DISCLAIMER: Plausible concepts, attributed sources, oversimplifications, reasonably. Rigorous mere academia NOT primary.

mechDive

Mechanical actuators, versatile for all wetware harnessing purposes. Tunneling (direct neural interface), force feedback, hard exoskeleton, soft exoskeleton, tactile precepts (temperature, pressure, vibration, stretch), and compliance.

Many channels (>100) of continious controlled tension at low cost by water cooled eddy current brake (>10kgF), artificial muscle (<1mm compact).

Force multiplication if needed by a second stage of push/pull hydraulic amplifiers powered by hydrostatic transmission pumps, steam waste heat from eddy current brake, etc.

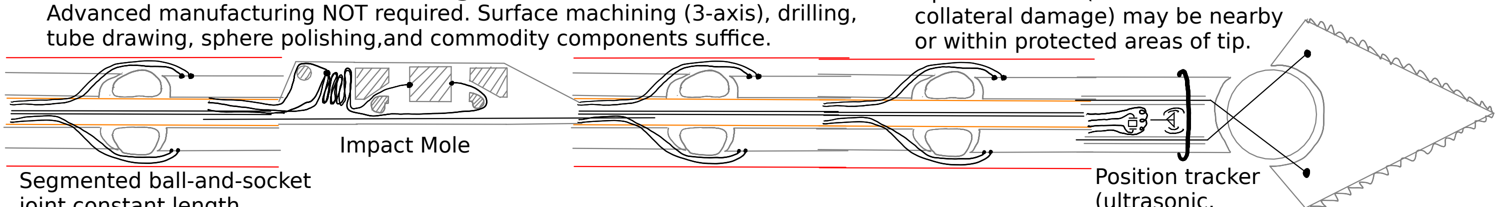
Tunneling

Nerve (peripherial, spinal, optic, cranial), NOT neocortex, interface placement.

Directional Tunneling (2mm)

Advanced manufacturing NOT required. Surface machining (3-axis), drilling, tube drawing, sphere polishing,and commodity components suffice.

May be abrasive and sharp, or blunt. Optical sensors (ie. to minimize collateral damage) may be nearby or within protected areas of tip.

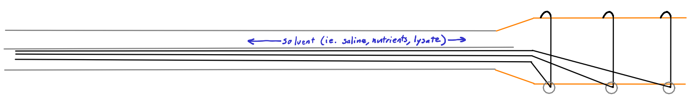


Segmented ball-and-socket joint constant length bowden tubing. Resembles vertebrae joints.

Position tracker (ultrasonic, magnetic, RF, optical, etc).

Steerable high angle tip.

Triple Ring Squeeze Tube Pump (<<2mm tubing)

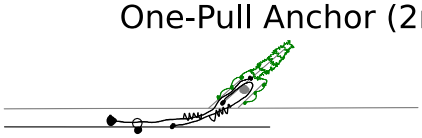


Uses three pull-strings around the perimeter of a tubing to allow entrance of material, confine material to a chamber, and squeeze the chamber after opening the other end. May pump fluid/suspension back, or open flow for solvent.

Biocompatible Lubricant

Polypropylene, fats, refined or synthetic oils, may be sufficiently biocompatible. If not, lubrication may be avoided for short distances near the ends of bowden tubes where leakage may occur.

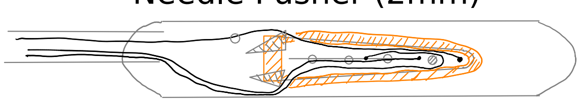
One-Pull Anchor (2mm)



Pull cables to deploy or withdraw needle. Mesh may remain after needle withdraw.

Pull with maximum force to disconnect breakaways, permanently freeing cable. Multiple anchors and other devices may share a single bowden cable. Avoid placing shared anchors in useful types of tissue, where sensors to minimize (ie. vascular) collateral damage may be necessary.

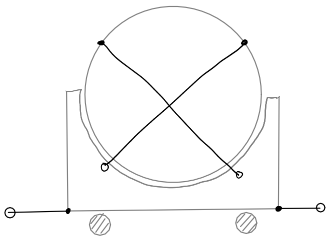
Needle Pusher (2mm)



Lifts soft-edge protective flap up to 90deg to create a working space, pulls needle down, then pulls needle back up. May be pulled along by directional impact mole. Twist bearing or wider plate may be required.

Force Feedback

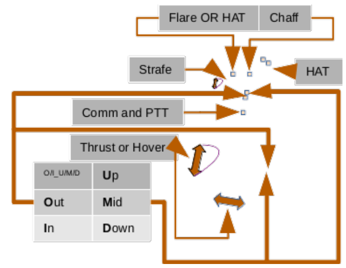
Muscle interface from iterative feedback loop converting position error to force.

