IN PARTNERSHIP WITH:
**CNRS**

**Université de Lorraine**

# Activity Report 2018

# 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

**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]
Francis Colas [Inria, Researcher, HDR]
Serena Ivaldi [Inria, Researcher, on maternity leave from Aug. 2018 to Nov. 2018]
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 from Oct. 2018]
Alexis Scheuer [Univ de Lorraine, Associate Professor]
Vincent Thomas [Univ de Lorraine, Associate Professor]

**Post-Doctoral Fellows**

Glenn Maguire [Inria, from Sep 2018]
Pauline Maurice [Inria]

Jonathan Spitz [Inria, until Jun 2018]

**PhD Students**

Waldez Azevedo Gomes Junior [Inria, from Jul 2018]
Adrian Bourgaud [Inria, until Jan 2018]
Konstantinos Chatzilygeroudis [Inria, until Sep 2018]
Oriane Dermy [Inria / Univ de Lorraine]
Yassine El Khadiri [Diatelic-Pharmagest]
Adam Gaier [Hochschule Bonn-Rhein-Sieg]
Nicolas Gauville [Inria, from Nov 2018]
Rituraj Kaushik [Inria]
Adrien Malaisé [Inria]
Vladislav Tempez [Univ de Lorraine, from Sep 2018]
Jérôme Truc [iFollow, from Sep 2018]
Eloise Zehnder [Univ de Lorraine, from Oct 2018]

**Technical staff**

Brice Clement [Inria]
Eloise Dalin [Inria, from Oct 2018]
Pierre Desreumaux [Inria, from Oct 2018]
Dorian Goepp [Inria, until Jun 2018, then for Oct. 2018]
Pauline Houlgatte [INSERM]
Debaleena Misra [Inria, from Oct 2018]
Luigi Penco [Inria, from Apr 2018]
Lucien Renaud [Inria]
Vassilis Vassiliades [Inria, until May 2018]

**Interns**

Marie Adler [Inria, from Jun 2018 until Jul 2018]
Clelie Amiot [Inria, from Jun 2018 until Jul 2018]
Thomas Goward [Inria, from Apr 2018 until Aug 2018]
Geremy Hutin [Inria, from Jun 2018 until Aug 2018]
Jiaqi Liu [Inria, from Mar 2018 until Sep 2018]
Adam Meoni [Inria, from Apr 2018 until Jul 2018]
Ahmed Taha Moumen [Univ de Lorraine, from Jul 2018 until Aug 2018]
Nicolas Paris [Inria, from Jun 2018 until Jul 2018]
Luigi Penco [Inria, until Feb 2018]
Vishnu Radhakrishnan [Inria, from Sep 2018]
Guy Richard [Inria, from Jun 2018 until Aug 2018]
Vladislav Tempez [Ecole Normale Supérieure Rennes, from Feb 2018 until Jun 2018]
Elsa Thuus [Inria, from Apr 2018 until Jul 2018]
Julien Uzzan [Univ de Lorraine, from Mar 2018 until Aug 2018]

**Administrative Assistants**

Véronique Constant [Inria]
Antoinette Courrier [CNRS]
Annick Jacquot [CNRS, from Jul 2018]

**Visiting Scientists**

Marie Charbonneau [Italian Institute of Technology, from Jan 2018 to Nov. 2018]
Niels Justesen [IT University of Copenhagen, from Sep 2018 until Nov 2018]
Moe Matsuki [Kyushu Institute of Technology Japan, from Sep 2018 until 23 dec 2018]
Debaleena Misra [Agence Erasmus+ France, from Feb 2018 until Aug 2018]

**External Collaborators**

Ludivine Allienne-Diss [Univ Jules Vernes Picardie, until Feb 2018]

Augusto Cesar Francisco [Univ. of Technology Dresden, Germany, from Jun 2018 until Nov 2018]
Valerio Modugno [Univ Sapienza, from Jun 2018]

# 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 [34], [42]. 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 [34], [40].

### 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 [39].

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 [33] 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 [48], [40]. However, current reinforcement learning algorithms require hundreds of trials/episodes to learn a single, often simplified, task [40], 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 [41], [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 [38]. 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 [46], [38], [32]).

## 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 [51]. Most Human-Robot Interaction (HRI) studies focus on verbal communication [47] 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 [49] and robotic co-workers [44]. 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 [35].

**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) [50] 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 [37], 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 [36]. 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

BEST PAPER AWARD:

[17]
A. GAIER, A. ASTEROTH, J.-B. MOURET. *Data-efficient Neuroevolution with Kernel-Based Surrogate Models*, in "GECCO 2018 - Genetic and Evolutionary Computation Conference", Kyoto, Japan, July 2018, https://arxiv.org/abs/1804.05364 [*DOI :* 10.1145/3205455.3205510], https://hal.inria.fr/hal-01768248

# 6. New Software and Platforms

## 6.1. Limbo

*LIbrary for Model-based Bayesian Optimization*
KEYWORDS: Black-box optimization - C++ - Global optimization - Machine learning - Policy Learning - Bayesian optimization - Gaussian processes

[1] See the Robotics 2020 Multi-Annual Roadmap [43].
[2] OHS (*Office d'Hygiène Sociale*) is an association managing several rehabilitation or retirement home structures.
[3] See the Robotics 2020 Multi-Annual Roadmap [43], section 2.5.

FUNCTIONAL DESCRIPTION: Limbo is an open-source C++11 library for Gaussian processes and Bayesian Optimization which is designed to be both highly flexible and very fast. It can be used to optimize functions for which the gradient is unknown, evaluations are expensive, and where runtime cost matters (e.g., on embedded systems or robots). Benchmarks on standard functions show that Limbo is about 2 times faster than BayesOpt (another C++ library) for a similar accuracy.
NEWS OF THE YEAR: - publication of a paper in the Journal of Open Source Software - several bug fixes and performance improvement

- Partners: UPMC - Imperial College London
- Contact: Jean-Baptiste Mouret
- Publication: Limbo: A Flexible High-performance Library for Gaussian Processes modeling and Data-Efficient Optimization
- URL: http://www.resibots.eu/limbo

## 6.2. sferes2

*A lightweight generic C++ framework for evolutionary computation*
KEYWORDS: Evolutionary Algorithms - Evolution - Global optimization - Multi-objective optimisation
FUNCTIONAL DESCRIPTION: Sferes2 is a high-performance, multi-core, lightweight, generic C++11 framework for evolutionary computation. It is intently kept small to stay reliable and understandable.

Sferes2 relies heavily on template-based meta-programming in C++ to get both abstraction and execution speed.
NEWS OF THE YEAR: - integration of a new set of classes for quality diversity, based on Antoine Cully's paper (IEEE TEC, 2018) - new documentation in Sphinx - new random generator (more thread safe, C++11) - drop the C++98 support (now C++11 only)

- Partner: UPMC
- Contact: Jean-Baptiste Mouret
- Publication: Sferes_v2: Evolvin' in the Multi-Core World
- URL: http://github.com/sferes2/sferes2/

## 6.3. xsens_driver

KEYWORD: IMU driver
FUNCTIONAL DESCRIPTION: This is a driver for the third and fourth generation of Xsens IMU devices. The driver is in two parts, a small implementation of most of the MT protocol in Python and a ROS node. It works both on serial and USB interfaces.

