Activity Report 2019

Team Auctus

Designing the collaborative robotics cells of the future

Inria teams are typically groups of researchers working on the definition of a common project, and objectives, with the goal to arrive at the creation of a project-team. Such project-teams may include other partners (universities or research institutions).

RESEARCH CENTER
Bordeaux - Sud-Ouest

THEME
Robotics and Smart environments

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Team Auctus

Creation of the Project-Team: 2020 April 01

Keywords:

Computer Science and Digital Science:

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Other Research Topics and Application Domains:

B1.2.2. - Cognitive science
B2.8. - Sports, performance, motor skills
B5.1. - Factory of the future
B5.2. - Design and manufacturing
B5.6. - Robotic systems
B9.6. - Humanities
B9.9. - Ethics

1. Team, Visitors, External Collaborators

Research Scientists

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PhD Students

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2. Overall Objectives

2.1. Overall Objectives

The project of the Auctus team is to design the collaborative robotics cells of the future.

The robotics community still tends to separate the cognitive (HRI) and physical (pHRI) aspects of human/robot interaction. One of the main challenges is to characterize the task as well as mechanical, physiological and cognitive capacities of humans in the form of physical constraints or objectives for the design of cobotized workstations. This design is understood in a large sense: the choice of the robot's architecture (cobot, exoskeleton, etc.), the dimensional design (human/robot workspace, trajectory calculation, etc.), the coupling mode (comanipulation, teleoperation, etc.) and control. The approach then requires the contributions of the human and social sciences to be considered in the same way as those of exact sciences. The topics considered are broad, ranging from cognitive sciences, ergonomics, human factors, biomechanics and robotics.

The first challenge is to evaluate the hardship at work, the well-being of the operators and, further upstream, their cognitive state which impacts their sensorimotor strategy for performing a task. In industry, the ergonomic analysis of the task is carried out by an ergonomist based on direct but often ad hoc observations. However, the context is changing: the digitization of factories, through the installation of on-site sensors, allows longitudinal observation of machines and humans. The information available can thus allow us to rethink the way in which the evaluation of activities is carried out. Currently, an emerging subdomain named *ergonomic robotics* adapts the available ergonomic evaluation criteria (RULA, REBA, etc.). However, they are related to the (quasi-static) posture of the operator, which limits the understanding of human motor strategies over a long period of time. Similarly, kinematic or biomechanical analysis may tend to see humans as a high-performance machine to be optimized. This may make sense for a top-level athlete, but repeating actions in the industry over a day, months or years of work means that a temporary change of posture, possibly poorly rated according to usual ergonomic criteria, can in fact be a good long-term strategy. These questions make a direct link between motor and cognitive aspects that can be reflected in particular strategies as the fatigue or the expertise (manual and cognitive). This approach has not been widely explored in robotics to determine the right criteria to adapt the behavior of a cobot.

The second challenge is to define a methodology to link the analysis of the task and the human movements it induces to the robot design. Indeed, as we have been able to verify on several occasions in the context of industrial projects, between the ergonomist, expert in task analysis and psychology, and the robotician, expert in mechanics, control and computer science, there is a significant conceptual distance that makes it very difficult to analyze needs and define the specifications of the technical solution. To fill these methodological gaps, it is necessary, on the basis of case studies, to better define the notion of tasks in the context of a human/robot coupling and to establish a typology of this type of interaction by taking into account, with as much details as possible, the different physical and cognitive constraints and their potential psychological, organizational or ethical impacts.

The third challenge is related to the need to think about the control laws of collaborative robots in terms of human/robot coupling. The effectiveness of this coupling requires an ability to predict future human actions. This prediction should make the interaction more intuitive but also aims at an optimal coupling from the point of view of "slow" phenomena such as fatigue. The major challenge is therefore to move from reactive to predictive control laws, integrating a human prediction model, both in terms of movement strategies and decision strategies. Beyond the great computational complexity of predictive approaches, obtaining prediction models is an ambitious challenge. It is indeed necessary to learn models that are quite complex in terms of the physical realities they can account for and quite simple from a computational point of view.

3. Research Program

3.1. Analysis and modelling of human behavior

3.1.1. Scientific Context

The purpose of this axis is to provide metrics to assess human behavior. We place ourselves here from the point of view of the human being and more precisely of the industrial operator. We assume the following working hypotheses: the operator's task and environmental conditions are known and circumscribed; the operator is trained in the task, production tools and safety instructions; the task is repeated with more or less frequent intervals. We focus our proposals on assessing:

- the physical and cognitive fragility of operators in order to meet assistance needs;
- cognitive biases and physical constraints leading to a loss of operator safety;
- ergonomic, performance and acceptance of the production tool.

In the industrial context, the fields that best answer these questions are work ergonomics and cognitive sciences. Scientists typically work on 4 axes: physiological/biomechanical, cognitive, psychological and sociological. More specifically, we focus on biomechanical, cognitive and psychological aspects, as described by the ANACT [24], [26]. The aim here is to translate these factors into metrics, optimality criteria or constraints in order to implement them in our methodologies for analysis, design and control of the collaborative robot.

To understand our desired contributions in robotics, we must review the current state of ergonomic workstation evaluation, particularly at the biomechanical level. The ergonomist evaluates the gesture through the observation of workstations and, generally, through questionnaires. This requires long periods of field observation, followed by analyses based on ergonomic grids (e.g. RULA [42], REBA [32], LUBA [37], OWAS [36], ROSA [60],...). Until then, the use of more complex measurement systems was reserved for laboratories, particularly biomechanical laboratories. The appearance of inexpensive sensors such as IMUs (Inertial Measurement Units) or RGB-D cameras makes it possible to consider a digitalized, and therefore objective, observation of the gesture, postures and more generally of human movement. Thanks to these sensors, which are more or less intrusive, it is now possible to permanently install observation systems on production lines. This completely changes paradigms and opens the door to longitudinal observations. It should be noted that this is comparable to the evolution of maintenance, which becomes predictive.

On the strength of this new paradigm, *ergonomic robotics* has recently taken an interest in this type of evaluation to adapt the robot's movements in order to reduce ergonomic risk scores. This approach complements the more traditional approaches that only consider the performance of the action produced by the human in interaction with the robot. However, we must go further. Indeed, the ergonomic criteria are based on the principle that the comfort positions are distant from the human articular stops. In addition, the notation must be compatible with an observation of the human being through the eye of the ergonomist. In practice, evaluations are inaccurate and subjective [63]. Moreover, they are made for quasi-static human positions without taking into account the evolution of the person's physical, physiological and psychological state. The repetition of gestures, the solicitation of muscles and joints is one of the questions that must complete these analyses. One of the methods used by ergonomists to limit biomechanical exposures is to increase variations in motor stress by rotating tasks [61]. However, this type of extrinsic method is not always possible in the industrial context [40].

One of Auctus' objectives is to show how, through a cobot, the operator's environment can be varied to encourage more appropriate motor strategies. To do so, we must focus on a field of biomechanics that studies the intrinsic variability of the motor system allowed by the joint redundancy of the human body. This motor variability refers to the natural alternation of postures, movements and muscle activity observed in the individual to respond to a requested task [61]. This natural variation leads to differences between the motor coordinates used by individuals, which evokes the notion of motor strategy [33].

