IN PARTNERSHIP WITH:
CNRS

Université de Lorraine

Activity Report 2019

Project-Team LARSEN

Lifelong Autonomy and interaction skills for Robots in a Sensing ENvironment

IN COLLABORATION WITH: Laboratoire lorrain de recherche en informatique et ses applications (LORIA)

RESEARCH CENTER
Nancy - Grand Est

THEME
Robotics and Smart environments

Table of contents

Project-Team LARSEN

Creation of the Team: 2015 January 01, updated into Project-Team: 2017 December 01

Keywords:

Computer Science and Digital Science:

A5.10. - Robotics
A5.10.1. - Design
A5.10.2. - Perception
A5.10.3. - Planning
A5.10.4. - Robot control
A5.10.5. - Robot interaction (with the environment, humans, other robots)
A5.10.6. - Swarm robotics
A5.10.7. - Learning
A5.10.8. - Cognitive robotics and systems
A5.11.1. - Human activity analysis and recognition
A8.2.2. - Evolutionary algorithms
A9.2. - Machine learning
A9.5. - Robotics
A9.7. - AI algorithmics
A9.9. - Distributed AI, Multi-agent

Other Research Topics and Application Domains:

B2.1. - Well being
B2.5.3. - Assistance for elderly
B5.1. - Factory of the future
B5.6. - Robotic systems
B7.2.1. - Smart vehicles
B9.6. - Humanities
B9.6.1. - Psychology

1. Team, Visitors, External Collaborators

Research Scientists

François Charpillet [Team leader, Inria, Senior Researcher, HDR]
Olivier Buffet [Inria, Researcher, from Jul 2019, HDR]
Francis Colas [Inria, Researcher, HDR]
Serena Ivaldi [Inria, Researcher]
Pauline Maurice [CNRS, Researcher, From Oct. 2019]
Jean-Baptiste Mouret [Inria, Senior Researcher, HDR]

Faculty Members

Amine Boumaza [Univ de Lorraine, Associate Professor]
Karim Bouyarmane [Univ de Lorraine, Associate Professor, on leave]
Alexis Scheuer [Univ de Lorraine, Associate Professor]
Vincent Thomas [Univ de Lorraine, Associate Professor]

Post-Doctoral Fellows

Mihai Andries [Inria, from May 2019]
Glenn Maguire [Inria]
Pauline Maurice [Inria, until Sep 2019]

PhD Students

Lina Achaji [Inria, from Oct 2019]
Waldez Azevedo Gomes Junior [Inria]
Jessica Colombel [Inria, from Feb 2019]
Yassine El Khadiri [Diatelic]
Yoann Fleytoux [Inria, from Apr 2019]
Adam Gaier [Hochschule Bonn-Rhein-Sieg]
Nicolas Gauville [Inria, until April 2019]
Nicolas Gauville [PSA, from May 2019]
Rituraj Kaushik [Inria]
Adrien Malaisé [Inria]
Luigi Penco [Inria, from Apr 2019]
Niyati Rawal [Inria, from Oct 2019]
Vladislav Tempez [Univ de Lorraine]
Lorenzo Vianello [Univ de Lorraine, from Dec. 2019]
Jerôme Truc [iFollow, until Jul 2019]
Julien Uzzan [PSA]
Yang You [Inria, from Oct 2019]
Eloise Zehnder [Univ de Lorraine]

Technical staff

Brice Clement [Inria, Engineer]
Eloise Dalin [Inria, Engineer]
Pierre Desreumaux [Inria, Engineer]
Pauline Houlgatte [INSERM, Engineer]
Debaleena Misra [Inria, Engineer, until Mar 2019]
Luigi Penco [Inria, Engineer, until Mar 2019]
Lucien Renaud [Inria, Engineer]

Interns and Apprentices

Lina Achaji [Inria, from May 2019 until Jul 2019]
Clelie Amiot [Inria, from Feb 2019 until Aug 2019]
Timothee Anne [Ecole normale supérieure de Rennes, from Sep 2019]
Gabriel Belouze [Ecole normale supérieure (Paris), from Jun 2019 to Jul 2019]
Alex Coudray [Ecole normale supérieure de Rennes, from Jun 2019 to Jul 2019]
Ivan Bergonzani [Inria, from Oct 2019]
Guillaume Courrier [Inria, from Jun 2019 until Sep 2019]
Amelie Delain [Univ de Lorraine, from May 2019 until Jul 2019]
Sylvain Geiser [Univ de Lorraine, from Sep 2019]
Pierre Laclau [Inria, from Aug 2019]
Andrea Macri [Inria, from Sep 2019]
Celian Muller Machi [Univ de Lorraine, from Sep 2019]
Vishnu Radhakrishnan [Inria, until Jan 2019]
Niyati Rawal [Inria, from May 2019 until Sep 2019]
Lucas Romary [Inria, from Jun 2019 until Aug 2019]
Louisa Takorabet [Inria, from May 2019 until Aug 2019]
Lorenzo Vianello [Inria, from Mar 2019 until Aug 2019]
Luan Wei [Inria, from Mar 2019 until Aug 2019]
Lingxiao Xun [Inria, from Mar 2019 until Sep 2019]

Yang You [Univ de Lorraine, from May 2019 until Aug 2019]

Visiting Scientist

Anji Ma [Beijing Institute of Technology, from Sep 2019]

2. Overall Objectives

2.1. Overall Objectives

The goal of the LARSEN team is to move robots beyond the research laboratories and manufacturing industries: current robots are far from being the fully autonomous, reliable, and interactive robots that could co-exist with us in our society and run for days, weeks, or months. While there is undoubtedly progress to be made on the hardware side, robotics platforms are quickly maturing and we believe the main challenges to achieve our goal are now on the software side. We want our software to be able to run on low-cost mobile robots that are therefore not equipped with high-performance sensors or actuators, so that our techniques can realistically be deployed and evaluated in real settings, such as in service and assistive robotic applications. We envision that these robots will be able to cooperate with each other but also with intelligent spaces or apartments which can also be seen as robots spread in the environments. Like robots, intelligent spaces are equipped with sensors that make them sensitive to human needs, habits, gestures, etc., and actuators to be adaptive and responsive to environment changes and human needs. These intelligent spaces can give robots improved skills, with less expensive sensors and actuators enlarging their field of view of human activities, making them able to behave more intelligently and with better awareness of people evolving in their environment. As robots and intelligent spaces share common characteristics, we will use, for the sake of simplicity, the term robot for both mobile robots and intelligent spaces.

Among the particular issues we want to address, we aim at designing robots having the ability to:

- handle dynamic environment and unforeseen situations;
- cope with physical damage;
- interact physically and socially with humans;
- collaborate with each other;
- exploit the multitude of sensors measurements from their surrounding;
- enhance their acceptability and usability by end-users without robotics background.

All these abilities can be summarized by the following two objectives:

- *life-long autonomy*: continuously perform tasks while adapting to sudden or gradual changes in both the environment and the morphology of the robot;
- *natural interaction with robotics systems*: interact with both other robots and humans for long periods of time, taking into account that people and robots learn from each other when they live together.

3. Research Program

3.1. Lifelong Autonomy

3.1.1. Scientific Context

So far, only a few autonomous robots have been deployed for a long time (weeks, months, or years) outside of factories and laboratories. They are mostly mobile robots that simply “move around” (e.g., vacuum cleaners or museum “guides”) and data collecting robots (e.g., boats or underwater “gliders” that collect data about the water of the ocean).

A large part of the long-term autonomy community is focused on simultaneous localization and mapping (SLAM), with a recent emphasis on changing and outdoor environments [25], [34]. A more recent theme is life-long learning: during long-term deployment, we cannot hope to equip robots with everything they need to know, therefore some things will have to be learned along the way. Most of the work on this topic leverages machine learning and/or evolutionary algorithms to improve the ability of robots to react to unforeseen changes [25], [32].

3.1.2. Main Challenges

The first major challenge is to endow robots with a stable situation awareness in open and dynamic environments. This covers both the state estimation of the robot itself as well as the perception/representation of the environment. Both problems have been claimed to be solved but it is only the case for static environments [30].

In the LARSEN team, we aim at deployment in environments shared with humans which imply dynamic objects that degrade both the mapping and localization of a robot, especially in cluttered spaces. Moreover, when robots stay longer in the environment than for the acquisition of a snapshot map, they have to face structural changes, such as the displacement of a piece of furniture or the opening or closing of a door. The current approach is to simply update an implicitly static map with all observations with no attempt at distinguishing the suitable changes. For localization in not-too-cluttered or not-too-empty environments, this is generally sufficient as a significant fraction of the environment should remain stable. But for life-long autonomy, and in particular navigation, the quality of the map, and especially the knowledge of the stable parts, is primordial.

A second major obstacle to move robots outside of labs and factories is their fragility: Current robots often break in a few hours, if not a few minutes. This fragility mainly stems from the overall complexity of robotic systems, which involve many actuators, many sensors, and complex decisions, and from the diversity of situations that robots can encounter. Low-cost robots exacerbate this issue because they can be broken in many ways (high-quality material is expensive), because they have low self-sensing abilities (sensors are expensive and increase the overall complexity), and because they are typically targeted towards non-controlled environments (e.g., houses rather than factories, in which robots are protected from most unexpected events). More generally, this fragility is a symptom of the lack of adaptive abilities in current robots.

3.1.3. Angle of Attack

To solve the state estimation problem, our approach is to combine classical estimation filters (Extended Kalman Filters, Unscented Kalman Filters, or particle filters) with a Bayesian reasoning model in order to internally simulate various configurations of the robot in its environment. This should allow for adaptive estimation that can be used as one aspect of long-term adaptation. To handle dynamic and structural changes in an environment, we aim at assessing, for each piece of observation, whether it is static or not.

We also plan to address active sensing to improve the situation awareness of robots. Literally, active sensing is the ability of an interacting agent to act so as to control what it senses from its environment with the typical objective of acquiring information about this environment. A formalism for representing and solving active sensing problems has already been proposed by members of the team [24] and we aim to use this to formalize decision making problems of improving situation awareness.

Situation awareness of robots can also be tackled by cooperation, whether it be between robots or between robots and sensors in the environment (led out intelligent spaces) or between robots and humans. This is in rupture with classical robotics, in which robots are conceived as self-contained. But, in order to cope with as diverse environments as possible, these classical robots use precise, expensive, and specialized sensors, whose cost prohibits their use in large-scale deployments for service or assistance applications. Furthermore, when all sensors are on the robot, they share the same point of view on the environment, which is a limit for perception. Therefore, we propose to complement a cheaper robot with sensors distributed in a target environment. This is an emerging research direction that shares some of the problematics of multi-robot operation and we are therefore collaborating with other teams at Inria that address the issue of communication and interoperability.