These MT* devices can store their configuration and will retrieve it at each boot and then stream data according to this configuration. The node only forwards the data streamed onto ROS topics. In order to configure your device, you can use the mtdevice.py script (or the vendor tool on Windows).

RELEASE FUNCTIONAL DESCRIPTION: bug fixes
NEWS OF THE YEAR: version 2.1.0 (2017-04-14) - several bugfixes and a new option.

- Contact: Francis Colas
- URL: https://github.com/ethz-asl/ethzasl_xsens_driver

## 6.4. SeekPlans

KEYWORDS: Robotics - Depth map

FUNCTIONAL DESCRIPTION: The SeekPlanes software is a high-performance C99 micro library which seeks planes in a depth image. It provides the height, the pitch and the roll of the camera that takes the image, in order to use the same orthonormal model for multi-camera acquisition. In addition, this library provides all the image planes: walls, ceiling, but also the top of a table or a bed, etc. Ultra fast, written in full portable C99 with optional X86 vectorizations (SSE and/or AVX), it has been tested on Linux and Windows, in 32 and 64 bits, and also on a Raspberry PI model 3.

- Contact: François Charpillet

# 7. New Results

## 7.1. Lifelong Autonomy

### *7.1.1. Foundations of Reinforcement Learning*

*7.1.1.1. $\rho$-POMDPs have Lipschitz-Continuous $\epsilon$-Optimal Value Functions*

**Participant:** Vincent Thomas.

*Collaboration with Jilles Dibangoye (INSA Lyon).*

Many state-of-the-art algorithms for solving Partially Observable Markov Decision Processes (POMDPs) rely on turning the problem into a “fully observable” problem—a belief MDP—and exploiting the piece-wise linearity and convexity (PWLC) of the optimal value function in this new state space (the belief simplex $\Delta$). This approach has been extended to solving $\rho$-POMDPs—i.e., for information-oriented criteria-when the reward $\rho$ is convex in $\Delta$. General $\rho$-POMDPs can also be turned into “fully observable” problems, but with no means to exploit the PWLC property. In this paper, we focus on POMDPs and $\rho$-POMDPs with $\lambda$ $\rho$-Lipschitz reward function, and demonstrate that, for finite horizons, the optimal value function is Lipschitz-continuous. Then, value function approximators are proposed for both upper-and lower-bounding the optimal value function, which are shown to provide uniformly improvable bounds. This allows proposing two algorithms derived from HSVI which are empirically evaluated on various benchmark problems.

Publication: [14]

*7.1.1.2. Addressing Active Sensing Problem through MCTS*

**Participants:** Vincent Thomas, Geremy Hutin.

The problem of active sensing is of paramount interest for building self awareness in robotic systems. It consists of a system to make decisions in order to gather information (measured through the entropy of the probability distribution over unknown variables) in an optimal way.

In the past, we have proposed an original formalism *$\rho$-POMDP* and new algorithms for representing and solving active sensing problems [33] by using point-based algorithms. This year, new approaches based on Monte-Carlo Tree Search algorithms (MCTS) and Partially Observable Monte-Carlo Planning (POMCP) [45] have been proposed to build the policies of an agent whose aim is to gather information.

### *7.1.2. Robot Learning*

*Our main objective is to design data-efficient trial-and-error learning algorithms (reinforcement learning) that can work with continuous states and continuous actions. The main use-case is robot damage recovery: a robot has to to discover new behaviors by trial-and-error without a diagnosis of the damage.*

*7.1.2.1. Adaptive and Resilient Soft Tensegrity Robots*

**Participant:** Jean-Baptiste Mouret.

*Collaboration with John Rieffel (Union College, USA).*

Living organisms intertwine soft (e.g., muscle) and hard (e.g., bones) materials, giving them an intrinsic flexibility and resiliency often lacking in conventional rigid robots. The emerging field of soft robotics seeks to harness these same properties to create resilient machines. The nature of soft materials, however, presents considerable challenges to aspects of design, construction, and control—and up until now, the vast majority of gaits for soft robots have been hand-designed through empirical trial-and-error. In this contribution, we introduced an easy-to-assemble tensegrity-based soft robot capable of highly dynamic locomotive gaits and demonstrating structural and behavioral resilience in the face of physical damage. Enabling this is the use of a machine learning algorithm able to discover effective gaits with a minimal number of physical trials. These results lend further credence to soft-robotic approaches that seek to harness the interaction of complex material dynamics to generate a wealth of dynamical behaviors.

Publication: [10]

*7.1.2.2. Bayesian Optimization with Automatic Prior Selection for Data-Efficient Direct Policy Search*

**Participants:** Konstantinos Chatzilygeroudis, Jean-Baptiste Mouret.

One of the most interesting features of Bayesian optimization for direct policy search is that it can leverage priors (e.g., from simulation or from previous tasks) to accelerate learning on a robot. In this contribution, we are interested in situations for which several priors exist but we do not know in advance which one fits best the current situation. We tackle this problem by introducing a novel acquisition function, called Most Likely Expected Improvement (MLEI), that combines the likelihood of the priors and the expected improvement. We evaluate this new acquisition function on a transfer learning task for a 5-DOF planar arm and on a possibly damaged, 6-legged robot that has to learn to walk on flat ground and on stairs, with priors corresponding to different stairs and different kinds of damages. Our results show that MLEI effectively identifies and exploits the priors, even when there is no obvious match between the current situations and the priors.

Publication: [23]

*7.1.2.3. Multi-objective Model-based Policy Search for Data-efficient Learning with Sparse Rewards*

**Participants:** Rituraj Kaushik, Konstantinos Chatzilygeroudis, Jean-Baptiste Mouret.

The most data-efficient algorithms for reinforcement learning in robotics are model-based policy search algorithms, which alternate between learning a dynamical model of the robot and optimizing a policy to maximize the expected return given the model and its uncertainties. However, the current algorithms lack an effective exploration strategy to deal with sparse or misleading reward scenarios: if they do not experience any state with a positive reward during the initial random exploration, they are very unlikely to solve the problem. To address this challenge, we proposed a novel model-based policy search algorithm, Multi-DEX, that leverages a learned dynamical model to efficiently explore the task space and solve tasks with sparse rewards in a few episodes. To achieve this, we frame the policy search problem as a multi-objective, model-based policy optimization problem with three objectives: (1) generate maximally novel state trajectories, (2) maximize the cumulative reward and (3) keep the system in state-space regions for which the model is as accurate as possible. We then optimize these objectives using a Pareto-based multi-objective optimization algorithm. The experiments show that Multi-DEX is able to solve sparse reward scenarios (with a simulated robotic arm) in much lower interaction time than VIME, TRPO, GEP-PG, CMA-ES and Black-DROPS.