As shown by the cognitive dimension of ergonomics (see above), we believe that some of these motor strategies are a physically quantifiable reflection of the operator's cognitive state. For example, fatigue [57] and its anticipation or the manual expertise (dexterous and cognitive) of the operator which allows him to anticipate his movements over long periods of time in order to preserve his body, his performance and his pain.

3.1.2. Methodology

How can we observe, understand and quantify these human motor strategies to better design and control the behavior of the cobotic assistant? When we study the systems of equations considered (kinematic, static, dynamic, musculoskeletal), several problems appear and explain our methodological choices:

- the large dimensions of the problems to be considered, due to joint, muscle and placement redundancy,
- the variabilities of the parameters, for example: physiological (consider not an operator, but a set of operators), geometric (consider a set of possible placements of the operator) and static (consider a set of forces that the operator must produce);
- the uncertainties of measurement, model approximation.

The idea is to start from a description of redundant workspaces (geometric, static, dynamic...). To do this, we use set theory approaches, based on interval analysis [3], [48], which allow us to respond to the uncertainties and variability issues previously mentioned. In addition, one of the advantages of these techniques is that they allow the results to be certified, which is essential to address safety issues. Some members of the team has already achieved success in mechanical design for performance certification and robot design [44]. The adaptation of these approaches allows us to obtain a mapping of ergonomic and efficient movements in which we can project the operators' motor strategies and thus define a metric quantifying the sensorimotor commands chosen with regard to the cognitive criteria studied.

It is therefore necessary to:

- propose new indices linking different types of performance (ergonomic biomechanical robotics, but also influence of fatigue, stress, level of expertise on the evolution of performance);
- divide the gesture into homogeneous phases: this process is complex and depends on the type of index used and the techniques used. We are exploring several ways: inverse optimal control, learning methods, or the use of techniques from signal processing.
- develop interval extensions of the identified indices. These indices are not necessarily the result of a direct model, and algorithms need to be developed or adapted (calculation of manipulability, UCM, etc.).

- Aggregate proposals into a dedicated interval analysis library (use of and contribution to the existing ALIAS-Inria and the open source IBEX library).

The originality and contribution of the methodology is to allow an analysis taking into account in the same model the measurement uncertainties (important for on-site use of analytical equipment), the variability of tasks and trajectories, and the physiological characteristics of the operators.

Other avenues of research are being explored, particularly around the inverse optimal control [49] which allows us to project human movement on the basis of performance indices and thus to offer a possible interpretation in the analysis of behaviors.

We also use automatic classification techniques: 1) to propose cognitive models that will be learned experimentally 2) for segmentation or motion recognition, for example by testing Reservoir Computing [34] approaches.

3.2. Operator / robot coupling

3.2.1. Scientific Context

Thanks to the progress made in recent years in the field of p-HRI (Physical Human-Robot Interaction), robotic systems are beginning to operate in the same workspace as humans, which is profoundly changing industrial issues and allowing a wide variety of human-robot coupling solutions to be considered to perform the same task [25]. Different types of interactions exist. They can be classified in different ways: according to the degree of autonomy of the robot and its proximity to the user [31] with particularities for "wearable robots" [30], [29], or for collaborative robotics [62], or according to the role of the human being [58]. From a cognitive point of view, classifications are more concerned with autonomy, the complexity of information processing and the type of communication and representation of the human being by the robot [47], [64].

We proposed a classification of cobotic systems according to the configuration of the schema of interactions between humans, robots and the environment [45], [55].

The parameters of the coupling being numerous and complex, the determination of the most appropriate type of coupling for a type of problem is an open problem [50], [2], [46], [41]. The traditional approach consists in trying to identify and classify the various possible options and to select the one that seems most relevant with regard to the feasibility, efficiency, budget envelope and acceptability of the operator. One of the main objectives of our research project is to define a typology of cobots or cobotic systems in order to specify the methodology for developing the best solution: what are the criteria for defining the best robotic architecture, what type of coupling, what autonomy of the robot, what role for the operator, what risks for the human, what overall performance? These are the key issues that need to be addressed. To meet this methodological need, we propose an approach guided by experience on use cases obtained thanks to our industrial partners.

3.2.2. Methodology

Task analysis and human behavior modelling, discussed in the previous sections, should help to characterize the different types of coupling and interaction modalities, their advantages and disadvantages, in order to assist in the decision-making process. One of the ideas we would like to develop is to try to break down the task into a sequence of elementary gestures corresponding to simple motor actions performed in a clearly identified context and to evaluate for each of them the degree of feasibility in automatic mode or in robot assistance mode. The assessment must take into account a large number of parameters that relate to physical interactions, human-robot communication, reliability and human factors, including acceptability and impact on the valuation or devaluation of the operator's work. Concerning the evaluation of human factors, we have already begun to work on the subject within the more general framework of human systems interactions by operating Bayesian networks, drawing inspiration from the work of [28], [56].

The adoption of assessment criteria for a single domain (e. g. robotics or ergonomics) cannot guarantee that the performance of this coupling will be maximized. From design to evaluation, cross-effects must be constantly considered:

- impact of the cobot design on the user's performance: intuitiveness, adaptation to intra- and inter-individual variations, affordance, stress factors (noise, vibrations,...), fatigue factors (control laws, necessary attention,...) and motivation factors (effectiveness, efficiency, aesthetics,...);
- impact of user performance on cobot exploitation: risks of human error (attention error, perseveration, circumvention of procedures, syndrome outside the loop) [28].

In addition to purely physical assistance, some cobotic systems are designed to assist the operator in his decision-making. The issues of trust, acceptance, sharing of representations and co-construction of a shared awareness of the situation are then to be addressed [59].

3.3. Design of cobotic systems

3.3.1. Architectural design

Is it necessary to cobotize, robotize or assist the human being? Which mechanical architecture meets the task challenges (a serial cobot, a specific mechanism, an exoskeleton)? What type of interaction (H/R cohabitation, comanipulation, teleoperation)? These questions are the first requests from our industrial partners. For the moment, we have few comprehensive methodological answers to provide them. Choosing a collaborative robot architecture is a difficult problem [38]. It is all the more when the questions are approached from both a cognitive ergonomics and robotics perspective. There are indeed major methodological and conceptual differences in these areas. It is therefore necessary to bridge these representational gaps and to propose an approach that takes into consideration the expectations of the robotician to model and formalize the general properties of a cobotic system as well as those of the ergonomist to define the expectations in terms of an assistance tool.

To do this, we propose a user-centered design approach, with a particular focus on human-system interactions. From a methodological point of view, this requires first of all the development of a structured experimental approach aimed at characterizing the task to be carried out through a "system" analysis but also at capturing the physical markers of its realization: movements and efforts required, ergonomic stress. This characterization must be done through the prism of the systematic study of the exchange of information (and their nature) by humans in their performance of the considered task. On the basis of these analyses, the main challenge is to define a decision support tool for the choice of the robotic architecture and for the specifications of the role assigned to the robot and the operator as well as their interactions.

The evolution of the chosen methodology is for the moment empirical, based on the user cases regularly treated in the team (see sections on contracts and partnerships).

It can be summarized for the moment as:

- identify difficult jobs on industrial sites. This is done through visits and exchanges with our partners (manager, production manager, ergonomist...);
- select some of them, then observe the human in its ecological environment. Our tools allow us to produce a motion analysis, currently based on ergonomic criteria. In parallel we carry out a physical evaluation of the task in terms of expected performance and an evaluation of the operator by means of questionnaires.
- Synthesize these first results to deduce the robotic architectures to be initiated, the key points of human-robot interaction to be developed, the difficulties in terms of human factors to be taken into account.