To address the fragility problem, the traditional approach is to first diagnose the situation, then use a planning algorithm to create/select a contingency plan. But, again, this calls for both expensive sensors on the robot for the diagnosis and extensive work to predict and plan for all the possible faults that, in an open and dynamic environment, are almost infinite. An alternative approach is then to skip the diagnosis and let the robot discover by trial and error a behavior that works in spite of the damage with a reinforcement learning algorithm [39], [32]. However, current reinforcement learning algorithms require hundreds of trials/episodes to learn a single, often simplified, task [32], which makes them impossible to use for real robots and more ambitious tasks. We therefore need to design new trial-and-error algorithms that will allow robots to learn with a much smaller number of trials (typically, a dozen). We think the key idea is to guide online learning on the physical robot with dynamic simulations. For instance, in our recent work, we successfully mixed evolutionary search in simulation, physical tests on the robot, and machine learning to allow a robot to recover from physical damage [33], [1].

A final approach to address fragility is to deploy several robots or a swarm of robots or to make robots evolve in an active environment. We will consider several paradigms such as (1) those inspired from collective natural phenomena in which the environment plays an active role for coordinating the activity of a huge number of biological entities such as ants and (2) those based on online learning [29]. We envision to transfer our knowledge of such phenomenon to engineer new artificial devices such as an intelligent floor (which is in fact a spatially distributed network in which each node can sense, compute and communicate with contiguous nodes and can interact with moving entities on top of it) in order to assist people and robots (see the principle in [37], [29], [23]).

3.2. Natural Interaction with Robotic Systems

3.2.1. Scientific Context

Interaction with the environment is a primordial requirement for an autonomous robot. When the environment is sensorized, the interaction can include localizing, tracking, and recognizing the behavior of robots and humans. One specific issue lies in the lack of predictive models for human behavior and a critical constraint arises from the incomplete knowledge of the environment and the other agents.

On the other hand, when working in the proximity of or directly with humans, robots must be capable of safely interacting with them, which calls upon a mixture of physical and social skills. Currently, robot operators are usually trained and specialized but potential end-users of robots for service or personal assistance are not skilled robotics experts, which means that the robot needs to be accepted as reliable, trustworthy and efficient [42]. Most Human-Robot Interaction (HRI) studies focus on verbal communication [38] but applications such as assistance robotics require a deeper knowledge of the intertwined exchange of social and physical signals to provide suitable robot controllers.

3.2.2. Main Challenges

We are here interested in building the bricks for a situated Human-Robot Interaction (HRI) addressing both the physical and social dimension of the close interaction, and the cognitive aspects related to the analysis and interpretation of human movement and activity.

The combination of physical and social signals into robot control is a crucial investigation for assistance robots [40] and robotic co-workers [36]. A major obstacle is the control of physical interaction (precisely, the control of contact forces) between the robot and the human while both partners are moving. In mobile robots, this problem is usually addressed by planning the robot movement taking into account the human as an obstacle or as a target, then delegating the execution of this “high-level” motion to whole-body controllers, where a mixture of weighted tasks is used to account for the robot balance, constraints, and desired end-effector trajectories [26].

The first challenge is to make these controllers easier to deploy in real robotics systems, as currently they require a lot of tuning and can become very complex to handle the interaction with unknown dynamical systems such as humans. Here, the key is to combine machine learning techniques with such controllers.

The second challenge is to make the robot react and adapt online to the human feedback, exploiting the whole set of measurable verbal and non-verbal signals that humans naturally produce during a physical or social interaction. Technically, this means finding the optimal policy that adapts the robot controllers online, taking into account feedback from the human. Here, we need to carefully identify the significant feedback signals or some metrics of human feedback. In real-world conditions (i.e., outside the research laboratory environment) the set of signals is technologically limited by the robot's and environmental sensors and the onboard processing capabilities.

The third challenge is for a robot to be able to identify and track people on board. The motivation is to be able to estimate online either the position, the posture, or even moods and intentions of persons surrounding the robot. The main challenge is to be able to do that online, in real-time and in cluttered environments.

3.2.3. Angle of Attack

Our key idea is to exploit the physical and social signals produced by the human during the interaction with the robot and the environment in controlled conditions, to learn simple models of human behavior and consequently to use these models to optimize the robot movements and actions. In a first phase, we will exploit human physical signals (e.g., posture and force measurements) to identify the elementary posture tasks during balance and physical interaction. The identified model will be used to optimize the robot whole-body control as prior knowledge to improve both the robot balance and the control of the interaction forces. Technically, we will combine weighted and prioritized controllers with stochastic optimization techniques. To adapt online the control of physical interaction and make it possible with human partners that are not robotics experts, we will exploit verbal and non-verbal signals (e.g., gaze, touch, prosody). The idea here is to estimate online from these signals the human intent along with some inter-individual factors that the robot can exploit to adapt its behavior, maximizing the engagement and acceptability during the interaction.

Another promising approach already investigated in the LARSEN team is the capability for a robot and/or an intelligent space to localize humans in its surrounding environment and to understand their activities. This is an important issue to handle both for safe and efficient human-robot interaction.

Simultaneous Tracking and Activity Recognition (STAR) [41] is an approach we want to develop. The activity of a person is highly correlated with his position, and this approach aims at combining tracking and activity recognition to benefit one from another. By tracking the individual, the system may help infer its possible activity, while by estimating the activity of the individual, the system may make a better prediction of his/her possible future positions (especially in the case of occlusions). This direction has been tested with simulator and particle filters [28], and one promising direction would be to couple STAR with decision making formalisms like partially observable Markov decision processes (POMDPs). This would allow us to formalize problems such as deciding which action to take given an estimate of the human location and activity. This could also formalize other problems linked to the active sensing direction of the team: how the robotic system should choose its actions in order to have a better estimate of the human location and activity (for instance by moving in the environment or by changing the orientation of its cameras)?

Another issue we want to address is robotic human body pose estimation. Human body pose estimation consists of tracking body parts by analyzing a sequence of input images from single or multiple cameras.

Human posture analysis is of high value for human robot interaction and activity recognition. However, even if the arrival of new sensors like RGB-D cameras has simplified the problem, it still poses a great challenge, especially if we want to do it online, on a robot and in realistic world conditions (cluttered environment). This is even more difficult for a robot to bring together different capabilities both at the perception and navigation level [27]. This will be tackled through different techniques, going from Bayesian state estimation (particle filtering), to learning, active and distributed sensing.

4. Application Domains

4.1. Personal Assistance

During the last fifty years, many medical advances as well as the improvement of the quality of life have resulted in a longer life expectancy in industrial societies. The increase in the number of elderly people is a matter of public health because although elderly people can age in good health, old age also causes embrittlement, in particular on the physical plan which can result in a loss of autonomy. That will force us to re-think the current model regarding the care of elderly people. [1] Capacity limits in specialized institutes, along with the preference of elderly people to stay at home as long as possible, explain a growing need for specific services at home.

Ambient intelligence technologies and robotics could contribute to this societal challenge. The spectrum of possible actions in the field of elderly assistance is very large. We will focus on activity monitoring services, mobility or daily activity aids, medical rehabilitation, and social interactions. This will be based on the experimental infrastructure we have built in Nancy (Smart apartment platform) as well as the deep collaboration we have with OHS. [2]

4.2. Civil Robotics

Many applications for robotics technology exist within the services provided by national and local government. Typical applications include civil infrastructure services [3] such as: urban maintenance and cleaning; civil security services; emergency services involved in disaster management including search and rescue; environmental services such as surveillance of rivers, air quality, and pollution. These applications may be carried out by a wide variety of robot and operating modality, ranging from single robots or small fleets of homogeneous or heterogeneous robots. Often robot teams will need to cooperate to span a large workspace, for example in urban rubbish collection, and operate in potentially hostile environments, for example in disaster management. These systems are also likely to have extensive interaction with people and their environments.

The skills required for civil robots match those developed in the LARSEN project: operating for a long time in potentially hostile environment, potentially with small fleets of robots, and potentially in interaction with people.

5. Highlights of the Year

5.1. Highlights of the Year

- Arrival of a Talos robot in our team (Fig. 1). This is a full-scale humanoid (1.7 m / 100kg / 32 degrees of freedom) that can be fully torque-controlled. The robot is made by PAL Robotics, a Spanish company and is funded by the CPER “Cyber-Entreprise”.
- Arrival of Pauline Maurice as a CRCN (CNRS).

5.1.1. Awards

- International Society for Artificial Life (ISAL) award for the Outstanding Publication of the Decade 2004-2014: Clune J, Mouret JB, Lipson H. The evolutionary origins of modularity. Proceedings of the Royal Society b: Biological sciences. 2013 Mar 22;280(1755):20122863.

BEST PAPER AWARD:

[16]
N. GAUVILLE, F. CHARPILLET. *Exploration et couverture par stigmergie d’un environnement inconnu avec une flotte de robots autonomes réactifs*, in "JFSMA 2019 - 27emes Journées Francophones sur les Systèmes Multi-Agents", Toulouse, France, Cépaduès 2019, ISBN 9782364937192, July 2019, https://hal.inria.fr/hal-02195812

[1] See the Robotics 2020 Multi-Annual Roadmap [35].
[2] OHS (*Office d’Hygiène Sociale*) is an association managing several rehabilitation or retirement home structures.
[3] See the Robotics 2020 Multi-Annual Roadmap [35], section 2.5.

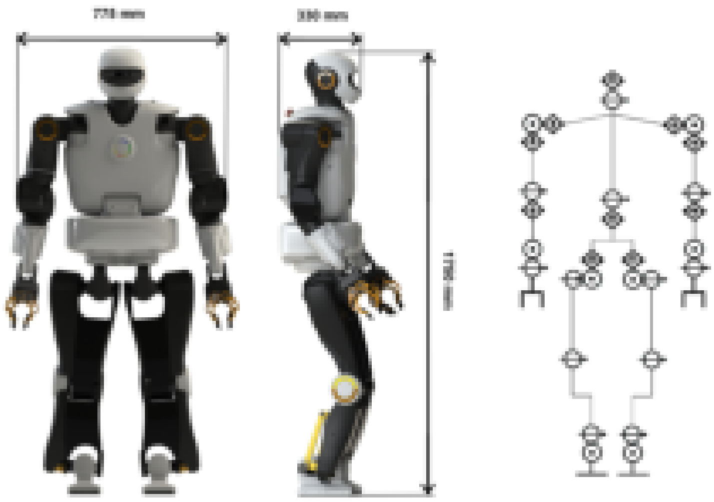

Figure 1. The Talos robot.

6. New Software and Platforms

6.1. ROS Qt Control

KEYWORDS: Control - Robot Operating System (ROS) - 2D

SCIENTIFIC DESCRIPTION: This ROS module allows to easily develop different controllers for wheeled mobile robots: Controller class just has to be inherited, the new class only needing a constructor and a chooseVelocities method. A graphical user interface using Qt makes it easy to choose a controller and to set its parameters, and it displays odometric data sent by ROS and the velocities sent to ROS by the controller.

NEWS OF THE YEAR: The code structure has been modified in order to propose a class hierarchy, with controllers aiming to reach a given state and others built to follow a selected trajectory.

- Participant: Alexis Scheuer
- Contact: Alexis Scheuer

6.2. ISeeML

Introducing a Smooth, Efficient and Easy-to-use Motion Library

KEYWORDS: Mobile Computing, Transportation - Optimal control - Planning

SCIENTIFIC DESCRIPTION: The main interest of this library is to offer smooth (continuous-curvature) efficient (close to the optimal) motions for mobile robots. Obtained paths correspond to locally optimal motions with constant velocity for wheeled mobile robots, either car-like or with differential-wheels (e.g. Thymio or Turtlebot). Classical paths (with a discontinuous curvature profile) are also provided. Both paths can also be used for aerial robots, as the motion constraints of those are similar to those of wheeled mobile robots.

