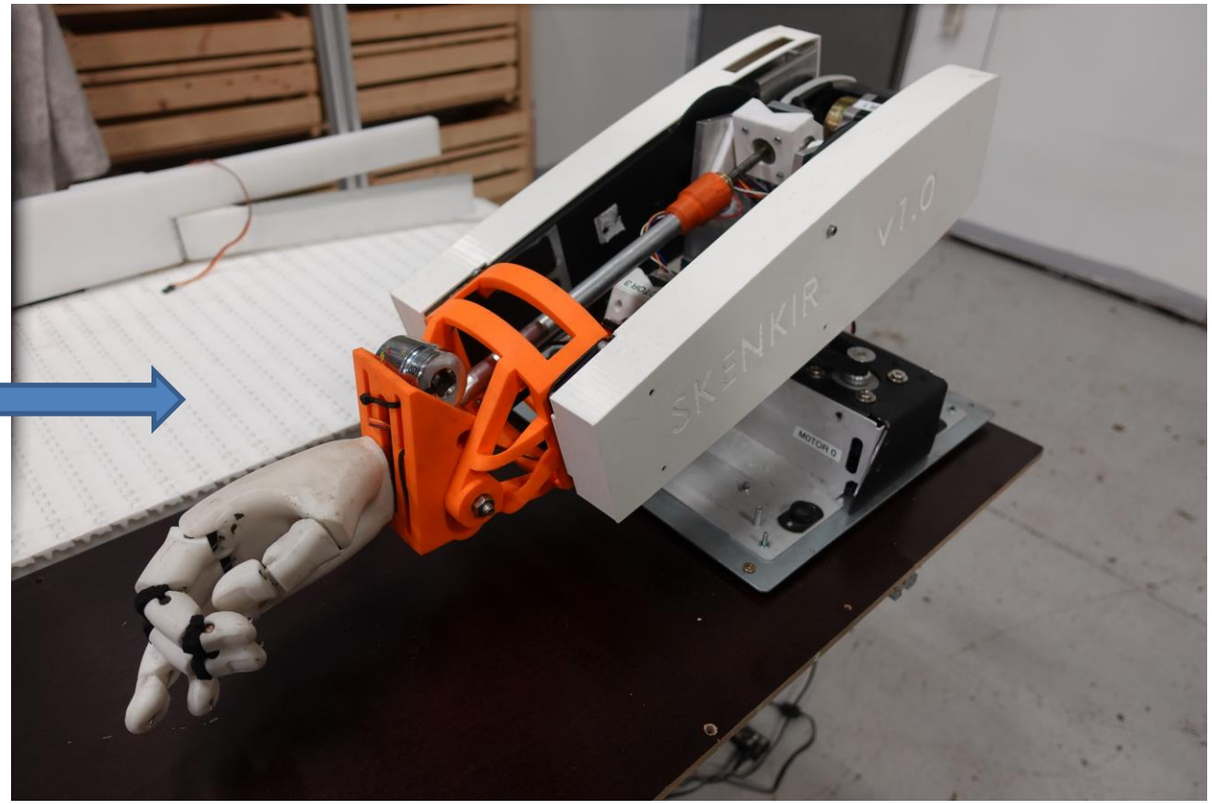
- Only model what’s necessary for a motion assembly
- No time to include bearings, bolts etc.
- Use assembly mates instead
- 3D print small sized fit tests for bearings, rods
- Use plenty of clearance for bolts

Bearing fit test

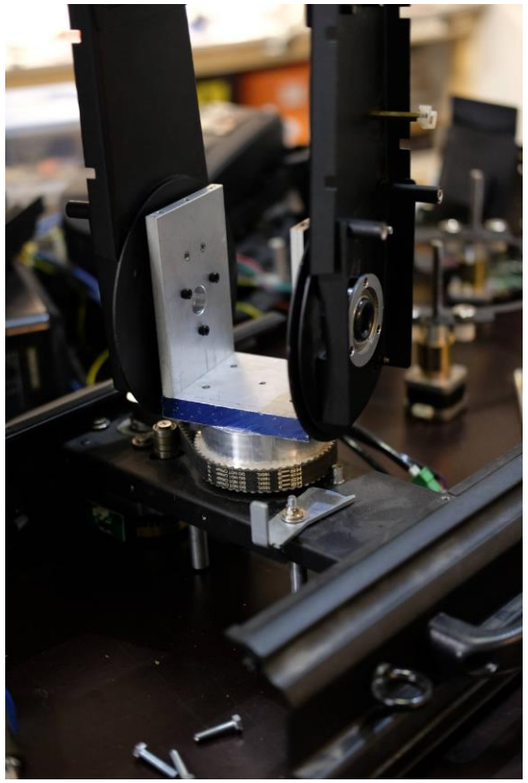


Transform old theatre light into robotic arm

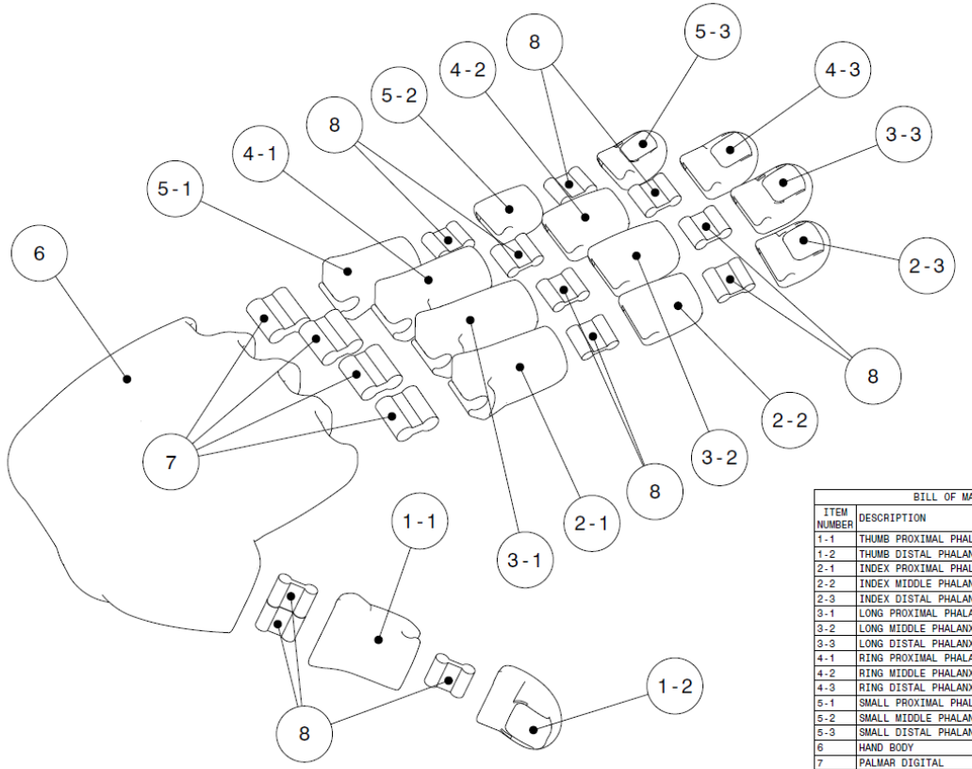




Turn it upside down



3D printed TPU hand from Thingiverse



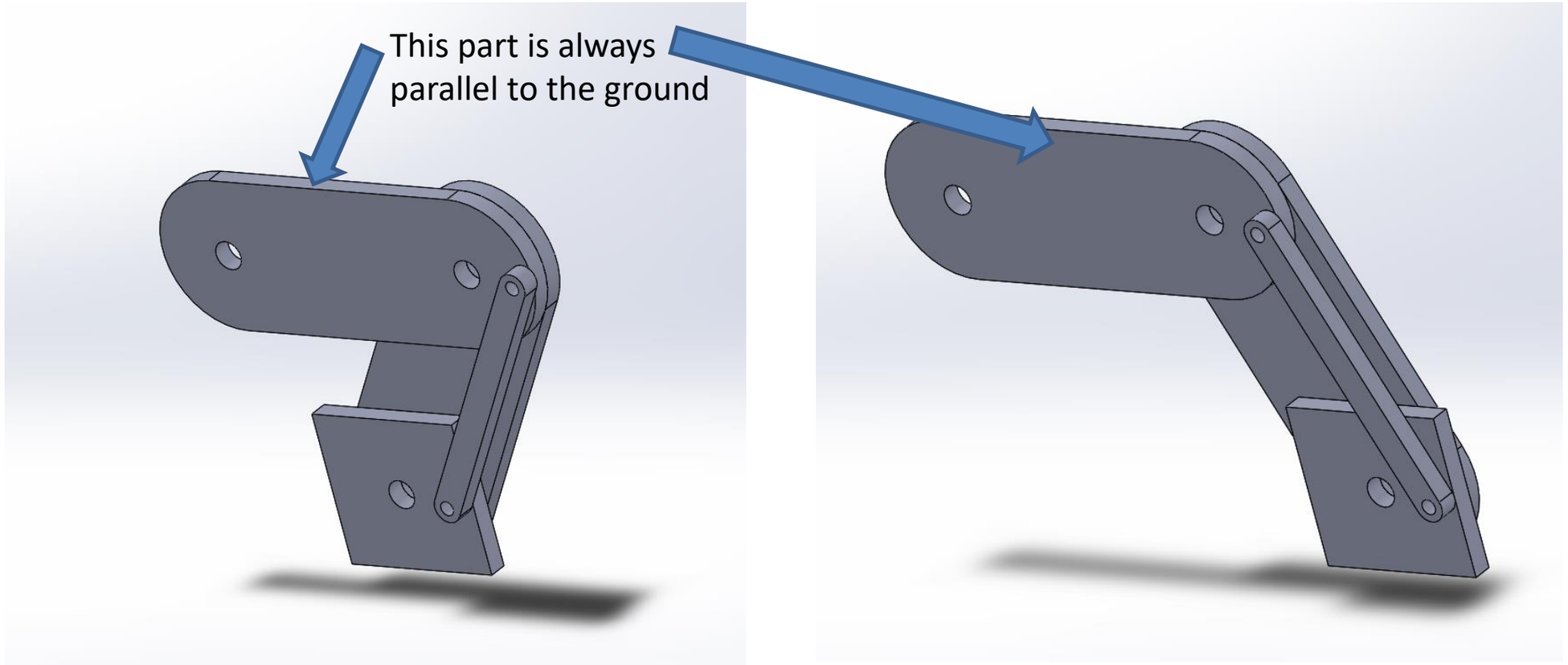
EXPLODED VIEW

BILL OF MATERIALS		
ITEM NUMBER	DESCRIPTION	NUMBER OFF
1-1	THUMB PROXIMAL PHALANX	1
1-2	THUMB DISTAL PHALANX	1
2-1	INDEX PROXIMAL PHALANX	1
2-2	INDEX MIDDLE PHALANX	1
2-3	INDEX DISTAL PHALANX	1
3-1	LONG PROXIMAL PHALANX	1
3-2	LONG MIDDLE PHALANX	1
3-3	LONG DISTAL PHALANX	1
4-1	RING PROXIMAL PHALANX	1
4-2	RING MIDDLE PHALANX	1
4-3	RING DISTAL PHALANX	1
5-1	SMALL PROXIMAL PHALANX	1
5-2	SMALL MIDDLE PHALANX	1
5-3	SMALL DISTAL PHALANX	1
6	HAND BODY	1
7	PALMAR DIGITAL	4
8	PROXIMAL AND DISTAL INTERPHALANGEAL	11