In addition, the different human and task analyses take advantage of the different expertise available within the team. We would like to gradually introduce the evaluation criteria presented above. Indeed, the team has already worked on the current dominant approach: the use of a virtual human to design the cobotic cell through virtual tools [1]. However, the very large dimensions of the problems treated (modelling of the body's ddl and the constraints applied to it) makes it difficult to carry out a certified analysis. We then choose to go through the calculation of the body's workspace, representing its different performances, which is not yet done in this field. The idea here is to apply set theory approaches, using interval analysis and already discussed in section

3.1.2. The goal is then to extend to intervals the constraints played in virtual reality during the simulation. This would allow the operator to check his trajectories and scenarios not only for a single case study but also for sets of cases. For example, it can be verified that, regardless of the bounded sets of simulated operator physiologies, the physical constraints of a simulated trajectory are not violated. Thus, the assisted design tools certify cases of use as a whole. Moreover, the intersection between the human and robot workspaces provides the necessary constraints to certify the feasibility of a task. This allows us to better design a cobotic system to integrate physical constraints. In the same way, we will look for ways in which human cognitive markers can be included in this approach.

Thus, we summarize here the contributions of the other research axes, from the analysis of human behavior in its environment for an identified task, to the choice of a mechanical architecture, via an evaluation of torque and interactions. All the previous analyses provide design constraints. This methodological approach is perfectly integrated into an Appropriate Design approach used for the dimensional design of robots, again based on interval analysis. Indeed, to the desired performance of the human-robot couple in relation to a task, it is sufficient to add the constraints limiting the difficulty of the operator's gesture as described above. The challenges are then the change of scale in models that symbiotically consider the human-robot pair, the uncertain, flexible and uncontrollable nature of human behavior and the many evaluation indices needed to describe them.

3.3.2. Control design

The control laws of collaborative robots from the major robot manufacturers differ little or not at all from the existing control laws in the field of conventional industrial robotics. Security is managed a posteriori, as an exception, by a security PLC / PC. It is therefore not an intrinsic property of the controller. This quite strongly restricts the possibilities of physical interaction [1] and collaboration and leads to sub-optimal operation of the robotic system. It is difficult in this context to envision real human-robot collaboration. Collaborative operation requires, in this case, a control calculation that integrates safety and ergonomics as a priori constraints.

The control of truly collaborative robots in an industrial context is, from our point of view, underpinned by two main issues. The first is related to the macroscopic adaptation of the robot's behaviour according to the phases of the production process. The second is related to the fine adaptation of the degree and/or nature of the robot's assistance according to the ergonomic state of the operator. If this second problem is part of a historical dynamic in robotics that consists in placing safety constraints, particularly those related to the presence of a human being, at the heart of the control problem [31] [43], [35], it is not approached from the more subtle point of view of ergonomics where the objective cannot be translated only in terms of human life or death, but rather in terms of long-term respect for their physical and mental integrity. Thus, the simple and progressive adoption by a human operator of the collaborative robot intended to assist him in his gesture requires a self-adaptation in the time of the command. This self-adaptation is a fairly new subject in the literature [51], [52].

At the macroscopic level, the task plan to be performed for a given industrial operation can be represented by a finite state machine. In order not to increase the human's cognitive load by explicitly asking him to manage transitions for the robot, we propose to develop a decision algorithm to ensure discrete transitions from one task (and the associated assistance mode) to another based on an online estimate of the current state of the human-robot couple. The associated scientific challenge requires establishing a link between the robot's involvement and a given working situation. To do so, we propose an incremental approach to learning this complex relationship. The first stage of this work will consist in identifying the general and relevant control variables to conduct this learning in an efficient and reusable way, regardless of the particular method of calculating the control action. Physically realistic simulations and real word experiments will be used to feed this learning process.
In order to handle mode transitions, we propose to explore the richness of the multi-tasking control formalism under constraints [39] in order to ensure a continuous transition from one control mode to another while guaranteeing compliance with a certain number of control constraints. Some of these constraints are based

[1] In the ISO TS 15066 technical specification on collaborative robotics, human-robot physical interaction is allowed but perceived as a situation to be avoided.

on ergonomic specifications and are dependent on the state of the robot and of the human operator, which, by nature, is difficult to predict accurately. We propose to exploit the interval analysis paradigm to efficiently formulate ergonomic constraints robust to the various existing uncertainties.
Purely discrete or reactive adaptation of the control law would make no sense given the slow dynamics of certain physiological phenomena such as fatigue. Thus, we propose to formulate the control problem as a predictive problem where the impact of the control decision at a time t is anticipated at different time horizons. This requires a prediction of human movement and knowledge of the motor variability strategies it employs. This prediction is possible on the basis of the supervision at all times of the operational objectives (task in progress) in the short term. However, it requires the use of a virtual human model and possibly a dynamic simulation to quantify the impact of these potential movements in terms of performance, including ergonomics. It is impractical to use a predictive command with simulation in the loop with an advanced virtual manikin model. We therefore propose to adapt the prediction horizon and the complexity of the corresponding model in order to guarantee a reasonable computational complexity.
The planned developments require both an approach to modelling human sensorimotor behaviour, particularly in terms of accommodating fatigue via motor variability, and validating related models in an experimental framework based on observation of movement and quantification of ergonomic performance. Experimental developments must also focus on the validation of proposed control approaches in concrete contexts. To begin with, the Woobot project related to gesture assistance for carpenters (Nassim Benhahib's thesis) and a collaboration currently being set up with Safran on assistance to operators in shrink-wrapping tasks (manual knotting) in aeronautics are rich enough background elements to support the research conducted. Collaborative research projects with PSA will also soon provide a larger set of contexts in which the proposed research can be validated.

4. Application Domains

4.1. Factory 4.0

The 4th industrial revolution (factory 4.0) is characterized by the integration of digital technologies into the production process, in order to meet the challenge of customizing services and products. This agility requires making manufacturing and maintenance lines flexible and versatile. This capacity for adaptation is the characteristic of the human being, which puts him at the center of the production apparatus. However, this can no longer be done at the expense of their health and well-being. How then can we reconcile the enhancement of our manual and analytical expertise, the ever desired increase in productivity and manufacturing quality, while reducing the hardship at work? Collaborative robotics, which we are seeking to build, is one of the central solutions to meet this societal challenge. By assisting humans in their most dangerous and painful tasks, it complements or replaces them in their phases of physical and cognitive fragility.

More generally, we are interested in workstation cobotization, in the manufacturing and assembly industry but also in the construction and craft industries. The application areas are related to regional needs in aeronautics, including maintenance, water and waste treatment. In most of these cases, it is possible to define the tasks, evaluate the stakes and added value of our work.

5. Highlights of the Year

5.1. Highlights of the Year

- Jean-Marc Salotti has been elected Member of the International Academy of Astronautics
- The startup Touch Sensity [2] has been created by Ganna Pugach.

[2] http://touchsensity.com/

6. New Software and Platforms

6.1. HuMoSoft

Human Motion Analysis Software

KEYWORDS: Movement analysis - 3D movement

FUNCTIONAL DESCRIPTION: HuMoSoft is based on the ROS platform. The acquisition data can come from different depth sensors, for example Kinect, via the Nuitrack JDK. An extended Kalman filter has been implemented, and motion analysis uses the RULA method.