RELEASE FUNCTIONAL DESCRIPTION: Additionnal functionnalities for optimal control using ROS.

NEWS OF THE YEAR: Additionnal functionnalities for optimal control using ROS.

- Participant: Alexis Scheuer
- Contact: Alexis Scheuer
- Publication: inria-00527913v1
- URL: http://iseeml.loria.fr

7. New Results

7.1. Lifelong autonomy

7.1.1. Motion planning for robot audition

Participants: François Charpillet, Francis Colas, Van Quan Nguyen.

We collaborated on this subject with Emmanuel Vincent from the Multispeech team (Inria Nancy – Grand Est).

Robot audition refers to a range of hearing capabilities which help robots explore and understand their environment. Among them, sound source localization is the problem of estimating the location of a sound source given measurements of its angle of arrival with respect to a microphone array mounted on the robot. In addition, robot motion can help quickly solve the front-back ambiguity existing in a linear microphone array. In this work, we focus on the problem of exploiting robot motion to improve the estimation of the location of an intermittent and possibly moving source in a noisy and reverberant environment. We first propose a robust extended mixture Kalman filtering framework for jointly estimating the source location and its activity over time. Building on this framework, we then propose a long-term robot motion planning algorithm based on Monte Carlo tree search to find an optimal robot trajectory according to two alternative criteria: the Shannon entropy or the standard deviation of the estimated belief on the source location. Experimental results show the robustness of the proposed estimation framework to false angle of arrival measurements within $\pm 20°$ and 10% false source activity detection rate. The proposed robot motion planning technique achieves an average localization error 48.7% smaller than a one-step-ahead method.

Publication: [10]

7.1.2. Addressing Active Sensing Problems through Monte-Carlo Tree Search (MCTS)

Participants: Vincent Thomas, Gabriel Belouze, Sylvain Geiser, Olivier Buffet.

The problem of active sensing is of paramount interest for building self awareness in robotic systems. It consists in planning actions in a view to gather information (*e.g.*, measured through the entropy over certain state variables) in an optimal way. In the past, we have proposed an original formalism, ρ-POMDPs, and new algorithms for representing and solving such active sensing problems [24] by using point-based algorithms, assuming either convex or Lipschitz-continuous criteria. More recently, we have developed new approaches based on Monte-Carlo Tree Search (MCTS), and in particular Partially Observable Monte-Carlo Planning (POMCP), which provably converge only assuming the continuity of the criterion. We are now going towards algorithms more suitable to certain robotic tasks by allowing for continuous state and observation spaces.

Publication: [20]

7.1.3. Heuristic Search for (Partially Observable) Stochastic Games

Participants: Olivier Buffet, Vincent Thomas.

Collaboration with Jilles Dibangoye (INSA-Lyon, Inria team CHROMA) and Abdallah Saffidine (University of New South Wales (UNSW), Sydney, Australia).

Many robotic scenarios involve multiple interacting agents, robots or humans, *e.g.*, security robots in public areas. We have mainly worked in the past on the collaborative setting, all agents sharing one objective, in particular through solving Dec-POMDPs by (i) turning them into occupancy MDPs and (ii) using heuristic search techniques and value function approximation [2]. A key idea is to take the point of view of a central planner and reason on a sufficient statistic called *occupancy state*. We are now working on applying similar approaches in the important 2-player zero-sum setting, *i.e.*, with two competing agents. As a preliminary step, we have proposed and evaluated an algorithm for (fully observable) stochastic games, which does not require any problem transformation. Then we have proposed an algorithm for partially observable stochastic games, here turning the problem into an occupancy Markov game.

[This line of research will be pursued through Jilles Dibangoye's ANR JCJC PLASMA.]

7.1.4. Interpretable Action Policies

Participant: Olivier Buffet.

Collaboration with Iadine Chadès and Jonathan Ferrer Mestres (CSIRO, Brisbane, Australia), and Thomas G. Dietterich (Oregon State University, USA).

Computer-aided task planning requires providing user-friendly plans, in particular, plans that make sense to the user. In probabilistic planning (in the MDP formalism), such interpretable plans can be derived by constraining action policies (if X happens, do Y) to depend on a reduced subset of (abstract) states or state variables. We have (i) formalized the problem of finding a set of at most K abstract states (forming a partition of the original state space) such that any optimal policy of the induced abstract MDP is as close as possible to optimal policies of the original MDP, and (ii) proposed 3 solution algorithms with theoretical and empirical evaluations.

7.1.5. Perspective: hierarchical quality diversity, from materials to machines

Participant: Jean-Baptiste Mouret.

Collaboration with CSIRO (Australia) and Vrije Universiteit Amsterdam (Netherlands).

Natural lifeforms specialize to their environmental niches across many levels, from low-level features such as DNA and proteins, through to higher-level artefacts including eyes, limbs and overarching body plans. We propose 'multi-level evolution', a bottom-up automatic process that designs robots across multiple levels and niches them to tasks and environmental conditions. Multi-level evolution concurrently explores constituent molecular and material building blocks, as well as their possible assemblies into specialized morphological and sensorimotor configurations. Multi-level evolution provides a route to fully harness a recent explosion in available candidate materials and ongoing advances in rapid manufacturing processes. We outline a feasible architecture that realizes this vision, highlight the main roadblocks and how they may be overcome, and show robotic applications to which multi-level evolution is particularly suited. By forming a research agenda to stimulate discussion between researchers in related fields, we hope to inspire the pursuit of multi-level robotic design all the way from material to machine.

Publication: [5]

7.1.6. Improving Embodied Evolutionary Robotics

Participant: Amine Boumaza.

Multi-robots learning is a hard still unsolved problem. When framed into the machine learning theoretical setting, it suffers from a high complexity when seeking optimal solutions. On the other hand, when sub-optimal solutions are acceptable Embodied Evolutionary Robotics, can provide solutions that perform well in practice. Improving these algorithms in terms of run-time or solution quality is an important research question.

It has been long known from the theoretical work on evolution strategies, that recombination improves convergence towards better solution and improves robustness against selection error in noisy environment. We propose to investigate the effect of recombination in online embodied evolutionary robotics, where evolution is decentralized on a swarm of agents. We hypothesize that these properties can also be observed in these algorithms and thus could improve their performance. We introduce the $(\mu/\mu, 1)$-On-line Embedded Evolutionary Algorithm (EEA) which uses a recombination operator inspired from evolution strategies and apply it to learn three different collective robotics tasks, locomotion, item collection and item foraging. Different recombination operators are investigated and compared against a purely mutative version of the algorithm. The experiments show that, when correctly designed, recombination improves significantly the adaptation of the swarm in all scenarios.

Publication: [13] [12]

7.1.7. Multi-robot exploration of an unknown environment

Participants: Nicolas Gauville, François Charpillet.

Different approaches exist for multi-robot autonomous exploration. These include frontier approaches, where robots are assigned to unexplored areas of the map, which provide good performance but require sharing the map and centralizing decision-making. The Brick and Mortar approaches, on the other hand, use a ground marking with local decision-making, but give much lower performance. The algorithm developped by Nicolas Gauville during his pre-thesis period is a trade-off between these two approaches, allowing local decision-making and, surprisingly, performances are closed to centralized frontier approaches. We also propose a comparative study of the performance of the three different approaches : *Brick & Mortar*, *Global Frontiers* and *Local Frontiers*. Our local algorithm is also complete for the exploration problem and can be easily distributed on robots with a minor loss of performance. This work follows the *Cart-O-Matic* project in which our team participated, which aimed to explore and map a building while recognizing specific objects inside with a team of 5 mobile robots.

Publication: [16]

7.2. Natural Interaction with Robotics Systems

Thanks to the arrival of Pauline Maurice and the AnDy H2020 project, our activities about interaction are currently focused on ergnonomic interaction, which requires good foundations in motion analysis.

7.2.1. Digital human modeling for collaborative robotics

Participant: Pauline Maurice.

Collaboration with Vincent Padois (Inria Bordeaux and Sorbonne Université), Yvan Measson (CEA-LIST) and Philippe Bidaud (ONERA and Sorbonne Université).

Work-related musculoskeletal disorders in industry represent a major and growing health problem in many developed countries. Collaborative robotics, which allows the joint manipulation of objects by both a robot and a person, is a possible solution provided that it is possible to assess the ergonomic benefit they offer. Using a digital human model (DHM) can cut down the development cost and time by replacing the physical mock-up by a virtual one easier to modify. The first part of this work details the challenges of digital ergonomic assessment for collaborative robotics. State-of-the-art work on DHM simulations with collaborative robots is reviewed to identify which questions currently remain open. The second part of this work focuses on a specific use case and presents a DHM-based method to optimize design parameters of a collaborative robot for an industrial task.

Publication: [21]

7.2.2. Probabilistic decision making for collaborative robotics

Participants: Yang You, Vincent Thomas, Olivier Buffet, François Charpillet, Francis Colas.

Collaboration with Rachid Alami (LAAS, France).

This work is part of the ANR Flying Co-Worker project and focuses on high-level decision making for collaborative robotics. When a robot has to assist a human worker, it does not have direct access to his current intention or his preferences but has to adapt its behaviour to help the human completing his task. To achieve this, we followed what has been proposed by [31] to model a situation of interaction as a Partially Observable Markov Decision Process (POMDP) by assuming that (i) the robot and the human act sequentially, one after another, and that (ii) the human is rational and makes his decision without considering the future robot's action.

7.2.3. Ativity recognition and prediction

Participants: François Charpillet, Francis Colas, Serena Ivaldi, Niyati Rawal, Vincent Thomas.

This work is part of the ANR Flying Co-Worker project and focuses on activity recognition and long-term prediction for collaborative robotics. Recognizing and predicting human activities is fundamental for a robot to help a human. Previous work in the team on activity recognition [6] rely on Hidden Markov Models (HMM) with, in particular, the Markov assumption stating that the distribution on the next state is independent from former states given the current state. This assumption, at the heart of the recurrent expression of the inference in HMM, has the unfortunate consequence to constrain the a priori distribution on the duration in each state to exponential distributions. However, it can be observed in datasets that this is not the case for many activities, which have a typical duration. This discrepancy is negligeable for recognition where HMM models achieve good performance thanks to the observations, but prevents longer-term activity prediction.

In the master project of Niyati Rawal, we investigated a slightly different model, Explicit Duration Hidden Markov Model (EDHMM), in which the duration of the activity can be modeled more finely. Preliminary results show that the recognition performance was similar to HMM but with a better prediction performance.

7.2.4. Humanoid Whole-Body Movement Optimization from Retargeted Human Motions

Participants: Waldez Azevedo Gomes Junior, Vishnu Radhakrishnan, Luigi Penco, Valerio Modugno, Jean-Baptiste Mouret, Serena Ivaldi.