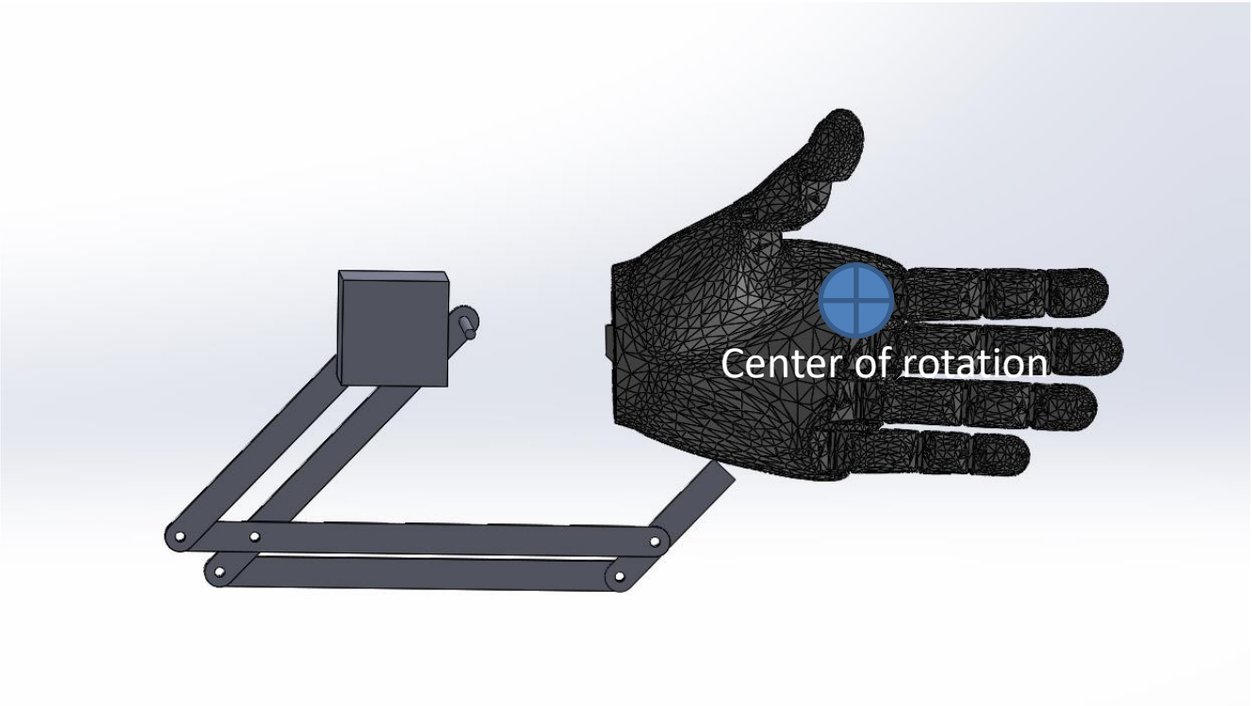
3D printed TPU hand from Thingiverse

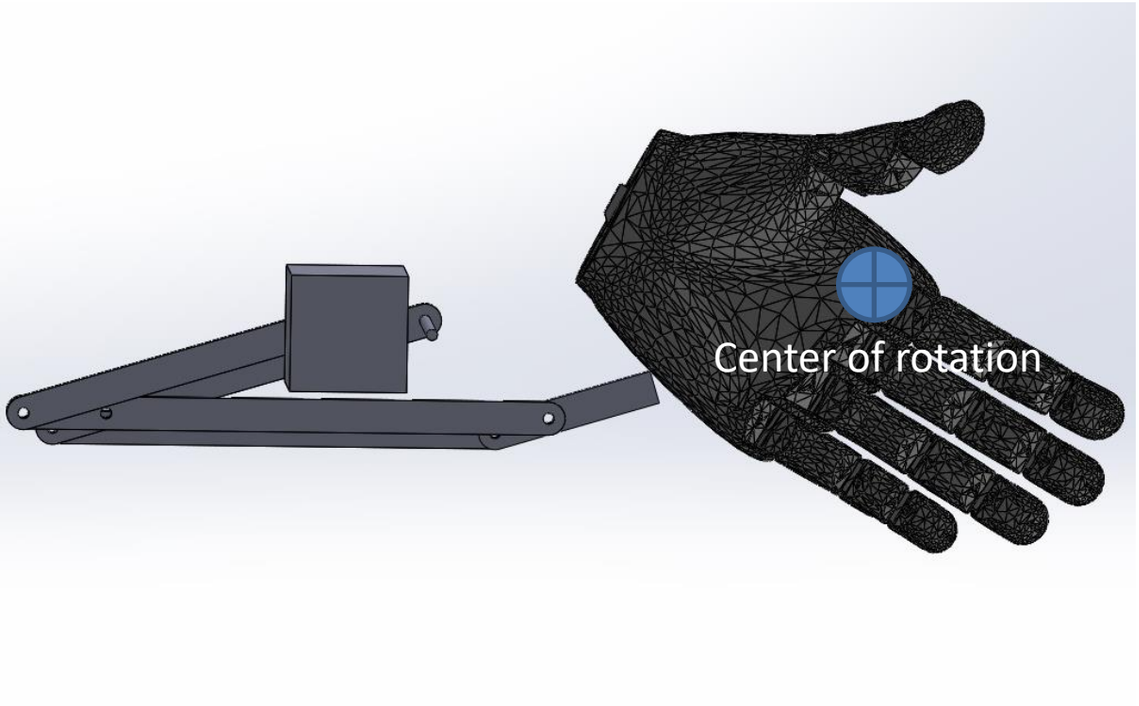
Made some modifications

Simple parallel linkage test



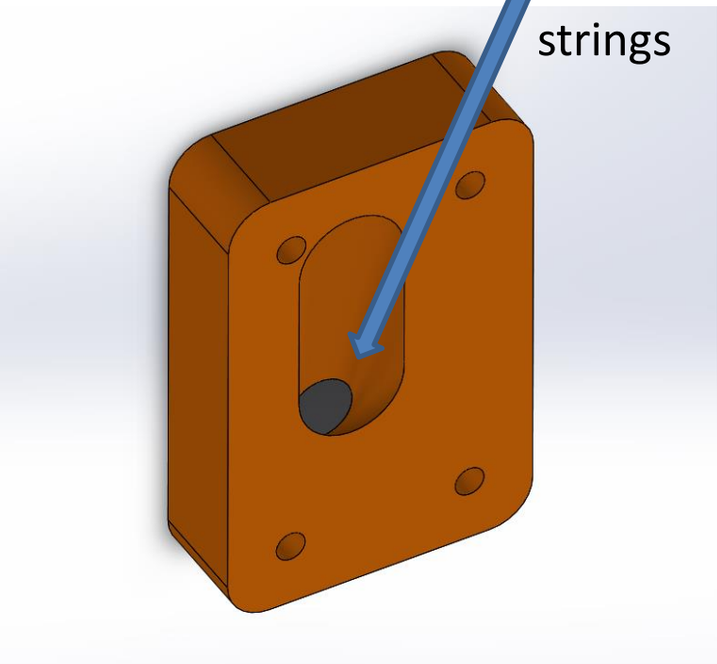
Advanced parallel linkage test

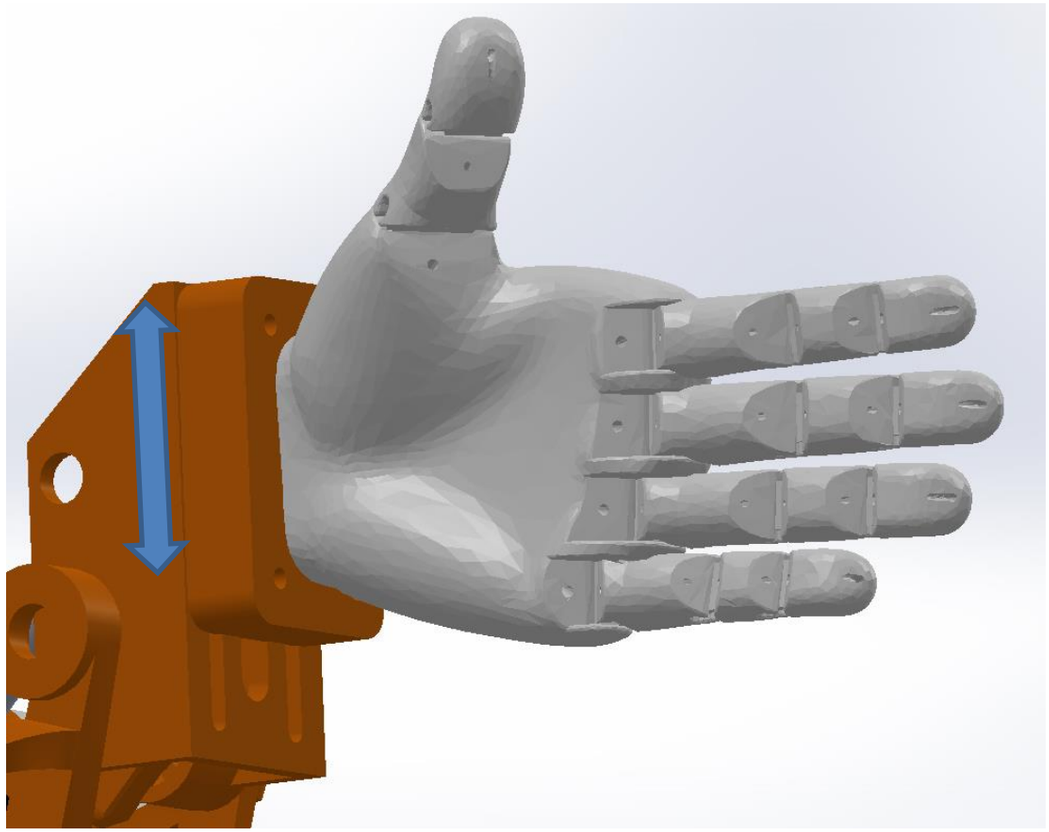




This mechanism shifts the center of rotation to the center of the hand. This was intended to pour smoothly out of a wine glass. But it’s big and complicated.

Adjustable hand height

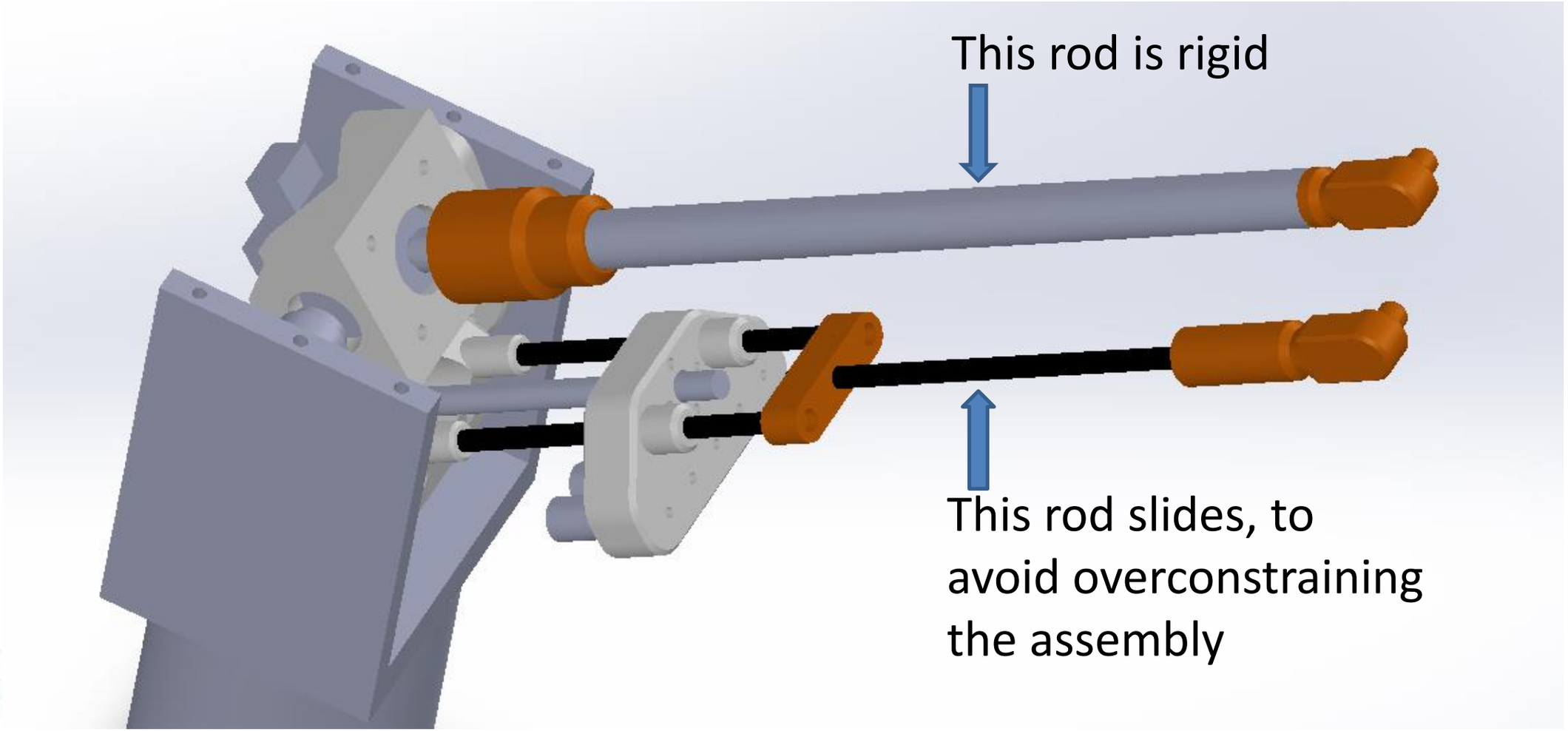




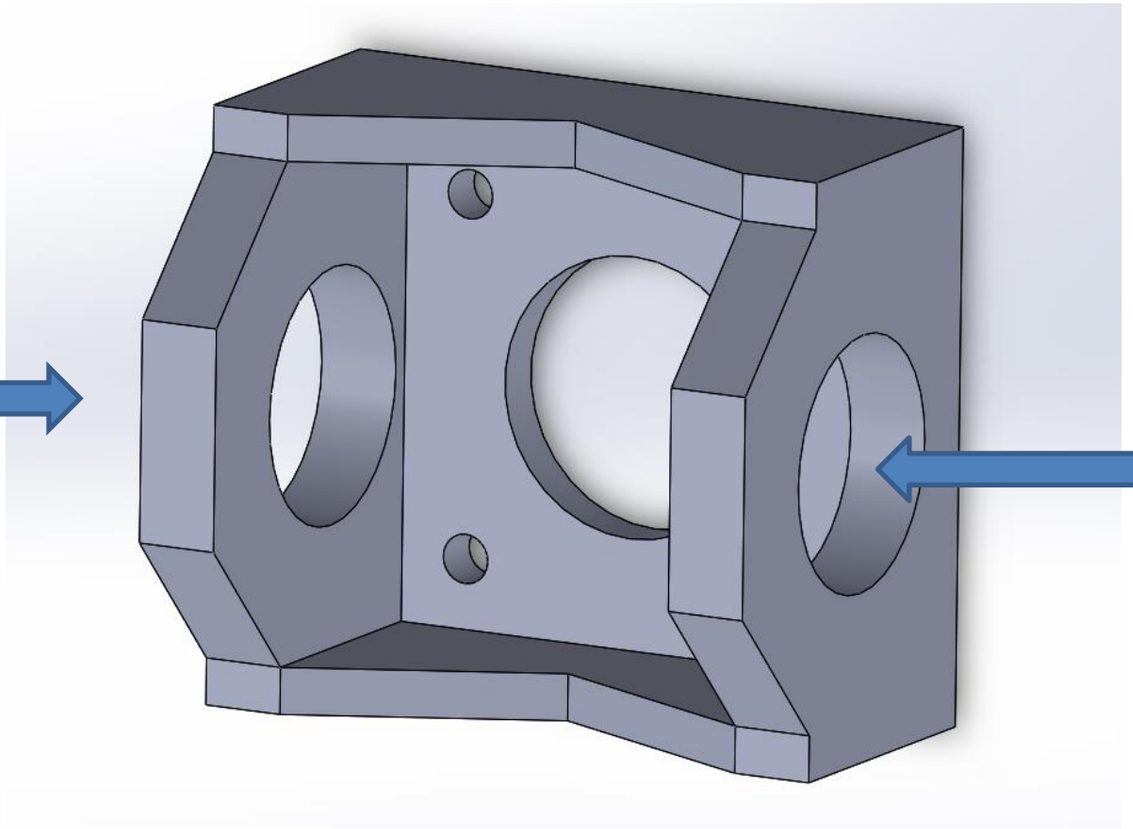
Working with STL files in SolidWorks is not fun.

I imported the hand into Fusion 360, reduced the polygon count drastically, converted it into a Brep solid and then I could use it in a SolidWorks assembly.

Parallel linkage with two steppers



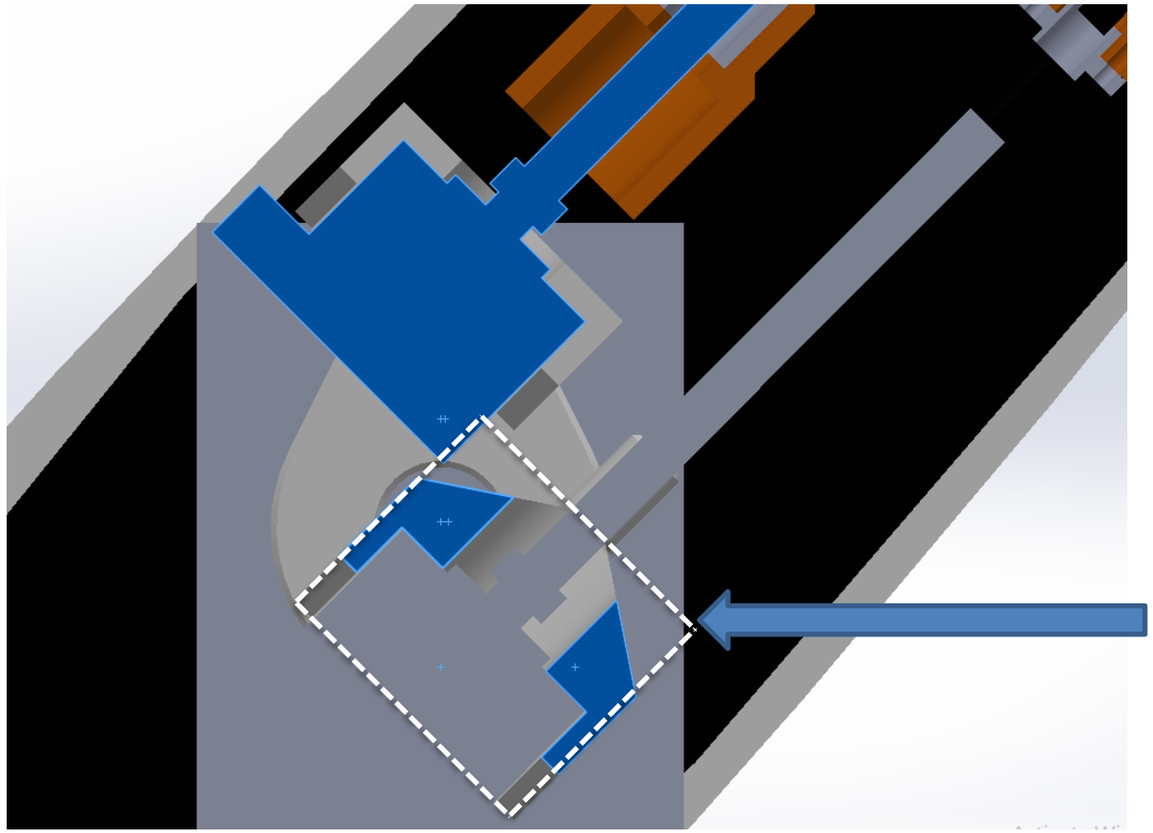
Top stepper bracket



2x press fit bearings

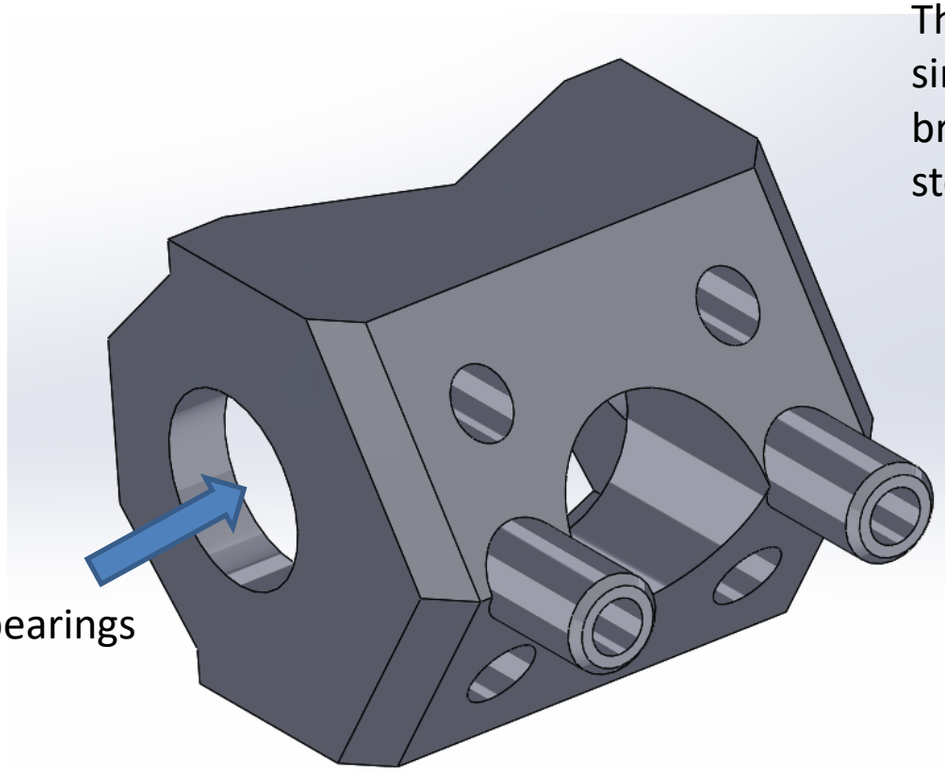
Silly mistake: Too little clearence for the stepper. Printed again. Don’t press fit a stepper into a bracket!

