IN PARTNERSHIP WITH:
**CNRS**
**Université de Lorraine**

# Activity Report 2017

# 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:**

B2.5.3. - Assistance for elderly
B5.1. - Factory of the future
B5.6. - Robotic systems
B7.2.1. - Smart vehicles

# 1. Personnel

**Research Scientists**

François Charpillet [Team leader, Inria, Senior Researcher, HDR]
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Serena Ivaldi [Inria, Researcher]
Jean-Baptiste Mouret [Inria, Senior Researcher, HDR]

**Faculty Members**

Amine Boumaza [Univ de Lorraine, Associate Professor]
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Vincent Thomas [Univ de Lorraine, Associate Professor]

**Post-Doctoral Fellows**

Pauline Maurice [Inria, from Jun 2017]
Jonathan Spitz [Inria]
Vassilis Vassiliades [Inria, until Nov 2017]

**PhD Students**

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Konstantinos Chatzilygeroudis [Inria]
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Nassim Kalde [Univ de Lorraine, until 12 Dec 2017]
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**Technical staff**

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**Interns**

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Luigi Penco [Inria, from Oct 2017]
Antoine Pigne [Inria, from Mar 2017 until Sep 2017]
Kapil Sawant [Inria, from Jul 2017]

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Ludivine Allienne-Diss [Univ Jules Vernes Picardie, from Mar 2017]

# 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 [44], [56]. 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 [44], [53].

### *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 [51].

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 [43] 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 [64], [53]. However, current reinforcement learning algorithms require hundreds of trials/episodes to learn a single, often simplified, task [53], 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 [54], [2].

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 [50]. 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 [61], [50], [42]).

## 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 [67]. Most Human-Robot Interaction (HRI) studies focus on verbal communication [63] 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 [65] and robotic co-workers [59]. 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 [47].

**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) [66] is an approch 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 possible future positions (which can be very effective in case of occlusion). This direction has been tested with simulator and particle filters [49], and one promising direction would be to couple STAR with decision making formalisms like partially observable Markov decision processes, POMDPs). This would allow 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 might 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 [48]. 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 build 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

[1] See the Robotics 2020 Multi-Annual Roadmap [57].
[2] OHS (*Office d'Hygiène Sociale*) is an association managing several rehabilitation or retirement home structures.
[3] See the Robotics 2020 Multi-Annual Roadmap [57], section 2.5.

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

### *5.1.1. Awards*

- "2017 ISAL Award for Distinguished Young Investigator in the field of Artificial Life" to Jean-Baptiste Mouret
- "Prix du stage de recherche" awarded by the École Polytechnique to Rémi Pautrat (intern, supervised by Jean-Baptiste Mouret)
- "Prix de thèse DGA" awarded to Antoine Cully (former PhD student, co-supervised by Jean-Baptiste Mouret)

### *5.1.2. New Projects*

- beginning of the AnDy project (H2020)
- beginning of the collaboration with ScanPyramds about "Minimally invasive robotics for heritage buildings"
- beginning of a new collaboration with Diatelic, a subsidiary of the Pharmagest group, for the development of an innovative tele-assistance service based on smart home technologies in order to allow elderlies to stay in their home longer. A PhD thesis has been funded by Diatelic to support this collaboration.

BEST PAPERS AWARDS:

[27]
A. GAIER, A. ASTEROTH, J.-B. MOURET. *Data-Efficient Exploration, Optimization, and Modeling of Diverse Designs through Surrogate-Assisted Illumination*, in "Genetic and Evolutionary Computation Conference (GECCO 2017)", Berlin, Germany, 2017, https://arxiv.org/abs/1702.03713 [*DOI :* 10.1145/3071178.3071282], https://hal.inria.fr/hal-01518698

[26]
A. GAIER, A. ASTEROTH, J.-B. MOURET. *Aerodynamic Design Exploration through Surrogate-Assisted Illumination*, in "18th AIAA/ISSMO Multidisciplinary Analysis and Optimization Conference", Denver, Colorado, United States, 2017, https://hal.inria.fr/hal-01518786

# 6. New Software and Platforms

## 6.1. ProMP_iCub

*iCub Learning Trajectories with ProMP*
KEYWORDS: Gaussian processes - Robotics

FUNCTIONAL DESCRIPTION: A set of matlab modules to learn, replay and infer the continuation of trajectories in robotics using Probabilistic Movement Primitives (ProMP).