Motion retargeting and teleoperation are powerful tools to demonstrate complex whole-body movements to humanoid robots: in a sense, they are the equivalent of kinesthetic teaching for manipulators. However, retargeted motions may not be optimal for the robot: because of different kinematics and dynamics, there could be other robot trajectories that perform the same task more efficiently, for example with less power consumption. We propose to use the retargeted trajectories to bootstrap a learning process aimed at optimizing the whole-body trajectories w.r.t. a specified cost function. To ensure that the optimized motions are safe, i.e., they do not violate system constraints, we used constrained optimization algorithms. We compared both global and local optimization approaches, since the optimized robot solution may not be close to the demonstrated one. We evaluated our framework with the humanoid robot iCub on an object lifting scenario, initially demonstrated by a human operator wearing a motion-tracking suit. By optimizing the initial retargeted movements, we can improve robot performance by over 40%.

Publication: [14]

7.2.5. Tele-operation of Humanoids

Participants: Luigi Penco, Waldez Gomes, Valerio Modugno, Serena Ivaldi.

We envision a world where robots can act as physical avatars and effectively replace humans in hazardous scenarios by means of teleoperation, which we see as a particular way of interacting with a robot. However, teleoperating humanoids is a challenging task because of differences in kinematics (e.g., structure and joint limits) and dynamics (e.g., mass distribution, inertia) are still significant. Another crucial issue is ensuring the dynamic balance of the robot while trying to imitate the human motion. We propose a multi-mode teleoperation framework for controlling humanoid robots for loco-manipulation tasks that address the aforementioned challenges by using two levels of teleoperation: a low-level for manipulation, realized via whole-body teleoperation, and a high-level for locomotion, based on the generation of reference velocities that are then tracked by the humanoid. We believe that this combination of different modes of teleoperation will considerably ease the burden of controlling humanoids, ultimately increasing their adaptability to complex situations which cannot be handled satisfactorily by fully autonomous systems.

Publication: [11]

7.2.6. Activity Recognition for Ergonomics Assessment of Industrial Tasks with Automatic Feature Selection

Participants: Adrien Malaisé, Pauline Maurice, Francis Colas, Serena Ivaldi.

In industry, ergonomic assessment is currently performed manually based on the identification of postures and actions by experts. We aim at proposing a system for automatic ergonomic assessment based on activity recognition. In this work, we define a taxonomy of activities, composed of four levels, compatible with items evaluated in standard ergonomic worksheets. The proposed taxonomy is applied to learn activity recognition models based on Hidden Markov Models. We also identify dedicated sets of features to be used as input of the recognition models so as to maximize the recognition performance for each level of our taxonomy. We compare three feature selection methods to obtain these subsets. Data from 13 participants performing a series of tasks mimicking industrial tasks are collected to train and test the recognition module. Results show that the selected subsets allow us to successfully infer ergonomically relevant postures and actions.

Publication: [6]

7.2.7. Human movement and ergonomics: An industry-oriented dataset for collaborative robotics

Participants: Pauline Maurice, Adrien Malaisé, Serena Ivaldi.

With the participation of Clélie Amiot, Nicolas Paris and Guy-Junior Richard, interns from Université de Lorraine during the summer 2018.

Improving work conditions in industry is a major challenge that can be addressed with new emerging technologies such as collaborative robots. Machine learning techniques can improve the performance of those robots, by endowing them with a degree of awareness of the human state and ergonomics condition. The availability of appropriate datasets to learn models and test prediction and control algorithms, however, remains an issue. This work presents a dataset of human motions in industry-like activities, fully labeled according to the ergonomics assessment worksheet EAWS, widely used in industries such as car manufacturing. Thirteen participants performed several series of activities, such as screwing and manipulating loads under different conditions, resulting in more than 5 hours of data. The dataset contains the participants' whole-body kinematics recorded both with wearable inertial sensors and marker-based optical motion capture, finger pressure force, video recordings, and annotations by three independent annotators of the performed action and the adopted posture following the EAWS postural grid. Sensor data are available in different formats to facilitate their reuse. The dataset is intended for use by researchers developing algorithms for classifying, predicting, or evaluating human motion in industrial settings, as well as researchers developing collaborative robotics solutions that aim at improving the workers' ergonomics. The annotation of the whole dataset following an ergonomics standard makes it valuable for ergonomics-related applications, but we expect its use to be broader in the robotics, machine learning, and human movement communities.

Publication: [8]

7.2.8. Objective and Subjective Effects of a Passive Exoskeleton on Overhead Work

Participants: Pauline Maurice, Serena Ivaldi.

Collaboration with Jernej Čamernik, Daša Gorjan and Jan Babič (Jozef Stefan Institute, Ljubljana, Slovenia), with Benjamin Schirrmeister and Jonas Bornmann (Otto Bock SE & Co. KGaA, Duderstadt, Germany), with Luca Tagliapietra, Claudia Latella and Daniele Pucci (Istituto Italiano di Tecnologia, Genova, Italy), and with Lars Fritzsche (IMK Automotive, Chemitz, Germany).

Overhead work is a frequent cause of shoulder work-related musculoskeletal disorders. Exoskeletons offering arm support have the potential to reduce shoulder strain, without requiring large scale reorganization of the workspace. Assessment of such systems however requires to take multiple factors into consideration. This work presents a thorough in-lab assessment of PAEXO, a novel passive exoskeleton for arm support during overhead work. A list of evaluation criteria and associated performance metrics is proposed to cover both objective and subjective effects of the exoskeleton, on the user and on the task being performed. These metrics are measured during a lab study, where 12 participants perform an overhead pointing task with and without the exoskeleton, while their physical, physiological and psychological states are monitored. Results show that using PAEXO reduces shoulder physical strain as well as global physiological strain, without increasing low back strain nor degrading balance. These positive effects are achieved without degrading task performance. Importantly, participant' opinions of PAEXO are positive, in agreement with the objective measures. Thus, PAEXO seems a promising solution to help prevent shoulder injuries and diseases among overhead workers, without negatively impacting productivity.

Publication: [7], [19]

7.2.9. Assessing and improving human movements using sensitivity analysis and digital human simulation

Participant: Pauline Maurice.

Collaboration with Vincent Padois (Inria Bordeaux and Sorbonne Université), Yvan Measson (CEA-LIST) and Philippe Bidaud (ONERA and Sorbonne Université).

Enhancing the performance of technical movements aims both at improving operational results and at reducing biomechanical demands. Advances in human biomechanics and modeling tools allow to evaluate human performance with more and more details. Finding the right modifications to improve the performance is, however, still addressed with extensive time consuming trial-and-error processes. This work presents a framework for easily assessing human movements and automatically providing recommendations to improve their performances. An optimization-based whole-body controller is used to dynamically replay human movements from motion capture data, to evaluate existing movements. Automatic digital human simulations are then run to estimate performance indicators when the movement is performed in many different ways. Sensitivity indices are thereby computed to quantify the influence of postural parameters on the performance. Based on the results of the sensitivity analysis, recommendations for posture improvement are provided. The method is successfully validated on a drilling activity.

Publication: [9]

7.2.10. Human Motion analysis for assistance

Participants: François Charpillet, Jessica Colombel.

Collaboration with David Daney (Inria Bordeaux, Auctus Team)

Different sort of sensors can be used for rehabilitation at home. This year we have evaluated the usabily of a Kinect 2. The proposed approach is to improve joint angle estimates. It is based on a constrained extended Kalman Filter that tracks inputted measured joint centers. Since the proposed approach uses a biomechanical model, it allows to obtain physically consistent constrained joint angles and constant segment lengths. A practical method, that is not sensor specific, for the optimal tuning of the extended Kalman filter covariance matrices is provided. It uses reference data obtained from a stereophotogrammetric system but it has to be tuned only once since it is task specific only. The improvement of optimal tuning over classical methods for setting the covariance matrices is shown with a statistical parametric mapping analysis. The proposed approach was tested with six healthy subjects performing 4 rehabilitation tasks. Joint estimates accuracy was assessed with a reference stereophotogrammetric system. Even if some joints such as the internal/external rotations were not well estimated, the proposed optimized algorithm reached a satisfactory average root mean square difference of 9.7deg and a correlation coefficient 0.86 of for all joints. Our results show that affordable RGB-D sensor can be used for simple in-home rehabilitation when using a constrained biomechanical model.

A work carried out this year, takes the search for a sensor for personal assistance a step further with the study of the new Kinect Azure. Human-robot interaction requires a robust estimate of human motion in real-time. This work presents a fusion algorithm for joint center positions tracking from multiple depth cameras to improve human motion analysis accuracy. The proposed algorithm is based on body tracking measurements fusion with an extended Kalman filter and anthropomorphic constraints. However, the effectiveness and robustness of such algorithm depends on the A direct comparison of joint center positions estimated with a reference stereophotogrammetric system and the ones estimated with the new Kinect 3 (Azure Kinect) sensor and its older version the Kinect 2 (Kinect for Windows) has been made. The proposed approach improves body tracker data even for Kinect 3 which has not the same characteristics than Kinect 2. This study shows also the importance of defining good heuristics to merge data depending on how the body tracking works. Thus, with proper heuristics, the joint center position estimates are improved by at least 14.6 %. Finally, we propose an additional comparison between Kinect 2 and Kinect 3 exhibiting the pros and cons of the two sensors. This study is now in submission for an international conference.

Finally, a state of the art on biological motion was realized. The purpose of this study is to understand and develop methods for decomposing motion. The EWalk dataset (http://gamma.cs.unc.edu/GAIT/#EWalk) will allow us to test emotion recognition from simple decompositions and classifiers. Then, we will extend the methods to other cognitive parameters.

7.2.11. Reliable localization of pedestrians in a smart home using multi-sensor data fusion

Participants: François Charpillet, Lina Achaji.

Collaboration with Maan Badaoui EL Najjar(Cristal Laboratory Lille, DiCOT Team), Mohamad Daher (the Lebanese University Faculty of technology, Tripoli)

One objective of the Larsen team is to develop technologies allowing older people to live independently as long as possible in their own homes instead of in specialized institutions. However, elderly people face physical problems that reduce their autonomy, and consequently their capacity to achieve daily activities. The integration of environmental or body sensors in what is called nowadays smart habitats is a solution that is appealing to provide a better quality of life with safer conditions. Localization and tracking of people in indoor environments are one of the primary services to be developed to follow them up at home, permitting to evaluate their physical states through the observation of their Activities of Daily Living (ADL). We proposed during the internship of Lina Achaji to localize and track the center of pressure (CoP) of people (one or two) in a smart home using a load sensing floor equipped with around 400 load sensors as well as wearable sensors. The data fusion is made using an informational filter where an inverted pendulum bio-mechanical model is introduced. The obtained results are very promising and were validated using a motion tracking system and force plates.

Publication: [4]

7.2.12. Ambient assisting living

Participants: François Charpillet, Yassine El Khadiri.

Collaboration with Cedric Rose from Diatelic compagny.