Bottom stepper bracket changed



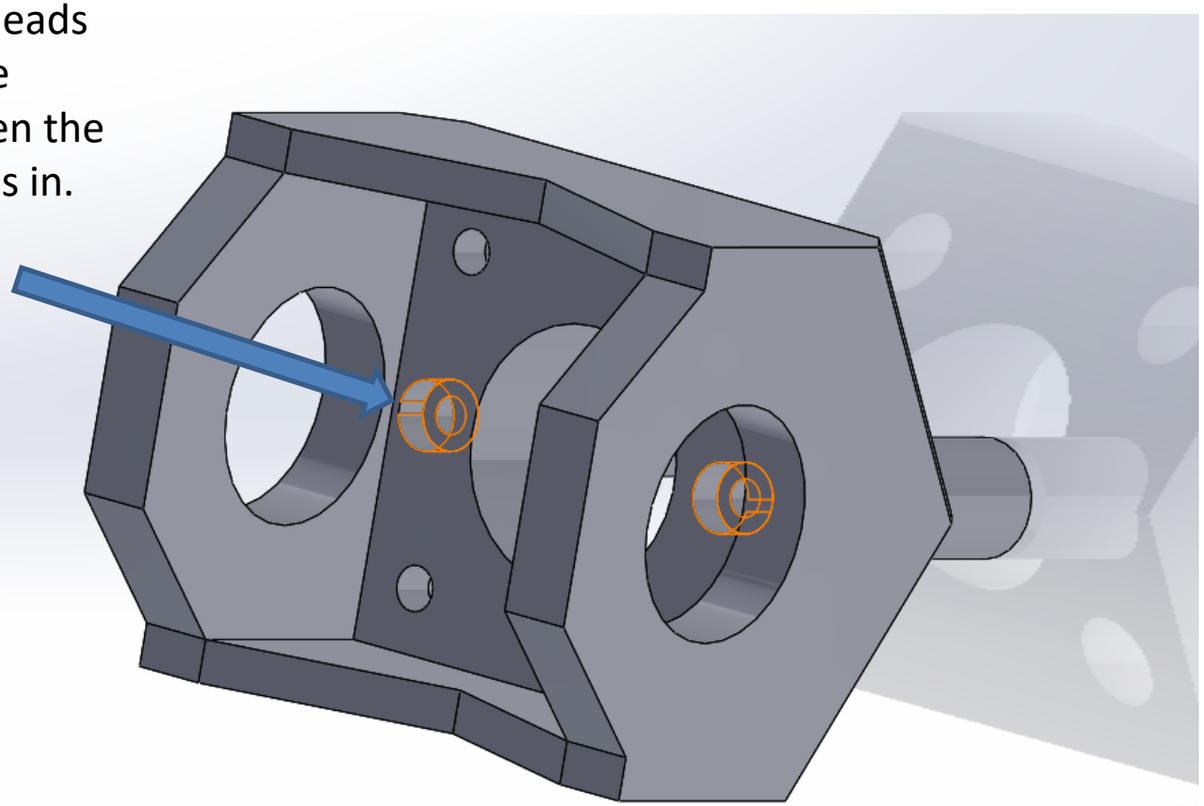
The original design bumps into the top stepper bracket when the arm is raised. Huge chamfers were added before printing.

Bottom stepper bracket

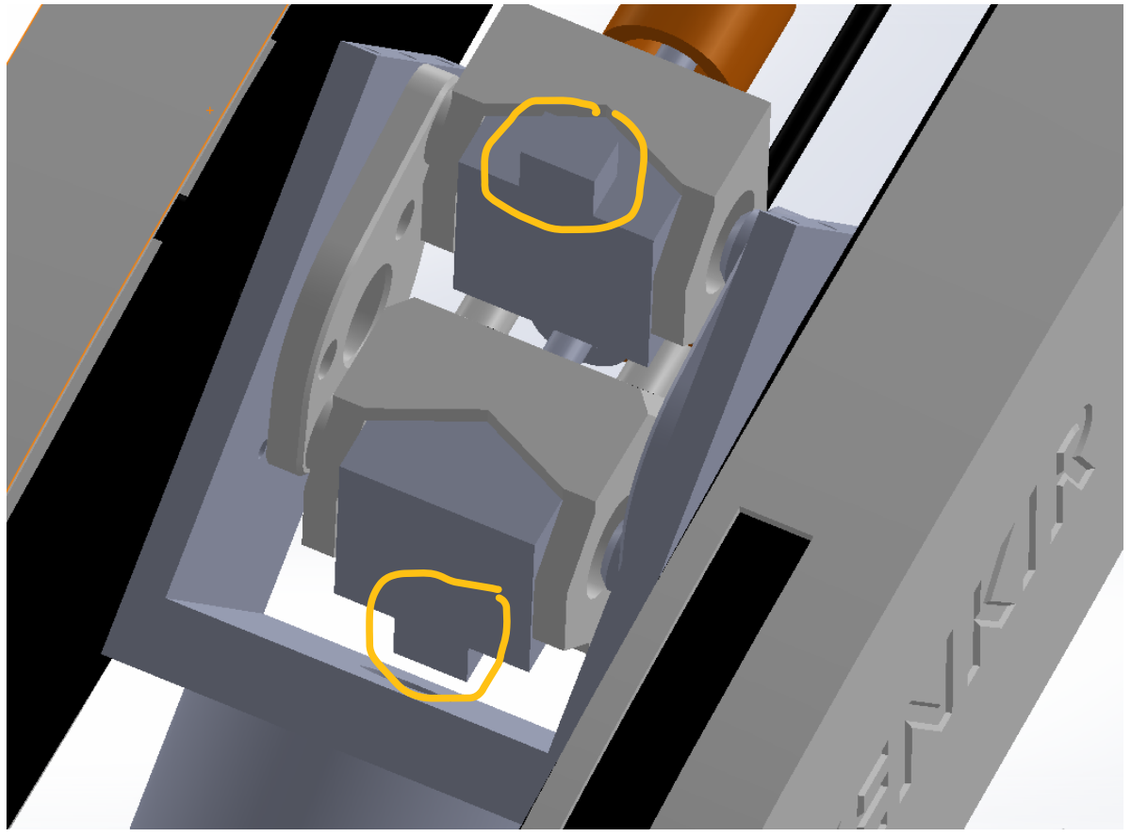


2x bearings

The screw heads sink into the bracket. Then the stepper goes in.

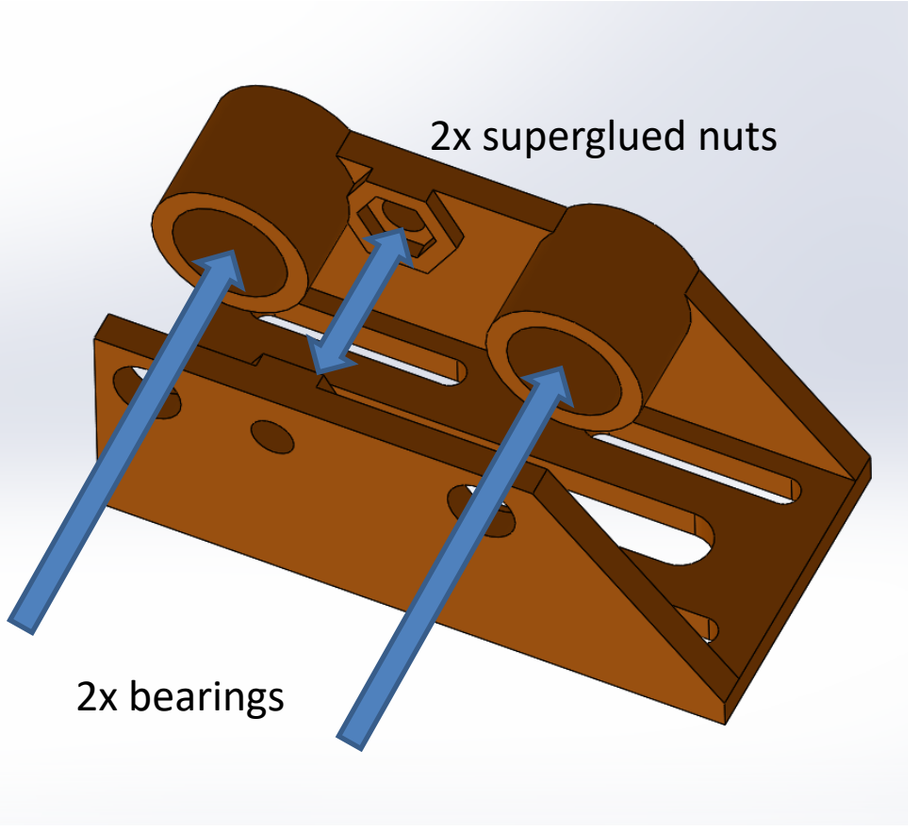


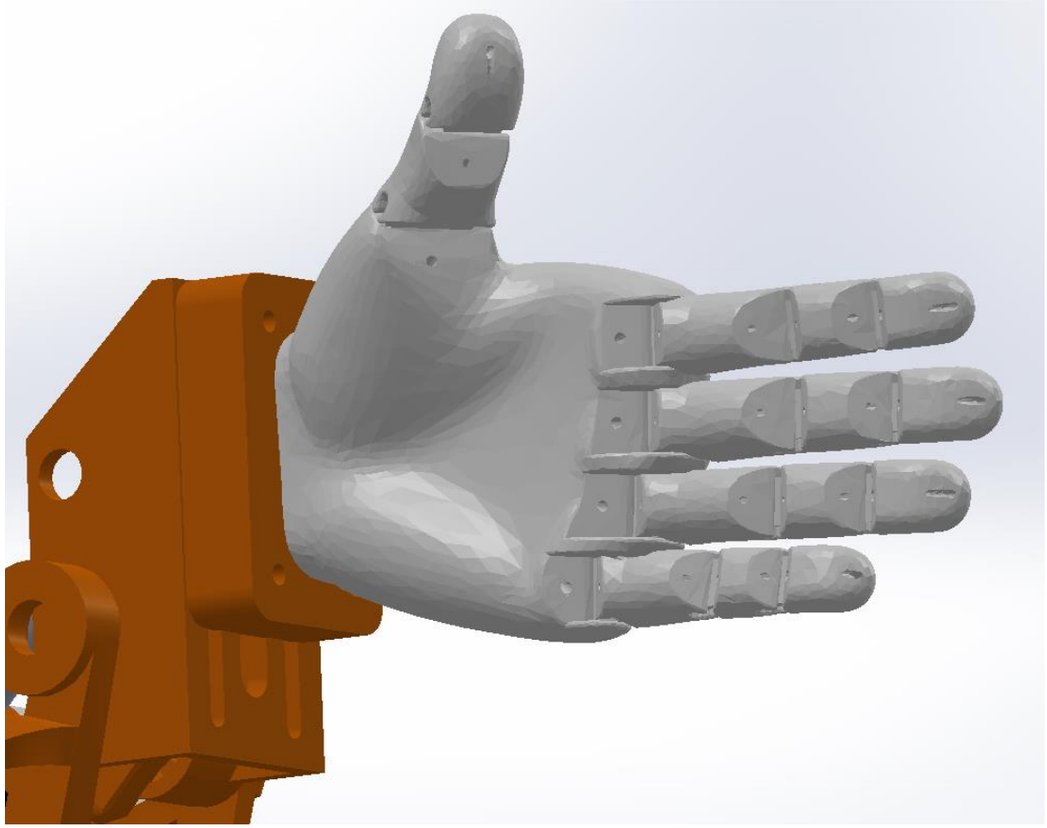
Stepper wire connectors



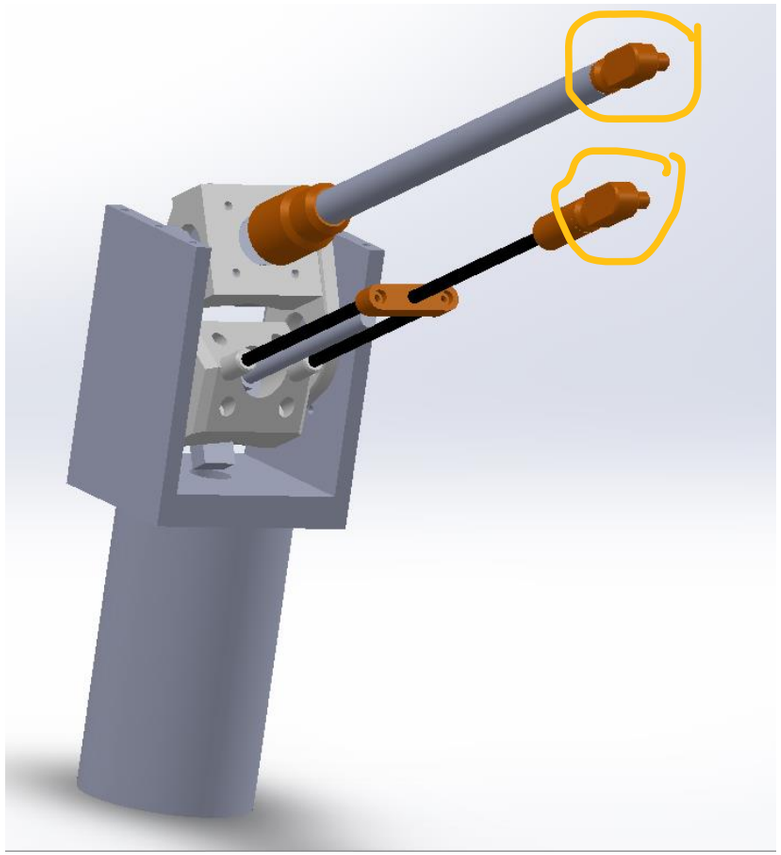
This is the only possible configuration for the wire connectors. Otherwise something bumps into them when the arm moves.