- Authors: Jessica Colombel and David Daney
- Contact: Sylvain Pion
- URL: https://gitlab.inria.fr/auctus/kombos-server

6.2. KCADL

Kinematic Chain Appropriate Design Library

KEYWORDS: Interval analysis - Uncertainty - Kinematics

FUNCTIONAL DESCRIPTION: Software for the modelling and analysis of imprecise serial kinematic chains. Chain objects are built by iteratively adding rigid-body segments with associated joint connections (e.g., fixed, revolute, prismatic). Several standard options are provided to model each segment (e.g., Denavit-Hartenberg parameters, transformation matrices, twists). Each option accepts interval and non-interval arguments, allowing to model the uncertainties and variabilities of imprecise serial kinematic chains and also the conventional precise serial kinematic chains. Forward Kinematic (FK) and Inverse Kinematic (IK) solvers are available for Chain objects. The FK solver computes an outer bound of the set of poses associated with a set of joint configurations. The IK solver computes an outer bound of the set of joint configurations associated with a set of poses.

- Participant: Joshua Pickard
- Contact: Joshua Pickard
- Publication: hal-02367664, version 1
- URL: https://gitlab.inria.fr/auctus/kinematic-chain-appropriate-design-library

6.3. AUCTUS-MOVER

AUCTUS panda MOVER project

KEYWORDS: Automatic control - Variability

FUNCTIONAL DESCRIPTION: Software for controlling the Franka Emika Panda robot to study human motor variabilities. Consists of a torque-based controller for the Franka Emika Panda collaborative robot with the following actuation modes: auto mode - the robot follows a predefined trajectory, manual mode - the robot is in a constrained gravity compensation mode (the constraints may be adapted online). A graphical interface allows the operator to switch between modes. Software for calibrating the robot with respect to the Optitrack motion capture system is also included.

- Contact: Joshua Pickard
- URL: https://gitlab.inria.fr/auctus/auctuspanda/tree/mover_project

6.4. AUCTUS-RT

AUCTUS - Redunancy Tubes

KEYWORD: Variability

FUNCTIONAL DESCRIPTION: Software for modelling and analyzing human motor variabilities along a path. Currently used to study the redundant motions associated with the upper limb. Anatomical constraints for the shoulder, elbow, and wrist may be customized for a human subject using: maximal and minimal bounding regression equations, spherical polygon constraints. A constrained imprecise kinematic model of the subject is obtained and the task redundancies and joint redundancies associated with the constrained imprecise kinematic model are able to be evaluated via branch-and-bound exploration to determine achievable and non-achievable redundant motions of the human. For n redundant degrees-of-freedom, this provides an n-dimensional redundant workspace describing the human's capabilities. Along a path, this provides an (n+1)-dimensional redundant workspace tube.

- Contact: Joshua Pickard
- URL: https://gitlab.inria.fr/auctus/redundancy-tubes

6.5. WoobotSim

KEYWORDS: Robotics - Dynamic Analysis

FUNCTIONAL DESCRIPTION: WoobotSim is a simulator that reports the dynamics of the parties involved in an industrial task implying a strong interaction between a machine tool, an operator and a handled object, it also offers the possibility to add a cobot as an actor. Developed on Matlab, this simulator allows to visualize the efforts exchanged by the participants during the task, as well as the dynamics of the object being manipulated. For the specific case of woodworking shaper. It includes a wood cutting model. A model of task control by the craftsman and a model of the robot.

- Contact: Nassim Benhabib

6.6. Arcol

The Arcol platform provides technical support for the short, medium and long term experimental developments carried out within the framework of Auctus' scientific and dissemination activities.

These technological developments are essentially software related in the context of human motion capture and real-time control of collaborative robots. Arcol aims at easing their implementation, deployment, documentation and support.

Implementations include:

- a software component for online estimation of the state of one or more human "subjects" of a collaborative robotics experiment; ǐsualization tool for replaying a number of simulated experiments;
- an integrating architecture allowing the simple addition of hardware components (sensors, robots,...) and the configuration of an experiment by describing the hardware components included, the nature of the treatments to be performed and the history files (logs) to be constituted.

To date the work done is:

- help and realization of an experimental setup for the study of the motor variability of a user ;
- assistance and realization of an experimental setup for the study of the interaction wrenches during a machining task of a piece of wood in an industrial context ;
- implementation and deployment of a method for using Inria integration tools for the team's code ;
- development of a solution allowing to simply interface the ROS framework with the Unity3D software, in a modular and easily deployable experimentation perspective.

7. New Results

7.1. Posture and motion capture by smart textile

The objective of Postex is to design an intelligent textile jacket, without the use of additional sensors, to determine an operator's posture.

Since 2017, we offer an innovative solution based on the electrical properties of a conductive stretch fabric that is used in the manufacture of an intelligent garment. We use Electrical Impedance Tomography (EIT) to identify fabric deformations. A neural network is used to correlate the different postures and movements measured using a reference device with the electric field measured in the intelligent textile.

By 2018, we had successfully identified the movements of an elbow and then filed a patent under the number FR1860192. In 2019, we identified the shoulder and worked on the design of the fabric parts. In order to valorize the technology, the Touch Sensity startup was created at the end of 2019.

7.2. Set-based evaluation of robot capabilities

Set-based approaches allow to model serial mechanisms with varying levels of geometric uncertainties. The Kinematic Chain Appropriate Design Library (KCADL) has been created for the purpose of modelling imprecise serial kinematic chains and provides numerous certified methods, implemented using the IBEX interval analysis library, for analyzing the capabilities of these modelled mechanisms. The KCADL software provides a set of public routines to build arbitrary serial mechanisms by incrementally adding rigid-body segments with associated parent-child uncertainties. Efficient Forward Kinematic (FK) and Inverse Kinematic (IK) solvers have been formulated and integrated into the software. These solvers are fully compatible with set-based inputs and are capable of handling sets of poses or sets of joint configurations. In addition to the FK and IK solvers, analysis routines which are applicable to imprecise kinematic chains with set-based inputs are also implemented in the software (e.g., evaluating the mechanism's: force/velocity/acceleration capabilities, precision). These routines provide offline analysis and design tools as well as online real-time capable tools for reliably evaluating current and future capabilities.

7.3. Redundancy tube

A set-based approach for modelling the human upper-limb and its complex articular constraints as a 7-degree-of-freedom (dof) constrained imprecise kinematic chain is formulated and implemented in the AUCTUS-RT software. This software allows to easily customize the geometric parameters and articular constraints. This permits to adapt the upper-limb model to each unique human subject and may also be used to model sets of human subjects. Various visualization tools are available for Python and Matlab to aid in the selection of appropriate articular constraints. When given a task with m redundant dofs and the desired workspace resolution, the software is capable of computing certified inside and outside regions of the (m+1)-dimensional redundant workspace associated with the task and upper-limb model. When a temporal dimension is added to the task description, the redundant workspace varies over time and produces a tube of redundant motions, which we refer to as the redundancy tube. The software accepts spatial-temporal task descriptions and allows to compute the full redundancy tube or slices of the tube. Furthermore, the software allows to model individual and/or sets of trajectories to describe tasks exactly or with varying level of uncertainties. Much effort has been put into improving the efficiency of the redundancy tube evaluations and parallel computing, both locally and non-locally via PlaFRIM, using OpenMP is supported. The AUCTUS-RT software is currently being used for the ongoing study of human motor-variabilities for the AUCTUS Mover project.