- Contact: Serena Ivaldi
- Publication: Prediction of Intention during Interaction with iCub with Probabilistic Movement Primitives
- URL: https://github.com/inria-larsen/icubLearningTrajectories

## 6.2. Limbo

*LIbrary for Model-based Bayesian Optimization*
KEYWORDS: Black-box optimization - C++ - Global optimization - Machine learning - Policy Learning - Bayesian optimization - Gaussian processes
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: Release 2.0 (2017) with: - serialization of Gaussian process models - new architecture for kernel and mean functions - automatic and extensive benchmarks for Gaussian processes regression and Bayesian optimization (generated weekly) - better random generator (thread-safe, c++11) - generation of the documentation for each release

- Partners: UPMC - Imperial College London
- Contact: Jean-Baptiste Mouret
- URL: http://www.resibots.eu/limbo

## 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: Support of fourth generation of devices. Support of ubuntu 16.04. Support of ROS Jade and ROS Kinetic.
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. sferes2

*A lightweight generic C++ framework for evolutionary computation*
FUNCTIONAL DESCRIPTION: Sferes2 is a high-performance, multi-core, lightweight, generic C++98 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.

- Partner: UPMC
- Contact: Jean-Baptiste Mouret
- URL: http://github.com/sferes2/sferes2/

## 6.5. libdynamixel

KEYWORD: Robotics
FUNCTIONAL DESCRIPTION: The libdynamixel is a high-performance C++11 interface to the Dynamixel actuators (including the Dynamixel Pro range). It provides a high-level interface (designed to be easy to sue), a low-level interface (designed to add no overhead on top of the protocol), and a command-line tool for scripting and maintenance operations. The main emphasis is on performance and compatibility with modern C++.

- Contact: Jean-Baptiste Mouret
- URL: http://github.com/resibots/libdynamixel

# 7. New Results

## 7.1. Lifelong Autonomy

### *7.1.1. Sensorized environment*

*7.1.1.1. Localisation of Robots on a Load-sensing Floor*

**Participants:** François Charpillet, Francis Colas, Vincent Thomas.

The use of floor-sensors in ambient intelligence contexts began in the late 1990's. We designed such a sensing floor in Nancy in collaboration with the Hikob company (http://www.hikob.com) and Inria SED. This is a load-sensing floor which is composed of square tiles, each equipped with two ARM processors (Cortex M3 and A8), 4 load cells, and a wired connection to the four neighboring cells. Ninety tiles cover the floor of our experimental platform (HIS).

This year, with Aurelien Andre (master student from Univ. Lorraine), we have focused on tracking robots on several scenarios based on data originated from the sensing tiles and collected the previous years. We have proposed a new approach to build relevant clusters of tiles (based on connexity). For single robot scenarios, we have focused on basic algorithms (for instance, Kalman filter) and on Probability Data Association Filter to consider the possibility of false positive in the bayesian filter. Then, for multi-target tracking, we have investigated elaborate strategies to associate atomic measures to the tracked targets like JPDAF (Joint Probability Data Association Filter algorithm [58]) and JPDAMF (Joint Probability Data Association Merged Filter [45]) in order to consider measures resulting from several targets.

*7.1.1.2. High Integrity Personal Tracking Using Fault Tolerant Multi-Sensor Data Fusion*

**Participants:** François Charpillet, Maan Badaoui El-Najjar.

Maan Badaoui El Najjar is professor at university of Lille and he is the head of the DiCOT Team "Diagnostic, Control and Observation for fault Tolerant Systems" of the CRIStAL Laboratory.

The objective of this PhD work is to study the possibilities offered by the above mentioned load-sensing floor. The idea is to combine the information from each sensor (load sensors and accelerometers) to identify daily living activities (walking, standing, lying down, sitting, falling) and to create a positioning system for the person in the apartment. The approach is based on information theory to address the detection of outliers during the fusion process. This is based on informational filters and fault detection to identify and eliminate faulty measurements. This work was carried through the PhD Thesis of Mohamad Daher under the supervision of François Charpillet and Maan Badaoui El Najjar. This thesis was defended at university of Lille on the 13th December 2017.

Publication: [14]

*7.1.1.3. Active Sensing and Multi-Camera Tracking*

**Participants:** François Charpillet, Vincent Thomas.

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.

This problem we are focusing on consists of following the trajectories of persons with the help of several controllable cameras in the smart environment. The approach we are working on is based on probabilistic decision processes in partial observability (POMDP - Partially Observable Markov Decision Processes) and particle filters. In the past, we have proposed an original formalism $rho$-*POMDP* and new algorithms for representing and solving active sensing problems [43] by tracking several persons with fixed camera based on particle filters and Simultaneous Tracking and Activity Recognition approach [49].