Publication: [18]

*7.1.2.4. Using Parameterized Black-Box Priors to Scale Up Model-Based Policy Search for Robotics*

**Participants:** Konstantinos Chatzilygeroudis, Jean-Baptiste Mouret.

Among the few model-based policy search algorithms, the recently introduced Black-DROPS algorithm exploits a black-box optimization algorithm to achieve both high data-efficiency and good computation times when several cores are used; nevertheless, like all model-based policy search approaches, Black-DROPS does not scale to high dimensional state/action spaces. In this paper, we introduce a new model learning procedure in Black-DROPS that leverages parameterized black-box priors to (1) scale up to high-dimensional systems, and (2) be robust to large inaccuracies of the prior information. We demonstrate the effectiveness of our approach with the “pendubot” swing-up task in simulation and with a physical hexapod robot (48D state space, 18D action space) that has to walk forward as fast as possible. The results show that our new algorithm is more data-efficient than previous model-based policy search algorithms (with and without priors) and that it can allow a physical 6-legged robot to learn new gaits in only 16 to 30 seconds of interaction time.

Publication: [12]

*7.1.2.5. Data-efficient Neuroevolution with Kernel-Based Surrogate Models*

**Participants:** Adam Gaier, Jean-Baptiste Mouret.

*Collaboration with Alexander Asteroth (Hochschule Bonn-Rhein-Sieg, Germany)*

Surrogate-assistance approaches have long been used in computationally expensive domains to improve the data-efficiency of optimization algorithms. Neuroevolution, however, has so far resisted the application of these techniques because it requires the surrogate model to make fitness predictions based on variable topologies, instead of a vector of parameters. Our main insight is that we can sidestep this problem by using kernel-based surrogate models, which require only the definition of a distance measure between individuals. Our second insight is that the well-established Neuroevolution of Augmenting Topologies (NEAT) algorithm provides a computationally efficient distance measure between dissimilar networks in the form of "compatibility distance", initially designed to maintain topological diversity. Combining these two ideas, we introduce a surrogate-assisted neuroevolution algorithm that combines NEAT and a surrogate model built using a compatibility distance kernel. We demonstrate the data-efficiency of this new algorithm on the low dimensional cart-pole swing-up problem, as well as the higher dimensional half-cheetah running task. In both tasks the surrogate-assisted variant achieves the same or better results with several times fewer function evaluations as the original NEAT.

Publication: [17] (best paper, GECCO 2018, Complex System track)

*7.1.2.6. Alternating Optimization and Quadrature for Robust Control*

**Participants:** Konstantinos Chatzilygeroudis, Jean-Baptiste Mouret.

*Collaboration with Shimon Whiteson (Oxford, UK).*

Bayesian optimization has been successfully applied to a variety of reinforcement learning problems. However, the traditional approach for learning optimal policies in simulators does not utilise the opportunity to improve learning by adjusting certain environment variables — state features that are randomly determined by the environment in a physical setting but are controllable in a simulator. In this wwork, we consider the problem of finding an optimal policy while taking into account the impact of environment variables. We present alternating optimization and quadrature (ALOQ), which uses Bayesian optimization and Bayesian quadrature to address such settings. ALOQ is robust to the presence of significant rare events, which may not be observable under random sampling, but have a considerable impact on determining the optimal policy. The experimental results demonstrate that our approach learns more efficiently than existing methods.

Publication: [22]

*7.1.2.7. Learning robust task priorities of QP-based whole-body torque-controllers*

**Participants:** Marie Charbonneau, Serena Ivaldi, Valerio Modugno, Jean-Baptiste Mouret.

Generating complex whole-body movements for humanoid robots is now most often achieved with multi-task whole-body controllers based on quadratic programming. To perform on the real robot, such controllers often require a human expert to tune or optimize the many parameters of the controller related to the tasks and to the specific robot, which is generally reported as a tedious and time consuming procedure. This problem can be tackled by automatically optimizing some parameters such as task priorities or task trajectories, while ensuring constraints satisfaction, through simulation. However, this does not guarantee that parameters optimized in simulation will also be optimal for the real robot. As a solution, the present paper focuses on optimizing task priorities in a robust way, by looking for solutions which achieve desired tasks under a variety of conditions and perturbations. This approach, which can be referred to as domain randomization, can greatly facilitate the transfer of optimized solutions from simulation to a real robot. The proposed method is demonstrated using a simulation of the humanoid robot iCub for a whole-body stepping task.

Publication: [11]

### 7.1.3. Quality Diversity Algorithms

*Quality diversity algorithms are a new kind of evolutionary algorithms that focuses on finding a large set of high-performing solutions (instead of the global optimum). We use them for design and as a step for data-efficient robot learning.*

#### 7.1.3.1. Data-Efficient Design Exploration through Surrogate-Assisted Illumination

**Participants:** Adam Gaier, Jean-Baptiste Mouret.

*Collaboration with Alexander Asteroth (Hochschule Bonn-Rhein-Sieg, Germany)*

Design optimization techniques are often used at the beginning of the design process to explore the space of possible designs. In these domains illumination algorithms, such as MAP-Elites, are promising alternatives to classic optimization algorithms because they produce diverse, high-quality solutions in a single run, instead of only a single near-optimal solution. Unfortunately, these algorithms currently require a large number of function evaluations, limiting their applicability. In this work, we introduce a new illumination algorithm, Surrogate-Assisted Illumination (SAIL), that leverages surrogate modeling techniques to create a map of the design space according to user-defined features while minimizing the number of fitness evaluations. On a 2-dimensional airfoil optimization problem SAIL produces hundreds of diverse but high-performing designs with several orders of magnitude fewer evaluations than MAP-Elites or CMA-ES. We demonstrate that SAIL is also capable of producing maps of high-performing designs in realistic 3-dimensional aerodynamic tasks with an accurate flow simulation. Data-efficient design exploration with SAIL can help designers understand what is possible, beyond what is optimal, by considering more than pure objective-based optimization.

Publication: [7]

#### 7.1.3.2. Discovering the Elite Hypervolume by Leveraging Interspecies Correlation

**Participants:** Vassilis Vassiliades, Jean-Baptiste Mouret.

Evolution has produced an astonishing diversity of species, each filling a different niche. Algorithms like MAP-Elites mimic this divergent evolutionary process to find a set of behaviorally diverse but high-performing solutions, called the elites. Our key insight is that species in nature often share a surprisingly large part of their genome, in spite of occupying very different niches; similarly, the elites are likely to be concentrated in a specific "elite hypervolume" whose shape is defined by their common features. In this paper, we first introduce the elite hypervolume concept and propose two metrics to characterize it: the genotypic spread and the genotypic similarity. We then introduce a new variation operator, called “directional variation”, that exploits interspecies (or inter-elites) correlations to accelerate the MAP-Elites algorithm. We demonstrate the effectiveness of this operator in three problems (a toy function, a redundant robotic arm, and a hexapod robot).

Publication: [25]

#### 7.1.3.3. Maintaining Diversity in Robot Swarms with Distributed Embodied Evolution

**Participants:** Amine Boumaza, François Charpillet.

We investigated how behavioral diversity can be maintained in evolving robot swarms by using distributed Embodied Evolution. In these approaches, each robot in the swarm runs a separate evolutionary algorithm, and populations on each robot are built through local communication when robots meet; therefore, genome survival results not only from fitness-based selection but also from spatial spread. To better understand how diversity is maintained in distributed embodied evolution, we propose a postanalysis diversity measure — global diversity (over the swarm), and local diversity (on each robot) —, on two swarm robotic tasks — navigation and item collection —, with different intensities of selection pressure, and compare the results of distributed embodied evolution to a centralized case. We conclude that distributed evolution intrinsically maintains a larger behavioral diversity when compared to centralized evolution, which allows for the search algorithm to reach higher performances, especially in the more challenging collection task.