Related publications: [16]

7.4. Mover project

The Mover project is an experiment-based project to evaluate and study the links between human motor-variability, expertise, and fatigue associated with repetitive tasks. A wireloop game serves as the experimental task where a human subject is tasked with moving a metal ring along a fixed conductive wire while trying to maximize a score which is a function of the task time and the number of ring-wire contacts. To more easily study motor-variabilities, the wireloop ring is actively constrained by a collaborative robot (the Frank Emika Panda), allowing to isolate desired task variabilities and easily modify the task (e.g., through applied disturbances, changes in robot stiffness, task guidance). A preliminary version of the experiment is currently being developed to test all aspects of the project (i.e., experimental protocol, robot control, motion capture, human modelling, and redundancy tube evaluation). All experimental aspects of the project will be finalized before March 2020.

7.5. Interactions with a chatbot

In the context of the CIFRE Orange PhD work by Nicolas Simonazzi under the supervision of Jean-Marc Salotti and with the objective of analyzing and identifying emotions during interactions with a chatbot, a first experiment was conducted. It involved a user, the use of a smartphone, viewing videos and asking questions about the content of the video and the feeling of the user just after the answer. The collected data were numerous: the accuracy of the answers to the questions, the emotional feeling (choice of emoticons by the user) as well as the real-time measurements of the accelerometer of the smartphone. An analysis of the data was carried out with Russell's relatively simple emotional model as an explanatory framework based on two variables, the positive or negative valence of the emotion, and the degree of excitement. The experimental results showed that there was a slight correlation between the valence indicated by the user, the accuracy of the answers to the questions and the accelerations of the smartphone. However, it was hoped that the videos would have an impact on the valence, because their content had an intrinsic valence, but it proved impossible to find a correlation with the valence indicated by the user, probably due to a lack of the user engagement and also because of the focus on the questions that followed and the accuracy of the answers. A new experimental protocol is currently being studied with a priori more impactful videos (likely to produce an emotion with a greater degree of excitement).

Related publications:[10], [19]

7.6. Prediction of human error in robotics

The INRS provides a database of accidents at work, from which we can extract those concerning robotics. Many accidents are due to a deterioration of situational awareness. However, as there are many different causes and human factors are not well understood, it is very difficult for experts to provide probabilistic risk assessments. We proposed to simplify the problem by classifying the accidents according to the main demons that degrade the consciousness of the situation (Endsley model) and to use a Bayesian approach with the Noisy-Or nodes. We had already tried such an interpretation in the field of aeronautics. We propose to extend it to the field of robotics. Even if the approach remains empirical and approximate, it is possible to infer general probabilities of risk of human error leading to accidents and to deduce actions to reduce risks.

Related publications: [18]

7.7. Securing industrial operators with collaborative robots: simulation and experimental validation for a carpentry task

In this work, a robotic assistance strategy is developed to improve the safety in an artisanal task that involves a strong interaction between a machine-tool and an operator. Wood milling is chosen as a pilot task due to its importance in carpentry and its accidentogenic aspect.

In order to analyze the wood milling task, a wood shaping training was conducted in collaboration with a carpentry learning institute which allowed to collect information related to the task (perceived effort, position of the operator, accident circumstances).

To analyze the human-machine interaction, a formalization of the problem as a dynamic exchange of spatial forces inspired by the grasping theory has been performed. This theory presents structural similarities with the studied task. Based on this formalization, a behavior simulator of the system "wood + human + tool" has been developed.

To propose a credible and a realistic assistance solution, accidentogenic situations are simulated (see Woobot-sim). Based on the observation made with these simulations, the use of a collaborative robot to secure wood instability cases has been explored and validated by an experiment. An operational space damping behaviour appears to be the most appropriate solution to improve safety in the studied cases.

The experiment was designed to reproduce two cases of instability during a carpentry milling task based on the entry and exit of the tool into and out of a wood node. For safety reasons, the experiment is performed on a safe but tangible simulation of the task. We then show how a robot ((Franka Emika's Panda, 7-DOF)) controlled in torque can instantly stabilize the wood to avoid an accident without modifying the carpenter's sensations.

Related publications: [22]

7.8. A software architecture for the control of a 7 dof robot for the conduct of several experiment

The Franka Emika Panda robot is a 7 dof robot. Using the Robot Operating System (ROS), an experimental setup has been built to exploit this robot. The experimental setup consists in:

- the Panda robot;
- several RGBD sensors (Kinects);
- a safety laser scanner.

Dedicated algorithms have been developed to exploit the capacities of the Kinects to visualize the environment surrounding the robot and compute the distance to the closest obstacle. Several Kinects can be used simultaneously. Specific drivers have been developed to exploit the data given by the laser scanner to also determine the closest distance between a human and a robot.

Within the framework of Arcol (see 6.6) A software architecture has been developed to ease the development of different controllers. The robot can be controlled in joint position, velocity and torque using standard state-of-the-art control technique or constrained convex optimization methods. Trajectories can be easily defined, played, and modified at run time. The robot can be simulated using the GAZEBO dynamic simulator or run on the real robot with similar behaviours. All this software architecture works on a real-time patched computer.

7.9. Modulation of the robot velocity capabilities according to the distance to a human

Using the setup described in 7.8, a controller has been defined to constrain the robot maximum velocity according to the distance to a human. The aim of this work is to be able to use the robot optimally at all time. When a human comes near the robot workspace, the robot must stop to avoid any dangerous interaction. Several strategies exist to reduce the robot velocity as a function of the distance to the human. In this work, the goal is to determine the maximum deceleration capabilities of the robot in real time and determine if the robot has the capacity to stop before a contact. If not, the maximum allowable joint velocities of the robot are reduced. When the human reaches the robot workspace, these joint velocities must be null to ensure safety. Simply reducing the joint velocity of the robot without modulating the trajectory would induce a bad tracking of the robot task. Hence, the trajectory is updated in real time to take into account the capacities of the robot. This work has been submitted for publication at the ICRA 2020 conference.

Related publications: [23]

7.10. Human motion analysis in ecological environment

The estimation of human motion from sensors that can be used in an ecological environment is an important issue being it for home assistance for frail people or for human/robot interaction in industrial contexts. We are continuing our work on data fusion from RGB-D sensors using extended Kalman filters. The original approach uses a biomechanical model of the person to obtain anthropomorphically constrained joint angles to make their estimation physically coherent. In addition, we propose a method for the optimal adjustment of the covariance matrices of the extended Kalman filter. The proposed approach was tested with six healthy subjects performing 4 rehabilitation tasks. The accuracy of the joint estimates was evaluated with a reference stereophotogrammetric system. Our results show that an affordable RGB-D sensor can be used for simple home rehabilitation when using a constrained biomechanical model. This work has led to the writing of an article now in submission to the MBEC (Medical & Biological Engineering & Computing).

In a second step, we compared the joint centre estimates obtained with the new Kinect 3 (Azure Kinect) sensor, the Kinect 2 (Kinect for Windows) and a reference stereophotogrammetric system. Regardless of the system used, we have shown that our algorithm improves the body tracker data. This study also shows the importance of defining good heuristics to merge the data according to the body tracking operation. This study is submitted for publication at ICRA 2020.