This year, approaches based on Monte-Carlo Tree Search algorithms (MCTS) like POMCP [60] have been used to build policies for following a single person with several controllable cameras in a simulated environment.

### 7.1.2. Partially Observable Markovian Decision Processes (POMDP)

#### 7.1.2.1. Solving $\rho$-POMDP using Lipschitz Properties

**Participant:** Vincent Thomas.

We are currently investigating how to solve continuous MDP and $\rho$-POMDP by using Lipschitz property (rather than classical Piecewise Linear and Convex property used to solve POMDP). We have proven that if the transition and reward functions are lipschtiz-continuous, the value function has the same property.

With Mathieu Fehr (Ulm ENS student), we have studied new algorithm based on HSVI (Heuristic Search Value Iteration [62]) to take advantage of the lipschitz continuity property. The properties of these algorithms are currently investigated.

### 7.1.3. Distributed Exploration of an Unknown Environment by a Swarm of Robots

**Participants:** Nassim Kalde, François Charpillet, Olivier Simonin.

Olivier Simonin is Professeur at INSA Lyon and is the scientific leader of Chroma Team.

In this PhD, we have explored the issue for a team of cooperating mobile robots to intelligently explore an unknown environment. This question has been addressed both in the framework of sequential decision making and frontier based exploration. Considered environments includes static or populated environments.

This work was carried through the PhD Thesis of Nassim Fates under the supervision of François Charpillet and Olivier Simonin. This thesis was defended on the 12th December 2017.

### 7.1.4. Robot Learning

#### 7.1.4.1. Black-box Data-efficient RObot Policy Search (Black-DROPS)

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

The most data-efficient algorithms for reinforcement learning (RL) in robotics are based on uncertain dynamical models: after each episode, they first learn a dynamical model of the robot, then they use an optimization algorithm to find a policy that maximizes the expected return given the model and its uncertainties. It is often believed that this optimization can be tractable only if analytical, gradient-based algorithms are used; however, these algorithms require using specific families of reward functions and policies, which greatly limits the flexibility of the overall approach. We introduced a novel model-based RL algorithm [23], called Black-DROPS (Black-box Data-efficient RObot Policy Search), that: (1) does not impose any constraint on the reward function or the policy (they are treated as black-boxes), (2) is as data-efficient as the state-of-the-art algorithm for data-efficient RL in robotics, and (3) is as fast (or faster) than analytical approaches when several cores are available. The key idea is to replace the gradient-based optimization algorithm with a parallel, black-box algorithm that takes into account the model uncertainties. We demonstrate the performance of our new algorithm on two standard control benchmark problems (in simulation) and a low-cost robotic manipulator (with a real robot).

Publications: [23]

*7.1.4.2. Reset-free Data-efficient Trial-and-error for Robot Damage Recovery*

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

The state-of-the-art RL algorithms for robotics require the robot and the environment to be reset to an initial state after each episode, that is, the robot is not learning autonomously. In addition, most of the RL methods for robotics do not scale well with complex robots (e.g., walking robots) and either cannot be used at all or take too long to converge to a solution (e.g., hours of learning). We introduced a novel learning algorithm called "Reset-free Trial-and-Error" (RTE) that (1) breaks the complexity by pre-generating hundreds of possible behaviors with a dynamics simulator of the intact robot, and (2) allows complex robots to quickly recover from damage while completing their tasks and taking the environment into account [13]. We evaluated our algorithm on a simulated wheeled robot, a simulated six-legged robot, and a real six-legged walking robot that are damaged in several ways (e.g., a missing leg, a shortened leg, faulty motor, etc.) and whose objective is to reach a sequence of targets in an arena. Our experiments show that the robots can recover most of their locomotion abilities in an environment with obstacles, and without any human intervention.

