New Actuators Types

Mechatronics, Lecture 12

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Variable Stiffness Actuators

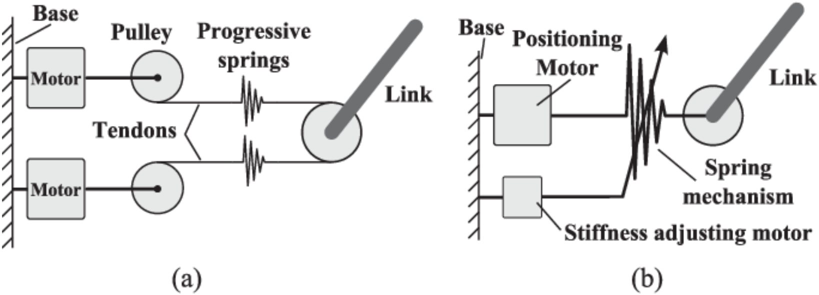


Figure 1: Wolf, Sebastian, et al. "Variable stiffness actuators: Review on design and components." IEEE/ASME transactions on mechatronics 21.5 (2015): 2418-2430.

Variable Stiffness Actuator - model, 1

Different types of Variable Stiffness Actuators (VSA) have different models. Qbmove actuator is described by the following one:

$$
\begin{cases}
L_1 \dot{I}_1 + R_1 I_1 + C_{w,1} \dot{\theta}_1 = u_1 \\
L_2 \dot{I}_2 + R_2 I_2 + C_{w,2} \dot{\theta}_2 = u_2 \\
J_1 \ddot{\theta}_1 + \mu_1 \dot{\theta}_1 = C_{\tau,1} I_1 - \tau_1 \\
J_2 \ddot{\theta}_2 + \mu_2 \dot{\theta}_2 = C_{\tau,2} I_2 - \tau_2 \\
J \ddot{\varphi} + \mu \dot{\varphi} = \tau_1 + \tau_2
\end{cases} \tag{1}
$$

where θ_1, θ_2 - orientation of the internal motor shaft, and φ - orientation of the output shaft, τ_1, τ_2 - torque produced by elastic elements, J, J_1, J_2 - moment of inertia, μ, μ_1, μ_2 - viscous friction coefficient, L, R, C_w, C_τ, I, u are inductance, resistance, back-EMF and torque coefficients, current and input voltage.

The torque produced by elastic elements for Qbmove is given as:

$$\tau_1 = \sigma \sinh(a_1(\theta_1 - \varphi)) \tag{2}$$

$$\tau_2 = \sigma \sinh(a_2(\theta_2 - \varphi)) \tag{3}$$

where a_1 and σ are model constants.

The non-linearity of this model allows us to control the stiffness of the VSA.

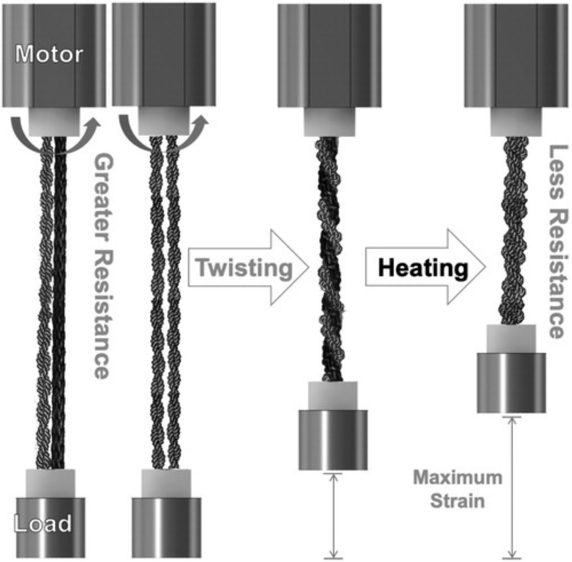
Stiffness $\mathcal{K}$ of an actuator can be defined as a partial derivative of the output torque with respect to the output shaft orientation:

$$\mathcal{K} = \frac{\partial(\tau_1 + \tau_2)}{\partial\varphi} \tag{4}$$

Note that if the torque was linear or affine with respect to φ, then stiffness of such actuator could not be influenced by internal variables θ_i or the orientation of the output shaft φ.