Publication: [16]

## 7.2. Natural Interaction with Robotics Systems

### *7.2.1. Control of Interaction*

*Because of the AnDy project, we are currently focused on interaction in industrial contexts, in particular to encourage ergonomic motions.*

#### *7.2.1.1. Robust Real-time Whole-Body Motion Retargeting from Human to Humanoid*

**Participants:** Serena Ivaldi, Luigi Penco, Brice Clement, Jean-Baptiste Mouret.

Transferring the motion from a human operator to a humanoid robot is a crucial step to enable robots to learn from and replicate human movements. The ability to retarget in real-time whole-body motions that are challenging for the humanoid balance is critical to enable human to humanoid teleoperation. In this work, we design a retargeting framework that allows the robot to replicate the motion of the human operator, acquired by a wearable motion capture suit, while maintaining the whole-body balance. We introduce some dynamic filter in the retargeting to forbid dangerous motions that can make the robot fall. We validate our approach through several experiments on the iCub robot, which has a significantly different body structure and size from the one of the human operator.

Publication: [24]

#### *7.2.1.2. Prediction of Human Whole-Body Movements with AE-ProMPs*

**Participants:** Serena Ivaldi, Oriane Dermy, Francis Colas, François Charpillet.

The ability to predict intended movements is crucial for collaborative robots to anticipate the human actions and for assistive technologies to alert if a particular movement is non-ergonomic and potentially dangerous for humans. In this paper, we address the problem of predicting the future human whole-body movements given early observations. We propose to predict the continuation of the high-dimensional trajectories mapped into a reduced latent space, using autoencoders (AE). The prediction is based on a probabilistic description of the movement primitives (ProMPs) in the latent space, which notably reduces the computational time for the prediction to occur, and hence enables to use the method in real-time applications. We evaluate our method, named AE-ProMPs, for predicting future movements belonging to a dataset of 7 different actions performed by a human, recorded by a wearable motion tracking suit.

Publication: [13]

Publications: [28],

### *7.2.2. Generating Assistive Humanoid Motions for Co-Manipulation Tasks with a Multi-Robot Quadratic Program Controller*

**Participants:** Karim Bouyarmane, Serena Ivaldi.

Human-humanoid collaborative tasks require that the robot takes into account the goals of the task, interaction forces with the human, and its own balance. We present a formulation for a real-time humanoid controller which allows the robot to keep itself stable, while also assisting the human in achieving their shared objectives. This is achieved with a multi-robot quadratic program controller, which solves for human motion reconstruction and optimal robot controls in a single optimization problem. Our experiments on a simulated robot platform demonstrate the ability to generate interactions motions and forces that are similar to what a human collaborator would produce.

Publication: [21]

#### *7.2.2.1. Activity Recognition With Multiple Wearable Sensors for Industrial Applications*

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

We address the problem of recognizing the current activity performed by a human operator, providing an information useful for automatic ergonomic evaluation for industrial applications. While the majority of research in activity recognition relies on cameras observing the human, here we explore the use of wearable sensors, which are more suitable in industrial environments. We use a wearable motion tracking suit and a sensorized glove. We describe our approach for activity recognition with a probabilistic model based on Hidden Markov Models, applied to the problem of recognizing elementary activities during a pick-and-place task inspired by a manufacturing scenario. We show that our model is able to correctly recognize the activities with 96% of precision if both sensors are used.

Publication: [19],[19]

*7.2.2.2. Activity Recognition for monitoring eldely people at home*

**Participants:** Yassine El Khadiri, François Charpillet.

Early detection of frailty signs is important for senior people who prefer to keep living in their homes instead of moving to a nursing home. Sleep quality is a good predictor for frailty monitoring. Thus we are interested in tracking sleep parameters like sleep wake patterns to predict and detect potential sleep disturbances of the monitored senior residents. We use an unsupervised inference method based on actigraphy data generated by ambient motion sensors scattered around the senior's apartment. This enables our monitoring solution to be flexible and robust to the different types of housings it can equip while still attaining accuracy of 0.94 for sleep period estimates.

Publication: [15]

### *7.2.3. Ethics*

*7.2.3.1. Ethical and Social Considerations for the Introduction of Human-Centered Technologies at Work*

**Participants:** Serena Ivaldi, Adrien Malaisé, Pauline Maurice, Ludivine Allienne.

Human-centered technologies such as collaborative robots, exoskeletons, and wearable sensors are rapidly spreading in industry and manufacturing because of their intrinsic potential at assisting workers and improving their working conditions. The deployment of these technologies, albeit inevitable, poses several ethical and societal issues. Guidelines for ethically aligned design of autonomous and intelligent systems do exist, however we argue that ethical recommendations must necessarily be complemented by an analysis of the social impact of these technologies.

In a recent paper[20], we report on our preliminary studies on the opinion of factory workers and of people outside this environment on human-centered technologies at work. In light of these studies, we discuss ethical and social considerations for deploying these technologies in a way that improves acceptance.

Publication: [20]

# 8. Bilateral Contracts and Grants with Industry

## 8.1. Cifre Diatelic-Pharmagest

**Participants:** François Charpillet, Yassine El Khadiri, Cedric Rose, Gabriel Corona.

Cedric Rose and Gabriel Corona are from Diatelic.

The ageing of the population and the increase in life expectancy will confront modern societies with an unprecedented demographic transformation. The placement of older people in a nursing home (EPHAD) is often only a choice of reason and can be rather poorly experienced by people. One answer to this societal problem is the development of Smart home technologies that facilitate elderly to stay in their homes longer than they can do today. This new collaboration with Diatelic a subsidiary of the Pharmagest group is supported through a PhD thesis (Cifre) which started in June 2017. The objective is to enhance the CareLib solution developed by Diatelic and Larsen Team through a previous collaboration (Satelor project). The Carelib offer is a solution, consisting of

- a connected box (with touch screen),
- a 3D sensor (capable (1)to measure characteristics of the gait such as the speed and step length, (2) to identify Activities of Daily Life and (3) to detect emergency situation such as Fall),
- universal sensors (motion, ...) installed in each part of the housing.

The objective of the PhD program is to provides personalized follow-up by learning life habits, the main objective being to track the Activities of Daily Life (ADL) and detect emergency situations needing external interventions (E.G fall detection). This year we have developed an algorithm capable to detect sleep-wake cycles using only motion sensors. The approach is based on bayesian inference. The algorithms have been evaluated using publicly available dataset and Diatelic's own dataset.

## 8.2. Cifre iFollow

**Participants:** Francis Colas, Jérôme Truc, Cédric Pradalier, Susana Sanchez Restrepo.

Cédric Pradalier is co-supervisor at GeorgiaTech Lorraine and Susana Sanchez Restrepo 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.