The ageing of the population confronts modern societies with an unprecedented demographic transformation. These include the imbalance in our pension systems and the cost of caring for the elderly. On this last point, apart from the economic aspects, the placement of elderly people is often only a choice of reason and can be quite badly experienced by people. One response to this societal problem is the development of technologies that make it easier to keep elderly people at home. The state of the art in this field abounds with upstream projects that are moving in this direction. Many of them are seeking to develop home monitoring systems. Their objectives are to detect and even prevent the occurrence of worrying or critical situations and to assess the physical condition or even fragility of the people being monitored. It is within this framework that this contribution is made. In this work, we have focused on the particular problem of monitoring the quality of sleep as well as the detection of nocturnal waking of a person living alone at home. The home is equipped with simple ambient sensors such as binary motion detectors. We have developed a Bayesian inference method that allows our solution to be flexible and robust enough for different types of installations and apartment configurations while maintaining a prediction accuracy of 0.94. This solution is currently being deployed on several dozen apartments in Lorraine by Diatelic and Pharmagest compagnies.

Publication: [15]

8. Bilateral Contracts and Grants with Industry

8.1. Bilateral Grants with Industry

8.1.1. Cifre with Diatelic Pharmagest

Participants: François Charpillet, Yassine El Khadiri.

We have a long term collaboration with Diatelic compagny which is a start-up created among other by François Charpillet in 2002. Currently we have a collaboration through a Cifre PhD whose the objective is to work on daily activity recognition for monitoring elderly people at home. The work will be included in a product that will be launched next year (carelib solution).

8.1.2. Cifre with PSA

Participants: François Charpillet, Julien Uzzan.

This work is done in collaboration with François Aioun, Thomas Hannagan and Franck Guillemard from PSA.

The subject of the thesis is : « Reinforcement learning for the autonomous vehicle in urban-like environments ». This PhD started in January on the Vélizy site where he stayed for 3 months and the he moved to Inria Nancy in the LARSEN team and we started working on applications of deep reinforcement learning algorithms for autonomous vehicles. The first one was a decision-making problem for autonomous driving on highways using the Deep Q-Networks algorithm. The aim was to build a controler outputing high level decisions (like changing to left/right lane, braking. . .) to navigate on highways and interacting with many other actors. Even though the results were convicing for simple simulations like a basic overtaking or just following a leader car, the performances on the general case were lackluster, so this is still an ongoing work. The other application we worked on later this year is a longitudinal control application. The aim was to create a controller able to drive behind a leader, but this time, the controller is low-level, meaning that it has to output direct commands, like an acceleration. More recently, we have been testing a idea meant to enhance the performances of the deep reinforcement learning algorithm by adding noise to the observations during training in order to obtain a safer and more cautious controller.

8.1.3. Cifre with SAFRAN

Participants: François Charpillet, Nicolas Gauville, Christophe Guettier.

The thesis began on May 6, 2019 after a "prethesis" of 6 month and is related to the Furious Project. The objective is to propose new Coordination mechanisms for a group of autonomous robotic evolving in an unknown environment for search and rescue (Robot Search and Rescue). The thesis is a continuation of a previous work made during the Cartomatic project which won in 2012 the French robotics contest Defi CAROTTE organized by the General Delegation for Armaments (DGA) and French National Research Agency (ANR).

8.1.4. Cifre iFollow

Participants: Francis Colas, Jérôme Truc, Cédric Pradalier, Nirmal Giftsun.

Cédric Pradalier is co-supervisor at GeorgiaTech Lorraine and Nirmal Giftsun is at iFollow.

iFollow is a startup, located in Paris area, providing solutions for shopping carts. Their first market of interest is logistics, wherein they develop robots for alleviating the workload of order pickers. Their second, longer-term, target is retail, with the development of intelligent shopping carts to help persons with disabilities.

The aim of this Cifre program is to endow the robots with more intelligent behaviors. In warehouses, the aim will be to improve the autonomy of the robots to better assist the pickers, leveraging the knowledge of the current order being prepared. In supermarket, the shopping carts should learn to properly interact with other carts and people while positioning themselves to better serve its current user.

This year, Jérôme Truc set up a simulated warehouse environment modeled on an actual warehouse from a logistic partner of iFollow. In this environment, he tested and compared several behaviors for a cart robot helping an order picker.

For personal reasons, Jérôme Truc had to resign from his PhD in July 2019.

9. Partnerships and Cooperations

9.1. Regional Initiatives

9.1.1. LUE C-Shift

Program: LUE Impact (Lorraine Université d'Excellence)

Project acronym: C-Shift

Project title: Cobots in the Service of Human activity at work In consistence with the challenges of Industry of the FuTure

Duration: October 2019 - December 2022

Coordinator: Benoit Iung (University of Lorraine)

PI for Inria/Loria: Serena Ivaldi

Abstract:

Le projet IMPACT « C-SHIFT » (Cobots in the Service of Human activity at work In consistence with the challenges of Industry of the FuTure) labélisé LUE (Lorraine Université d'Excellence) en collaboration avec les laboratoires de recherches LORIA, CRAN, CEREFIGE, PErSEUS, DevAH, LGIPM et les centres d'expertise et ressources AIPL-SMART et Ergosim et qui vise à étudier l'impact de la mise en œuvre de dispositifs collaboratifs intelligents tels que les cobots dans le cadre des défis de l'industrie du futur.

9.1.2. LUE Acceptability

Program: LUE PhD program (Lorraine Université d'Excellence)

Project title: elderly-technology interaction: accessibility and acceptability of assistive technology at home

Partners : Inria-Loria and Psychology and neuroscience lab - EA7489 (2LPN)

participants : Jérome Dinet, François Charpillet, Eloïse Zehner

Duration: October 2018 - September 2021

Abstract:

This PhD program is funded by the LUE PhD program, which among other has the objective to strength cooperation with associated institutions or companies supporting one of the six socio-economic challenges, here "Ageing and Health" challenge. This Ph.D. thesis, is aiming:

- at identifying sustainable actions to promote seniors' quality of life, intended to investigate this kind of interaction in terms of accessibility and acceptability that senior citizen experience with technological devices autonomy at home;
- at understanding more of technology use by older people. We have insight in the actual situation on older people's use and acceptance of technology, but locally and segmented, and more descriptive than explanatory. Most attention goes to the role of technology in the home with a particular focus on the interaction between people and assistive robots.

9.1.3. Project Psyphine Hors les Murs

Title: Psyphine Hors les Murs

Program: PEPS blanc 2019 de l'INS2I

Duration: January 2017 - January 2019

Coordinator: LORIA UMR (UMR 7503)

LARSEN member: Amine Boumaza

Psyphine is an interdisciplinary and exploratory project that gathers philosophers, psychologists, ethnologist, and computer scientists. The long term goal of the project is to explore the idea of assignments of intelligence or intentionality. Assuming that our intersubjectivity and our natural tendency to anthropomorphize plays a central role in this process, the project members investigate the elements that drive humans to attribute intelligence to robotic devices. Some of the questions that we aim to answer are: is it possible to give the illusion of cognition and/or intelligence through a technical device? How elaborate must be the control algorithms or "behaviors" of such a device so as to fool the observer? How many degrees of freedom must it have?

Partner institutions: InterPsy (EA 4432), ATILF (UMR 7118), Archives Henri-Poincaré (UMR7117), Inria Bordeaux Sud-Ouest, Loria (UMR7503) and MSH Lorraine (USR3261).

9.2. National Initiatives

9.2.1. ANR : The Flying Co-Worker

Program: ANR

Project acronym: Flying Co-Worker

Project title: Flying Co-Worker

Duration: October 2019 - october 2023

Coordinator: Daniel Sidobre (Laas Toulouse)

PI for Inria: François Charpillet

Abstract: Bringing together the recent progresses in physical and decisional interaction between humans and robots with the control of aerial manipulators, this project addresses the flying coworker, an aerial manipulator robot that act as a teammate of a human worker to transport a long bar or to realise complex tasks. Safety and human-aware robot abilities are at the core of the proposed research to progressively build robots capable to do cooperative handling and to assist a worker by notably delivering objects directly in a safe, efficient, pertinent and acceptable manner. The methodologies developed for ground manipulators cannot be directly used for aerial manipulator systems because of the floating base, of a limited payload, and of strong actuation and energy constraints. From the perception and the interpretation of the human activity, the objective of the project is to build an aerial manipulator capable to plan and control human aware motions to achieve collaborative tasks.

9.3. European Initiatives

9.3.1. FP7 & H2020 Projects

9.3.1.1. RESIBOTS

Title: Robots with animal-like resilience

Program: H2020

Type: ERC

Duration: May 2015 - April 2020

Coordinator: Inria

Inria contact: Jean Baptiste Mouret

Despite over 50 years of research in robotics, most existing robots are far from being as resilient as the simplest animals: they are fragile machines that easily stop functioning in difficult conditions. The goal of this proposal is to radically change this situation by providing the algorithmic foundations for low-cost robots that can autonomously recover from unforeseen damages in a few minutes. It is here contended that trial-and-error learning algorithms provide an alternate approach that does not require diagnostic, nor pre-defined contingency plans. In this project, we will develop and study a novel family of such learning algorithms that make it possible for autonomous robots to quickly discover compensatory behaviors.

9.3.1.2. ANDY

Title: Advancing Anticipatory Behaviors in Dyadic Human-Robot Collaboration

Programme: H2020

Type: ICT RIA (No. 731540)

Duration: January 2017 - December 2020

Coordinator: IIT

PI for Inria: Serena Ivaldi

Recent technological progress permits robots to actively and safely share a common workspace with humans. Europe currently leads the robotic market for safety-certified robots, by enabling robots to react to unintentional contacts. AnDy leverages these technologies and strengthens European leadership by endowing robots with the ability to control physical collaboration through intentional interaction.

To achieve this interaction, AnDy relies on three technological and scientific breakthroughs. First, AnDy will innovate the way of measuring human whole-body motions by developing the wearable AnDySuit, which tracks motions and records forces. Second, AnDy will develop the AnDyModel, which combines ergonomic models with cognitive predictive models of human dynamic behavior in collaborative tasks, which are learned from data acquired with the AnDySuit. Third, AnDy will propose the AnDyControl, an innovative technology for assisting humans through predictive physical control, based on AnDyModel.

By measuring and modeling human whole-body dynamics, AnDy provides robots with an entirely new level of awareness about human intentions and ergonomy. By incorporating this awareness on-line in the robot's controllers, AnDy paves the way for novel applications of physical human-robot collaboration in manufacturing, health-care, and assisted living.

AnDy will accelerate take-up and deployment in these domains by validating its progress in several realistic scenarios. In the first validation scenario, the robot is an industrial collaborative robot, which tailors its controllers to individual workers to improve ergonomy. In the second scenario, the robot is an assistive exoskeleton which optimizes human comfort by reducing physical stress. In the third validation scenario, the robot is a humanoid, which offers assistance to a human while maintaining the balance of both.