Publications: [13]

### *7.1.5. Illumination & Quality Diversity Algorithms*

*7.1.5.1. Using Centroidal Voronoi Tessellations to Scale up the MAP-Elites Algorithm*

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

The MAP-Elites algorithm [55] is a key step of our "Intelligent Trial and Error" approach [46] for data-efficient damage recovery. It works by discretizing a continuous feature space into unique regions according to the desired discretization per dimension. While simple, this algorithm has a main drawback: it cannot scale to high-dimensional feature spaces since the number of regions increase exponentially with the number of dimensions. We addressed this limitation by introducing a simple extension of MAP-Elites that has a constant, pre-defined number of regions irrespective of the dimensionality of the feature space [21]. Our main insight is that methods from computational geometry could partition a high-dimensional space into well-spread geometric regions. In particular, our algorithm uses a centroidal Voronoi tessellation (CVT) to divide the feature space into a desired number of regions; it then places every generated individual in its closest region, replacing a less fit one if the region is already occupied. We demonstrated the effectiveness of the new "CVT-MAP-Elites" algorithm in high-dimensional feature spaces through comparisons against MAP-Elites in maze navigation and hexapod locomotion tasks.

Publications: [21], [37], [38]

*7.1.5.2. Aerodynamic Design Exploration through Surrogate-Assisted Illumination*

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

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 a single, near-optimal solution. Unfortunately, these algorithms currently require a large number of function evaluations, limiting their applicability. In our recent work [27], [26], we introduced a new illumination algorithm, called Surrogate-Assisted Illumination (SAIL), that creates a map of the design space according to user-defined features by leveraging surrogate modeling and intelligent sampling to minimize the number of 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 [55] or CMA-ES [52]. As shown in this article, SAIL can also produce maps of high-performing designs in a more realistic 3-dimensional aerodynamic task with an accurate flow simulation. Overall, SAIL can help designers understand what is possible, beyond what is optimal, by considering more than pure objective-based optimization.

Publications: [27], [26]

### 7.1.6. Applications – civil robotics

#### 7.1.6.1. Minimally Invasive Exploration of Heritage Buildings

**Participants:** Jean-Baptiste Mouret, Lucien Renaud, Kapil Sawant.

In 2017, the team officially joined the ScanPyramids mission, which aims at better understanding how the pyramids of the Old Kingdom were built, but also to encourage innovations in various fields (muography, virtual reality, simulation, ...) that could be useful for the pyramids as well as for other monuments. The ScanPyramids team has discovered several previously unknown voids in the pyramid of Cheops, one of them with a size similar to the one of the Grand Gallery, called « ScanPyramids' Big Void ».

We participated to the article about the ScanPyramids' Big Void [17] and we designed several prototypes for minimally invasive exploration. We envision exploration to take place in two stages. At first, a tubular robot fitted with an omnidirectional camera would be inserted to take high-resolution pictures of the inaccessible place. In a second stage, the team would use the same hole to send an exploration robot operated remotely to travel through corridors and help mapping the interior. For this second step, we are currently designing a miniature blimp that would be folded during the insertion, then remotely inflated once in the inaccessible place. When the exploration is over, the blimp would come back to its base, be deflated, then extracted from the insertion hole.

Publications: [17]

### 7.1.7. Humanoid Robotics

#### 7.1.7.1. Trial-and-error Learning of Repulsors for Humanoid QP-based Whole-Body Control

**Participants:** Karim Bouyarmane, Serena Ivaldi, Jean-Baptiste Mouret, Jonathan Spitz, Vassilis Vassiliades.

Whole body controllers based on quadratic programming allow humanoid robots to achieve complex motions. However, they rely on the assumption that the model perfectly captures the dynamics of the robot and its environment, whereas even the most accurate models are never perfect. We introduced a trial-and-error learning algorithm that allows whole-body controllers to operate in spite of inaccurate models, without needing to update these models [35]. The main idea is to encourage the controller to perform the task differently after each trial by introducing repulsors in the quadratic program cost function. We demonstrated our algorithm on (1) a simple 2D case and (2) a simulated iCub robot for which the model used by the controller and the one used in simulation do not match.

Publications: [35]

#### 7.1.7.2. Safe Trajectory Optimization for Whole-body Motion of Humanoids

**Participants:** Serena Ivaldi, Valerio Modugno.

Multi-task prioritized controllers generate complex behaviors for humanoids that concurrently satisfy several tasks and constraints. In our previous work we automatically learned the task priorities that maximized the robot performance in whole-body reaching tasks, ensuring that the optimized priorities were leading to safe behaviors. Here, we take the opposite approach: we optimize the task trajectories for whole-body balancing tasks with switching contacts, ensuring that the optimized movements are safe and never violate any of the robot and problem constraints. We use (1+1)-CMA-ES with Constrained Covariance Adaptation as a constrained black box stochastic optimization algorithm, with an instance of (1+1)- CMA-ES for bootstrapping the search. We apply our learning framework to the prioritized whole-body torque controller of iCub, to optimize the robot's movement for standing up from a chair.