The PhD thesis of Jérôme Truc has started in September with bibliography work on human detection and pose estimation, as well as socially acceptable motion planning.

# 9. Partnerships and Cooperations

## 9.1. Regional Initiatives

### *9.1.1. Project PsyPhINe: Cogitamus ergo sumus*

Title: Cogitamus ergo sumus

Program: PEPS CNRS

Duration: January 2016 - January 2018

Coordinator: MSH Lorraine (USR3261)

LARSEN member: Amine Boumaza

Psyphine is an interdisciplinary and exploratory project (see 9.1.1) between philosophers, psychologists and computer scientists. The goal of the project is related to cognition and behavior. Cognition is a set of processes that are difficult to unite in a general definition. The project aims to explore the idea of assignments of intelligence or intentionality, assuming that our intersubjectivity and our natural tendency to anthropomorphize play a central role: we project onto others parts of our own cognition. To test these hypotheses, our aim is to design a "non-verbal" Turing Test, which satisfies the definitions of our various fields (psychology, philosophy, neuroscience and computer science) using a robotic prototype. Some of the questions that we aim to answer are: is it possible to give the illusion of cognition and/or intelligence through such a technical device? How elaborate must be the control algorithms or "behaviors" of such a device so as to fool test subjects? How many degrees of freedom must it have?

Partner institutions: InterPsy (EA 4432), APEMAC, EPSaM (EA4360), Archives Henri-Poincaré (UMR7117), Inria Bordeaux Sud-Ouest, Loria (UMR7503) and MSH Lorraine (USR3261).

## 9.2. European Initiatives

### *9.2.1. FP7 & H2020 Projects*

#### *9.2.1.1. 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.

#### *9.2.1.2. 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. International Initiatives

### *9.3.1. Lifelong Learning Machines program (DARPA) — STELLAR project*

Title: STELLAR (Super Turing Evolving Lifelong Learning ARchitecture)

Coordinator: HRL laboratory (Malibu, USA)

Coordinator for Inria: Jean-Baptiste Mouret

Partners: Stanford University (USA), University of California Irvine (USA), University of Texas Austin (USA), IT University of Copenhagen (Denmark), Loughborough University (United Kingdom), Inria – Nancy Grand Est

Objective: Develop a general-purpose neural super Turing machine for lifelong learning and demonstrate supra-human performance in a simulated autonomous driving context. Our Super Turing Evolving Lifelong Learning ARchitecture (STELLAR) system will power a self-driving agent that continually improves its performance and updates its knowledge unsupervised, rapidly adapts to unforeseen contexts, and learns and consolidates new tasks without forgetting old ones. The project involves deep world models, neuroevolution, quality diversity algorithms, and plastic neural networks.

#### *9.3.1.1. Informal International Partners*

- Oxford University (Shimon Whiteson): data-efficient robot learning[22]
- Union College (John Rieffel): resilient tensegrity robots [10]
- Italian Institute of Technology (Enrico Mingo-Hoffman, Daniele Pucci, Nikos Tsagarakis): whole-body control of humanoids [11], [24], [27]
- IT University Copenhagen (Sebastian Risi): quality diversity algorithms
- Imperial College (Antoine Cully): data-efficient learning and quality diversity
- Hochschule Bonn-Rhein-Sieg (Alexander Asteroth): surrogate modelling [17], [7]
- Kyushu Institute of Technology, Japan (Sozo Inoue, Moe Matsuki): activity recognition

## 9.4. International Research Visitors

### *9.4.1. Visits of International Scientists*

- Enrico Mingo Hoffman (Post-doc, Italian Institute of Technology) – from Feb 2018 to Feb 2018

- Niels Justesen (PhD student, IT University Copenhagen, Denmark) – from Sep 2018 to Dec 2018
- Marie Charbonneau (PhD student, IIT, Italy) – from May 2018 to Oct 2018
- Moe Matsuki (PhD student, Kyushu Institute of Technology, Japan) –fom sept 2018 to Dec 2018

# 10. Dissemination

## 10.1. Promoting Scientific Activities

### *10.1.1. Scientific Events Organisation*

#### *10.1.1.1. General chair, scientific chair*

- Co-organized the French days for Humanoid Robotics (JNRH – "Journées Nationales de la Robotique Humanoïde"), sponsored by the GT7 of the GDR Robotics [Serena Ivaldi, Karim Bouyarmane, Pauline Maurice, Jean-Baptiste Mouret, François Charpillet]
- Co-organized an international workshop at IROS 2018 (*Assistance and Service Robotics in a Human Environment*) [Francis Colas]
- Co-organized an international workshop at IEA 2018 (*Collaborative Robotics and Ergonomics*) [Pauline Maurice, Serena Ivaldi]

#### *10.1.1.2. Member of the Organizing Committees*

- Publicity chair for IEEE ARSO 2018 (Advances in Robotics and its Social Impact) [Serena Ivaldi]
- Co-organized the JFPDA2018 ("Journées Francophones sur la Planification, la Décision et l'Apprentissage pour la conduite de systèmes") [Vincent Thomas]
- Co-organized the Robotics and Artificial Intelligence day at the JFPDA 2018 [Serena Ivaldi]

### *10.1.2. Special issues*

- Co-edited a special issue about "Human-Robot Interaction" in ERCIM News [Serena Ivaldi].

### *10.1.3. Scientific Events Selection*

#### *10.1.3.1. Member of the Conference Program Committees*

- Associate Editor for IEEE Humanoids 2018 [Serena Ivaldi]
- Robotics Science and Systems (RSS) [Serena Ivaldi]
- ALIFE 2018 (European Conference on Artificial Life) [Amine Boumaza, Jean-Baptiste Mouret]
- EVO* 2018 (EvoStar) [Jean-Baptiste Mouret]
- GECCO2018 (Genetic and Evolutionary Computation Conference) [Amine Boumaza, Jean-Baptiste Mouret]
- CEC 2018 (Congress on Evolutionary Computation) [Amine Boumaza]
- ICAART 2018(International Conference on Agents and Artificial Intelligence)[François Charpillet]
- IJCAI-ECAI 2018 (International Joint Conference on Artificial Intelligence and European Conference on Artificial Intelligence [François Charpillet]
- AAAI 2019 (AAAI Conference on Artificial Intelligence) [François Charpillet]

#### *10.1.3.2. Reviewer for Peer-reviewed Conferences*

- CoRL (Conference on Robot Learning) [Jean-Baptiste Mouret, Konstantinos Chatzilygeroudis]
- ICRA 2019 (2019 IEEE International Conference on Robotics and Automation) [Karim Bouyarmane, Francis Colas, Serena Ivaldi, Jean-Baptiste Mouret]
- IJCAI ECAI 2018 (27th International Joint Conference on Artificial Intelligence and the 23rd European Conference on Artificial Intelligence) [Francis Colas, Vincent Thomas]

- IROS 2018 (IEEE/RSJ International Conference on Intelligent Robots and Systems) [Karim Bouyarmane, Francis Colas, Jean-Baptiste Mouret]
- HUMANOIDS 2018 (IEEE/RSJ International Conference on Humanoid Robots) [Francis Colas]
- IEEE ARSO 2018 (Advanced Robotics and its Social Impact) [Serena Ivaldi]

### 10.1.4. Journal

#### 10.1.4.1. Member of the Editorial Boards

- IEEE Robotics and Automation Letters [Serena Ivaldi, associate editor]
- Frontiers in AI and Robotics [Amine Boumaza, Serena Ivaldi, Jean-Baptiste Mouret]

#### 10.1.4.2. Reviewer - Reviewing Activities

- Journal of Field Robotics [Francis Colas]
- Robotics and Automation Letters [Francis Colas]
- IEEE Robotics and Automation Letters [Jean-Baptiste Mouret, Serena Ivaldi]
- IEEE Transactions on Robotics [Serena Ivaldi]
- Autonomous Robots [Serena Ivaldi]
- CEAS Aeronautical Journal [Alexis Scheuer]

### 10.1.5. Scientific expertise

- Serena Ivaldi evaluated a project for the Université Libre de Bruxelles.

