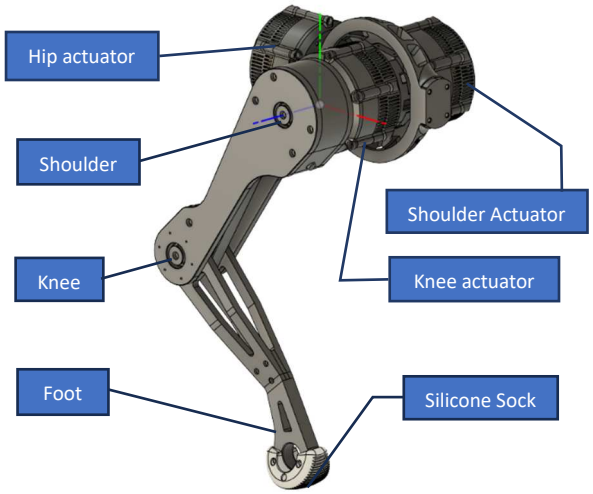
Portfolio

Aniket Mandhare
CAD | CAM | 3d-Printing | CNC milling| Resin Casting

Schvaan™

- A dynamic quadruped composed of 3d-printed parts (80%) and standard hardware (20%).
- 12 DOFs, each driven by a proprioceptive actuator.
- Capable of executing a leg-homing routine, stand-up routine and walking with a trot gait.

A fully independent, self-funded project, completed over a year in a team of 2.



Series Configuration 3-DOF Leg

- 3DOFs:
  Adduction-Abduction at hip. (about axis||x)
  Flexion-extension at shoulder. (about axis||y)
  Flexion-extension at knee. (about axis||y)
- Toothed belt actuator-knee transmission
- Silicone sock on the foot for improved traction

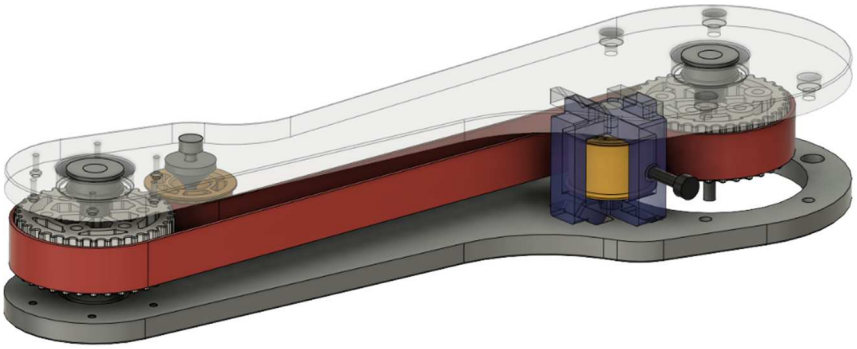
Proprioceptive actuator

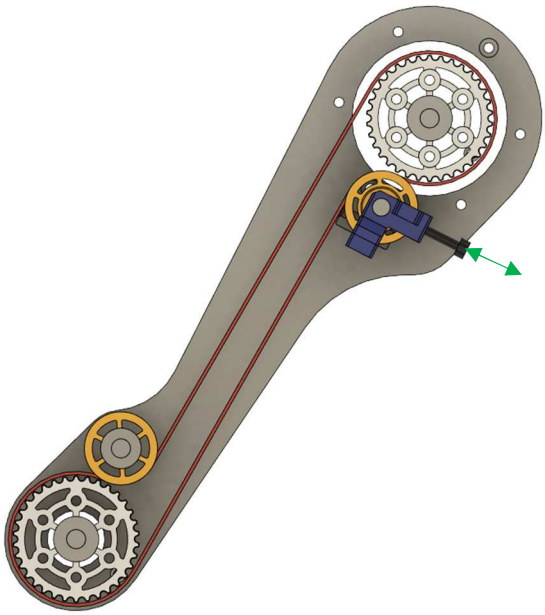
- 1:10 cycloidal gearbox
- Generic 8308 BLDC at input
- FOC based driver
  -Magnetic encoder for position sensing/commutation
  -Phase current sensing for torque estimation.
- Front and rear mounting options

