Shared-autonomy control for improving Human-Robot collaboration in haptic teleoperation.

Context and objectives

The industrial workplace must be reorganized to address fundamental human challenges: maintaining the human expertise and adaptability at the center of the activity, while preserving physical and mental health of the workers. Human-robot collaboration could meet such issues, by exploiting the robot perceptive and motor abilities to assist the operator and reduce risks and drudgery of work. However, only an advanced and interactive cooperation between the human and robotic agents could leverage the robot potential. The project aims at **rethinking human-robot collaboration, in terms of agents' role and autonomy, to increase their interaction and effectively share the activity**. Therefore, the robot would gain responsibility on the task, adapt its behavior, coordinate and share the action with the Human, to ultimately act as a collaborator.

Among human-robot interaction modalities, haptic teleoperation is a promising method to enable Humans and robots to jointly perform the activity. It enables the human operator to remotely control the robot while receiving feedback about the task interaction. It naturally combines human high-level intelligence and robot physical capabilities while maintaining safety and comfort of the human operator. It also intrinsically creates a rich multisensory interaction since visual, haptic and auditory cues must be exchanged between the co-workers to remotely communicate and perceive the environment. The project will focus on **improving human-robot collaboration in such haptic teleoperation scenarios of industrial assembly or manipulation tasks**.

Methodology and research axes

The PhD Thesis is part of the **ANR research program ASAP-HRC** "Rethinking Autonomy for Shared Action and Perception in Human-Robot collaboration", between the *RoBioSS team* (Robotique, Biomécanique, Sport et Santé) at Pprime institute (University of Poitiers, CNRS), the *AUCTUS team* (Augmenter l'hUmain par CoboT pour un Usage en Symbiose) at INRIA Bordeaux, and the Interaction team at CeRCA (Centre de Recherche sur la Cognition et l'Apprentissage, University of Poitiers, CNRS). The ASAP-HRC program is articulated around the shared-autonomy framework, depicted in Figure 1. It is divided in three main objectives : understanding human perception-action and multisensory integration mechanisms in interaction with a robot; creating a shared and multimodal perception between the human and the robot through an augmented haptic interface; **merging human inputs and robot functional autonomy into a safe and consistent shared action**. This last shared-action activity is the purpose of the PhD project. It involves technical challenges in advanced robotic control, haptic teleoperation, human-robot multimodal interaction, safety in cobotics.

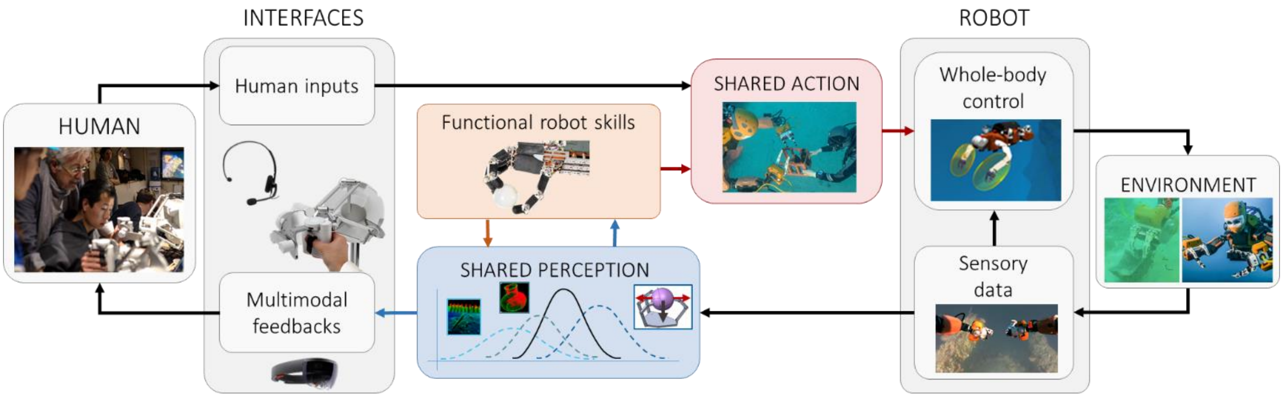

Figure 1. Shared-autonomy framework in haptic teleoperation

The PhD thesis will develop **shared-autonomy control concepts** to merge the human inputs (motions and forces applied by the Human through the teleoperation device) and the robot functional skills (task-oriented robot behavior) into a safe and unified action. The shared-control strategy must allocate the actions and the authority between the actors, with respect to their intent and to the task context and goal. Three scientific axes can be covered by the thesis works, depending on the interests of the candidate:

