04/6201 Mechanisms – Biologically inspired joints for innovative articulations concepts

Type of activity: Extended Study (6 months, 35 KEUR)

Despite the dramatic improvements in the fields of materials, actuators, and control strategies, the vast majority of articulated systems are based on conventional linear or rotational rigid couplings (typically ball bearing rigid pinned hinges).

The rigid pinned hinge concept is as old as the wheel, and similarly, it is an extremely useful concept, but (as for the wheel itself) pretty much an artificial construction which does not find an equivalent in the natural world.

The typical natural animal-world solution for achieving articulated systems are dramatically different from the "rigid pinned hinge" concept, not only for what the materials are concerned (clearly dominated by living tissues and fluids) but also for the geometries of the coupled surfaces and for the trajectories allowed to the articulated members.

Even if it is true that airplanes do not fly like birds, it is true that in some instances animal-like or human-like motion is specifically desired (e.g. for replacing astronauts during EVA operations or whenever "human" interfaces are already implemented). Furthermore a number of technological studies are currently dealing with "muscle-like" actuator development, which can better be implemented in skeletal type of articulated structure.

It is believed that innovative articulations / joints concepts, inspired by animal-like forms could exploit the current research programs in the field of innovative actuation concepts, and could mimic to a much higher extent human motion in particular an natural motion in general.

Study Objectives

This study shall assess the feasibility, practical implications and potentials of adopting innovative, animal or human-like articulation concepts in the frame of robotic or more generally articulated structures. The purpose is to exploit synergies with innovative actuation type concepts which can reproduce the muscular functionality (e.g. electro active polymers), and achieve superior performances in terms of higher degree of natural motion mimicking. The study shall proceed according to the following steps:

- Review of the studies related to the same topic, and state of the art identification.
- Analysis of the bio-mechanical aspects associated with the different articulation types which are found in the animal Kingdom, with particular reference to the main ones specific to the human body. Namely articulation types (e.g. vertebrae, elbow, knee…), characteristics (shapes of coupled surfaces, ligaments structure / functions, lubrication concepts..), motion type in relation to kinematics (e.g. changes in rotational axis position during movement, obliquity of rotational axes, limited rotational capabilities…), lay-

out and functional aspects of the muscular actuation (e.g. force amplification factors, multiple joint actuation with single muscular actuation…).

- Identification of conventional mechanical joints / reduction schemes / actuators typologies and comparison with the "human-like" ones. Emphasis should be given to the advantages / disadvantages of the complete system: joint / actuator / reduction stage, in terms of mutual compatibility / suitability (e.g. suitability of a motor plus harmonic drive reducer to actuate an indefinitely rotation pinned joint hinge, as compared to a limited angle linkage system, actuated by a muscle type linear actuator).
- Identification of one (or more) human-like articulation type which shows potential for being reproduced and implemented in a robotic application, and study of its feasibility. Candidate mechanical configurations for the complete joint (articulation, actuator, reduction stage if present…) shall be identified, with specific attention to the practical implementation aspects (complexity, materials / technologies availability…) and potentials (or limits) for improvements and for higher performances. Predicted performances shall be analysed, compared with the "natural" articulation equivalent and reported. Specific aspects related to space applications and to space environment in particular (vacuum compatibility, extreme temperatures, radiations..) shall be addressed, but shall not drive the selection for the candidate material / technologies.