Actuator Front

Actuator rear

3-DOF Leg: Design Features



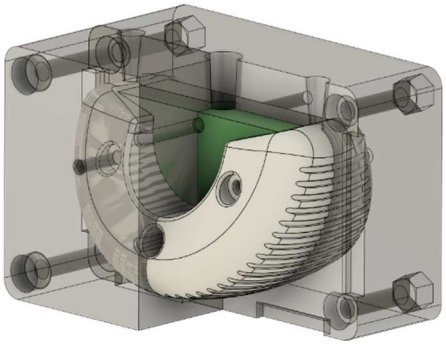


1:1 Toothed belt transmission

- Belt specs:134 teeth, 15mm width, 5mm pitch, Gates GT3 tooth profile
- Pulley specs: 34 teeth, 20 mm width Custom 3d-printed pulley with GT3 tooth profile.
- Belt-wrap angle around pulleys increased to ~270° from 180° (standard wrap for 1:1 ratio.
- Tooth engagement increased from 17 to 25 teeth.
- Radial force on pulley support bearings due to belt tension reduced from 2T to 1.4T, where T is tension in the belt.
- Idler movement during tensioning:(arrow) Parallel to tangent at end of wrap, so that wrap angle remains constant.

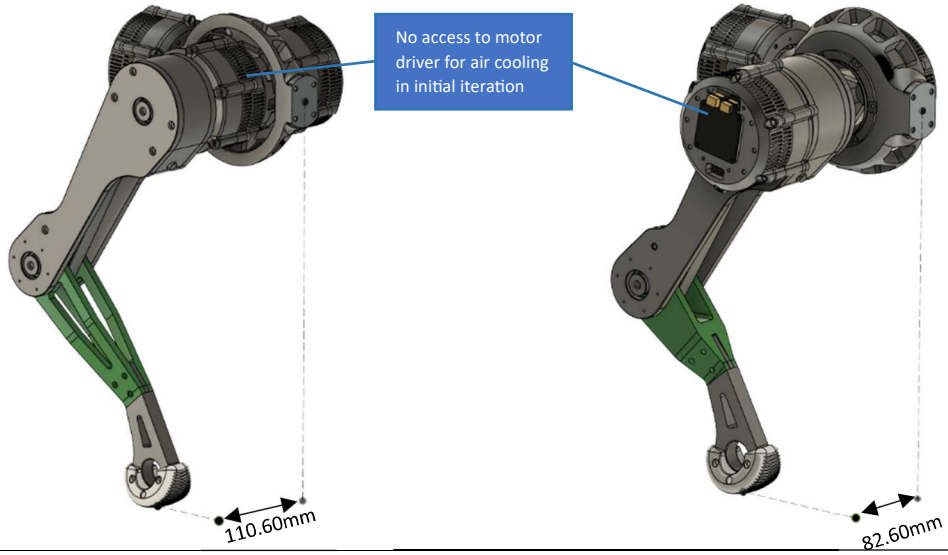
Custom cast silicone sock

- Cast in 30A, two part silicone RTV
- 3D-printed three part mold; Left half, right half,inner boss