7.11. Human motion decomposition

The aim of the work is to find ways of representing human movement in order to extract meaningful physical and cognitive information.

After the realization of a state of the art on human movement, several methods are compared: principal component analysis (PCA), Fourier series decomposition and inverse optimal control.

These methods are used on a signal comprising all the angles of a walking human being. PCA makes it possible to understand the correlations between the different angles during the trajectory. Fourier series decomposition methods are used for a harmonic analysis of the signal. Finally, inverse optimal control sets up a modeling of the engine control to highlight qualitative properties characteristic of the whole motion. These three methods are tested, combined and compared on data from the EWalk database (http://gamma.cs.unc.edu/GAIT/#EWalk) in order to test emotion recognition based on these decompositions and simple classifiers.

7.12. New method for cobotic task evaluation

Two industrial studies allowed us improving our methodology for cobotic task evaluation.

- Thanks to the partnership with Suez and the work of ENSC student Nina Docteur under Auctus supervision, there are several interesting results: first, the methodological approach has been reinforced. There was a detailed analysis of an accident-prone gesture (the pipe cover raising), meetings with field agents, supervisory teams, discussions with SUEZ ergonomic expert and field observations. Second, there was a theoretical framework - a model - for the general evaluation of a cobotic task, as well as the exploration of rules for evaluating the components of this model. Five main components have been proposed for the evaluation: bio-mechanics, cognitics, usability, hedonism and social impact. An important difficulty was to mix every component and to unify the evaluation. In order to mature the model, it has been decided to carry on the partnership with a PhD work.
- The PORTAGE project (Plateforme de RoboTisation et d'Automatisation GénériquE de bâtis industriels) involves AKKA Technologies, Ez-Wheel, IIDRE and IMS laboratory. It aims at developing semi-autonomous solutions for moving heavy structures within industrial environments (e.g. aircraft industry). Our contributions is concerned with human-robot interactions, and especially accounting for real-life constraints of operators' job within their industrial environment, and translate them into design choices and requirements for the to-be-developed robotic solution. In order to identify relevant elements from the work situation, three Human Factors models have been used: Reason's model [54], Situation Awareness model [27], and Skill Rule Knowledge (SRK) model [53]. The Reason's model details the different layers to explain accidents, notably in the aircraft industry. These layers gather equipment, procedure, training, management, policies and even psychological precursors of the operator. Therefore, this model allows investigations on potential latent causes of accident in complement with "obvious" patent causes usually more easily identified. The Situation Awareness model of Endsley describes cognitive mechanisms involved in a given situation for a person when performing actions, based on 1) the perception of elements of the current situation, 2) the understanding of the current situation, and 3) the projection of the future status of the situation. This model leads to identifying 8 daemons where situation awareness can be deteriorated, potentially resulting in accidents. The SRK model describes the decision process of an operator (or any person) performing a given task, based on his/her familiarity with this task. This model, coupled with the Situation Awareness model, can be leveraged to identify elements to be accounted when developing collaborative robots in industrial environments.

7.13. Situation awareness analysis

Baptiste Prébot, PhD student under the direction of Jean-Marc Salotti developed a methodology to analyze and assess representation sharing and situation awareness in groups of humans, possibly involving robots or artificial intelligence systems. An experiment has been carried out with two persons and a vehicle. The first person was assigned the role of mission control and the second person the role of an astronaut driving a vehicle using a real driving interface but in a simulated environment (surface of Mars in virtual reality). The two persons were located in different rooms and could communicate only by voice. Mission control had to guide the driver to a specific location. Every minute, the experiment was stopped and the two persons were asked to make a cross on a map corresponding to what they believe was the location of the vehicle. Comparisons of crosses on the maps, including ground truth locations, enabled us to determine the exactness of the localization and the degree of correct sharing of the situation. This experiment helped us better understanding communication and sharing issues, which are particularly relevant for the design of tasks and procedures for robotic operations.

Related publications:[12], [13], [9]

8. Bilateral Contracts and Grants with Industry

8.1. Bilateral collaboration with SAFRAN EP

An industrial collaboration has been initiated with SAFRAN EP (Villemur-sur-Tarn) on the analysis of manual industrial activities for the improvment of working conditions in highly demanding tasks. Vincent Padois and Jean-Marc Salotti have supervised the internship of Gaëlle Lannuzel who was focusing on knot tying activities for electrical cables. A CIFRE PhD thesis is being discussed to pursue this work.

8.2. Bilateral collaboration with SUEZ

A contract has been signed with Suez (see 7.12) for a 6-month internship under Auctus supervision (David Daney and jean-Marc Salotti). The objective was the development of a new method to improve strenuous manual activities and an implementation of the method for the specific activity of pipe cover raising. This study has been performed by Nina Doctor, ENSC student (recruitment February - September 2019).

8.3. Bilateral collaboration with PSA

An industrial collaboration has been initiated with PSA on the synthesis and dynamic analysis of shared workspaces for safety in collaborative robotics. A CIFRE PhD thesis has been approved by ANRT and will start in February 2020.

9. Partnerships and Cooperations

9.1. Regional Initiatives

9.1.1. Woobot

The main objective of Woobot is to propose a methodology for designing and controlling a collaborative robotic system to assist and secure an operator's actions. The system must preserve the health and sensory expertise of the operator while guaranteeing his or her mobility. Motivated by a pilot case from carpentry, the determination of the behavior of the collaborative robot will be based on a human-centered approach and based on a precise ergonomic analysis of the task and the biomechanical performances and needs of the operator. Two scientific issues are important: the choice of the system architecture (type of collaborative robot, number of degrees of freedom, level of redundancy with respect to the task, type of interaction of the collaborative robot with the task and/or the human...), and the behavior of the collaborative robot that must be implemented in the control. To answer these questions, it is then necessary to consider in the same formalism the human and task constraints from the point of view of:

- of the performance necessary for the task (cutting forces, trajectories);
- of the operator's biomechanical performance (kinematics -i.e. dexterity; static -i.e. manipulability and human dynamics).
- ergonomic (task, work environment, human posture).

Other partners: Région Nouvelle-Aquitaine, BTP CFA Blanquefort [3], Aerospline [4]

9.1.2. Portage

The global objective of this project is to develop a semi-autonomous carrier dedicated to the transport of heavy structures in industrial factories. The Auctus team has been assigned the role of task analysis and human systems interactions analysis in order to determine the best interface, to improve ergonomics, to reduce risks and to account for acceptability. A postdoctoral student, Charles Fage, has been recruited for the first year of the study.

A 2-years contract (2019-2021) has been signed with AKKA Technologies as part of a consortium, which included two other companies, IIDRE and Ez-Wheel, and another research team from IMS laboratory.

9.2. European Initiatives

Program: COVR (https://safearoundrobots.com/)

Project acronym: HARRY[2]

Project title: **H**ighly s**A**fe **R**obot integ**R**ation for the industr**Y** throug**H** an **A**dvanced cont**R**ol and monito**R**ing strateg**Y**

Duration: 2019/07 – 2020/03

Coordinator: Vincent Padois

Other partners: RoBioSS [5], PPRIME (Poitiers, France), Fuzzy Logic Robotics [6] (Paris France)

Abstract: he objective of the HARRY2 project is to attain more advanced workspace sharing capabilities through fully exploiting the collaborative possibilities defined by ISO TS 15066. We will achieve this by:

- Developing PLC software and motion controllers using robot-agnostic industrially-rated components to ease and standardize the development of safe robotic applications with workspace sharing.
- Integrating state-of-the-art energy-based control algorithms using these industrial hardware components, so that safety is no longer treated as an exception but considered as a constraint when computing the control solution in real-time.
- Enabling the use of high-level and intuitive teaching interfaces reducing robot programming time and difficulty.
- Developing a systematic and practical methodology for quantitative safety evaluation.

