PhD position at LORIA - INRIA Nancy (France)

User-specific planning of a collaborative robot behavior to help prevent musculoskeletal disorders

Context

The development of collaborative robots allowing direct physical collaboration between the human and the robot opens a whole new realm of applications [1]. These robots are drawing great attention from industry, owing to their potential to improve work conditions by providing physical assistance to the workers. They are therefore a possible answer to the problem of work-related musculoskeletal disorders (WMSD), which are a major societal issue [2]. Recently, several studies have proposed to use collaborative robots to guide the user toward a more ergonomic posture [3, 4]. These works are based on the notion of an optimal gesture that remains the same through time. However, studies in ergonomics suggest that motor variability – i.e., varying the motor strategy used to perform a task– might be beneficial to delay the onset of physiological fatigue and, in the longer term reduce the risk of developing of WMSDs [5]. Along this line, recent works have proposed to reactively adapt the movement of a collaborative robot according to the user’s physiological fatigue [6]. However, such purely reactive approach does not guarantee that the resulting behavior is optimal in the long term. It might, for instance, result in sudden changes in the robot’s motion that surprise the user, possibly increasing the cognitive load and/or degrading productivity.

Objective

The objective of the proposed work is to plan a policy for a collaborative robot that takes into account the user’s specificities, in order to optimize the long term health and comfort of the user as well as the task efficiency.

Work Plan

The problem that will be addressed involves many uncertainties due to: i) the stochastic evolution of the system since, for the same action of the robot, the human can adopt several postural responses depending on his/her fatigue or on some preferences, ii) the partial knowledge of the system’s state since some variables related to the user’s physiological state or profile are not directly observable, iii) noisy observations since the human response to an action of the robot is identified through sensors data which can be noisy.

To answer this decision making under uncertainty problem, we will use the formal Partially Observable Markov Decision Process framework (POMDP) which allows to mix Bayesian state estimation and optimal control problem within the same model [7, 8]. The POMDP framework will be combined with a physics-engine based simulation tool including a digital human model [9]. The simulation will allow to generate the different possible postural responses of the human to a robot action, in order to evaluate the costs of these responses in terms of fatigue [10], ergonomics and, quality of task execution. These costs will then be used for the calculation of the optimal policy of the decision problem. We will first focus on the fatigue of a typical user, and then enrich the modeling by taking into account inter-individual differences through user profiles.

The proposed approach raises several questions related to the fact that the variables considered are continuous (evolution of fatigue, human choice of posture, robot’s action within its workspace...), whereas POMDPs are usually used to model problems with discrete variables. Part of the work will therefore consist in proposing models and associated resolution techniques that are both representative and computable. Another question will address the formulation of the reward function that will aggregate criteria of different natures (fatigue, ergonomics, cognitive cost, quality of task execution, productivity...).
The proposed work will also include experimental aspects, such as human-robot collaboration experiments on test tasks. These experiments will be paramount in several stages of the work. Experimental data will serve to construct models of human behavior, for instance regarding the links between the user’s profile or physiological state and his/her choice of postural reaction. User experiments will also be crucial to validate the robot’s policies computed with the developed tool.

Requirements

- **Training**: MSc degree (or equivalent) in Mechanical Engineering, Biomedical Engineering or Computer Science, with training in Robotics;
- **Skills**: Modeling and control for robotics, Probabilistic modeling (Markov processes), C++/Python programming, Knowledge in biomechanics and human motion analysis are a plus;
- **Language**: English or French.

Advising and Organization

The student will be co-supervised by 3 researchers from the Larsen team from LORIA-INRIA Nancy:

- Pauline Maurice: pauline.maurice@loria.fr;
- Vincent Thomas: vincent.thomas@loria.fr;
- Francis Colas: francis.colas@inria.fr.

The student will be registered at the IAEM Doctoral School (Computer Science, Automatic Control, Electrical Engineering, Mathematics and Architectural Sciences) of the University of Lorraine, in Nancy, France.

Salary: 2135€ / month (gross salary) plus benefits.

Application

To apply, please send the following documents to all 3 supervisors, with “[PhD ROOIBOS] Application” as subject of the email:

- resume;
- cover letter explaining your interest in the subject;
- MSc transcripts (or equivalent);
- copy of your MSc thesis (or equivalent);
- letter of recommendation from your MSc thesis supervisor.

Only the applications including all the above documents will be reviewed (unless justifying missing pieces). Interested candidates can nevertheless contact the supervisors by email prior to their application for any questions.
References