3-DOF Leg: Problems & Solutions

Initial iterations	Final iteration



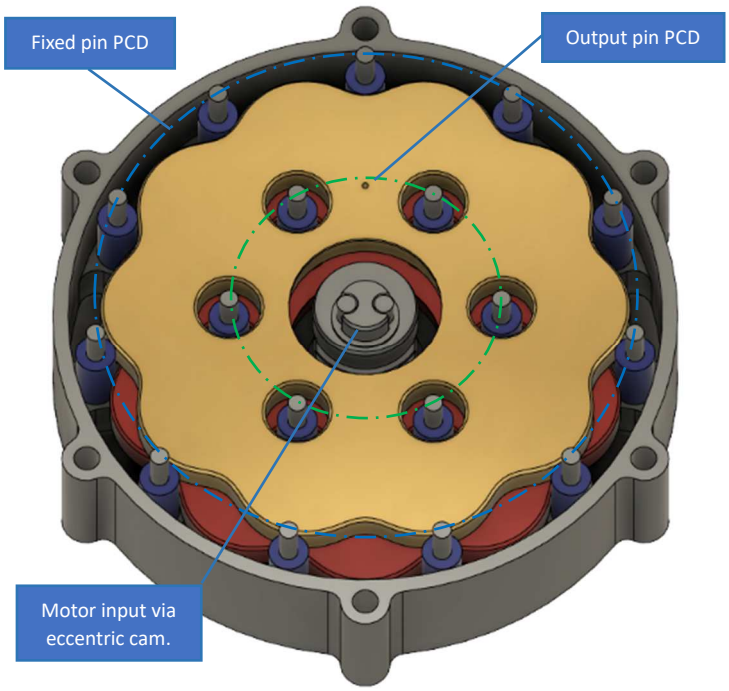
- Shorter and single piece tibia (highlighted in green) of the lower leg. The newer tibia was designed to be compatible with the existing knee and foot joints.
- Knee actuator was moved outwards and flipped 180°, thus being better positioned for passive air-cooling of the motor driver.
- Length of moment arm acting on the hip (adduction-abduction) actuators was reduced.

- The rib structure in the upper leg (highlighted in red) was extended , significantly improving the torsional and bending stiffness along the longitudinal axis of the leg.

Even though we observed a reliable walking gait in simulations, the actual gait of the robot was quite unstable in the initial iterations. This is because the control was designed assuming a perfectly rigid system, while the robot was comparatively flexible due to 3d-printed parts. The above changes contributed to a significant increase in the rigidity of the robot, and also made the robot more compact. This closed the gap between assumed and actual system, improving the stability of the robot.

Proprioceptive actuator: Design features

Proprioception: The sense of self-movement, force and position.

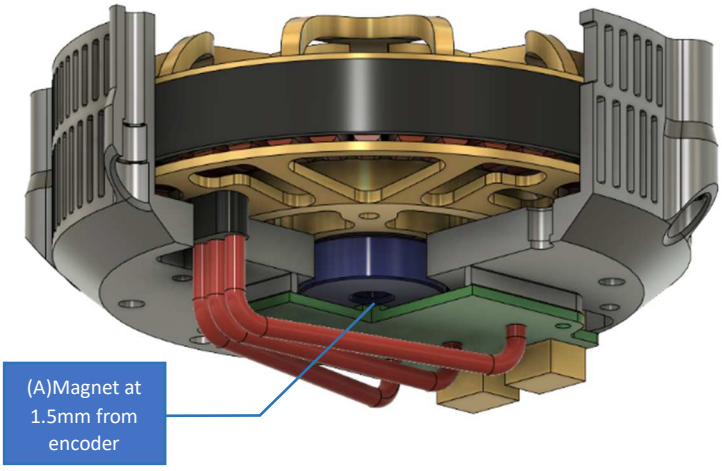


1:10 cycloidal reduction

- Dual cycloidal discs (red and yellow), counter-balanced for minimum vibration.
- Rolling instead of sliding contact between discs and fixed/output pins, using needle roller bearings (blue), minimizing internal friction.
- Very low backlash, allowing accurate output position estimation via input encoder
- High back-drivability (low internal friction), allowing regenerative braking and accurate output torque estimation via phase current sensing at input.