### 10.1.6. Invited Talks

- Jean-Baptiste Mouret gave a keynote at the CONTROLO 2018 conference (13th APCA International Conference on Automatic Control and Soft Computing, in Ponta Delgada, São Miguel Island, Azores, Portugal), and invited talks at the IEEE ICRA 2018 workshop “Self-healing, Growing and Evolving Soft Robots” (Brisbane, Australia), the IEEE ICRA 2018 workshop “Autonomous Robot Design”, the Frontiers Research and Artificial Intelligence Workshop organized by the ERC (Bruxelle, Belgium), the German-French Conference on Humanoids and Legged Robots (Munich, Germany), the French Academy of Science and Leopolodina symposium “Data Science versus Motion Intelligence” (Paris, France), the Workshop on Learning Applications for Intelligent Autonomous Robots organized at the IAS 15 Conference (Baden Baden, Germany), as well as at Uber AI labs (San Francisco, California), the Advanced Telecommunications Research (ATR, near Kyoyo, Japan), and Safran R&D (Saclay, France).
- Serena Ivaldi gave an invited talk at the Workshop on Learning Applications for Intelligent Autonomous Robots organized at the IAS 15 Conference (Baden Baden, Germany) and at the atelier santé of the Journée Federation Charles Hermite (Nancy).
- Adrien Malaisé gave an invited talk at IEEE ARSO 2018 (Genova, Italy).

### 10.1.7. Research administration

- Francis Colas is member of the local commissions:
  - “Commission des Utilisateurs des Moyens Informatiques” (CUMI),
  - “Commission de Développement Technologique” (CDT),
  - “Comité du Centre Inria Nancy Grand-Est”,
  - “bureau de la Commission de la Mention Informatique” (CMI) of the IAEM doctoral school.
- Serena Ivaldi was a member of the commitee for the researcher selection at Inria Nancy Grand Est (Jury CR),

- François Charpillet was a member of the commitee for professor selection at Université Technologique de Troyes (PR LM2S No 4049 “Traitement du signal”),
- François Charpillet was a member of the HCERES commitee for U2IS,
- François Charpillet is member of the scientific council of the GDR Robotics.

## 10.2. Teaching - Supervision - Juries

### *10.2.1. Teaching*

Master: Pauline Maurice, “Analyse du comportement”, 16 eq. TD, M2 “Sciences Cognitives”, Univ. Lorraine, France

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

Master: Francis Colas, “ROS”, 6h eq. TD, M1, Mines de Nancy, France.

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

Master : Vincent Thomas, “Apprentissage numérique”, 15h eq. TD, M2, Université de Lorraine, France.

Master : Vincent Thomas, “Optimisation et métaheuristique”, 15h eq. TD, M1, Université de Lorraine, France.

Master : Vincent Thomas, “Game Design”, 16h eq. TD, M1, Université de Lorraine, France.

Master : Vincent Thomas, “Agents intelligents et collectifs”, 16h eq. TD, M1, Université de Lorraine, France.

Master : Vincent Thomas, “Serious Game”, 12h eq. TD, M2, Université de Lorraine, France.

Master : Alexis Scheuer, “Vie artificielle”, 22,5h eq. TD, M2, CentraleSupélec, France.

Master : Alexis Scheuer, “Introduction à la robotique mobile”, 30h eq. TD, M1, Université de Lorraine, France.

Master : Alexis Scheuer, “Boucle sensori-motrice et comportement autonome”, 15h eq. TD, M2, Université de Lorraine, France.

Master : Alexis Scheuer, “Modélisation et commande en robotique”, 16h eq. TD, M2, Université de Lorraine, France.

### *10.2.2. Supervision*

PhD: Konstantinos Chatzilygeroudis, 14 Dec. 2018, “*Micro-Data Reinforcement Learning for Adaptive Robots*”, started in Oct. 2015, Jean-Baptiste Mouret (advisor).

PhD: Oriane Dermy, 17 Dec. 2018, “*Prédiction de l’intention: du geste au mouvement corps complet*”, started Oct. 2015, François Charpillet (advisor), Serena Ivaldi

PhD in progress: Waldez Avedo Gomes Junior, “*Intelligent Collaboration between Humans and Robots*”, started in Oct. 2018, Jean-Baptiste Mouret (advisor), Serena Ivaldi

PhD in progress: Rituraj Kaushik, “Fast adaptation to damage by exploiting trajectory data”, started in Oct. 2016, Jean-Baptiste Mouret (advisor).

PhD in progress: Adam Gaier ,“*Optimisation aerodynamic design through illumination of surrogate models*”, started in June 2017, Jean-Baptiste Mouret (advisor), Alexander Asteroth.

PhD in progress: Vladislav Tempez, “*Apprentissage data-efficace de lois de commandes pour robots volants*”, started in Sept. 2018, Jean-Baptiste Mouret (advisor).

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

PhD in progress: Jérôme Truc, "*Apprentissage de comportement et interactions prédictives pour un robot d'assistance en environnement structuré*", started in September 2018, Francis Colas (advisor).

PhD in progress: Yassine El Khadiri, "*Apprentissage automatique pour l'assistance à l'autonomie à domicile*", started in September 2018, François Charpillet(advisor).

PhD in progress: Eloise Zehnder, "*Interaction entre technologie et personnes âgées : adaptabilité et acceptabilité des technologies d'assistance (AT) à domicile*", François Charpillet, Jérome Dinet (advisors).

### *10.2.3. Juries*

- Francis Colas was a reviewer for the PhD of Marie-Lou Barnaud (Univ. Grenoble Alpes).
- Serena Ivaldi was a reviewer for the PhD of Pavan Kanajar (Italian Institute of Technology, Italy).
- François Charpillet was a reviewer for the PhD of Nicolas Duminy (Univ. Bretagne Sud),
- François Charpillet was a reviewer for the PhD of Aurélien Massein (Univ. Côte d'Azur),
- François Charpillet was a reviewer for the PhD of Jules Waldhart (Univ. Fédérale Toulouse Midi-Pyrénées),
- François Charpillet was a reviewer for the PhD of Farhood Negin (Univ. Côte d'Azur),
- François Charpillet was a reviewer for the PhD of Mathieu Lelerre (Univ. Normandie),
- François Charpillet was a reviewer for the HDR of Dominique Vaufreydaz (Univ. Grenoble Alpes).