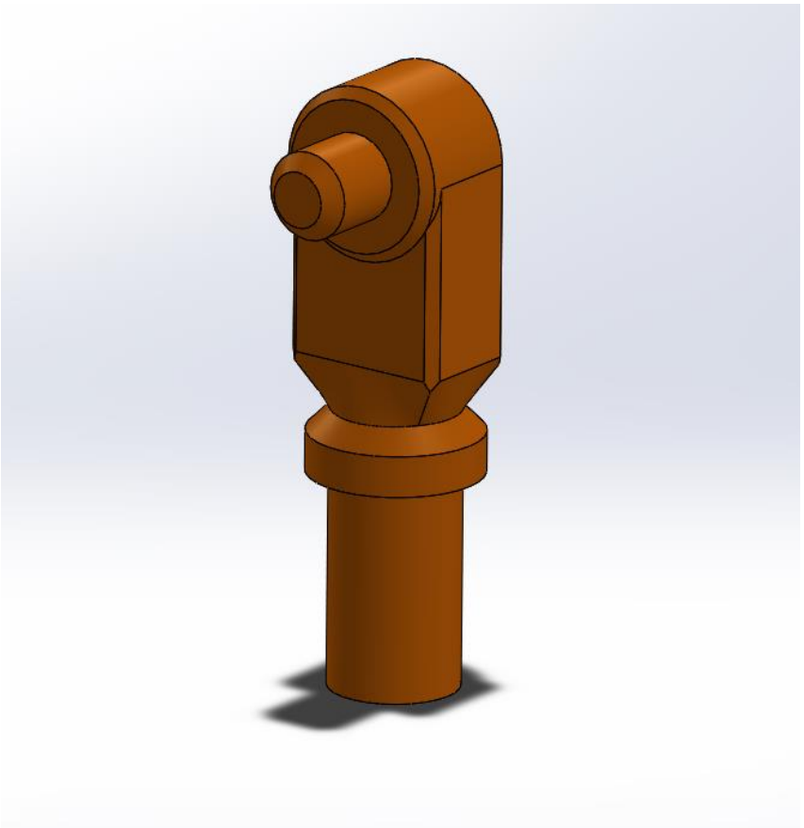
Level platform for the hand

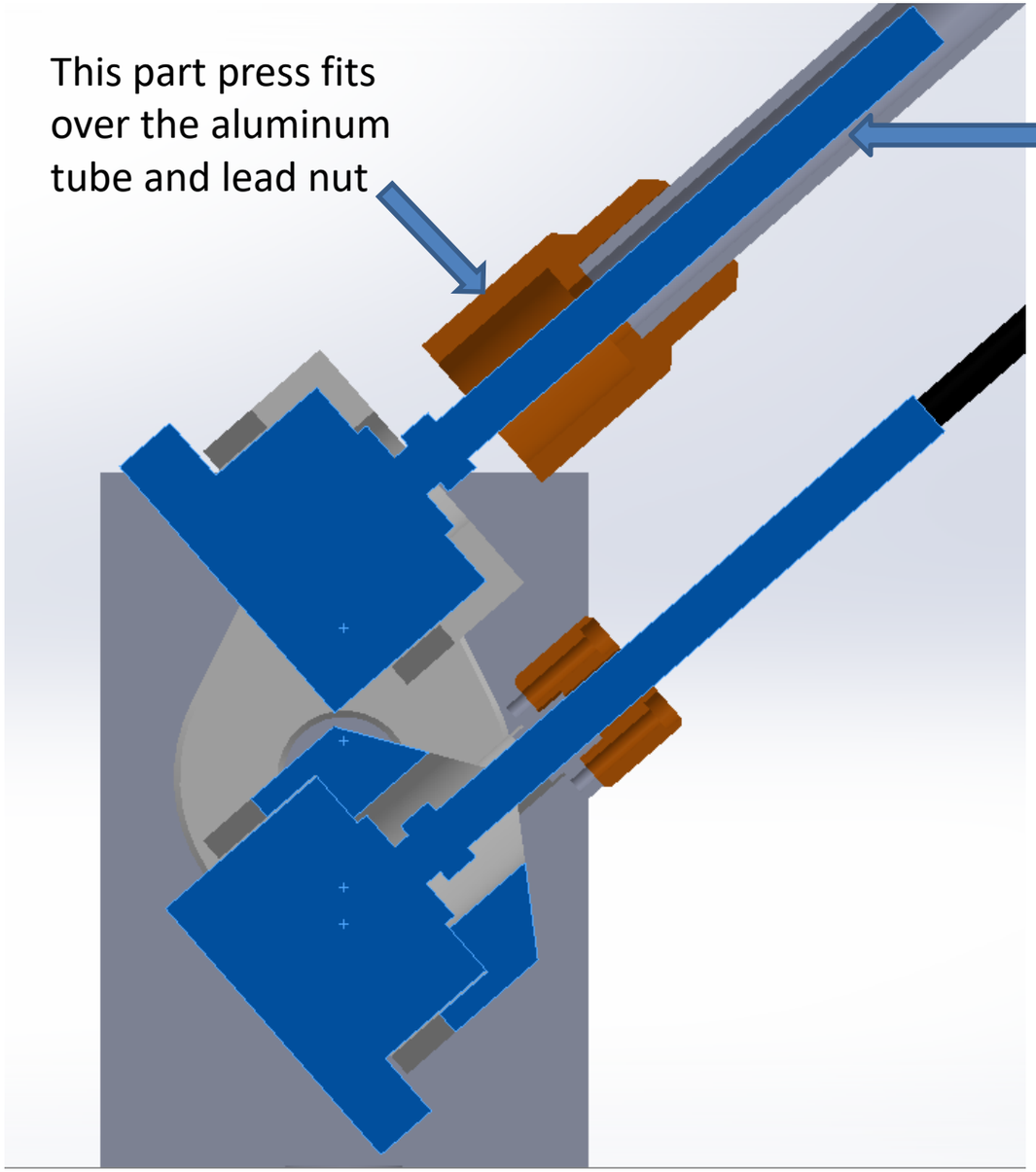




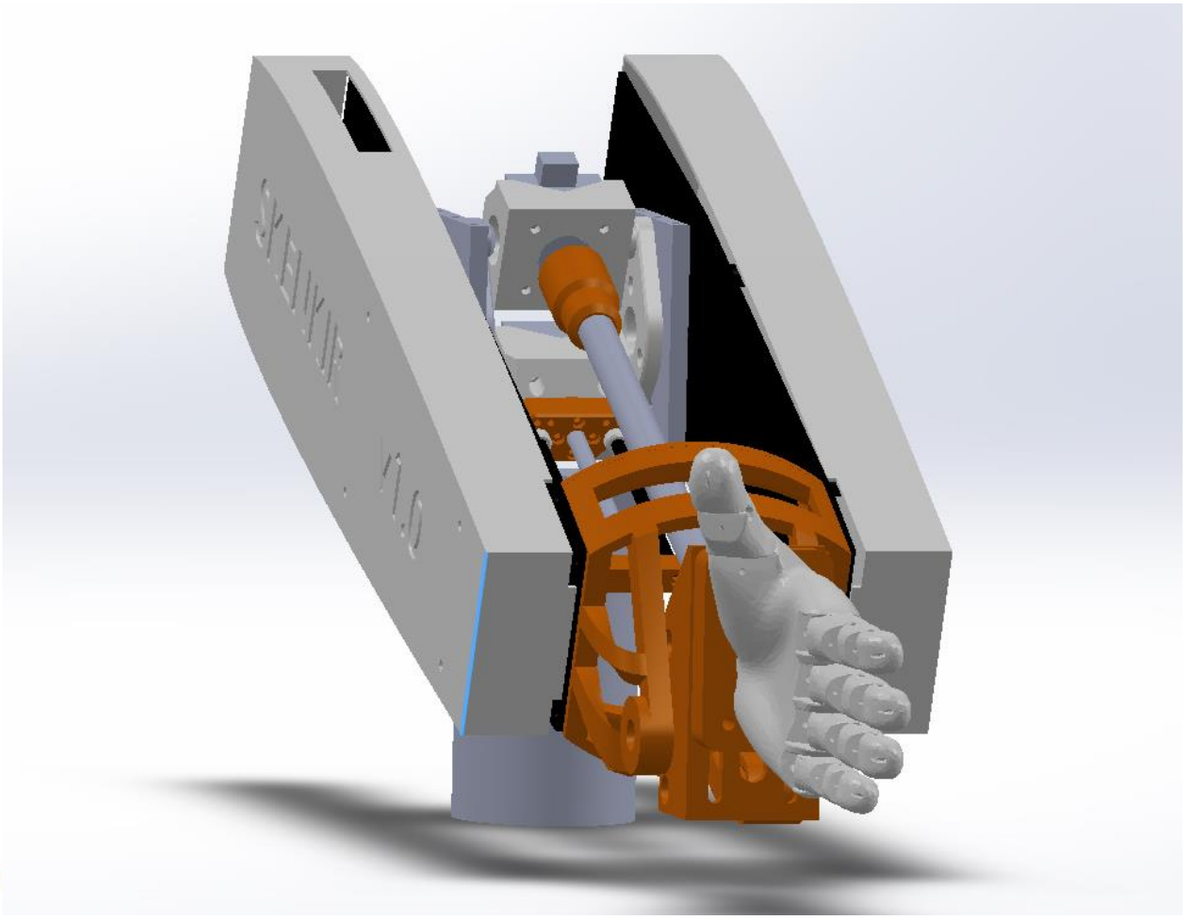
Rod end






This part press fits over the aluminum tube and lead nut
The linear stepper motor’s screw is inside the aluminum tube.
The stepper pushes the tube away, tilting the hand.

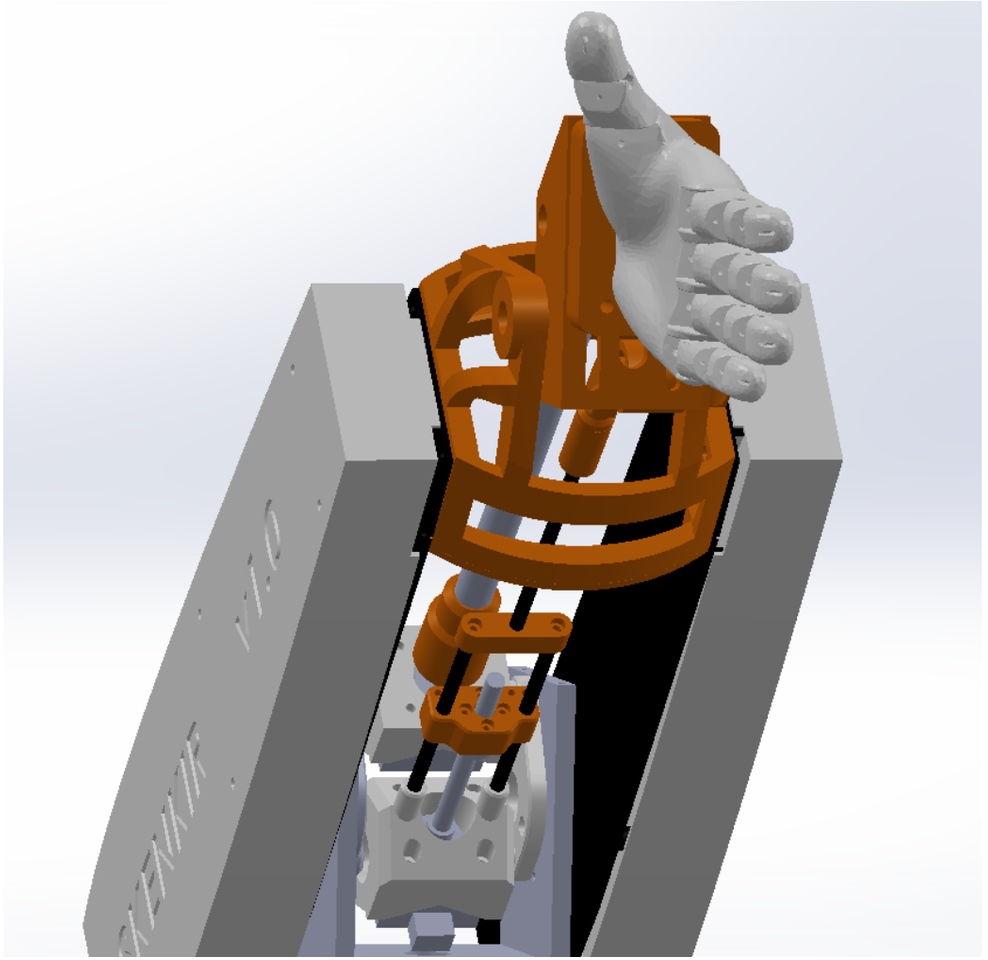
Robot arm assembly



Assembly had to be completed before 3D printing, because all the parts depend on each other.

I also couldn't be sure that the parallel linkage worked until I saw it moving in SolidWorks.

Robot arm assembly



Motion is convincing.
Let’s print!

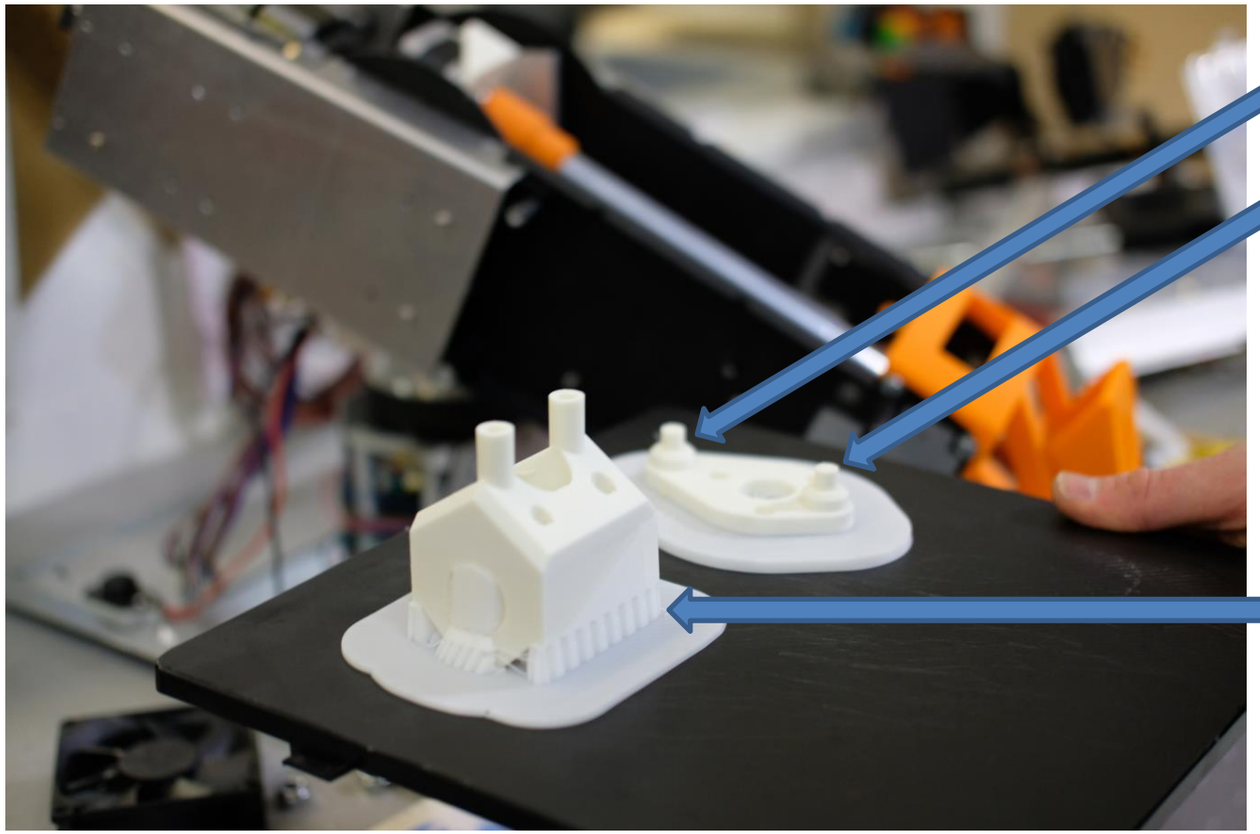
150 hours of printing on 2x Statasys Dimension 1200, Ultimaker and Creality CR-10 S5. About 2 kg of plastic.

Slicing software: Insight, Simplify3D, Cura.

3D printing is very slow, but you can run parts overnight. For parts like the main bracket (32 h), plan ahead and do other stuff while it prints.

Support removal and fit checking. A few failed, canceled and broken prints.