- **Inferring the human intent to optimally select the robot autonomous skills and online adjust the robot behavior.** To continuously switch the robot autonomy and refine its assistive behavior, a first module will decode the user commands to infer his/her intention. This intent prediction will be based on existing methods of the literature [Los18], such as Hidden Markov Models [Aar08], Maximum Entropy inference [Mue17], or Dynamic Bayesian Networks [Sch07]. It will predict the most likely elementary action, encoded as a force-motion manipulation pattern, that the Human wants to do. A second module will then select the control objective within a library of generic robot autonomous skills, according to the human inferred intent. The autonomous skill will be scaled thanks to perceived task features (workspace, contact constraints…). Continuously drifting robot autonomy will make it behave more naturally and instantly react to human needs. But, such online autonomy transitions must be carefully bounded to maintain safe and stable change in the control objective.
- **Developing arbitration methods to combine the human commands and the robot skills into a consistent and coordinated action**. When robot autonomous skills have been selected to help toward the predicted human task goal, they must be merged with the human commands to compute the final robot control input. Blending robot autonomy and human desired task force-motion into a joint action makes a consensus within the team. Arbitration methods will synthesize the human and robot commands, which can overlap or be contrary, into a common policy. Several arbitration methods will be tested among Gaussian product [Zee18], probabilistic blending [Tra15], or simple linear blending of the inputs [And10]. A generic blending policy, transferable on different industrial tasks, will be developed to merge all commands into a unified force-motion shared control of the action.
- **Defining algorithms to distribute the authority on the task between the actors**, which is the individual decision-making power on the action to be carried out. The blending policy will be modulated with respect to the decision weight given to each agent on the task. These arbitration parameters will set the authority distribution. They can be computed according to some task criteria [Web09], the user confidence [Usm15], trust in the human intent prediction [Dra13], the agents' expertise (MABA-MABA [Par00]), or other safety and reliability criteria. This control authority will be continuously shifted between the actors. It encodes the way the human and the robot will share the action and can be inspired from human-teaming coordination mechanisms and joint-action processes.

All theoretical developments and controllers will be regularly simulated and experimentally evaluated on several use cases. A haptic teleoperation cell is available on the lab platform to validate the shared-action strategy through tangible demonstrations. The setup will facilitate precise data collection for evaluation purpose.

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Project team

The PhD candidate will be closely working with researchers of the *RoBioSS* and *AUCTUS* teams. Research works at *RoBioSS* team include design, modeling, and control of novel mechatronic systems (haptic devices, robot arms, dexterous grippers…) for an open and flexible collaborative robotics. The team is also interested in human motion analysis to evaluate the biomechanical comfort of human operators at work and during physical interactions with production machines. The *AUCTUS* team is interested in three main research topics : understanding cognitive and biomechanical human behaviors, evaluating and improving Human-Robot interactions in collaborative robotics, and developing safe hardware and control software in this man/machine context.

The recruited PhD student will be mainly working at the *RoBioSS* team facilities :

Equipe RoBioSS, Institut Pprime, CNRS, Université de Poitiers
SP2MI Téléport 2, 11 Boulevard Marie et Pierre Curie
86360 CHASSENEUIL-DU-POITOU

Skills

Technical skills in Robotic Control, Robot Kinematic and Dynamic Modeling, Programming (C++, Python), and Experimental Robotics are required. Experiences in Haptics, Trajectory Planning or Vision would be appreciated.

Contact and application

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You can submit your application by email to Margot Vulliez. The application must include your resume, a cover letter, and your Master’s grades.