## 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*

- Jean-Baptiste Mouret gave interviews for France Culture (radio), France 3 Lorraine (TV), and Socialter (printed magazine)
- François Charpillet gave an interview which gave an article on Re.Med. La revue de la Recherche Médicale du CHRU de Nancy.

### *10.3.3. Education*

- Vincent Thomas was member of the organization comitee of the "24h des DUT informatique" event (Nancy, 2018) and organized the Artificial Intelligence competition during the event (218 students from 25 DUT of computer science).
- Serena Ivaldi is in the scientific committee for the robotics exhibition at the "Cité des sciences et de l'industrie" in Paris (starting in April 2019).
- Serena Ivaldi presented our activities in robotics at the Lycée Henri Loritz in Nancy

### *10.3.4. Interventions*

- Public workshop on robot programming with Thymio for the Ada Lovelace Day [Alexis Scheuer]
- Public workshop on robot programming with Thymio at "Fête de la Science" [Alexis Scheuer, Olivier Rochel, Francis Colas]
- The team showed demonstrations for the Ada Lovelace Day (around 20 female students)
- Participated to a panel at the "Forum des Sciences Cognitives" (Nancy, France) [Jean-Baptiste Mouret]
- Tutorials on "physics simulation" and "path planning" for teachers during "journées ISN-EPI" (Nancy, France) [Vincent Thomas]

### *10.3.5. Internal action*

- Jean-Baptiste Mouret gave a talk for the Colloquium organied by 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

[3] S. IVALDI, S. LEFORT, J. PETERS, M. CHETOUANI, J. PROVASI, E. ZIBETTI. *Towards engagement models that consider individual factors in HRI: on the relation of extroversion and negative attitude towards robot to gaze and speech during a human-robot assembly task*, in "International Journal of Social Robotics", June 2016, http://arxiv.org/abs/1508.04603

## Publications of the year

### Doctoral Dissertations and Habilitation Theses

[4] K. CHATZILYGEROUDIS. *Micro-Data Reinforcement Learning for Adaptive Robots*, Universite´ de Lorraine ; Inria Nancy - Grand Est (Villers-lès-Nancy, France), December 2018, https://tel.archives-ouvertes.fr/tel-01966770

[5] O. DERMY. *Movement Prediction: From Simple Gesture to Whole-Body Movements*, Université de Lorraine (Nancy), December 2018, https://tel.archives-ouvertes.fr/tel-01966873

### Articles in International Peer-Reviewed Journals

[6] A. CULLY, K. CHATZILYGEROUDIS, F. ALLOCATI, J.-B. MOURET. *Limbo: A Flexible High-performance Library for Gaussian Processes modeling and Data-Efficient Optimization*, in "Journal of Open Source Software", June 2018, vol. 3, n$^o$ 26 [*DOI :* 10.21105/JOSS.00545], https://hal.inria.fr/hal-01884299

[7] A. GAIER, A. ASTEROTH, J.-B. MOURET. *Data-Efficient Design Exploration through Surrogate-Assisted Illumination*, in "Evolutionary Computation", 2018, vol. 26, n$^o$ 3, pp. 381-410 [*DOI :* 10.1162/EVCOA_00231], https://hal.inria.fr/hal-01817505

[8] S. IVALDI. *Intelligent Human-Robot Collaboration with Prediction and Anticipation*, in "ERCIM News", 2018, https://hal.archives-ouvertes.fr/hal-01859614

[9] S. IVALDI, M. PATERAKI. *Introduction to the Special Theme on Human-Robot Interaction*, in "ERCIM News", 2018, https://hal.archives-ouvertes.fr/hal-01859728

[10] J. RIEFFEL, J.-B. MOURET. *Adaptive and Resilient Soft Tensegrity Robots*, in "soft robotics", 2018, vol. 5, n$^o$ 3, pp. 318–329, https://arxiv.org/abs/1702.03258 [*DOI :* 10.1089/SORO.2017.0066], https://hal.inria.fr/hal-01800749

## International Conferences with Proceedings


[11] M. CHARBONNEAU, V. MODUGNO, F. NORI, G. ORIOLO, D. PUCCI, S. IVALDI. *Learning robust task priorities of QP-based whole-body torque-controllers*, in "HUMANOIDS 2018 - IEEE-RAS 18th International Conference on Humanoid Robots", Beijing, China, November 2018, https://hal.archives-ouvertes.fr/hal-01895146

[12] K. CHATZILYGEROUDIS, J.-B. MOURET. *Using Parameterized Black-Box Priors to Scale Up Model-Based Policy Search for Robotics*, in "ICRA 2018 - International Conference on Robotics and Automation", brisbane, Australia, May 2018, https://arxiv.org/abs/1709.06917 , https://hal.inria.fr/hal-01768285

[13] O. DERMY, M. CHAVEROCHE, F. COLAS, F. CHARPILLET, S. IVALDI. *Prediction of Human Whole-Body Movements with AE-ProMPs*, in "IEEE-RAS 18th International Conference on Humanoid Robots (HUMANOIDS 2018)", Beijing, China, November 2018, https://hal.archives-ouvertes.fr/hal-01895148

[14] J. S. DIBANGOYE, M. FEHR, O. BUFFET, V. THOMAS, J. DIBANGOYE. *$\rho$-POMDPs have Lipschitz-Continuous $\epsilon$-Optimal Value Functions*, in "NIPS 2018 - Thirty-second Conference on Neural Information Processing Systems", Montréal, Canada, December 2018, https://hal.inria.fr/hal-01903685

[15] Y. EL KHADIRI, G. CORONA, C. ROSE, F. CHARPILLET. *Sleep Activity Recognition using Binary Motion Sensors*, in "ICTAI 2018 - 30th International Conference on Tools with Artificial Intelligence", Volos, Greece, IEEE, November 2018, https://hal.inria.fr/hal-01943463

[16] I. FERNÁNDEZ PÉREZ, A. BOUMAZA, F. CHARPILLET. *Maintaining Diversity in Robot Swarms with Distributed Embodied Evolution*, in "ANTS 2018 - International Conference on Swarm Intelligence", Rome, Italy, October 2018, https://hal.inria.fr/hal-01937119

[17] *Best Paper*
A. GAIER, A. ASTEROTH, J.-B. MOURET. *Data-efficient Neuroevolution with Kernel-Based Surrogate Models*, in "GECCO 2018 - Genetic and Evolutionary Computation Conference", Kyoto, Japan, July 2018, https://arxiv.org/abs/1804.05364 [*DOI :* 10.1145/3205455.3205510], https://hal.inria.fr/hal-01768248.