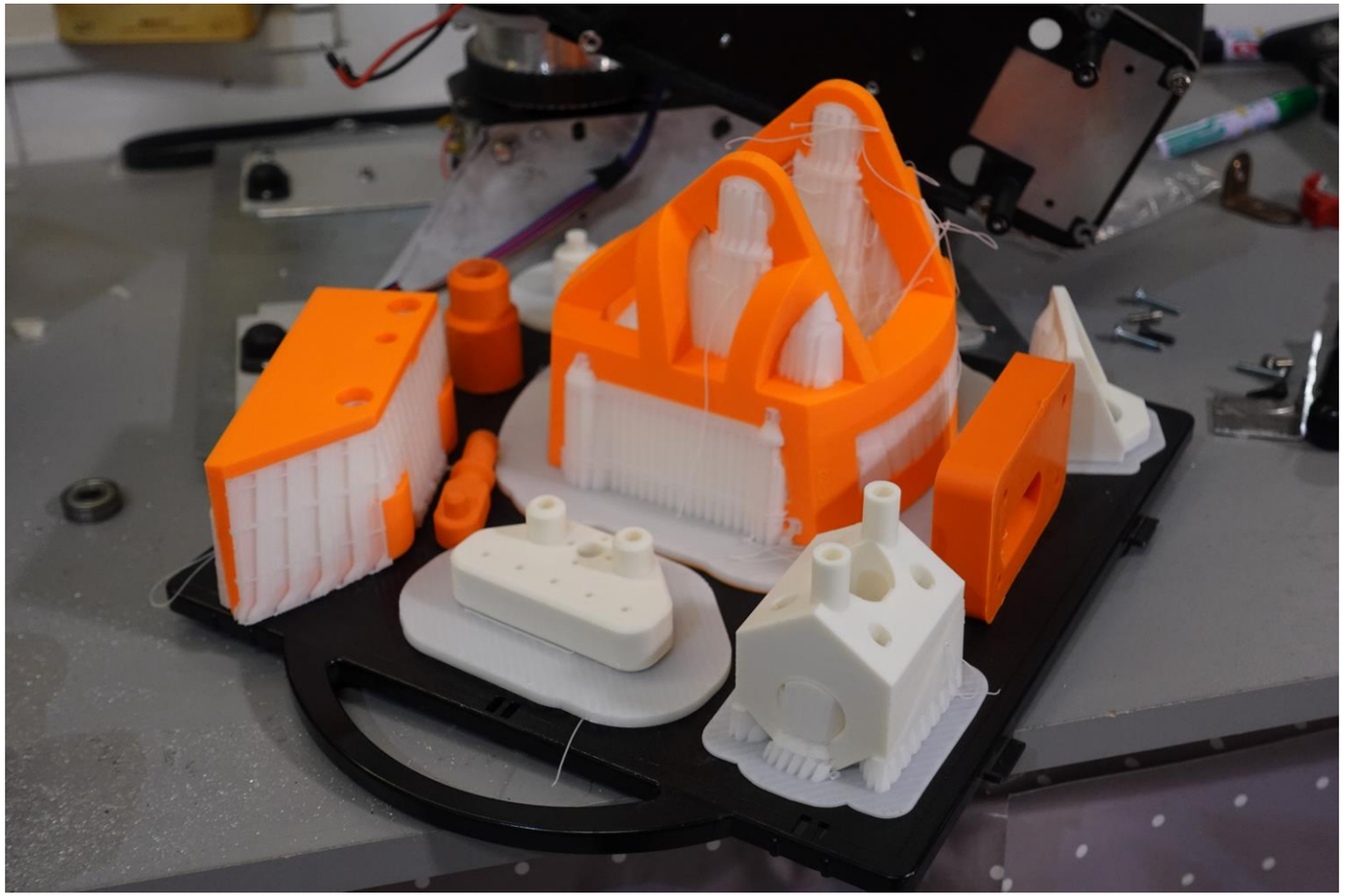
Solid ABS parts hot off the printer (80°C)



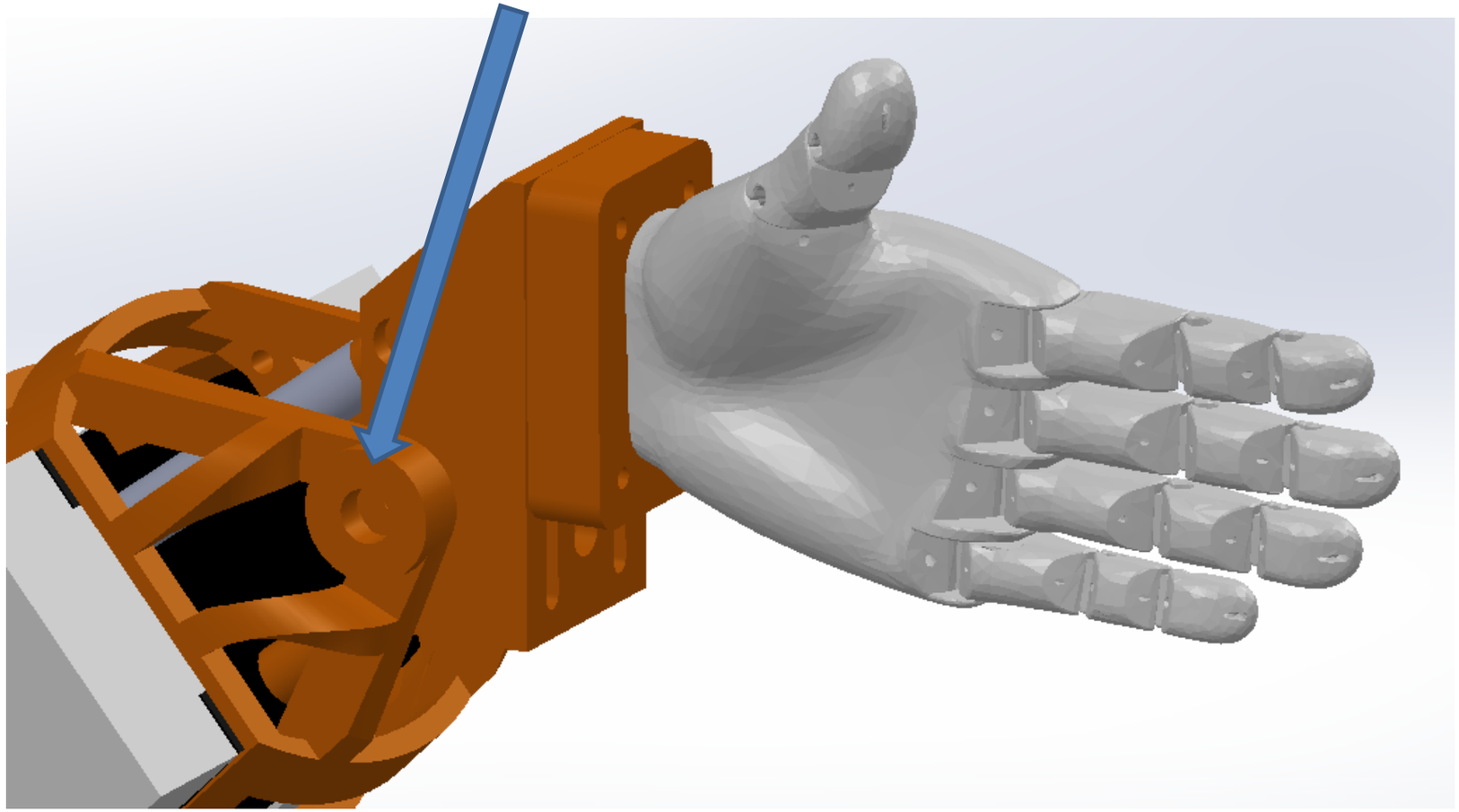
Bearing axles 3D printed for convenience

HIPS supports can easily be broken away

More parts



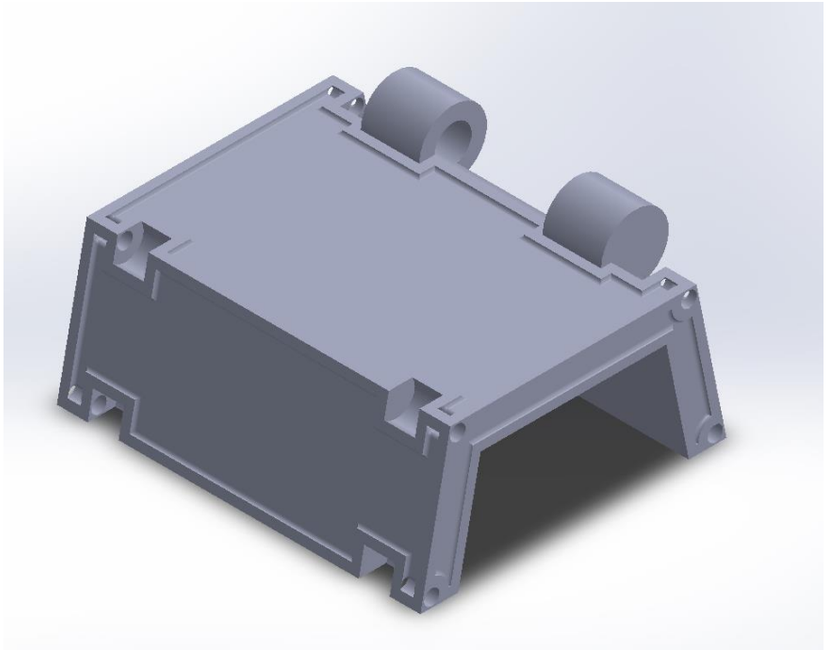
Main bracket

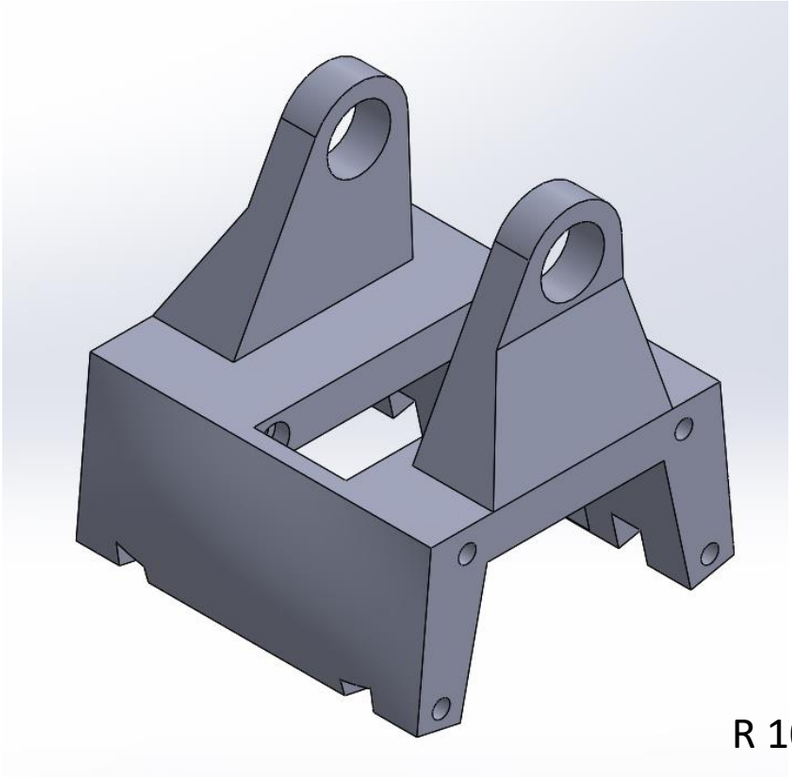


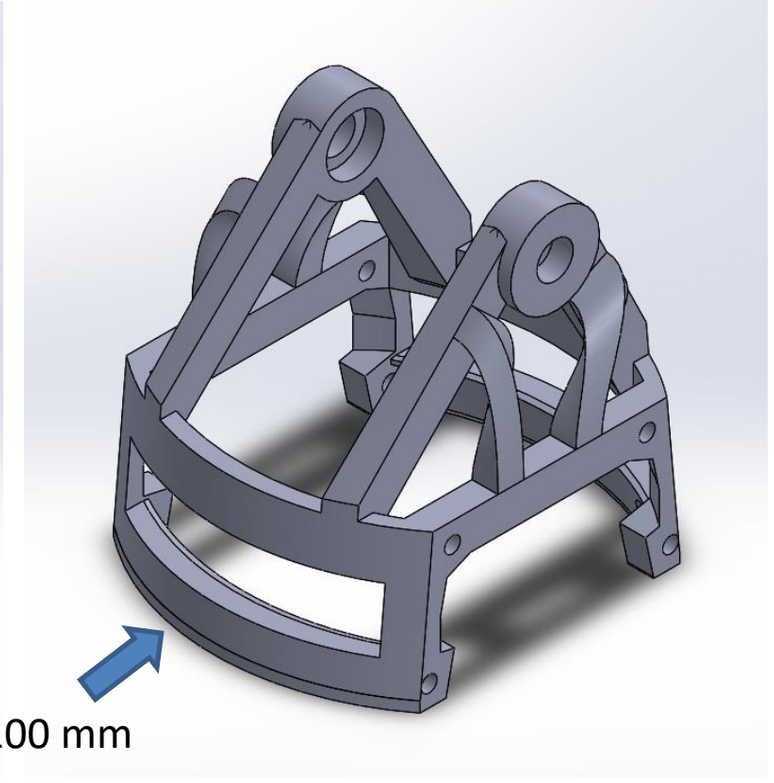
Main bracket: Generative design

- Interesting results
- Ultimately too blobby and unsymmetrical

Main bracket design iterations



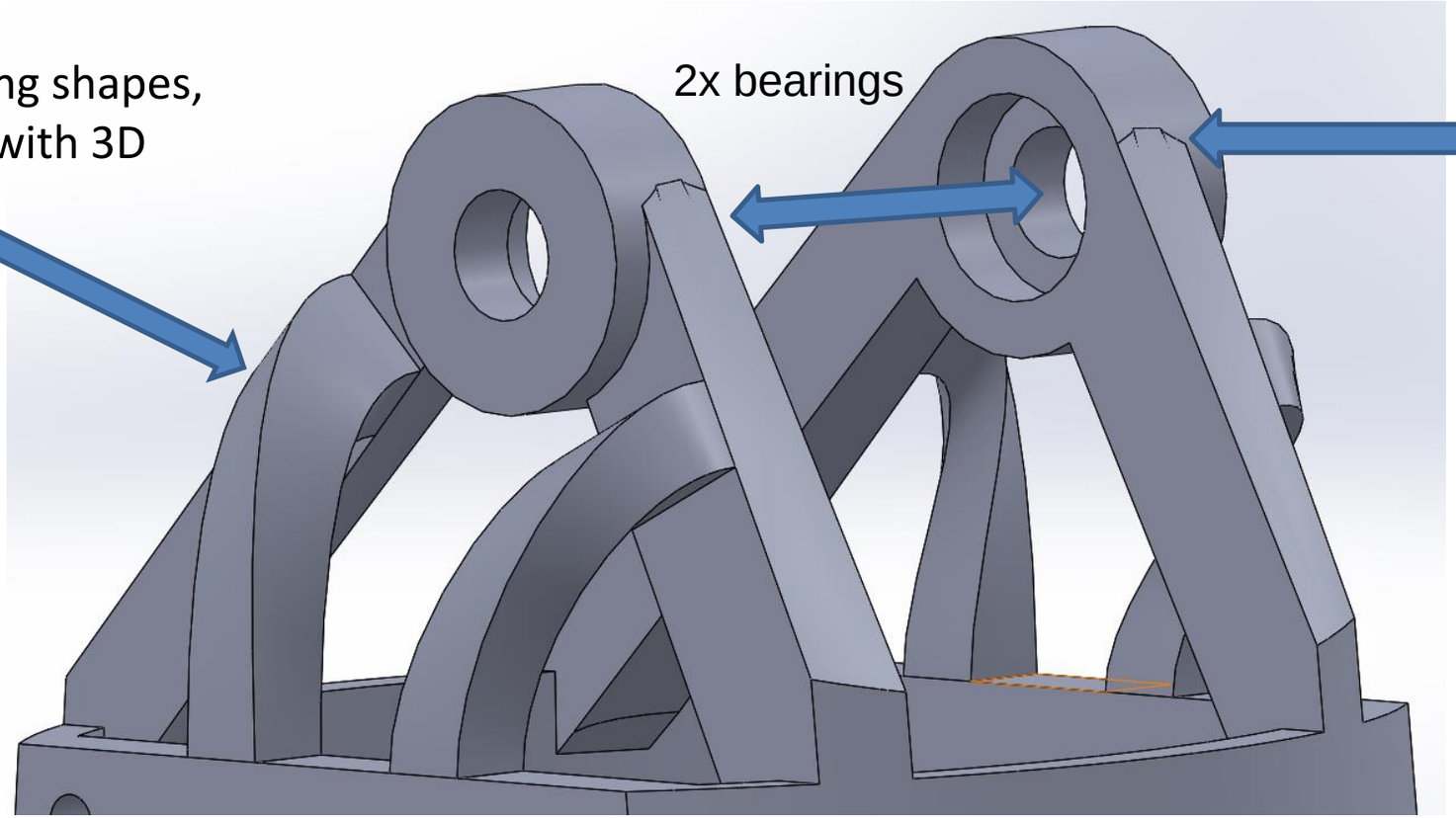




The final design was inspired by the generative design results.
The large radius gives the parallel rods space to move. It was made with a guide curve in a loft.