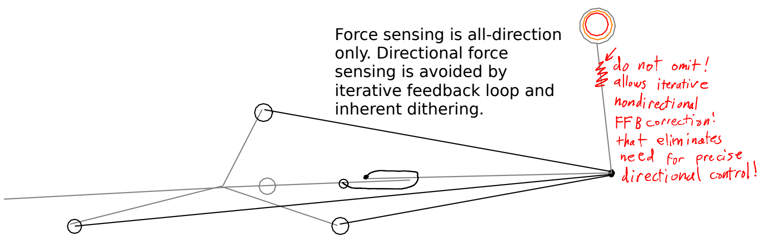


Two or more pairs of crossed cables (perhaps ideally one pair on each of four sides - eight cables total) are expected to provide adequate 3-axis iterative FFB control of a ball-and-socket joint.

Adding a single linear translation 'thrust/hover' axis under one such assembly fulfills all requirements of'extendedInterface' 'commonControlScheme' for single-stick tool and vehicle control, with force feedback notching near such dynamic conditions as cornering speed, formation keeping, optimum climb, spacecraft stabilization as well as hints of such dynamic limits as remaining time before severe turbulence causes structural failure from inelastic deformation. Stick center may be indicated by ~50Hz/60Hz vibration.

Optical center position markings (or other at least intermittently accurate position tracker) expected for stick/HOTAS control.

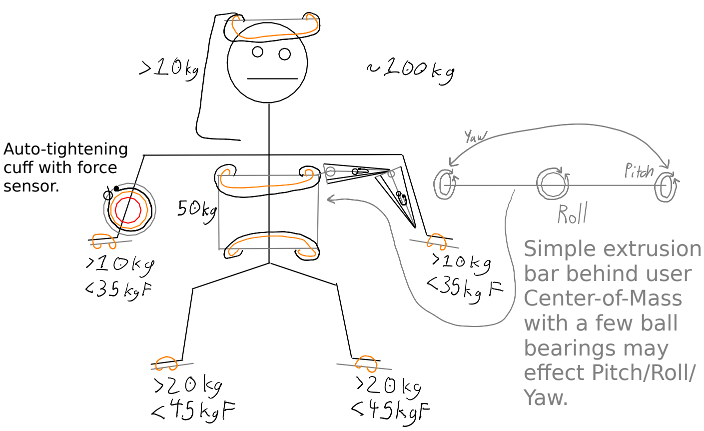




Bowden cables may extend beyond tubing spanning rigid structures as 'open construction'. Multiple layers of bowden cables, some only under small amounts of force particlularly for finer movements, may reduce vibration from backlash. Especially appropriate where large forces and ranges of motion may be necessary.

Exoskeleton

Muscle interface structure for VR from Force Feedback actuators.



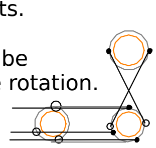
Hard exoskeletons may apply bowden cables (or similar force concentration devices capable of >10kgF) to rigid structures with suitable bearings.

Limbs are supported relative to Center-of-Mass body area. Three-axis plus extension is sufficient to apply force feedback and posture support to all limbs and head.
Force <10kgF is mostly adequate to maintain posture and inform user by force feedback.

Center-of-Mass body area is strapped to a cross bar capable of Pitch/Roll/Yaw.
Roll - large 'Lazy Susan' (aka. 'turntable') bearing.
Pitch - plain bearing between pipes or ball bearing.
Yaw - cylinder track.
All three axes of body rotation may also be provided by a single sphere driven by wheels with some friction or by a single rotatable wheel.

Soft exoskeletons are feasible, externally following internal musculature. Particularly useful as 'paw' (ie. hand/foot) joints.

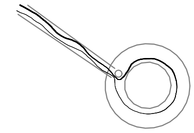
However, shoulder/hip joints may be problematic due to lack of surface rotation.



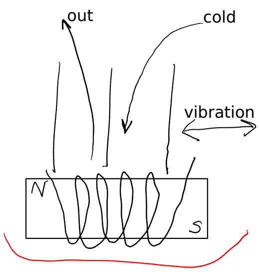
Exoskeleton users *must* have at least one safety gesture/word available out-of-band (eg. unique voice command, unique electromyographic activity pattern, glove swipe pattern, finger mounted button combination, etc). Applied tension must cease when safety stop is called, although software may continue processing positions without the force feedback if appropriate.