[18] R. KAUSHIK, K. CHATZILYGEROUDIS, J.-B. MOURET. *Multi-objective Model-based Policy Search for Data-efficient Learning with Sparse Rewards*, in "CoRL 2018 - Conference on Robot Learning", Zurich, Switzerland, October 2018, https://arxiv.org/abs/1806.09351 , https://hal.inria.fr/hal-01884294

[19] A. MALAISÉ, P. MAURICE, F. COLAS, F. CHARPILLET, S. IVALDI. *Activity Recognition With Multiple Wearable Sensors for Industrial Applications*, in "ACHI 2018 - Eleventh International Conference on Advances in Computer-Human Interactions", Rome, Italy, March 2018, https://hal.archives-ouvertes.fr/hal-01701996

[20] P. MAURICE, L. ALLIENNE, A. MALAISÉ, S. IVALDI. *Ethical and Social Considerations for the Introduction of Human-Centered Technologies at Work*, in "IEEE Workshop on Advanced Robotics and its Social Impacts (ARSO)", Genova, Italy, 2018, https://hal.archives-ouvertes.fr/hal-01826487

[21] K. OTANI, K. BOUYARMANE, S. IVALDI. *Generating Assistive Humanoid Motions for Co-Manipulation Tasks with a Multi-Robot Quadratic Program Controller*, in "ICRA 2018 - International Conference on Robotics and Automation", Brisbane, Australia, May 2018, https://hal.archives-ouvertes.fr/hal-01590678

[22] S. PAUL, K. CHATZILYGEROUDIS, K. CIOSEK, J.-B. MOURET, M. A. OSBORNE, S. WHITESON. *Alternating Optimisation and Quadrature for Robust Control*, in "AAAI 2018 - The Thirty-Second AAAI Conference on Artificial Intelligence", New Orleans, United States, February 2018, https://arxiv.org/abs/1605.07496 , https://hal.inria.fr/hal-01644063

[23] R. PAUTRAT, K. CHATZILYGEROUDIS, J.-B. MOURET. *Bayesian Optimization with Automatic Prior Selection for Data-Efficient Direct Policy Search*, in "ICRA 2018 - International Conference on Robotics and Automation", Brisbane, Australia, May 2018, https://arxiv.org/abs/1709.06919 , https://hal.inria.fr/hal-01768279

[24] L. PENCO, B. CLÉMENT, V. MODUGNO, E. M. HOFFMAN, G. NAVA, D. PUCCI, N. TSAGARAKIS, J.-B. MOURET, S. IVALDI. *Robust Real-time Whole-Body Motion Retargeting from Human to Humanoid*, in "HUMANOIDS 2018 - IEEE-RAS 18th International Conference on Humanoid Robots", Beijing, China, November 2018, https://hal.archives-ouvertes.fr/hal-01895145

[25] V. VASSILIADES, J.-B. MOURET. *Discovering the Elite Hypervolume by Leveraging Interspecies Correlation*, in "GECCO 2018 - Genetic and Evolutionary Computation Conference", Kyoto, Japan, July 2018, https://arxiv.org/abs/1804.03906 [*DOI :* 10.1145/3205455.3205602], https://hal.inria.fr/hal-01764739

### National Conferences with Proceedings

[26] O. BUFFET, J. S. DIBANGOYE, A. SAFFIDINE, V. THOMAS. *Recherche heuristique pour jeux stochastiques (à somme nulle)*, in "JFPDA 2018 - Journées Francophones sur la Planification, la Décision et l'Apprentissage pour la conduite de systèmes", Nancy, France, July 2018, pp. 1-8, https://hal.inria.fr/hal-01840591

### Conferences without Proceedings

[27] E. M. HOFFMAN, B. CLÉMENT, C. ZHOU, N. G. TSAGARAKIS, J.-B. MOURET, S. IVALDI. *Whole-Body Compliant Control of iCub: first results with OpenSoT*, in "IEEE/RAS ICRA Workshop on Dynamic Legged Locomotion in Realistic Terrains", Brisbane, Australia, May 2018, https://hal.archives-ouvertes.fr/hal-01790597

[28] A. MALAISÉ, P. MAURICE, F. COLAS, S. IVALDI. *Online Human Activity Recognition for Ergonomics Assessment*, in "SIAS 2018 - 9ème conférence internationale sur la sécurité des systèmes industriels automatisés", Nancy, France, October 2018, https://hal.archives-ouvertes.fr/hal-01808832

### Scientific Books (or Scientific Book chapters)

[29] S. IVALDI, B. UGURLU. *Chapter 35: Free Simulation Software and Library*, in "Humanoid Robotics: A Reference", Springer, June 2018, https://hal.archives-ouvertes.fr/hal-01614032

### Research Reports

[30] J. S. DIBANGOYE, O. BUFFET. *Learning to Act in Decentralized Partially Observable MDPs*, Inria Grenoble - Rhone-Alpes - CHROMA Team ; Inria Nancy, équipe LARSEN, June 2018, n° RR-9179, https://hal.inria.fr/hal-01809897

### Other Publications

[31] J. LEHMAN, J. CLUNE, D. MISEVIC, C. ADAMI, J. BEAULIEU, P. J. BENTLEY, S. BERNARD, G. BESLON, D. M. BRYSON, N. CHENEY, A. CULLY, S. DONCIUEX, F. C. DYER, K. O. ELLEFSEN, R. FELDT, S. FISCHER, S. FORREST, A. FRENOY, C. GAGNEÉ, L. L. GOFF, L. M. GRABOWSKI, B. HODJAT,

L. KELLER, C. KNIBBE, P. KRCAH, R. E. LENSKI, H. LIPSON, R. MACCURDY, C. MAESTRE, R. MIIKKULAINEN, S. MITRI, D. E. MORIARTY, J.-B. MOURET, A. D. NGUYEN, C. OFRIA, M. PARIZEAU, D. PARSONS, R. T. PENNOCK, W. F. PUNCH, T. S. RAY, M. SCHOENAUER, E. SHULTE, K. SIMS, K. O. STANLEY, F. TADDEI, D. TARAPORE, S. THIBAULT, W. WEIMER, R. WATSON, J. YOSINKSI. *The Surprising Creativity of Digital Evolution: A Collection of Anecdotes from the Evolutionary Computation and Artificial Life Research Communities*, March 2018, https://arxiv.org/abs/1803.03453 - working paper or preprint, https://hal.inria.fr/hal-01735473

## References in notes

[32] 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

[33] M. ARAYA-LÓPEZ, O. BUFFET, V. THOMAS, F. CHARPILLET. *A POMDP Extension with Belief-dependent Rewards*, in "Neural Information Processing Systems - NIPS 2010", Vancouver, Canada, Advances in Neural Information Processing Systems 23, MIT Press, December 2010, https://hal.inria.fr/inria-00535560

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

[35] 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

[36] 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

[37] 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

[38] 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

[39] 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

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

[41] 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

[42] 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

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

[44] 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

[45] D. Silver, J. Veness. *Monte-Carlo Planning in Large POMDPs*, in "Advances in Neural Information Processing Systems 23", Curran Associates, Inc., 2010, pp. 2164–2172

[46] 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

[47] N. Stefanov, A. Peer, M. Buss. *Role determination in human-human interaction*, in "3rd Joint EuroHaptics Conf. and World Haptics", 2009, pp. 51-56

[48] R. S. Sutton, A. G. Barto. *Introduction to Reinforcement Learning*, MIT Press, 1998

[49] 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

[50] 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

[51] 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