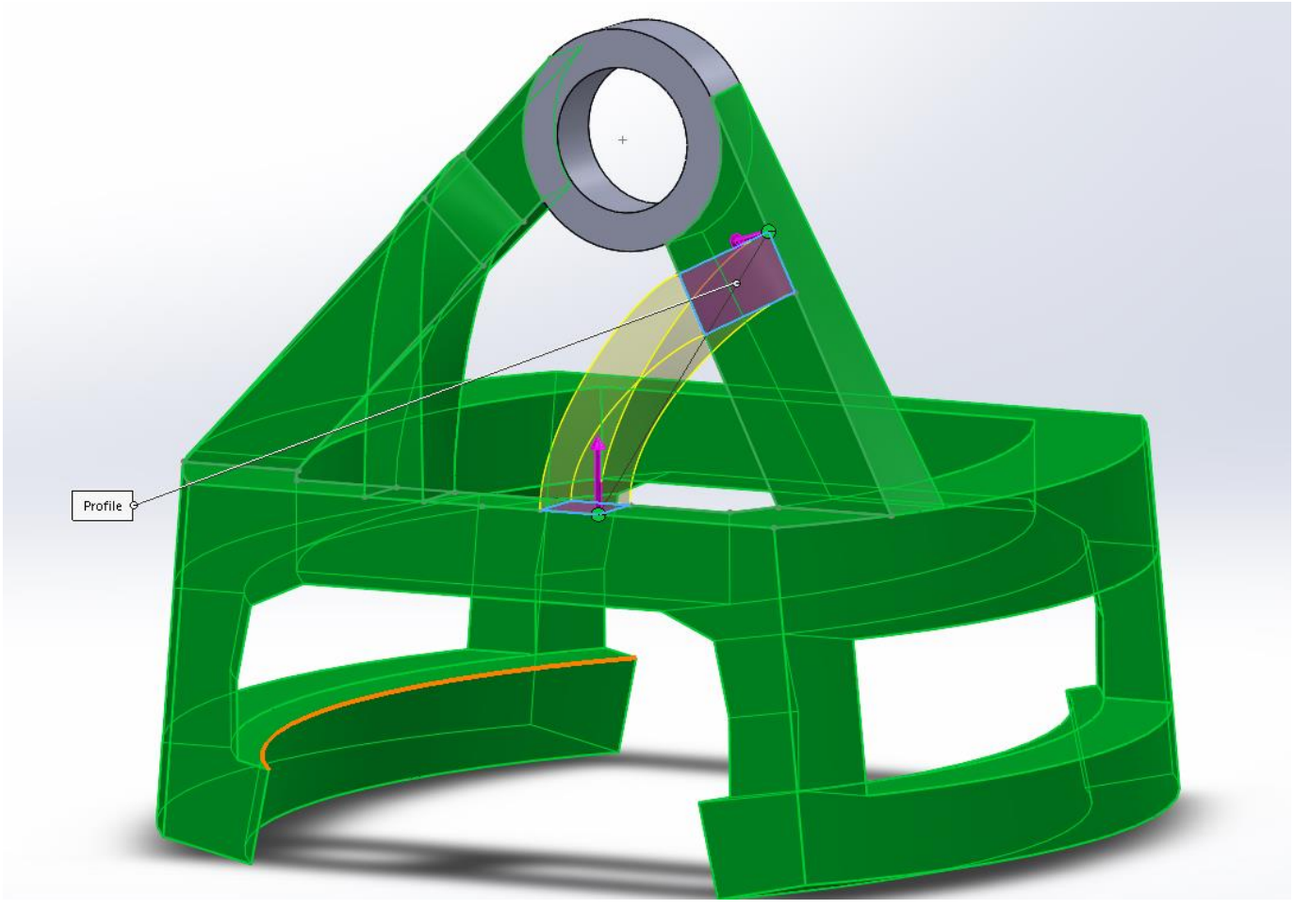
Lofts are useful

Light and strong shapes, only possible with 3D printing



Looks weird in CAD, but prints smooth

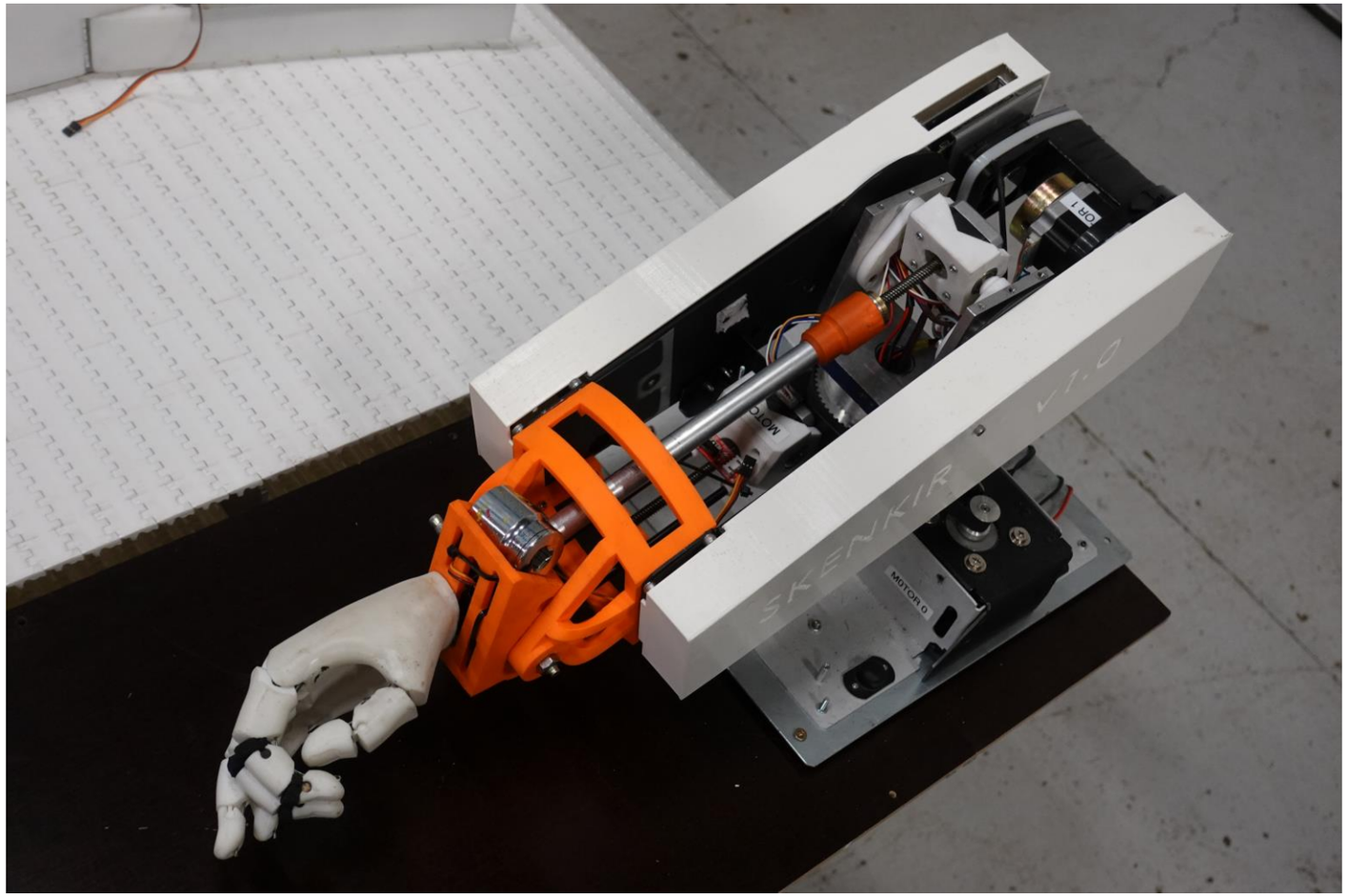
Loft in action



First assembly

It’s always level!

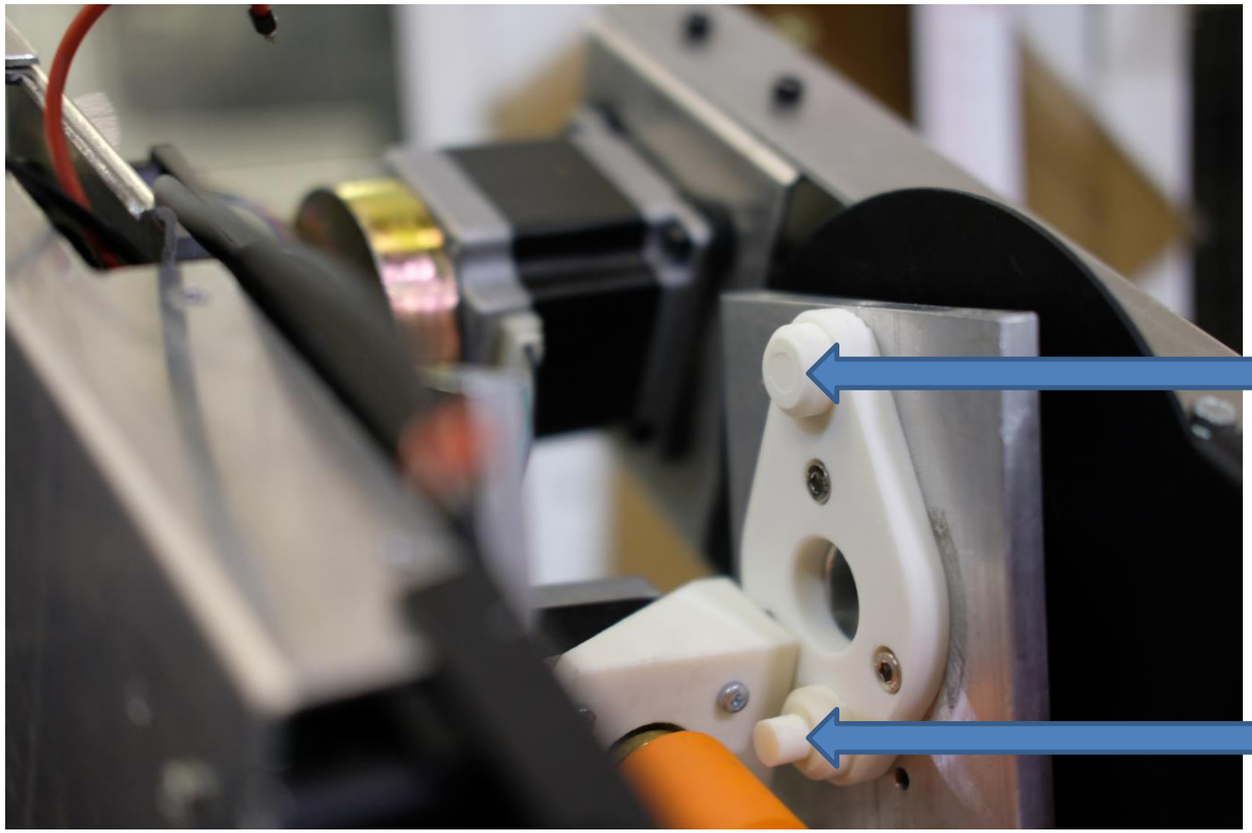
Everything fits in a compact package



Problems discovered

- A few parts broke (incl. main bracket, because the 3D print had low infill)
- Some parts didn’t fit (just small test fit parts)
- Some bad design

Don’t 3D print axles, even for prototyping



Broken
3D printed axle,
quite inconvenient

3D printed axle

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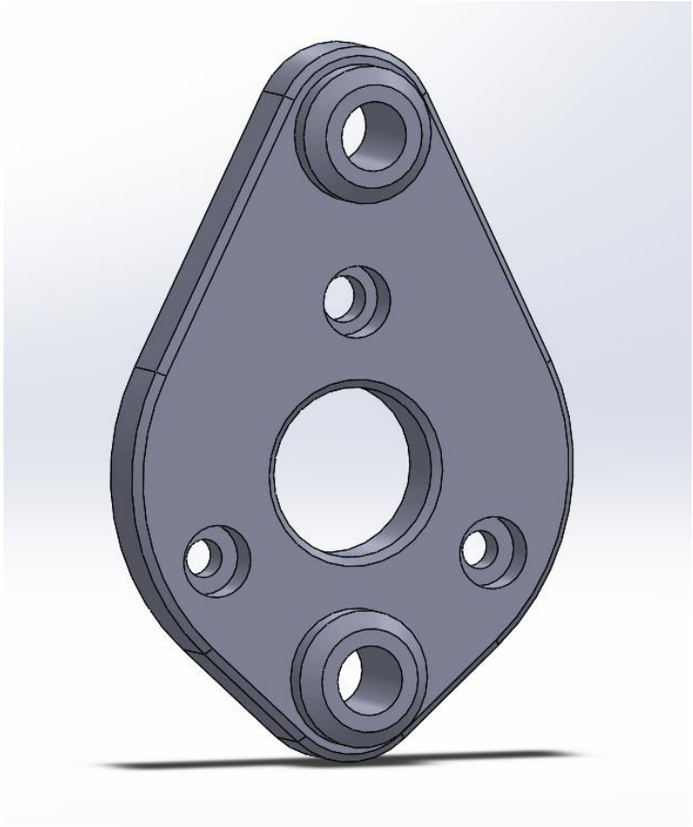
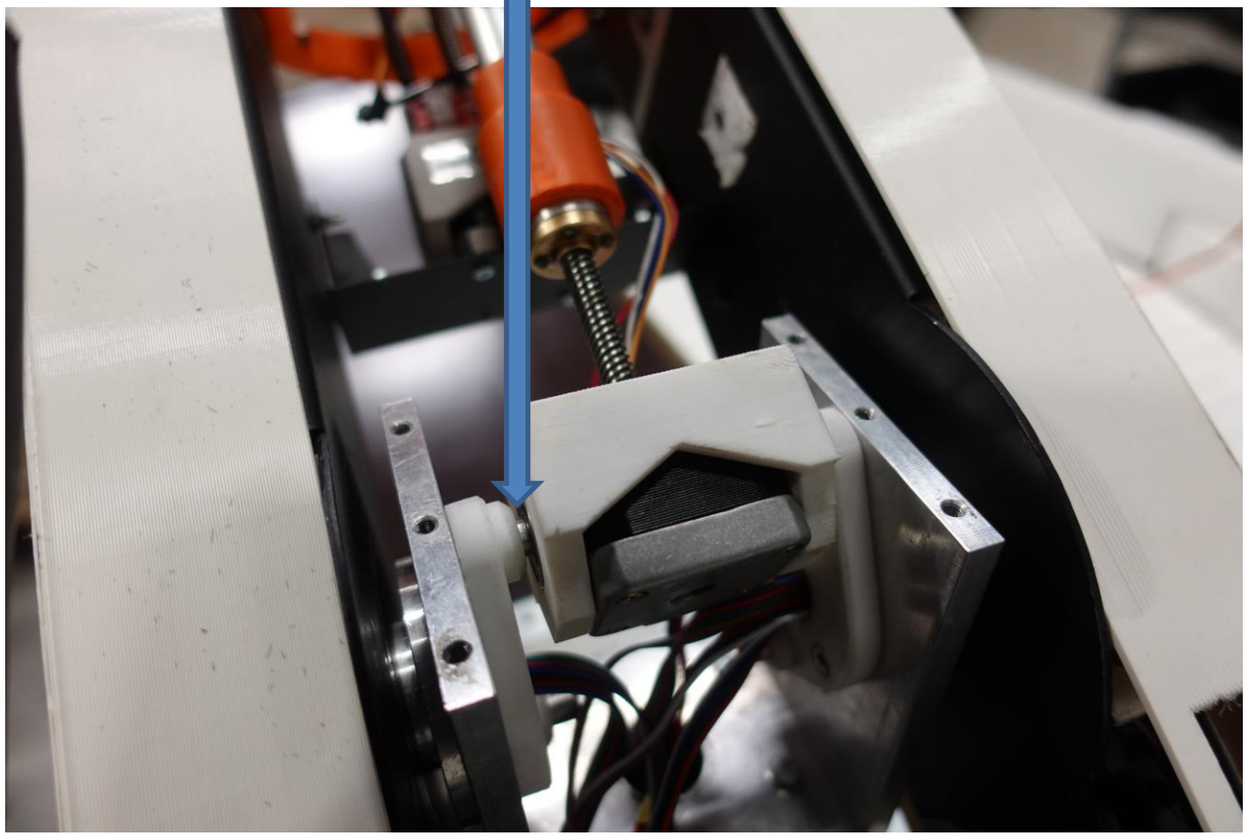
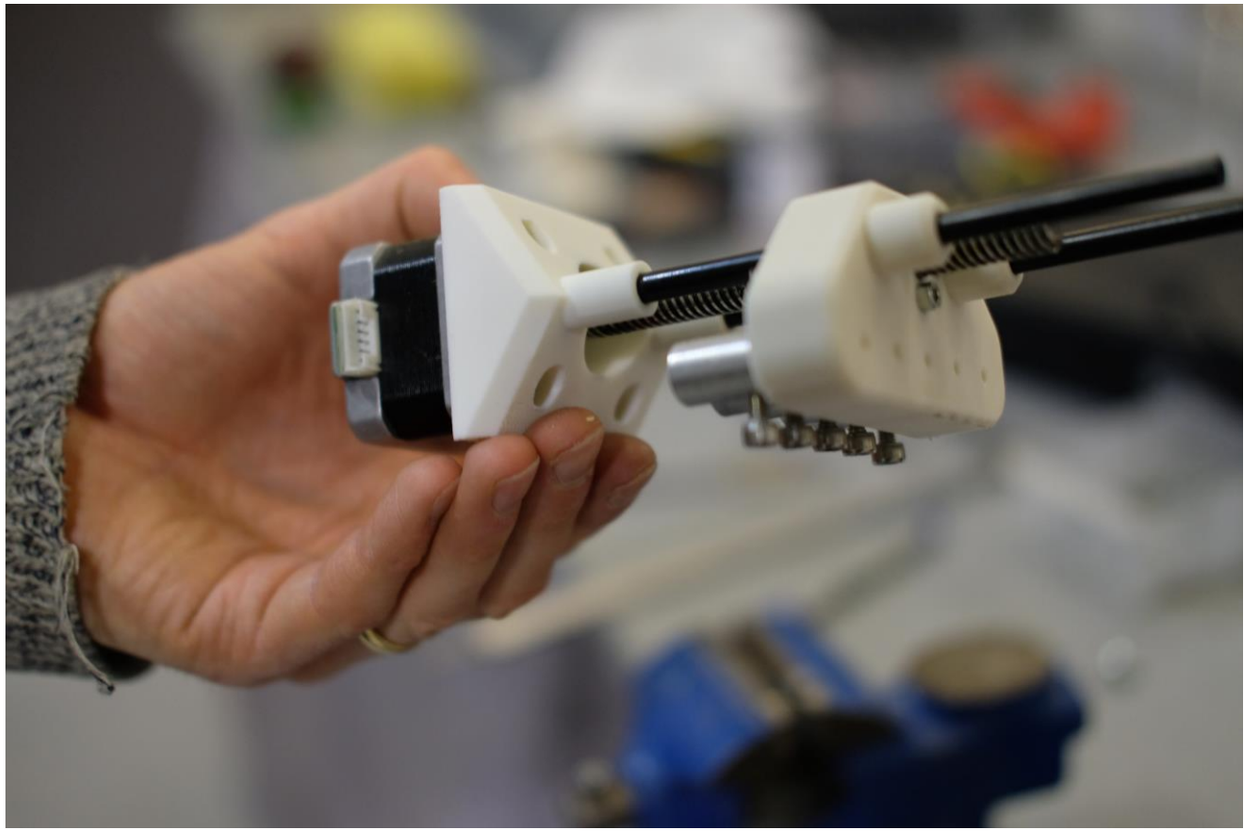
Part changed to include 8 mm aluminum rods