Tactile Precepts

Temperature, Pressure, Vibration, Stretch



Stretch, although for a mechanical interface rarely if ever essential, may require a continious loop of bowden cable (or similar) to effect continious rotation pressure on a wheel. Expected slippage (especially if user moves physically) is enough to preclude relying onlimited range of motion (eg. an expanding pneumatic piston).



Sensors
- Temperature
- Pressure
- Electromyography
- Electroconductivity
- Pulse Oximetry

One solenoid, controlling a pocket of fluid, which may be liquid, gas, etc (ie. air).

Closed
Open Out (<25% in out direction) (Default)
Open Cold (<25% in cold direction)
Open Both (Optional)

Temperature
Heat - Power dissipation of resistance in coil and eddy resistance in magnet at RF. Closed.
Cold - Chilled fluid allowed to flow through. Open Both.

Pressure - Open Cold to pressurize. Open Out to depressurize. Add heat if needed.

Vibration - Coil driven at three mechanoreceptor specific frequencies. Closed. Add cold if needed.

Implementations must place valve close to user for efficient vibration and resistance heating. Shared tubing from adjacent pockets must be at some distance from user to minimize cooling by 'cross talk' between separate channels.

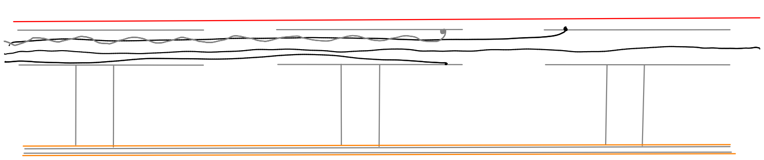
Sensors may improve temperature and pressure accuracy as well as sense the user's temperature, pressure (eg. blood pressure), electromyography, electroconductivity, and blood flow/oxygenation, at each channel. Such distributed sensing may improve mechanical posture support, prevent pressure wounds, prevent frostbite, reduce control latency, and add additional controls.

Electromyographic sensors particularly can allow adequate intuitive control of additional limbs, such as dorsum (aka. 'back') mounted 'wings', or ear pointing of active sensors.

Practical designs may include short tubing and sensors in a valve module, with a cold air bus and exhaust to atmosphere on the opposite side of fluid pockets. Low cost MCUs (<$0.50) may be used as digital GPIO I/O expanders, valves being digitally controlled, analog sensors using the slowest and lowest resolution ADCs (ie. voltage-to-frequency converter, capacitor discharge, multiplexing, etc).

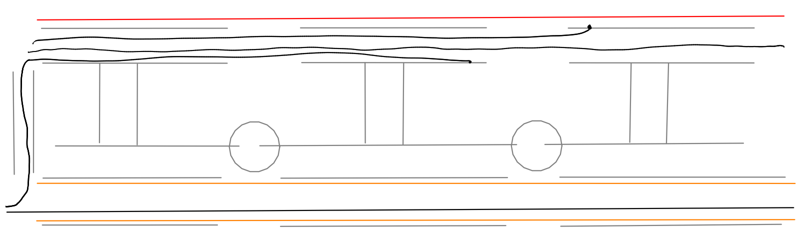
Compliance

Minimizing peak pressure with bendable surfaces and bendable cables.



Linear adjustable length cables anchored to a bendable constant length surface can reshape both surfaces. At least three segments required.

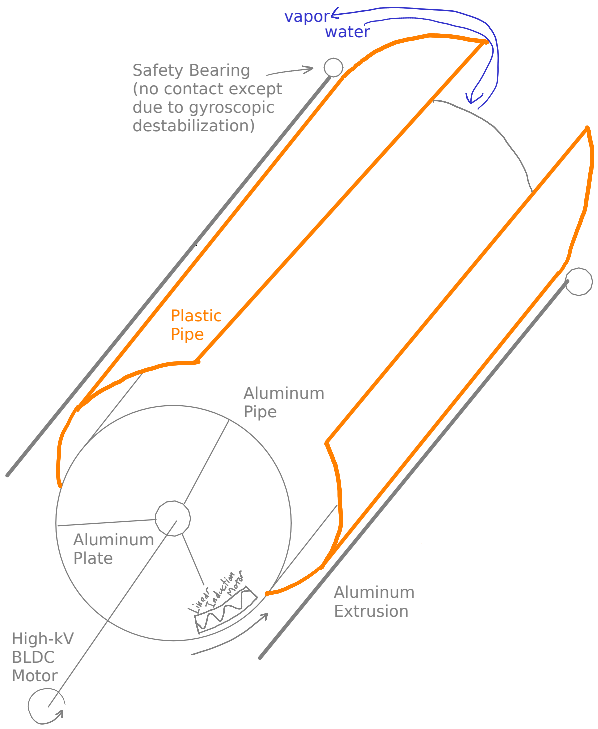
Muscular hydrostats are an extreme example.