9.3. International Initiatives

9.3.1. Inria International Partners

- Vincent Padois is collaborating with Alessandro Saccon from TU Eindhoven regarding research activities on the modeling and control of robots physically interacting with their environments and more specifically on impact models for such interactions. A ICRA 2020 paper has been submitted based on this collaboration [21].

[3] http://www.btpcfa-aquitaine.fr
[4] https://www.aerospline.eu
[5] https://www.pprime.fr/?q=fr/robioss
[6] https://www.flr.io

- Jean-Marc Salotti worked with Ephraim Suhir, Departments of Mechanical and Materials Engineering and Electrical and Computer Engineering, Portland State University. Ephraim Suhir is a world expert in systems reliability. He and Jean-Marc Salotti worked on human-in-the-loop issues and published a paper in an IEEE conference [14].

10. Dissemination

10.1. Promoting Scientific Activities

10.1.1. Scientific Events: Organisation

Jessica was member of the organizing committee of the Young Researchers' Day in Robotics 2019 (Journée Jeunes Chercheurs en Robotique) in Vittel, France the 14th October.

10.1.2. Member of the Conference Program Committees

- Journées Nationales de la Recherche en Robotique (JNRR) 2019. [David Daney, scientific Program Committee member]
- 44ème Congrès de la Sociéte de Biomécanique [Vincent Padois, scientific committee member]
- IROS 2019 (IEEE/RSJ International Conference on Intelligent Robots and Systems) [Vincent Padois, associate editor]
- ICRA 2020 (IEEE/RAS International Conference on Robotics and Automation) [Vincent Padois, associate editor]

10.1.3. Reviewer Activities: conferences

- ICRA 2020 (IEEE International Conference on Robotics and Automation) [Vincent Padois, David Daney, Lucas Joseph]
- IROS 2019 (IEEE/RSJ International Conference on Intelligent Robots and Systems) [David Daney, Vincent Padois, Jessica Colombel]
- ECC 2019 (European Control Conference) [Vincent Padois]
- 44ème Congrès de la Sociéte de Biomécanique [Vincent Padois]
- IEEE International Workshop on Metrology for Aerospace, Torino, June 2019 [Jean-Marc Salotti]
- CableCon 2019 @ 15th IFToMM World Congress, June 30 – July 4, 2019, Krakow, Poland [David Daney]

10.1.4. Reviewing Activities: journal

- ASME Journal of Mechanisms and Robotics [David Daney, Joshua Pickard]
- Mechanism and Machine Theory [David Daney]
- IEEE Robotics and Automation Letters [Vincent Padois, Jessica Colombel]
- IEEE Transactions on Human-Machine Systems [Vincent Padois]
- IEEE Transactions on Robotics [Vincent Padois]
- Acta Astronautica [Jean-Marc Salotti]
- Foresight [Jean-Marc Salotti]
- Behavioural Brain Research [jean-Marc Salotti]
- Computer Aided Geometric Design [Joshua Pickard]

10.1.5. Talks / Invited Talks

- David Daney – "Designing the collaborative robotics cells", Eighth International Congress on Design and Modeling of Mechanical Systems (CMSM'19), March 18-20, 2019 Hammamet, Tunisia.

- David Daney – “Concevoir les cellules de robotique collaborative du futur”, Colloque Augmentation de l’Humain, Talence, 28-29 mars 2019
- Vincent Padois – “Sécurité et Robotique collaborative: n’oublions pas la commande!” – États Généraux de la Robotique – 2019/03/07
- Lucas Joseph – “HARRY2: développement d’un contrôleur de robot industriel répondant à des contraintes de sécurité basées sur un critère énergétique” – Journée GDR Robotique “GT3 - GT6”: “Conception et contrôle pour la manipulation sûre et flexible” – 2019/09/27– CEA LIST Centre Nano-Innov-Palaiseau
- Vincent Padois – “Quelques problématiques sous-jacentes en Robotique collaborative” – Journées Nationales de la Recherche en Robotique – 2019/10/15
- Nassim Benhabib – “Methodology for designing and controlling a collaborative robotic system to assist and secure an operator’s gestures” – Journées Nationnales de la robotique Humanoïde) – 2019/11/{25,26} – LAAS, Toulouse
- Lucas Joseph, Vincent Padois – “HARRY2: développement d’un contrôleur de robot industriel répondant à des contraintes de sécurité basées sur un critère énergétique” – Launch of the ANR LabCom MACH4 between Iteca and PPrime – 2019/11/7 – Poitiers, France
- Joshua Pickard – “Appropriate Synthesis of a Crank-Rocker Linkage” World Congress of the International Federation for the Promotion of Mechanism and Machine Science (IFToMM), June 30 - July 4, 2019, Krakow, Poland
- Joshua Pickard – “Redundancy Tubes: Modelling Individual and Group Range-of-Motions Along a Path” 44 ème congres societe de biomecanique 28-30 octobre 2019, Poitiers, France

10.1.6. Leadership within the Scientific Community

- Vincent Padois is, together with Olivier Stasse from LAAS, the co-animator of GT7 “Humanoid Robotics” of the CNRS “Groupement de Recherche en Robotique” (GDR). The role of animator consists in organizing regular workshops in humanoid robotics with the members of the French research community in this domain. It also consists in reporting strategic elements to the GDR in order to better organize the structure of research in Robotics in France.

10.1.7. Scientific Expertise

- Vincent Padois is a reviewer for the 2nd European COVR call.
- Vincent Padois and David Daney are reviewers for the best PhD thesis award of GDR Robotique.
- David Daney is an expert of “Robot Boost” Nouvelle-Aquitain’s progam.
- Jean-Marc Salotti and David Daney are official animators of the Humans Systems Interactions AESE DAS (Strategic Activities Domain of the Aerospace Valley Pole), which gathers all regional actors concerned with human factors, human systems interactions, and collaborative robotics mainly in the aerospace sector, but not limited to that domain. At least 2 daily workshops are organized each year for the members of the group in order to focus on a specific issue. Jean-Marc Salotti and David Daney are also solicited to examine regional projects linked to the DAS in order to provide advice and eventually to participate to the labelling process of the pole.
- The Auctus team is involved in the “Aquitaine robotics” cluster, which brings together robotics players in Nouvelle-Aquitaine. David Daney and Jean-Marc Salotti respectively represent Inria and Ensc on the board of directors. David Daney is a member of the executive board. David Daney and Jean-Marc Salotti are respectively president and vice-president of the labelling committee which promotes all robotics projects for the Nouvelle-Aquitaine region.

10.1.8. Research Administration

- Sylvain Pion represents the Auctus team in the CUMI-R (Comité des Utilisateurs des Moyens Informatiques) committee of Inria Bordeaux.

- Jean-Marc Salotti participated to the Inria Committee directed by Clair Poignard and dedicated to the selection of research candidates for delegations, PhD and Postdoctoral positions.