Aluminum rods inserted

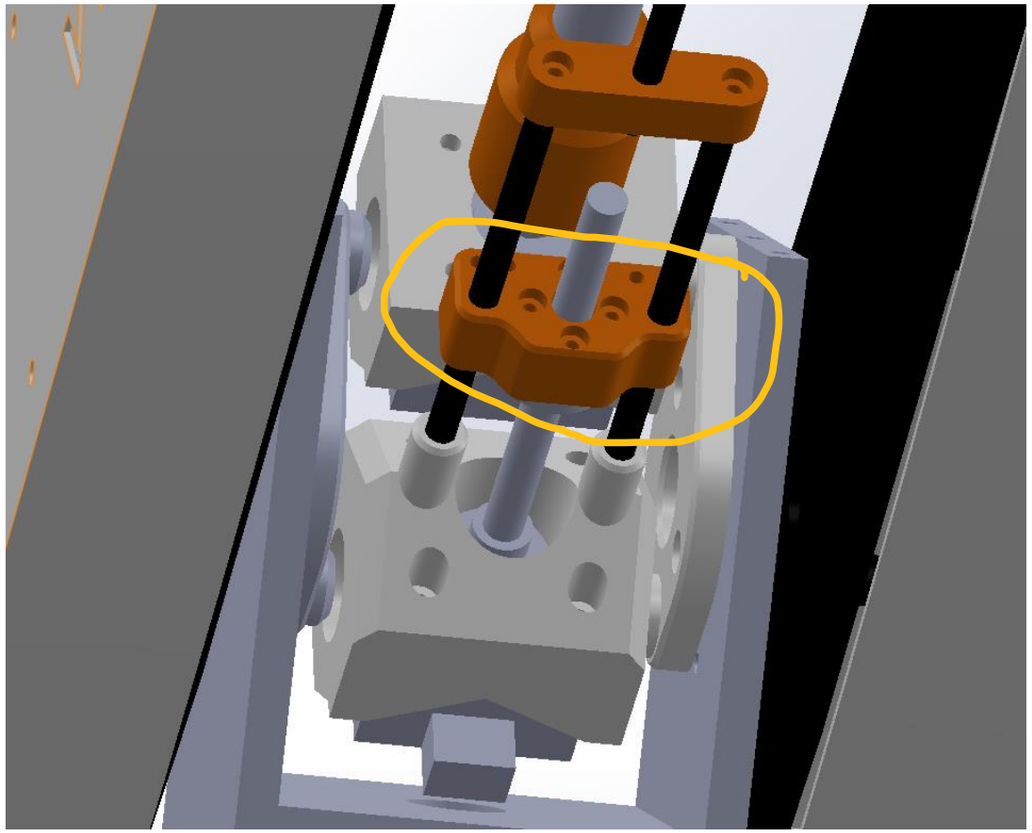


Linear motor pulls strings and closes hand

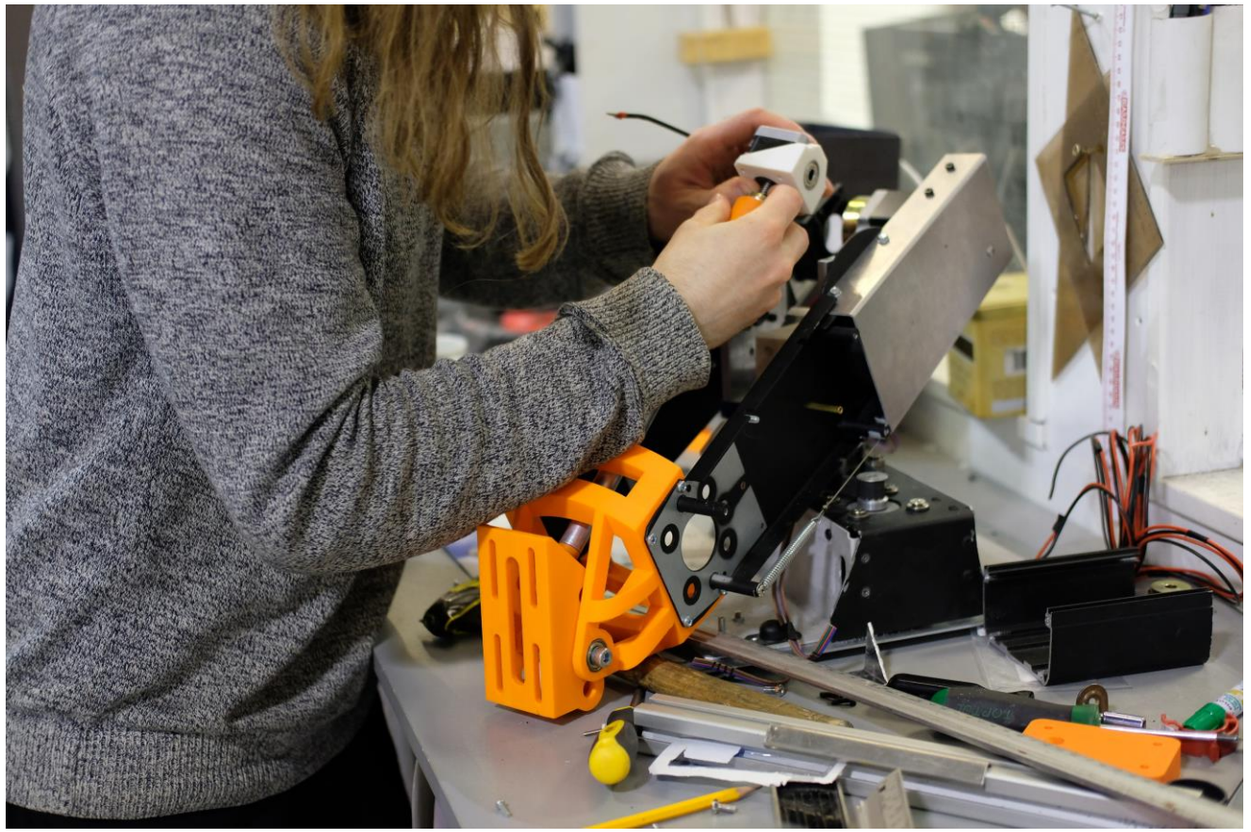


Heavy design, hangs on the strings.

New lightweight string puller

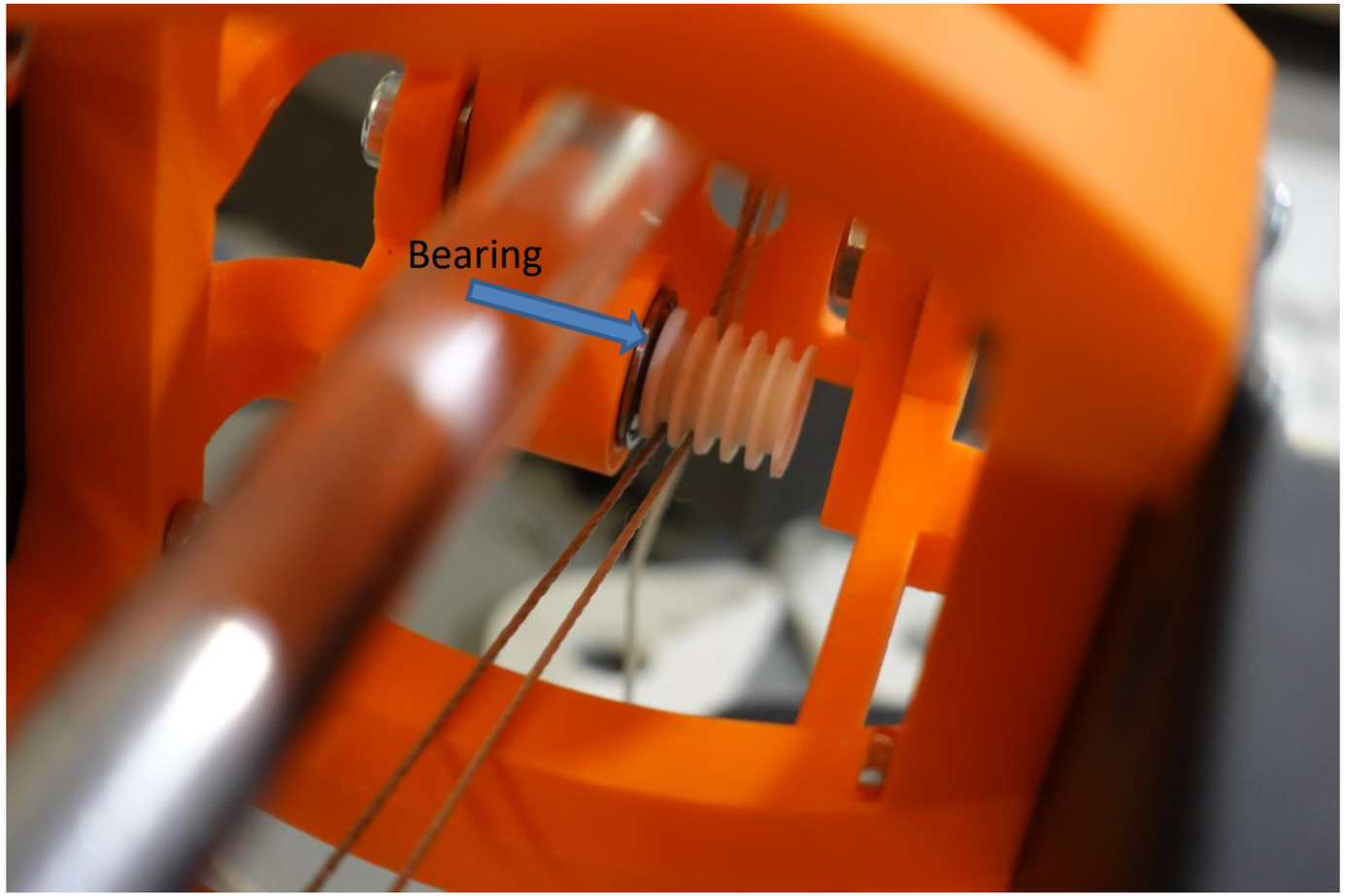


Second assembly

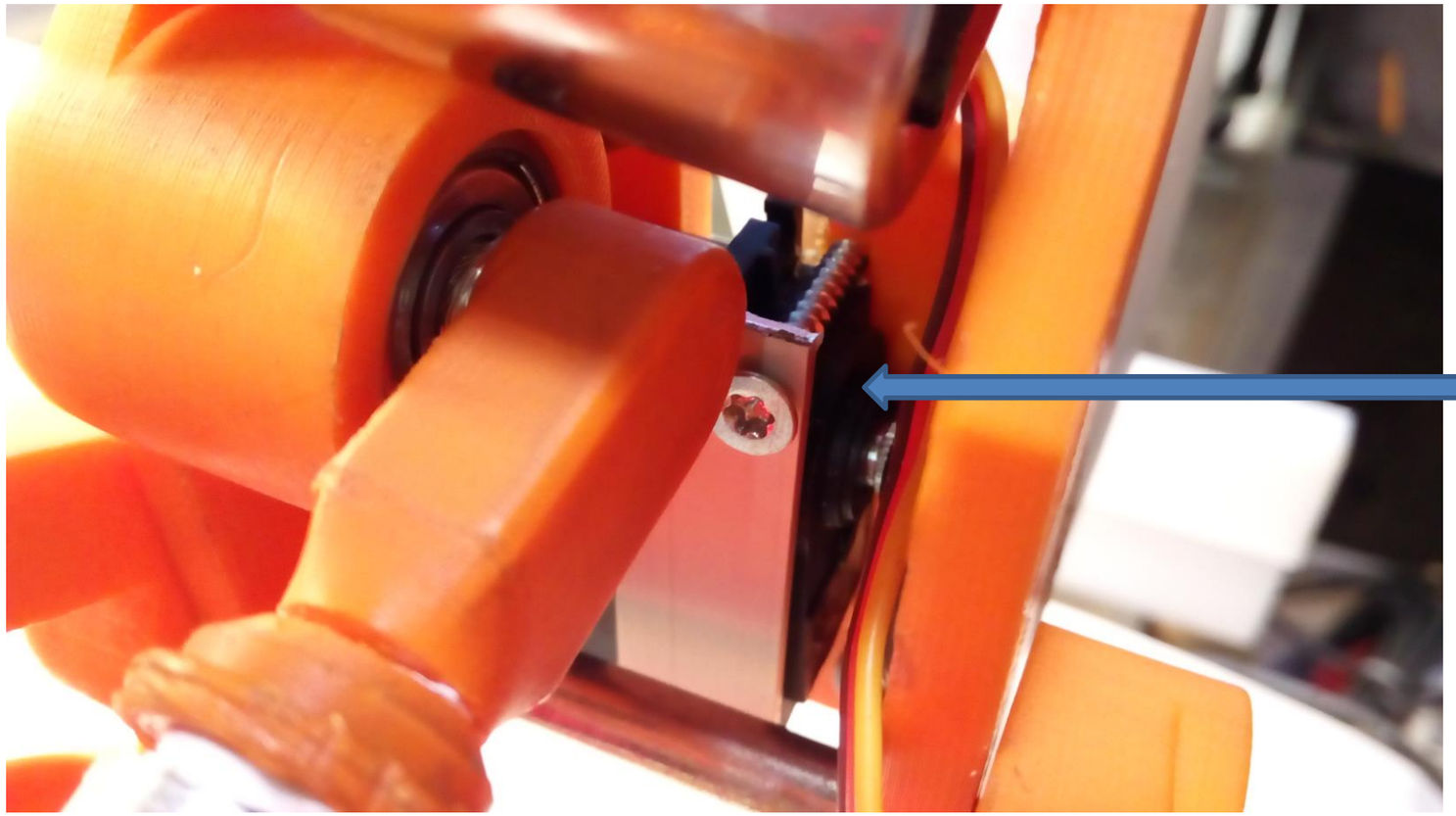


The new parts are thinner and printed 100% solid. New main bracket took another 32 hours.