Partners: Italian Institute of Technology (IIT, Italy, coordinator), Josef Stefan Institute (JSI, Slovenia), DLR (Germany), IMK Automotive Gmbh (Germany), XSens (Netherlands), AnyBody Technologies (Denmark)

9.3.2. Collaborations in European Programs, Except FP7 & H2020

9.3.2.1. HEAP

- Program: CHIST-ERA
- Project acronym: HEAP
- Project title: HEAP: Human-Guided Learning and Benchmarking of Robotic Heap Sorting

- Duration: March 2019–Feb. 2022
- Coordinator: Gerhard Neumann (Univ. of Lincoln, UK)
- PI for Inria: Serena Ivaldi
- Other partners: Italian Insitute of Technology (Italy), Technische Universitat Wien (Austria), Idiap Research Institute (Switzerland), Inria
- This project will provide scientific advancements for benchmarking, object recognition, manipulation and human-robot interaction. We focus on sorting a complex, unstructured heap of unknown objects –resembling nuclear waste consisting of a set of broken deformed bodies– as an instance of an extremely complex manipulation task. The consortium aims at building an end-to-end benchmarking framework, which includes rigorous scientific methodology and experimental tools for application in realistic scenarios. Benchmark scenarios will be developed with off-the-shelf manipulators and grippers, allowing to create an affordable setup that can be easily reproduced both physically and in simulation. We will develop benchmark scenarios with varying complexities, i.e., grasping and pushing irregular objects, grasping selected objects from the heap, identifying all object instances and sorting the objects by placing them into corresponding bins. We will provide scanned CAD models of the objects that can be used for 3D printing in order to recreate our benchmark scenarios. Benchmarks with existing grasp planners and manipulation algorithms will be implemented as baseline controllers that are easily exchangeable using ROS. The ability of robots to fully autonomously handle dense clutters or a heap of unknown objects has been very limited due to challenges in scene understanding, grasping, and decision making. Instead, we will rely on semi-autonomous approaches where a human operator can interact with the system (e.g. using tele-operation but not only) and giving high-level commands to complement the autonomous skill execution. The amount of autonomy of our system will be adapted to the complexity of the situation. We will also benchmark our semi-autonomous task execution with different human operators and quantify the gap to the current SOTA in autonomous manipulation. Building on our semi-autonomous control framework, we will develop a manipulation skill learning system that learns from demonstrations and corrections of the human operator and can therefore learn complex manipulations in a data-efficient manner. To improve object recognition and segmentation in cluttered heaps, we will develop new perception algorithms and investigate interactive perception in order to improve the robot's understanding of the scene in terms of object instances, categories and properties.

9.4. International Research Visitors

9.4.1. Visits of International Scientists

This year we had the visit of Professor Sozo Inoue from Kyushu Institute of Technology (https://sozolab.jp) for one week in September. He was accompanied with one PhD student and two Master students, and a Postdoc. The objective was to organise together the collection of a Dataset and propose an international challenge for testing action and activity recognition algorithms.

9.4.1.1. Internships

- Luan Wei (University of Osnabrück, Germany), 5 months (supervisor: Jean-Baptiste Mouret)
- Ivan Bergonzi (University of Roma — La Sapienza, Italy), 5 months (supervisor: Jean-Baptiste Mouret)
- Lorenzo Vianello (University of Roma — La Sapienza, Italy), 6 months (supervisor: Serena Ivaldi)
- Andrea Macrí (University of Roma — La Sapienza, Italy), 5 months (supervisor: Serena Ivaldi)
- Lina Achaji (University Lebanese University – Faculty of Engineering – Tripoli), 3 months (supervision: François Charpillet)
- Niyati Rawal (Rovira i Virgili University & Open University of Catalonia (Spain)), 5 months (supervision: Francis Colas, Serena Ivaldi, Vincent Thomas)

- Yang You (Cranfield University), 5 months (supervision Vincent Thomas, Olivier Buffet, François Charpillet).

9.4.2. PhD students

- Niels Justesen (IT University of Copenhagen), 3 months (supervisor: Jean-Baptiste Mouret)
- Anji Ma (Bejing Institute of Technology), 1 year (supervisor: Serena Ivaldi)
- Moe Matsuki (Kyushu Institute of Technology) 2 weeks (supervisor: François Charpillet).

10. Dissemination

10.1. Promoting Scientific Activities

10.1.1. Scientific Events: Organisation

10.1.1.1. General Chair, Scientific Chair

- Conference Chair for the 30th International Conference on Automated Planning and Scheduling (ICAPS 2020), which will take place in Nancy in June 2020 (https://icaps20.icaps-conference.org/) [Olivier Buffet].
- Co-chair and co-organizer with Olivier Simonin the JNRR (National bi-annual conference on Robotics) 2019, in Vittel [François Chapillet]

10.1.1.2. Member of the Organizing Committees

- Conference “Drôles d’objets - Un nouvel art de faire 2020” that will take place in La Rochelle in april 2020 [Amine Boumaza, co-organizer]
- Workshop at the International Conference on Robotics and Automation (ICRA 2019) (*Human movement science for physical human-robot collaboration)* [Pauline Maurice and Serena Ivaldi, co-organizers]
- Local Organization Committee of the 30th International Conference on Automated Planning and Scheduling (ICAPS 2020) [Vincent Thomas]
- Workshop “Women in Robotics V” at the international conference Robotics: Science and Systems (RSS 2019) [Serena Ivaldi]
- Workshop “Tele-operation of Humanoid Robots” at IEEE-RAS International Conference on Humanoid Robots (HUMANOIDS 2019) [Serena Ivaldi]

10.1.2. Scientific Events: Selection

10.1.2.1. Chair of Conference Program Committees

- Program chair of the 2019 IEEE-RAS International Conference on Humanoid Robots (Toronto, Canada) [Serena Ivaldi]
- Co-chair of the track “Evolutionary Machine Learning” at GECCO 2019 (Prague, Czech Republic) [Jean-Baptiste Mouret]

10.1.2.2. Awards Chair of Conference Program Committees

- Awards co-chair of the 12th International Workshop on Human-Friendly Robotics (HFR 2019) [Serena Ivaldi]

10.1.2.3. Member of the Conference Program Committees

- 24th European Conference on Artificial Intelligence (ECAI 2020) [Francis Colas, Vincent Thomas, F. Charpillet]
- 36th International Conference on Machine Learning (ICML 2019) [Olivier Buffet]

- 28th International Joint Conference on Artificial Intelligence (IJCAI 2019) [Olivier Buffet, Vincent Thomas]
- *Journées Francophones sur la Planification, la Décision et l'Apprentissage pour la conduite de systèmes* (JFPDA 2019) [Olivier Buffet, Vincent Thomas]
- 34th AAAI Conference on Artificial Intelligence (AAAI 2020) [Olivier Buffet, F. Charpillet]
- 33th AAAI Conference on Artificial Intelligence (AAAI 2019) [Olivier Buffet, F. Charpillet]
- ALIFE 2019 (European Conference on Artificial Life) [Amine Boumaza, Jean-Baptiste Mouret]
- GECCO 2019 (Genetic and Evolutionary Computation Conference) [Amine Boumaza, Jean-Baptiste Mouret]
- EA 2019 (Artificial Evolution) [Amine Boumaza, Jean-Baptiste Mouret]
- IEEE/RAS International Conference on Robotics and Automation (ICRA 2020) [Pauline Maurice – Associate editor]
- 12th International Workshop on Human-Friendly Robotics (HFR 2019) [Pauline Maurice]
- 27emes Journées Francophones sur les Systèmes Multi-Agents (JFSMA 2019)[François Charpillet]
- 11th International Conference on Agents and Artificial Intelligence (ICAART 2019)[François Charpillet]

10.1.2.4. Reviewer

- Robotics: Science and Systems (RSS 2019) [Francis Colas, Serena Ivaldi]
- IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS 2019) [Francis Colas, Pauline Maurice, Jean-Baptiste Mouret]
- IEEE International Conference on Robotics and Automation (ICRA 2020) [Pauline Maurice, Jean-Baptiste Mouret]
- IEEE-RAS International Conference on Humanoid Robots (Humanoids 2019) [Francis Colas, Jean-Baptiste Mouret]
- 24th European Conference on Artificial Intelligence (ECAI 2020) [Francis Colas, Vincent Thomas, François Charpillet]
- 36th International Conference on Machine Learning (ICML 2019) [Olivier Buffet, Vincent Thomas]
- 28th International Joint Conference on Artificial Intelligence (IJCAI 2019) [Olivier Buffet, Vincent Thomas]
- *Journées Francophones sur la Planification, la Décision et l'Apprentissage pour la conduite de systèmes* (JFPDA 2019) [Olivier Buffet, Vincent Thomas]
- 34th AAAI Conference on Artificial Intelligence (AAAI 2020) [Olivier Buffet]
- 33th AAAI Conference on Artificial Intelligence (AAAI 2020) [François Charpillet]
- IEEE International Conference on Advanced Robotics ans its Social Impacts (ARSO 2019) [Pauline Maurice]
- Conference on Robot Learning (CoRL 2019) [Jean-Baptiste Mouret]
- ACM WomeENcourage 2019 [Serena Ivaldi]
- 27emes Journées Francophones sur les Systèmes Multi-Agents (JFSMA 2019)[François Charpillet]
- 11th International Conference on Agents and Artificial Intelligence (ICAART 2019)[François Charpillet]

10.1.3. Journal

10.1.3.1. Member of the Editorial Boards

- IEEE Robotics and Automation Letters [Serena Ivaldi – associate editor]

- ACM Transactions on Evolutionary Learning and Optimization [Jean-Baptiste Mouret – associate editor]
- Frontiers in AI and Robotics – review editors [Amine Boumaza, Jean-Baptiste Mouret]

10.1.3.2. Reviewer - Reviewing Activities

- Artificial Intelligence Journal (AIJ) [Olivier Buffet]
- Journal of Artificial Intelligence Research (JAIR) [Olivier Buffet].
- Genetic Programming and Evolvable Machines [Amine Boumaza]
- Robotica [Francis Colas]
- Robotics and Automation Letter [Francis Colas, Jean-Baptiste Mouret]
- Artificial Life [Jean-Baptiste Mouret]
- ACM Transactions on Evolutionary Learning and Optimization (TELO) [Jean-Baptiste Mouret]
- ACM Transactions on Human-Robot Interaction [Pauline Maurice]
- PloS One [Pauline Maurice]
- Paladyn Journal of Behavioral Robotics [Pauline Maurice]
- The Journal on Multimodal User Interfaces [Pauline Maurice]
- Frontiers in Neurorobotics [Serena Ivaldi]
- IEEE Robotics and Automation Magazine [Serena Ivaldi]

10.1.4. Invited Talks

- Keynote at the 10th International Conference on Information, Intelligence, Systems and Applications, Patras (Greece) [Jean-Baptiste Mouret]
- Keynote at the 12th International Workshop on Human-Friendly Robotics (HFR 2019) in Reggio Emilia (Italy) [Serena Ivaldi]
- Invited talk at the Conference on “Novel technological innovations for occupational safety and health” organised by the Polish Central Institute for Labour Protection – National Research Institute (CIOP-PIB), Warsaw (Poland) [Pauline Maurice]
- Invited talk at the workshop on “Closing the Reality Gap in Sim2real Transfer for Robotic Manipulation” at RSS 2019, Freiburg (Germany) [Jean-Baptiste Mouret]
- Invited talk at the CNRS GDR ISIS (Information, Signal, Image et ViSion), special day on robot learning, Paris (France) [Jean-Baptiste Mouret]
- talk at Workshop on “Task-Informed Grasping” at RSS 2019,Freiburg (Germany) [Serena Ivaldi]
- invited talk at the HUMANOIDS 2019 Workshop “Can we build Baymax?”, Toronto (Canada) [Serena Ivaldi]
- invited talk at HUMANOIDS 2019 Workshop on “Humanoid Teleoperation”, Toronto (Canada) [Serena Ivaldi]
- invited talk at the HUMANOIDS 2019 Workshop on “Challenges and solutions for HRI and collaboration”, Toronto (Canada) [Serena Ivaldi]
- invited talk at the IROS 2019 “Cutting Edge Forum on Cognitive architecture for humanoids: where are we in our quest to achieve human-level AI in robotics?”, Macau (China) [Serena Ivaldi]
- invited talk at the IROS 2019 Workshop on “Progress in Ergonomic Physical Human-Robot Collaboration”, Macau (China) [Serena Ivaldi]
- invited talk at the IROS 2019 Workshop on “Open-Ended Learning for Object Perception and Grasping: Current Successes and Future Challenges”, Macau (China) [Serena Ivaldi]

10.1.5. Research Administration

- Serena Ivaldi is member of the scientific council of the Federation Charles Hermite

- Jean-Baptiste Mouret is a member of the “Bureau du Comité des Projets” of Inria Nancy – Grand-Est
- François Charpillet is member of the scientific commitee of the Robotic GDR (All the teams in France contributing to research in Robotics are members of the Groupe de Recherche (GDR) en Robotique, an open national Research Group established by the CNRS).
- François Charpillet is co-leading with Pr Rossignol the SCIARAT plateform of the CPER IT2MP

10.2. Teaching - Supervision - Juries

10.2.1. Teaching

Master: Alexis Scheuer, “Introduction à la robotique autonome”, 30h eq. TD, M1 informatique, Univ. Lorraine, France.