10.2. Teaching - Supervision - Juries

10.2.1. Teaching

Master: Jean-Marc Salotti, Intelligence Artificielle, 103,5h éqTD, M1, Ecole Nationale Supérieure de Cognitique / Bordeaux INP, France

Master: Jean-Marc Salotti, Facteurs Humains et Ingénierie Cognitique, 15h éqTD, M1, Ecole Nationale Supérieure de Cognitique / Bordeaux INP, France

Master: Jean-Marc Salotti, Interactions Hommes Robots, 15h éqTD, M2, Ecole Nationale Supérieure de Cognitique / Bordeaux INP, France. In this course, all students have practical works involving cobotic systems: programming NAOs and UR3 (Universal Robots) and testing an exoskeleton.

Master: David Daney, Interactions Hommes Robots, 2h éqTD, M2, Ecole Nationale Supérieure de Cognitique / Bordeaux INP, France.

Master: David Daney, Mathématiques pour la robotique, 30h éqTD, M2, Enseirb/Ensc, Bordeaux INP, France.

Master: David Daney, Décision, 7h éqTD, M2, Ecole Nationale Supérieure de Cognitique / Bordeaux INP, France.

Master: Vincent Padois, Literature review - What, Why and How?, 20h éqTD, M2, Enseirb/Ensc, Bordeaux INP, France.

Master: Vincent Padois, Enjeux technologiques de la maintenance aéronautique, 6h éqTD, M1, Enseirb-Matmeca, Bordeaux INP, France.

Master: Vincent Padois, Maintenance du futur - Cours introductif, 2h éqTD, M1, ENSPIMA, Bordeaux INP, France.

Master: Nassim Benhabib, Interactions Hommes Robots, 15h éqTD, M2, ENSC, Bordeaux INP, France.

Master: Jessica Colombel, Robot Operating System, 10h éqTD, M2, Enseirb/Ensc, Bordeaux INP, France.

Master: Charles Fage, Cognitive Disabilities and Assistive Technologies, , M2, Master de Sciences cognitives et Ergonomie, Université de Bordeaux, France.

Master: Charles Fage, Human-Computer Interactions, 15h éqTD, M1, Master de Sciences cognitives et Ergonomie, Université de Bordeaux, France.

Licence: Charles Fage, Disabilities Management and Ethics, 15h éqTD, L2, Licence de MIASHS, Université de Bordeaux, France.

Licence: Charles Fage, Alternative and Augmentative Communication, 15h éqTD, 2ème année, Institut de formation en ergothérapie de Bordeaux, France.

Licence: Charles Fage, Autism and Developmental Disorders, 15h éqTD, 2ème année, Institut de formation en ergothérapie de Bordeaux, France.

Licence: Charles Fage, Aging and Assistive Technologies, 15h éqTD, 2ème année, Institut de formation en ergothérapie de Bordeaux, France.

10.2.2. Supervision

PhD: Jonathan Savin, “Modeling motion variability using virtual humans for the ergonomic evaluation of work stations”, Sorbonne Université, 2019/11/22, Philippe Bidaud (Onera / Sorbonne Université) and Jacques Marsot (INRS) and Vincent Padois;

PhD: José Pedro Pontes, "Optimization and adaptation of robot locomotion in varying conditions: an evolutionnary approach", Sorbonne Université, 2019/3/12, Stéphane Doncieux (Sorbonne Université) and Vincent Padois and Cristina Santos (U. Minho, Portugal);

PhD in progress: Quoc Bach Hoa (Thèse ED SMAER, Paris), "Biomechanically plausible simulations of healthy and altered human locomotion", September 2017–, Vincent Padois and Faiz Ben Amar (Sorbonne Université)

PhD in progress: Nassim Benhabib (Inria / Région NA – Woobot project), "Méthodologie de conception et de commande d'un système robotique collaboratif pour assister et sécuriser les gestes d'un opérateur", November 2018 – , David Daney and Vincent Padois;

PhD in progress: Jessica Colombel (Inria), "Analyse du mouvement humain pour l'assistance à la personne", February 2019 – , François Charpillet and David Daney (Inria Nancy Grand-Est);

PhD in progress: Nicolas Simonazzi (CIFRE Orange), "Analyse comportementale et détection des émotions dans le cadre de l'utilisation de chat-bots en ligne", May 2018 –, Jean-Marc Salotti;

PhD in progress: Baptiste Prébot (DGA), "Partage des représentations et de la conscience de situation", January 2017 –, Jean-Marc Salotti and Bernard Claverie (ENSC, IMS laboratory;

PhD in progress: Olfa Jema (Cotutelle Université de Sousse, Tunisie), "Analyse du mouvement humain", December 2017 –, Lotfi Romdhane, Sami Bennour, David Daney;

PhD in progress: Pierre Laguillaumie (Thèse laboratoire PPRIME), "Méthodologie pour la mise en œuvre d'un robot collaboratif de nouvelle génération prenant en compte la sécurité et le confort biomécanique de l'opérateur en situation de travail", March 2018 – Jean-Pierre Gazeau and Vincent Padois.

10.2.3. Juries

Vincent Padois:

- HdR: Adrien Escande, "Numerical Optimization and Motion Generation in Robotics", Université de Montpellier, 2019/2/25;
- PhD: Nolwenn Briquet-Kerestedjian, Reviewer, "Impact detection and classification for safe physical Human-Robot Interaction under uncertainties", Université Paris-Saclay, 2019/7/10;
- PhD: Kai Pfeiffer, Examinor, "Efficient Kinematic and Algorithmic Singularity Resolution for Multi-Contact and Multi-Level Constrained Dynamic Robot Control", Université de Montpellier, 2019/12/4;
- PhD: Sonny Tarbouriech, Reviewer, "An energetic approach to safety in robotic manipulation", Sorbonne Université, 2019/12/5.

David Daney:

- PhD: Mathias Bordon, Examinor, "Modélisation et calibration pour une numérisation robotisée", 2019/06/06, École Normale Supérieure Paris-Saclay
- PhD: Thomas Le Mézo, Reviewer, "Bracketing largest invariant sets of dynamical systems; An application to drifting underwater robots in ocean currents", 2019/12/05, ENSTA Bretagne;
- PhD: Étienne Picard, Reviewer, "Modeling and robust control of cable-driven parallel robots for industrial applications", 2019/12/17, Université Bretagne Loire .

Jean-Marc Salotti:

- PhD: Damien L'Haridon, Reviewer,"Décision collective optimisée en milieu extrême: application aux situations inconnues en vol spatial habité", ISAE - Université de Toulouse, 2019/05/02
- PhD: Vanessa Haykal, Reviewer,"Modélisation des séries temporelles par apprentissage profond", Université de Tours, 2019/12/02;

10.3. Popularization

10.3.1. Interventions

- "Collaborative Robotics" – Demonstration at the 2019 Fête de la Sciences by Lucas Joseph – Cap Sciences, Bordeaux
- "Tame a robot" with Thymios II – Animation by Jessica Colombel at Fête de la Science, Université de Lorraine, Nancy, October 2019.
- Fage, C. "Communication Alternative et Améliorée – Aider les enfants et adultes avec difficultés de communication". Invited Oral Presentation at the Interphase Association (Autism care) by Charles Fage, Bordeaux, December 2019.

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