Discrete rigid or flexural joints may improve length constancy, which may be useful if a bowden tube must be available for other devices.

Tension

Eddy Current Brake.
Many channels of strong (>10kgF) continious tension, cheap.



Rotating metal drum.
Extremely cheap and low-maintenance, mostly just a ~$200 metal pipe.

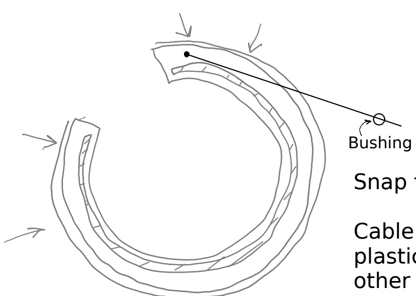
*) 1x ~6in diameter metal pipe
*) 1x >6in diameter plastic pipe
*) 2x identical aluminum plates
*) 2x identical aluminum plates
*) 3x aluminum extrusions or small pipes or small rods, etc
*) mountable bushings for bowden cables
*) either high-kV BLDC motor or Linear Induction Motor
*) cable pull plate for each channel

No brackets are required - recentering of cable pull plates along the drum is from their bowden cables. Metal pipe is aluminum or copper, but ferromagnetic materials and segmented superconductor coatings may work. Lower resistance may reduce rotation rates, increase force, and reduce power consumption due to reduced induced voltage drops from eddy currents. Copper pipe, coupling, or electroplating, may reduce power usage from aluminum by >2.5x. Plastic pipe chosen for negligible cost, material irrelevant.

Parts are all either cheap commodities (ie. plastic pipe, bushings, drum bearings) or flat plates for the most repetitive, lowest capital, lowest consumable, manufacturing (cable pull plates).

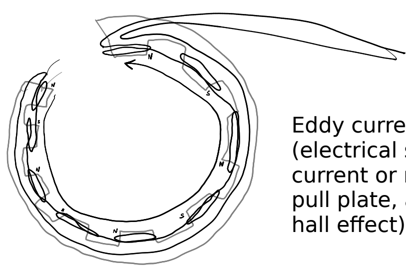
Heat dissipation is entirely at liquid or spray cooled metal drum.

A 1m length pipe with 100x 1cm cable pull plates is functionally equivalent to, but much cheaper, more compact, and much higher performance, than, 100x $20 DC motors.

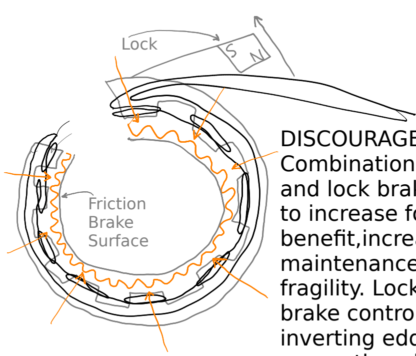


Snap fit cable pull plate.

Cable pull plate (of any kind) is a semicircle made to larger diameter than also semicircular plastic pipe. Such modules may be removed and replaced from slots without distrurbing any other cable pull plates stacked along pipe. Sheet metal may be added along cable pull plate and plastic pipe to reduce wear if necessary.



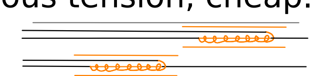
Eddy current brake - analog controlled tension - realized by adding laminated ferromagnetic (electrical steel if available) and wiring alternate magnetic polarity. When energized by DC current or not demagnetized, the eddy current brake exerts rotatry force to turn entire cable pull plate, applying tension to a bowden cable (or similar). Magnetic field strength sensor (ie. hall effect) strongly recommended to calibrate saturation and demagnetization.



DISCOURAGED
Combination eddy, friction, and lock brake integration to increase force. Doubtful benefit,increases maintenance, wear, and fragility. Lock and friction brake controlled by either inverting eddy brake magnetic polarity or AC induction force. Friction brake requires material similar to high quality vehicle brakes.

Artificial Muscle
Compact (<1mm) continious tension, cheap.

Artificial muscle bowden cable puller, inside bowden tube.



Large displacements, strong tension, fast response may be accumulated from entire length of bowden tube. Thin diameter (microns) and small number of actuators in expected applications (45 linear trestles), expensive materials (eg. multiwalled carbon nanotube assembles) may be used cheaply. Biological muscle is theoretically possible, however, other materials are much more efficient when response time is not the only performance criteria.

Resistance heating of 'fishing line' polymer/thread or shape memory alloy is suitable for large motions and strong tension. Piezoelectric elements may be uniquely suitable for nanopositioning (ie. step-stick).