Master: Alexis Scheuer, “Vie artificielle”, 22,5h eq. TD, 3ème année, CentraleSupélec, France.

Master: Francis Colas, “Robotique autonome”, 18h eq. TD, M2 “Systèmes Interactifs et Robotiques”, CentraleSupélec, France.

Master: Francis Colas, “Planification de trajectoires”, 12h eq. TD, M2 “Apprentissage, Vision, Robotique”, Univ. Lorraine, France.

Master: Alexis Scheuer, “Modélisation et commande en robotique”, 16h eq. TD, M2 “Apprentissage, Vision, Robotique”, Univ. Lorraine, France.

Master: Francis Colas, “Autonomous Robotics”, 39.5h eq. TD, M1, CentraleSupélec, France.

Master: Pauline Maurice, “Analyse Comportementale”, 10h eq. TD, M2 “Sciences Cognitives”, Univ. Lorraine, France.

Master: Jean-Baptiste Mouret, “Creative automatic design”, 3h, M2, M2 “Management de l’innovation”, Mines de Paris, France

Master: Serena Ivaldi, “Analyse Comportementale”, 16h CM/TD, M2 “Sciences Cognitives”, Univ. Lorraine, France.

Master: Amine Boumaza, “Méta-heuristiques et recherche locale stochastique”, 30h eq. TD, M1 informatique, Univ. Lorraine, France.

Tutorial: Olivier Buffet, “Planification dans l’incertain", 3h CM, CNRS Formation Entreprise.

Tutorial, Jean-Baptiste Mouret, “Evolutionary robotics”, 3h, ACM GECCO 2019 (with S. Doncieux and N. Bredeche, Sorbonne Université)

10.2.2. Supervision

PhD in progress: Adrien Malaisé, “*Capteurs portés dans la robotique collaborative : de l’apprentissage du mouvement à l’acceptabilité de cette technologie*”, started in January 2017, Francis Colas (advisor), Serena Ivaldi (co-advisor).

PhD in progress: Yang You, “*Modèles probabilistes pour la collaboration humain-robot*”, started in October 2019, Olivier Buffet (advisor), Vincent Thomas (co-advisor)

PhD canceled: Jérôme Truc, “*Apprentissage de comportement et interactions prédictives pour un robot d’assistance en environnement structuré*”, started in September 2018, canceled in July 2019, Francis Colas (advisor)

PhD in progress: Rituraj Kaushik, “*Damage recovery by trial and error and multiple simulation priors*”, started in October 2016, Jean-Baptiste Mouret (advisor)

PhD in progress: Adam Gaier, “*Surrogate-based illumination for aerodynamics*”, started in October 2016, Jean-Baptiste Mouret (Advisor)

PhD in progress: Vladislav Tempez, “*Learning to fly a micro-UAVs in highly confined environments*”, started in October 2018, Jean-Baptiste Mouret (advisor), Franck Ruffier (co-advisor, CNRS/Aix-Marseille Université)

PhD in progress: Waldez Azevedo Gomes Junior, "*Intelligent Human-Robot collaboration*", started in October 2018, Jean-Baptiste Mouret (advisor), Serena Ivaldi (co-advisor)

PhD in progress: Yoann Fleytoux, "*Human-guided manipulation learning of irregular objects*", started in April 2019, Jean-Baptiste Mouret (advisor), Serena Ivaldi (co-advisor)

PhD in progress: Luigi Penco, "*Intelligent whole-body tele-operation of humanoid robots*", started in April 2019, Jean-Baptiste Mouret (advisor), Serena Ivaldi (co-advisor)

PhD in progress: Lorenzo Vianello, "*Adaptation in human-robot collaboration*", started in December 2019, Alexis Aubry (advisor, CRAN, Univ. Lorraine), Serena Ivaldi (co-advisor)

PhD in progress : Yassine EL Khadiri, Cifre with Diatelic, "*Machine learning for Ambient Assisted Living (AAL)*", started in June 2017, François Charpillet adviser.

PhD in progress : Eloise Zehnder, "*Elderly-technology interaction: accessibility and acceptability of assistive technology (at) at home*", started October 2018, François Charpillet (advisor), Jérome Dinet (advisor, 2LPN).

PhD in progress : Julien Uzzan, Cifre with PSA, "*navigation of an autonomous vehicle in a complex environment using unsupervised or semi-supervised learning*", started in January 2019, François Charpillet (advisor), François Aioun (co-advisor, PSA).

PhD in progress : Jessica Colombel, "*Analysis of human movement for assistance*", started in Feburary 2019, François Charpillet (advisor) David Daney(advisor, Auctus team, Bordeaux)

PhD in progress : Nicolas Gauville, CIFRE with SAFRAN, "*Coordination of autonomous robots evolving in unstructured and unknown environment for Search and Rescue*", started in May 2019, François Charpillet (advisor), Christophe Guettier (co-adviser, Safran).

10.2.3. Juries

- François Charpillet was a reviewer for the HDR of Antony Fleury (Lille University)
- François Charpillet was a reviewer for the HDR of François Portet (LIG, Grenoble Alpes University)
- Pauline Maurice was an examinator for the PhD of Nolwenn Briquet-Kerestedjian (Univ. Paris-Saclay)
- Jean-Baptiste Mouret was a reviewer for the PhD of Christophe Reymann (INSA Toulouse / LAAS)
- Jean-Baptiste Mouret was a reviewer for the PhD of Daniele Gravina (University of Malta)
- Serena Ivaldi was an examiner for the PhD of Rohan Budhiraja (LAAS)
- François Charpillet was a reviewer for the PhD of Facundo Benavides Olivera (ISAE, Toulouse University & Universidad de la República, Uruguay)
- François Charpillet was a reviewer for the PhD of Mehdi Othmani-Guibourg (Sorbonne University)
- François Charpillet was a reviewer for the PhD of Sandra Castellanos (LIG, Grenoble Alpes University)
- François Charpillet was a examiner for the PhD of Pavan Vasishta(Grenoble Alpes University)

10.3. Popularization

10.3.1. Internal or external Inria responsibilities

- Amine Boumaza is a member of the editorial board of "Interstice".

10.3.2. Articles and contents

- Pauline Maurice gave an interview for Radio Canada (radio).
- Serena Ivaldi gave an interview to France 3 (TV) during the inauguration of the Creativ'Lab.

10.3.3. Education

- Vincent Thomas gave a tutorial on path planning for teachers during “journées ISN-EPI 2019” (Nancy, France).

10.3.4. Interventions

- Public workshop on robot programming with Thymio at “Fête de la Science” [Alexis Scheuer, Olivier Buffet, Jessica Colombel, Francis Colas, Yassine El Khadiri, Vincent Thomas, Yang You]
- Pauline Maurice gave a talk at the Forum Sciences Cognitives 2019 in Université de Lorraine.
- Jean-Baptiste Mouret was invited to debate about artificial intelligence at “La Tronche en Biais”, an online popularization channel (27k view for this video)
- Eloïse Dalin and Pierre Desreumaux participated to a “Café des Sciences” artificial intelligence and robotics at the “Cité des Sciences et de l’Industrie” (Paris)
- Serena Ivaldi participated to the “Fête de la Science” as tutor for school children in Inria/Loria

11. Bibliography

Major publications by the team in recent years

[1] A. CULLY, J. CLUNE, D. TARAPORE, J.-B. MOURET. *Robots that can adapt like animals*, in "Nature", May 2015, vol. 521, n^o^ 7553, pp. 503-507 [*DOI :* 10.1038/NATURE14422], https://hal.archives-ouvertes.fr/hal-01158243

[2] J. S. DIBANGOYE, C. AMATO, O. BUFFET, F. CHARPILLET. *Optimally Solving Dec-POMDPs as Continuous-State MDPs*, in "Journal of Artificial Intelligence Research", February 2016, vol. 55, pp. 443-497 [*DOI :* 10.1613/JAIR.4623], https://hal.inria.fr/hal-01279444

Publications of the year

Articles in International Peer-Reviewed Journals

[3] K. CHATZILYGEROUDIS, V. VASSILIADES, F. STULP, S. CALINON, J.-B. MOURET. *A survey on policy search algorithms for learning robot controllers in a handful of trials*, in "IEEE Transactions on Robotics", 2020, forthcoming, https://hal.inria.fr/hal-02393432

[4] M. DAHER, J. A. HAGE, M. EL BADAOUI EL NAJJAR, A. DIAB, K. MOHAMAD, F. CHARPILLET. *Toward High Integrity Personal Localization System Based on Informational Formalism*, in "IEEE Transactions on Instrumentation and Measurement", November 2019, vol. 68, n^o^ 11, pp. 4590-4599 [*DOI :* 10.1109/TIM.2018.2886976], https://hal.inria.fr/hal-02427488

[5] D. HOWARD, A. E. EIBEN, D. F. KENNEDY, J.-B. MOURET, P. VALENCIA, D. WINKLER. *Evolving embodied intelligence from materials to machines*, in "Nature Machine Intelligence", January 2019, vol. 1, n^o^ 1, pp. 12-19 [*DOI :* 10.1038/S42256-018-0009-9], https://hal.inria.fr/hal-01986599

[6] A. MALAISÉ, P. MAURICE, F. COLAS, S. IVALDI. *Activity Recognition for Ergonomics Assessment of Industrial Tasks with Automatic Feature Selection*, in "IEEE Robotics and Automation Letters", January 2019, vol. 4, n^o^ 2, pp. 1132-1139 [*DOI :* 10.1109/LRA.2019.2894389], https://hal.archives-ouvertes.fr/hal-01985013