Twisted Spring Actuators

Twisted Spring Actuator, 1



Twisted Spring Actuator, 2

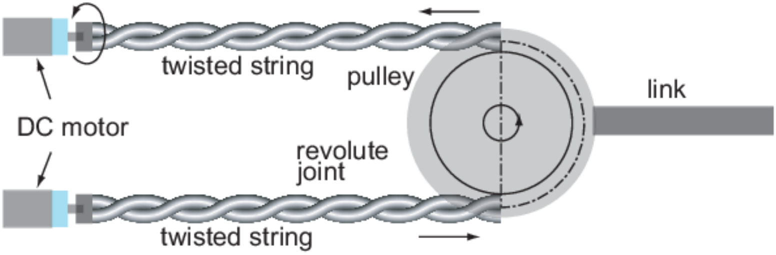
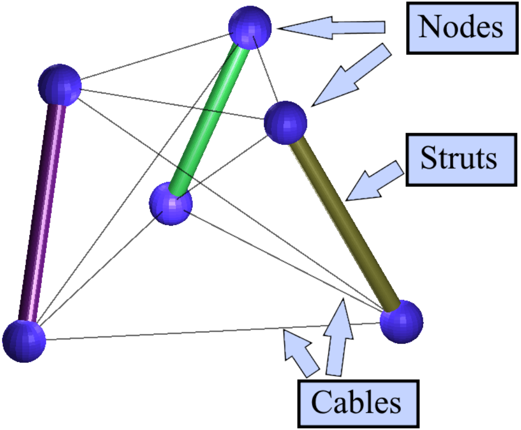


Figure 2: Inoue, T., Miyata, R. and Hirai, S., 2016, October. Force control on antagonistic twist-drive actuator robot. In 2016 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS) (pp. 3830-3835). IEEE.

Tensegrity structures



Note that cables are usually elastic and pre-stressed.

Elastic force acting between nodes $\mathbf{r}_i$ and $\mathbf{r}_j$ can be modelled as follows:

$$\mathbf{f}_{ij} = \mu_{ij}(||\mathbf{r}_i - \mathbf{r}_j|| - \rho_{ij})\frac{\mathbf{r}_i - \mathbf{r}_j}{||\mathbf{r}_i - \mathbf{r}_j||} \quad (5)$$

where μ_{ij} - cable stiffness, ρ_{ij} - undeformed cable length

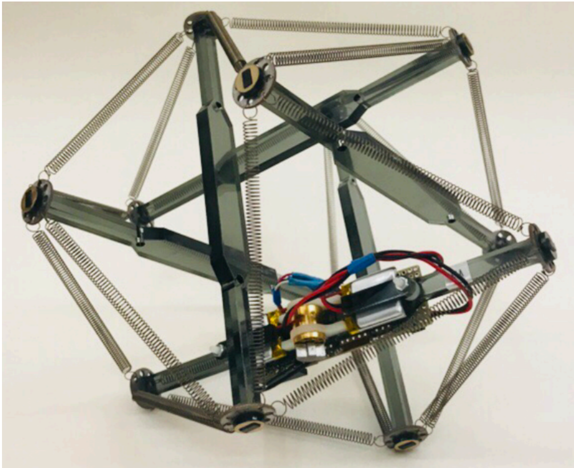


Figure 3: Rieffel, J. and Mouret, J.B., 2018. Adaptive and resilient soft tensegrity robots. Soft robotics, 5(3), pp.318-329.

Lecture slides are available via Github, links are on Moodle

You can help improve these slides at:
github.com/SergeiSa/Mechatronics-2023