Admittance Control of a Human Centered 3 DOF Robotic Arm using Differential Elastic Actuators

M.-A. Legault, M.-A. Lavoie, F. Cabana, Ph. Jacob-Goudreau, D. Létourneau, F. Michaud, *Member*, *IEEE*, M. Lauria, *Member*, *IEEE*

Extended Abstract

THIS video shows the functionalities of a 3 serial DOF robotic arm. Each DOF is actuated with a Differential Elastic Actuator (DEA) [1]. DEA uses a differential coupling between a high impedance mechanical speed source and a low impedance mechanical spring. Possible implementations of a mechanical differential include the use of a standard gearbox, harmonic drive, cycloidal gearbox, bar mechanism, cable mechanism and all other mechanism that implement a differential function between three mechanical ports. For the implementation reported in this video, we used a harmonic drive for a very compact design. A passive torsion spring (thus the name Elastic), with a known impedance characteristic corresponding to the spring stiffness, is used, with an electrical DC brushless motor. A non-turning sensor connected in series with the spring measures the torque output of the actuator. Figure 1 shows our detailed implementation design, and Figure 2 illustrates one DEA.

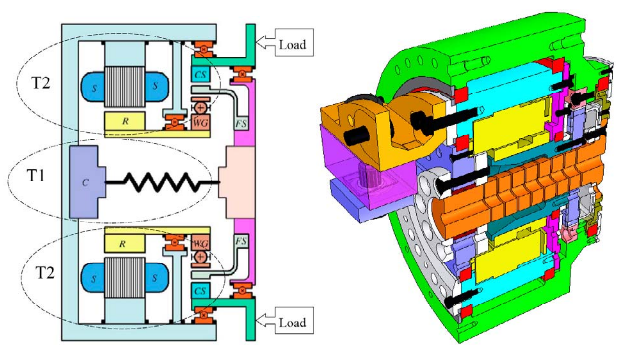

Fig. 1 - DEA implementation using a harmonic drive, a torsion spring and a brushless motor.

The purpose of the project is to create a robotic arm for human-robot interaction tasks. Design goals are:

- being intrinsically safe by having open-loop low impedance characteristics for each DOF (low stiffness, damping and inertia);
- having a kinematic design (relative axis arrangement of the DOF) similar to a human arm;
- having a workspace approaching the one of a child's arm.

The robotic arm structure (Fig. 3) is presented at the beginning of the video, clearly showing the three DEA and their rotation axis. The ranges of motion are shown by manually moving each unpowered actuator's output shaft. The end point of the arm is made of a soft rubbermade sphere.

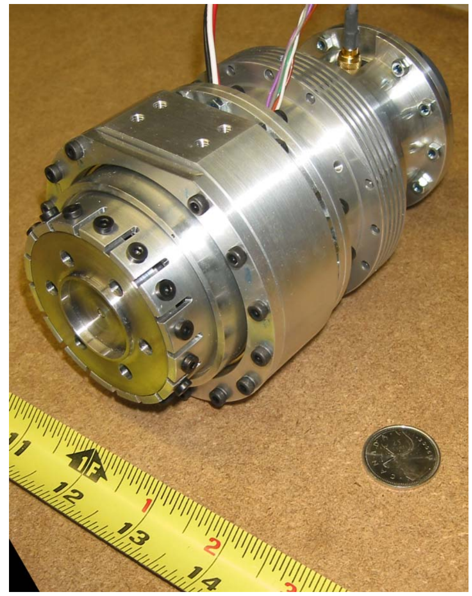

Fig. 2 – Differential Elastic Actuator

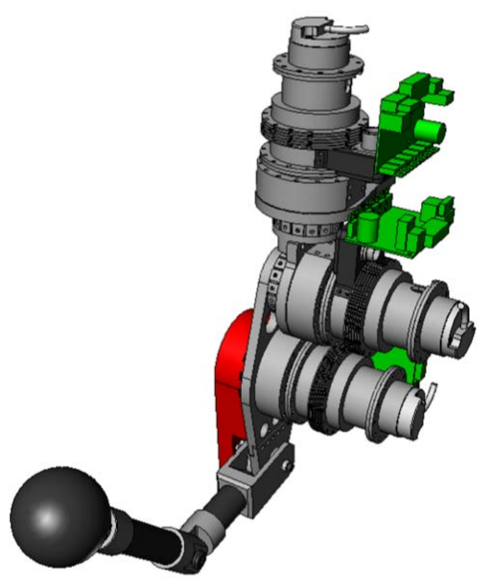

Fig. 3 – 3 DOF arm design

The next section of the video shows that the actuators can sustain impacts with human body (low impedance) or hard surface such as hammer (high impedance). This safe behavior exists with or without powering the arm's actuator.

Axis arrangement of the arm permits 3D movements of its end point. A mechanical admittance algorithm is implemented to control motion of the arm's end point. It is possible to define a 3D set point position in the workspace of the robot that behaves like the equilibrium position of a low stiffness virtual spring. As displayed in the video, the end point of the arm converges back to its targeted position when manually moved away from it. Therefore, interaction forces between the arm's end point and human body remain low even in case of unpredicted impacts.

The next section of the video presents the behavior of the arm when actuators' admittance is set high with gravity compensation. As shown in the video, very low forces have to be exerted by the user to move the end point of the arm.

One application of such low resistance behavior is motion learning applications. As presented in the next section of the video, the algorithm has been set to record the trajectory of the end point with the user manipulating it. This recorded trajectory is thereafter used as an input for the admittance control algorithm. This enables reproducing the « learned » trajectory. Furthermore when admittance is set to be high, having the arm reproduce this trajectory with interference from human interaction is, again, safe.

REFERENCES

[1] M. Lauria, M.-A. Legault, M.-A. Lavoie, F. Michaud, "Differential elastic actuator for robotic interaction task," *Proceedings IEEE International Conference on Robotics and Automation*, 2008.