[7] P. MAURICE, J. CAMERNIK, D. GORJAN, B. SCHIRRMEISTER, J. BORNMANN, L. TAGLIAPIETRA, C. LATELLA, D. PUCCI, L. FRITZSCHE, S. IVALDI, J. BABIČ. *Objective and Subjective Effects of a Passive Exoskeleton on Overhead Work*, in "IEEE Transactions on Neural Systems and Rehabilitation Engineering", 2019, forthcoming [*DOI :* 10.1109/TNSRE.2019.2945368], https://hal.archives-ouvertes.fr/hal-02301922

[8] P. MAURICE, A. MALAISÉ, C. AMIOT, N. PARIS, G.-J. RICHARD, O. ROCHEL, S. IVALDI. *Human Movement and Ergonomics: an Industry-Oriented Dataset for Collaborative Robotics*, in "The International Journal of Robotics Research", 2019, forthcoming [*DOI :* 10.1177/0278364919882089], https://hal.archives-ouvertes.fr/hal-02289107

[9] P. MAURICE, V. PADOIS, Y. MEASSON, P. BIDAUD. *Assessing and improving human movements using sensitivity analysis and digital human simulation*, in "International Journal of Computer Integrated Manufacturing", 2019, forthcoming [*DOI :* 10.1080/0951192X.2019.1599432], https://hal.archives-ouvertes.fr/hal-01221647

[10] Q. V. NGUYEN, F. COLAS, E. VINCENT, F. CHARPILLET. *Motion planning for robot audition*, in "Autonomous Robots", December 2019, vol. 43, n° 8, pp. 2293-2317 [*DOI :* 10.1007/s10514-019-09880-1], https://hal.inria.fr/hal-02188342

[11] L. PENCO, N. SCIANCA, V. MODUGNO, L. LANARI, G. ORIOLO, S. IVALDI. *A Multi-Mode Teleoperation Framework for Humanoid Loco-Manipulation*, in "IEEE Robotics and Automation Magazine", December 2019, https://hal.inria.fr/hal-02291907

International Conferences with Proceedings

[12] A. BOUMAZA. *Introducing Weighted Intermediate Recombination in On-line Collective Robotics, the (μ/μ W , 1)-On-line EEA*, in "Applications of Evolutionary Computation", Leipzig, Germany, April 2019, https://hal.inria.fr/hal-02185694

[13] A. BOUMAZA. *When Mating Improves On-line Collective Robotics*, in "GECCO'19 Proceedings of the 2019 Genetic and Evolutionary Computation Conference", Prague, Czech Republic, July 2019, https://hal.inria.fr/hal-02185645

[14] W. GOMES, V. RADHAKRISHNAN, L. PENCO, V. MODUGNO, J.-B. MOURET, S. IVALDI. *Humanoid Whole-Body Movement Optimization from Retargeted Human Motions*, in "IEEE/RAS Int. Conf. on Humanoid Robots", Toronto, Canada, August 2019, https://hal.archives-ouvertes.fr/hal-02290473

National Conferences with Proceedings

[15] Y. EL-KHADIRI, G. CORONA, C. ROSE, F. CHARPILLET. *Une Approche Bayésienne pour la reconnaissance des périodes de sommeil à l'aide de capteurs de mouvement*, in "Journées d'Etude sur la TéléSanté", Paris, France, Sorbonne Universités, May 2019, https://hal.archives-ouvertes.fr/hal-02161066

[16] *Best Paper*
N. GAUVILLE, F. CHARPILLET. *Exploration et couverture par stigmergie d'un environnement inconnu avec une flotte de robots autonomes réactifs*, in "JFSMA 2019 - 27emes Journées Francophones sur les Systèmes Multi-Agents", Toulouse, France, Cépaduès 2019, ISBN 9782364937192, July 2019, https://hal.inria.fr/hal-02195812.

[17] N. GAUVILLE, N. FATÈS, I. MARCOVICI. *Diagnostic décentralisé à l'aide d'automates cellulaires*, in "JFSMA 2019 - 27emes Journées Francophones sur les Systèmes Multi-Agents", Toulouse, France, Cépaduès, July 2019, ISBN 9782364937192, https://hal.inria.fr/hal-02195799

Conferences without Proceedings

[18] E. DALIN, P. DESREUMAUX, J.-B. MOURET. *Learning and adapting quadruped gaits with the "Intelligent Trial & Error" algorithm*, in "IEEE ICRA Workshop on "Learning legged locomotion"", Montreal, Canada, 2019, https://hal.inria.fr/hal-02084619

[19] P. MAURICE, J. CAMERNIK, D. GORJAN, B. SCHIRRMEISTER, J. BORNMANN, L. TAGLIAPIETRA, C. LATELLA, D. PUCCI, L. FRITZSCHE, S. IVALDI, J. BABIČ. *Evaluation of PAEXO, a novel passive exoskeleton for overhead work*, in "44ème Congrès de la Société de Biomécanique", Poitiers, France, October 2019, https://hal.archives-ouvertes.fr/hal-02348588

[20] V. THOMAS, G. HUTIN, O. BUFFET. *Planification Monte Carlo orientée information*, in "JFPDA 2019 - Journées Francophones sur la Planification, la Décision et l'Apprentissage pour la conduite de systèmes", Toulouse, France, July 2019, https://hal.archives-ouvertes.fr/hal-02350573

Scientific Books (or Scientific Book chapters)

[21] P. MAURICE, V. PADOIS, Y. MEASSON, P. BIDAUD. *Digital Human Modeling for Collaborative Robotics*, in "DHM and Posturography", August 2019, https://hal.archives-ouvertes.fr/hal-02389726

Other Publications

[22] O. DERMY, S. BOUCENNA, A. PITTI, A. BLANCHARD. *Developmental Learning of Audio-Visual Integration From Facial Gestures Of a Social Robot*, July 2019, working paper or preprint, https://hal.archives-ouvertes.fr/hal-02185423

References in notes

[23] M. ANDRIES, F. CHARPILLET. *Multi-robot taboo-list exploration of unknown structured environments*, in "2015 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS 2015)", Hamburg, Germany, September 2015, https://hal.inria.fr/hal-01196008

[24] M. ARAYA-LÓPEZ, O. BUFFET, V. THOMAS, F. CHARPILLET. *A POMDP Extension with Belief-dependent Rewards*, in "Advances in Neural Information Processing Systems (NIPS)", Vancouver, Canada, MIT Press, December 2010, https://hal.inria.fr/inria-00535560

[25] T. BARFOOT, J. KELLY, G. SIBLEY. *Special Issue on Long-Term Autonomy*, in "The International Journal of Robotics Research", 2013, vol. 32, n° 14, pp. 1609–1610

[26] A. DEL PRETE, F. NORI, G. METTA, L. NATALE. *Prioritized Motion-Force Control of Constrained Fully-Actuated Robots: "Task Space Inverse Dynamics"*, in "Robotics and Autonomous Systems", 2014, http://dx.doi.org/10.1016/j.robot.2014.08.016

[27] A. DIB, F. CHARPILLET. *Pose Estimation For A Partially Observable Human Body From RGB-D Cameras*, in "IEEE/RJS International Conference on Intelligent Robots and Systems (IROS)", Hamburg, Germany, September 2015, 8 p. , https://hal.inria.fr/hal-01203638

[28] A. FANSI TCHANGO, V. THOMAS, O. BUFFET, F. FLACHER, A. DUTECH. *Simultaneous Tracking and Activity Recognition (STAR) using Advanced Agent-Based Behavioral Simulations*, in "ECAI - Proceedings of the Twenty-first European Conference on Artificial Intelligence", Pragues, Czech Republic, August 2014, https://hal.inria.fr/hal-01073424

[29] I. FERNÁNDEZ PÉREZ, A. BOUMAZA, F. CHARPILLET. *Comparison of Selection Methods in On-line Distributed Evolutionary Robotics*, in "ALIFE 14: The fourteenth international conference on the synthesis and simulation of living systems", New York, United States, Artificial Life 14, July 2014 [*DOI :* 10.7551/978-0-262-32621-6-CH046], https://hal.inria.fr/hal-01091119

[30] U. FRESE. *Interview: Is SLAM Solved?*, in "KI - Künstliche Intelligenz", 2010, vol. 24, n^o 3, pp. 255-257, http://dx.doi.org/10.1007/s13218-010-0047-x

[31] A. KARAMI, L. JEANPIERRE, A. MOUADDIB. *Partially Observable Markov Decision Process for Managing Robot Collaboration with Human*, in "2009 21st IEEE International Conference on Tools with Artificial Intelligence", 2009, pp. 518-521

[32] J. KOBER, J. A. BAGNELL, J. PETERS. *Reinforcement Learning in Robotics: A Survey*, in "The International Journal of Robotics Research", August 2013

[33] S. KOOS, A. CULLY, J.-B. MOURET. *Fast damage recovery in robotics with the t-resilience algorithm*, in "The International Journal of Robotics Research", 2013, vol. 32, n^o 14, pp. 1700–1723

[34] F. POMERLEAU, P. KRÜSI, F. COLAS, P. FURGALE, R. SIEGWART. *Long-term 3D map maintenance in dynamic environments*, in "Robotics and Automation (ICRA), 2014 IEEE International Conference on", IEEE, 2014, pp. 3712–3719

[35] SPARC. *Robotics 2020 Multi-Annual Roadmap*, 2014, http://www.eu-robotics.net/ppp/objectives-of-our-topic-groups/

[36] J. SHAH, J. WIKEN, B. WILLIAMS, C. BREAZEAL. *Improved human-robot team performance using Chaski, A human-inspired plan execution system*, in "ACM/IEEE International Conference on Human-Robot Interaction (HRI)", 2011, pp. 29-36

[37] O. SIMONIN, T. HURAUX, F. CHARPILLET. *Interactive Surface for Bio-inspired Robotics, Re-examining Foraging Models*, in "23rd IEEE International Conference on Tools with Artificial Intelligence (ICTAI)", Boca Raton, United States, IEEE, November 2011, https://hal.inria.fr/inria-00617155

[38] N. STEFANOV, A. PEER, M. BUSS. *Role determination in human-human interaction*, in "3rd Joint EuroHaptics Conf. and World Haptics", 2009, pp. 51-56

[39] R. S. SUTTON, A. G. BARTO. *Introduction to Reinforcement Learning*, MIT Press, 1998

[40] A. TAPUS, M. MATARIĆ, B. SCASSELLATI. *The grand challenges in Socially Assistive Robotics*, in "IEEE Robotics and Automation Magazine - Special Issue on Grand challenges in Robotics", 2007, vol. 14, n^o 1, pp. 1-7

[41] D. Wilson, C. Atkeson. *Simultaneous Tracking and Activity Recognition (STAR) Using Many Anonymous, Binary Sensors*, in "Pervasive Computing", H.-W. Gellersen, R. Want, A. Schmidt (editors), Lecture Notes in Computer Science, Springer Berlin Heidelberg, 2005, vol. 3468, pp. 62-79, http://dx.doi.org/10.1007/11428572_5

[42] G. Wolbring, S. Yumakulov. *Social Robots: Views of Staff of a Disability Service Organization*, in "International Journal of Social Robotics", 2014, vol. 6, n^{o} 3, pp. 457-468