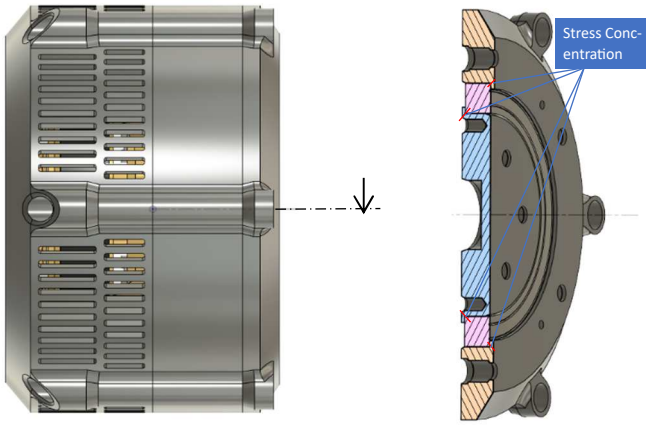
BLDC drive and closed-loop control

- Generic 8308 BLDC motor.
- PID controlled using FOC based motor driver.
- Diametrically polarized magnet affixed to motor shaft (A); angular position read by magnetic encoder on the driver board. Used for motor commutation and position control
- Phase current sensing for torque estimation and control.

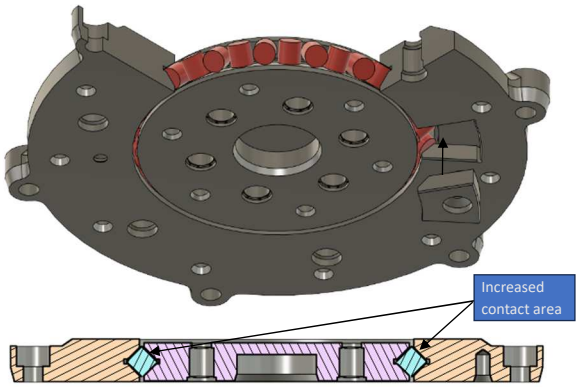


Proprioceptive actuator: Problems and solutions

Moment loads perpendicular to actuator axis



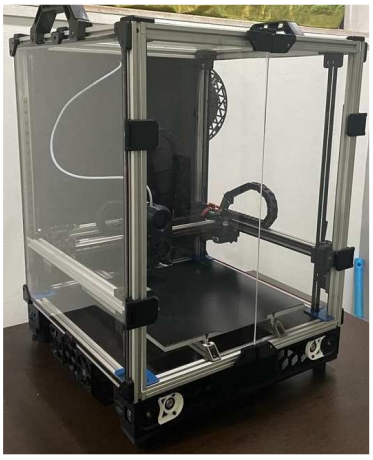
- Moment loads perpendicular to actuator axis cause high stress concentration at locations indicated.
- Knee and hip actuators do not see such moment loads, as their loads are end-supported.
- Incase of shoulder actuators, it is impossible to support the load on both ends and such moment loads do occur.



Integrated Crossed-roller bearing

- The radial bearing at the output was replaced with an integrated CRB to handle moment loads.
- Cross sectional area under load was increased.
- Significant improvement in actuator rigidity along axis
- Significant reduction in weight.

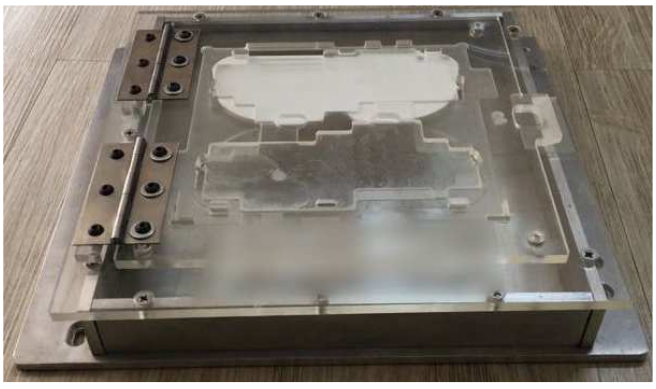
Miscellaneous Projects



Voron 2.4:
An enclosed, FDM 3d-printer

Self-designed CNC based on V-slot Al-extrusions.
Milling the build-plate for the Voron 2.4

Small volume batch manufacturing: Design: Fusion 360, FDM pre-processing: SuperSlicer
PCB enclosure w/ rubber gaskets. Designed to print without supports, requiring no post-processing.



PCB de-paneling fixture: Design: Solidworks, CAM: Fusion360
CNC milled from ESD polycarbonate and Al-tooling plate stock