String that actuates hand gets tangled

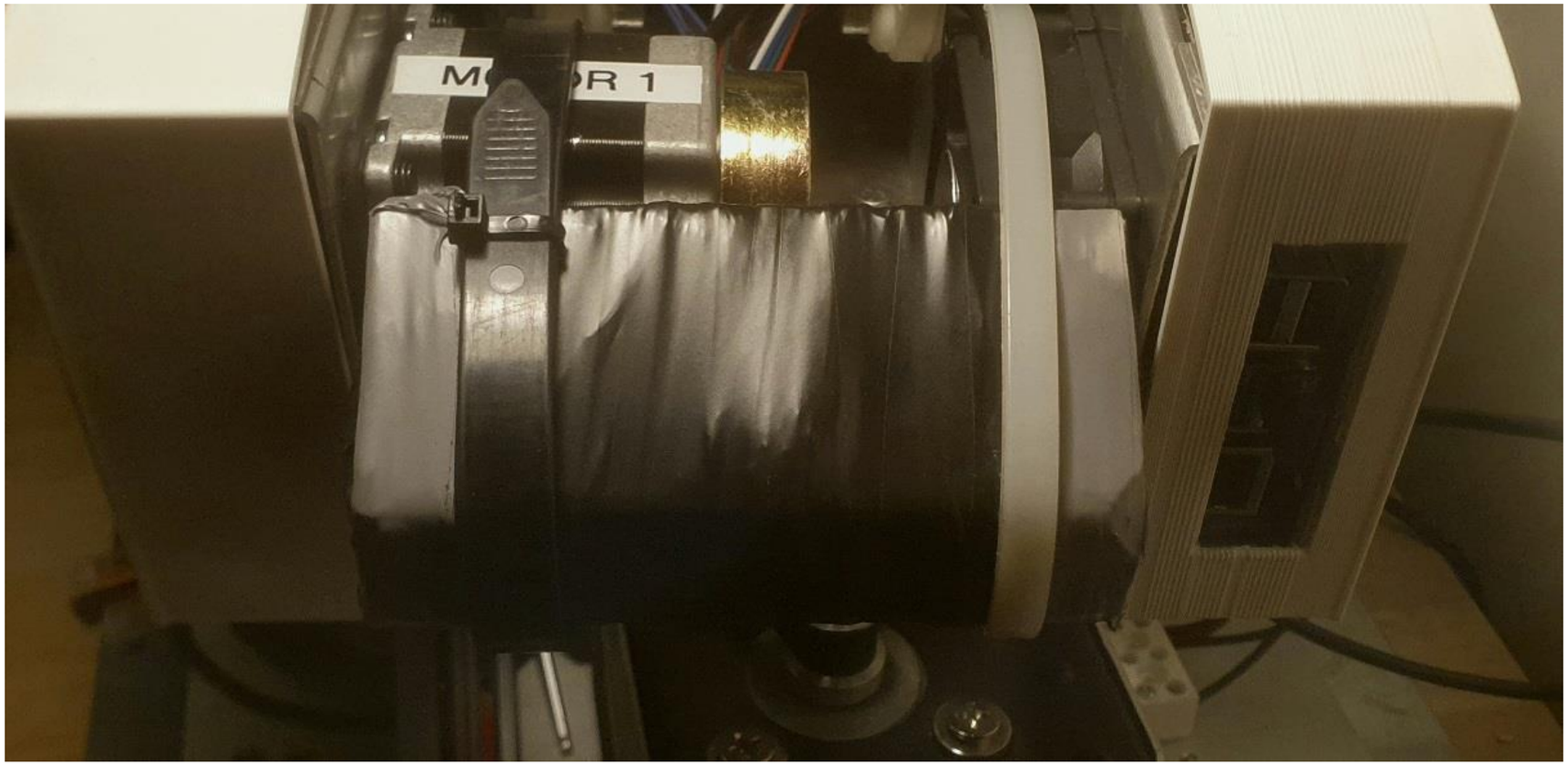


Solution: Servo instead of linear stepper



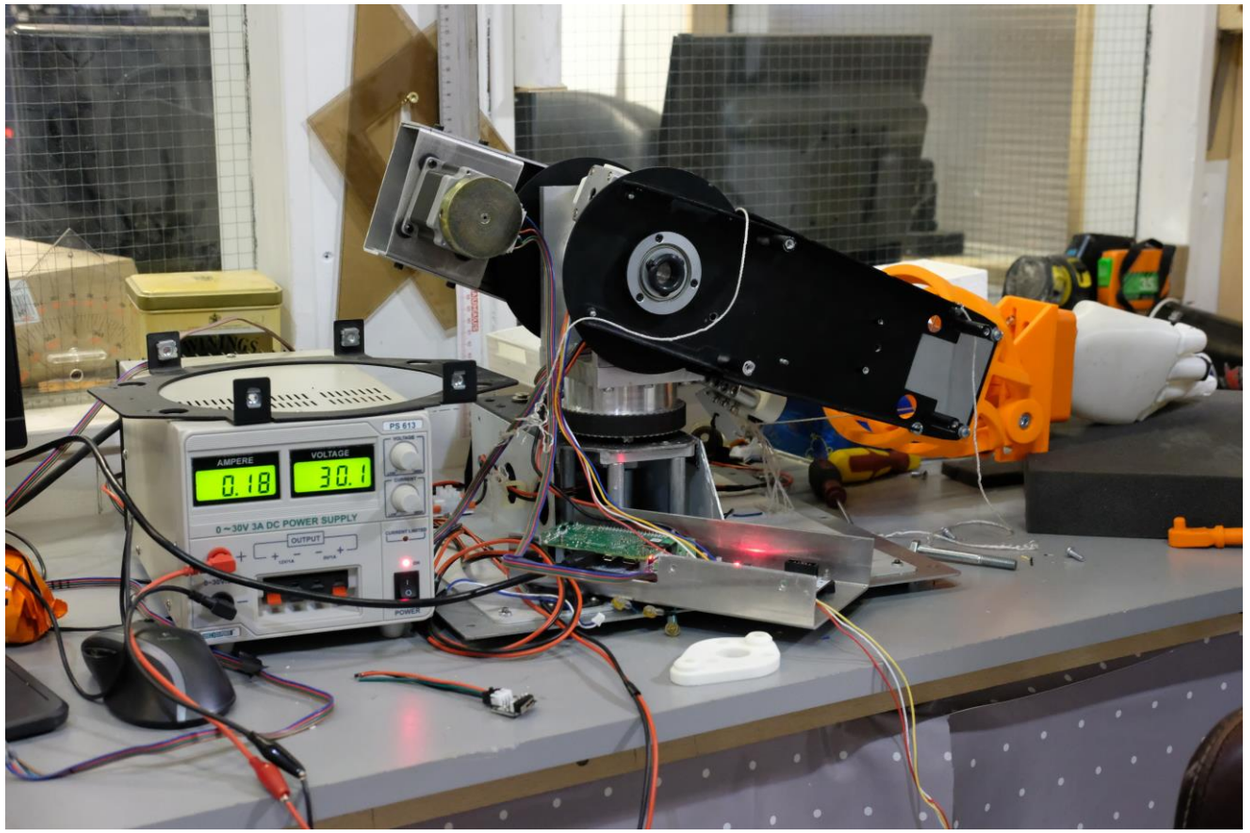
Servo is on the level platform with the hand

Added weight in the back for balance

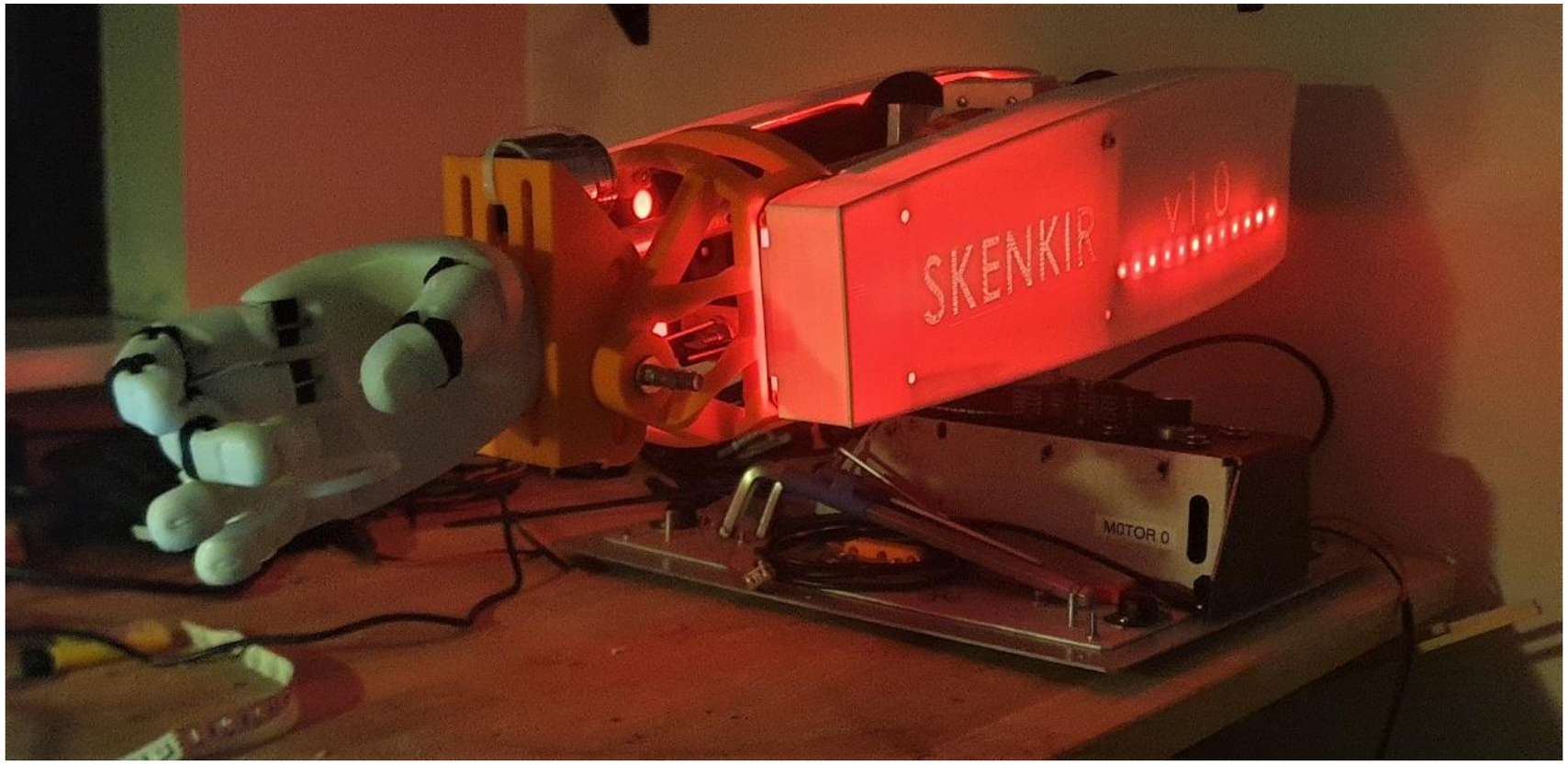


And a small weight in the front

Third assembly

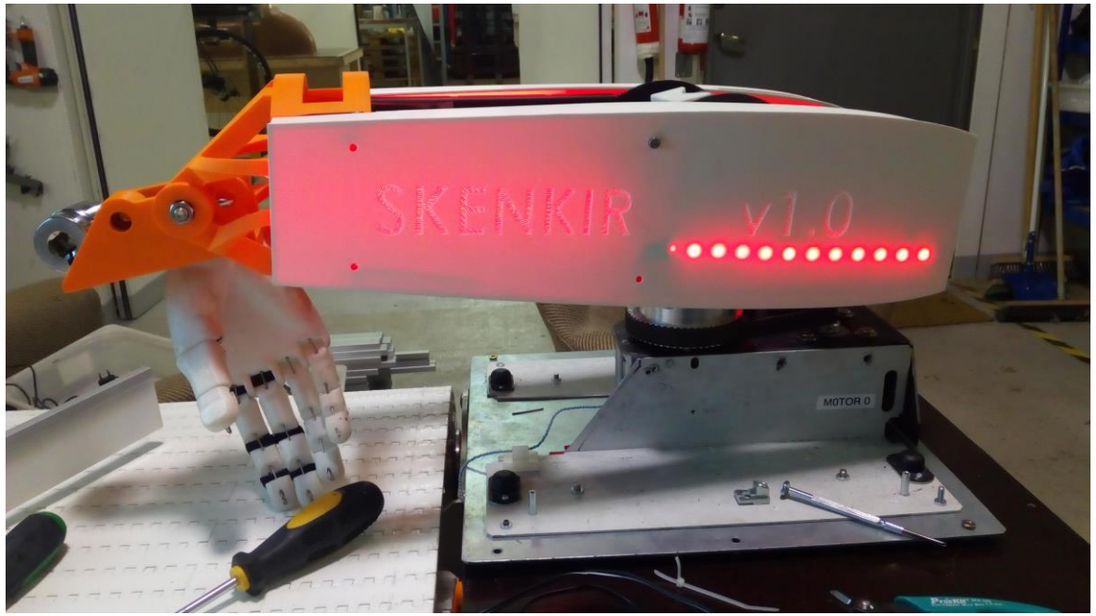


Skenkir v1.0



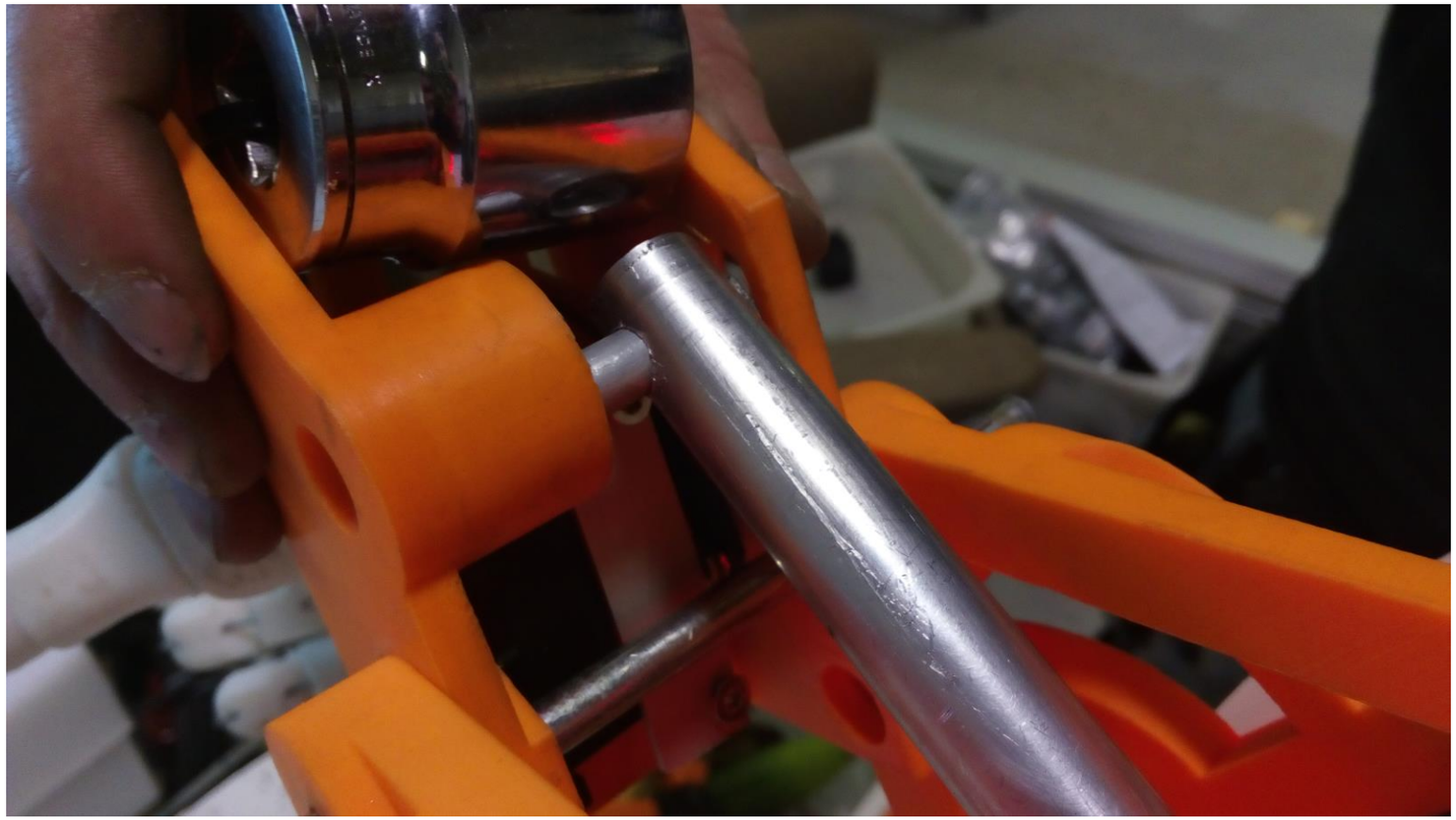
Includes 30 3D printed parts!

Again: don’t 3D print rods & axles!



Skenkir broke his wrist at presentation time on Wednesday. We fixed it but we were 1.5 h late to our presentation. Very inconvenient for everyone involved. Don’t 3D print rods & axles, people. Take it from me.

8 mm rod through the shaft instead of 3D print



Fourth assembly, Skenkir is operational

Project goals

- Robotic arm with 3 DOF ✓
- Smooth and repeatable motion ✓
- End effector always parallel to ground, until actuated ✓
- Create motion assembly before building ✓

Most useful 3D model ever!


SKENKIR
v1.0