The Soft Robotics Exo-Musculature is a bio-inspired, compliant, light-weight, adaptive, and cost-effective actuated artificial muscle network. For applications requiring full mobility network is driven by electric motor/battery which are more suitable than pneumatic or hydraulic actuators.

The typical human skeletal muscle (one of about 400 pairs) has one-hundred or more motor units whose recruitment affects both the overall muscle stiffness and muscle-load dynamics via spatially distributed attachments to the bone(s).

We introduced the modular “One-To-Many” (OTM) concept that allows a single electric motor to store energy in the form of elastic potential energy, and then, in a finely controllable manner, drive multiple (e.g. hundred) artificial muscle units. Critical to this concept is the modular OTM architecture that uses weight, high-speed, energy efficient, robust, and cost-effective clutches that provide positional feedback.

Our clutches can be easily miniaturized for more advanced applications. In essence, these clutches are the mechanical analogue of valves for pneumatic and hydraulic systems.

Possible applications range from biomedical, space, military, industrial robotics, arts/entertainment, 3D-printed etc.

Summary

Imagine

A modular, energy-efficient, cost-effective, adaptive system consisting of:

(1) A single electric motor and battery

(2) Light-weight Exo-Musculature, i.e. a network of finely controlled, actuated Degrees of Freedom (DoF) that can be utilized for variety of applications.

Imagine space robotics applications where single electric motor can engage number of exceptionally light-weight Exo-Musculature based robotics systems: robonaut, rover + arm, exercise machine, space suit...

Instead of having a dedicated, heavy, expensive and power consuming electric motor per joint DoF the OTM Exo-Musculature utilizes a single motor and hence significantly lowers the mass, cost and energy consumptions of overall system.

The OTM motor unit concept designs

Storing energy with a linear spring

[Diagram showing a linear spring with labeled components]

The single motor unit consists of 3 clutches (C1, C2, C3), 2 elastic elements (R1, E2), and 1 roller R3 that takes a "muscle" fiber slack. Rollers R1 and R2 are shared by many motor units from same or different "muscles".

Storing energy with a torsion spring

[Diagram showing a torsion spring with labeled components]

C1 (C2) is a rotational (linear) clutch. The “staked gears” are connected by a torsion spring. The “slip hearing” transmits torque in one direction but not the other. Both ratchet-type mechanisms are completely passive.

The advanced clutches designs

(A) clutch utilizing forked-roller mechanism with small stopper
(B) clutch utilizing claw/gear mechanism
(C) clutch utilizing sliding-gate mechanism
(D) electromagnetic linear clutch utilizing rollers
(E) electromagnetic slider clutch


The 1-to-1 OTM Demo (ICRA, 2012)

OTM system architecture

Shoulder brace actuation, transmission, sensing and control package (top) with physical demo (bottom) with brace attached to a mannequin arm with added weights tele-operated by Prof. Popovic

The 1-to-3 OTM Demo (Touch Tomorrow, 2012)

4 DoF Arm actuated by 1-to-3 OTM via Bowden Cables

Team pictured with demonstration platform which will be displayed at Touch Tomorrow, the NASA centennial challenge at Worcester Polytechnic Institute.

(Left to right, top row S. Koehler, M. Popovic, G. Iannacchione, bottom row T. Hunt, A. Blumenau, A. Ishak, & C. Berthelette)

For more information contact mpopovic@wpi.edu or visit http://www.users.wpi.edu/~mpopovic/PopovicLabs.html