Master Internship

Modeling and analyzing human biomechanical variability to inform the design of adaptive exoskeletons

Auctus team – Inria Bordeaux

Contacts : Pierre Puchaud, pierre.puchaud@inria.fr

Margot Vulliez, margot.vulliez@inria.fr

Context and objective

Recent progresses in assistive robotics and human-robot collaboration could make a reorganization of activities possible, to preserve the health of human workers by improving their working conditions, while enhancing the value of human expertise and skills. Among industrial assistive solutions, exoskeletons are particularly promising as they provide motion-force support through direct interaction with the operator [DeLooze16, Voilqué19].

But, the complete coupling between the human and assistive device can constrain rather than help if the exoskeleton is not perfectly suited to the user, as often described by a misalignment of the exoskeleton's joint instantaneous center of rotation with respect to the human kinematics [Näf18]. Such a kinematic misalignment induces unwanted forces and torques on the user that can result in torsional shear or soft tissue compression [Schiele08, Jarrassé11]. Moreover, human individuals exhibit large morphological variability [Loper15] - such as differences in body shape, mass distribution, and muscular capacity - which can lead to different motion even when performing a same given task. Although adaptive control strategies can adjust the exoskeleton assistance to different user capacity [Gallois25] or motion strategy [Souza24], it cannot compensate for kinematic incompatibility or for misplaced attachment points resulting from a rigid exoskeleton design mounted on users with diverse morphologies. Suitability of such assistive devices for individual users therefore requires adaptive design solutions, for examples modular, reconfigurable, or redundant mechanisms, that explicitly account for the specificity of human biomechanical variability. To build guidelines on the way to adapt designs of exoskeleton, one should first better understand variability in human morphological and musculoskeletal models. In this context, this internship aims at **reviewing and analyzing existing statistical models of human variability, specifically focusing on the upper-limb, to identify main axes of variation and consequently refine the need for design adaptation**.

Research activities

To build some insights on human-centered design requirements for an adaptive upper-limb exoskeleton, the internship will be structured in two parallel research axes combining biomechanical modeling and mechanisms analysis:

Existing statistical models of human variability.

The intern will read scientific articles and look for existing and open-sourced statistical human models, such as SMPL-X [Pavlakos19], that propose to modify the morphology and kinematic chain through "principal components". The intern will present his/her readings and test and install the associated software.

The intern will then compare the effect of principal components and axes of variation on the statistical human model among existing sotfware.

Based on this analysis, the intern will generate a set of human envelops (that represents a population) and will convert it into biomechanical kinematic chains [Keller23] in a multibody simulation engine. We will extract upper-limb parts into a Pinocchio-modeling [Carpentier19] compatible format in order to study the kinematic variability to inform exoskeleton design.

Requirements for adaptation solutions of exoskeleton design.

The intern will do a state of the art of exoskeleton design to survey existing technical solutions to adapt the device to user variability. Common solutions, as survey in [Näf18, Chen24], can be to add redundant and passive degrees of freedom to the kinematic chain [Manzano25], to design self-alignment mechanisms [Cempini12, Schorsch14], or to integrate compliance through flexible/soft mechanisms at the anchor point or within the mechanical structure [Lee16].

The existing adaptation solutions will be compared in terms of possible adjustment levels: degrees of freedom, direction and range of adjustment.

The intern will then extract from the human variability models recommendations to choose the number and axis direction of the adaptation degrees of freedom needed for an elbow exoskeleton. Extra settings (parameters) could also be considered for more adjustments.

Design optimization (optional)

The intern will optimize a set of parameters of the adaptation mechanisms of a given elbow exoskeleton to fit the kinematics of a user and a selected whole population. Existing design optimization methodologies [Sposito20, Zhou17] can be used to guide the optimization process.

The optimized exoskeleton will be compared to the initial one with respect to mobility and comfort metrics.

Research environment

This research internship will take place within the Auctus team at the Inria center of the University of Bordeaux (Talence). The Auctus team aims at meeting challenges of collaborative robotics for humans at work. The team's research is divided into three scientific axes: analysis and modeling of human behavior (biomechanical and cognitive); human-robot interaction and coupling; design and control of cobotic systems. This internship falls at the intersection of the first and third axis, by participating in the definition of human-centered specifications of assistive device, specifically exoskeleton. The project will benefit from the hardware and software resources of the lab experimental platform. The student will be supervised throughout the internship by the two supervisors.

Skills

The candidate should have solid skills in kinematic and dynamic modeling, data analysis, and programming (C++ or Python). Additional experience in biomechanics, statistics, machine-learning, or mechatronic design or experience with git would be appreciated.

Instruction to apply

To apply at this offer, please email a detailed CV, a motivation letter, and your Master courses/grades, to the two supervisors. If you have a portfolio of projects (software or design) don't hesitate to transmit them too.

References

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