Publications: [29]

#### 7.1.7.3. Humanoid Robot Fall Control

**Participant:** Karim Bouyarmane.

Falling is a major skill to be mastered by an autonomous humanoid robot, since no matter what balance controller we use, a humanoid robot will end up falling in certain circumstances. We proposed new approaches to control humanoid robots in general fall configurations and in general cluttered environment. From fall detection instant, a pre-imapct phase is triggered where a real-time configuration adaptation routine makes the robot quickly analyze the surrounding environment, choose best impact points on the environment, and adapts its configuration accordingly to meet the desired impact points (all calculations performed in the short duration of 0.7s to 1s that the fall lasts). Then right after impact a real-time motor PD gain adaptation controller allows to set the right values for the gains in real-time to comply actively with the impact while minimizing peak torque at impact. Finally, a model-predictive approach combined with a novel formulation of admissible force polytopes accounting for both torque limits and Coulomb friction limitation ensures that the robot safely comes to a steady-state resting state at the end of the fall.

Publications: [41], [34], [33]

##### 7.1.7.4. *Stability Proof of Weighted Multi-Task Humanoid QP Controller*

**Participant:** Karim Bouyarmane.

We proved that weighted multi-task controllers are locally exponentially stable under appropriate conditions of the task gain matrices. We also derived a number of stability properties of the underlying QP optimization problem.

Publications: [12]

##### 7.1.7.5. *Theoretical Study of Commonalities between Locomotion and Manipulation in Humanoid-like Locomotion-and-manipulation Integration System*

**Participant:** Karim Bouyarmane.

We published our theoretical study on common ground formulations of locomotion and manipulation, and thereby their extension to integrated locomotion-and-manipulation systems, by analytically deriving their planning and control solutions in low-dimensional proof-of-concept examples based on nonlinear control and differential geometry tools.

Publications: [11]

### 7.1.8. *Embodied Evolutionary Robotics*

##### 7.1.8.1. *Online Distributed Learning for a Swarm of Robots*

**Participants:** Iñaki Fernández Pérez, Amine Boumaza, François Charpillet.

We study how a swarm of robots adapts over time to solve a collaborative task using a distributed Embodied Evolutionary approach, where each robot runs an evolutionary algorithm and locally exchange genomes and fitness values. Particularly, we study a collaborative foraging task, where the robots are rewarded for collecting food items that are too heavy to be collected individually and need at least two robots to be collected. Furthermore, to promote collaboration, agents must agree on a signal in order to collect the items. Our experiments show that the distributed algorithm is able to evolve swarm behavior to collect items cooperatively. The experiments also reveal that effective cooperation is evolved due mostly to the ability of robots to jointly reach food items, while learning to display the right color that matches the item is done suboptimally. However, a closer analysis shows that, without a mechanism to avoid neglecting any kind of item, robots collect all of them, which means that there is some degree of learning to choose the right value for the color effector depending on the situation.

This work was carried through the PhD Thesis of Iñaki Fernández Pérez under the supervision of François Charpillet and Amine Boumaza. This thesis was defended on the 19th December 2017.

Publications: [25]

##### 7.1.8.2. *Phylogeny of Embodied Evolutionary Robotics*

**Participant:** Amine Boumaza.

We explore the idea of analyzing Embodied Evolutionary Robotics from the perspective of genes and their dynamics using phylogenetic trees. We illustrate a general approach on a simple question regarding the dynamics of the fittest and most copied genes as an illustration using tools from spectral graph theory or computational phylogenetics, and argue that such an approach may give interesting insights on the behavior of these algorithms. This idea seems promising and further investigations are underway, especially on the links with coalescence theory.

Publications: [22]

## 7.2. Natural Interaction with Robotics Systems

### *7.2.1. Control of Interaction*

*7.2.1.1. Towards Human-aware Whole-Body Controllers for Physical Human-Robot Interaction*

**Participants:** Oriane Dermy, Serena Ivaldi.

The success of robots in real-world environments is largely dependent on their ability to interact with both humans and said environment. The FP7 EU project CoDyCo focused on the latter of these two challenges by exploiting both rigid and compliant contacts dynamics in the robot control problem. Regarding the former, to properly manage interaction dynamics on the robot control side, an estimation of the human behaviours and intentions is necessary. We contributed to the building blocks of such a human-in-the-loop controller, and validate them in both simulation and on the iCub humanoid robot for the final demo of the CoDyCo project where a human assists the robot in standing up from being seated on a bench.

The controller is the basis for our current researches in the AnDy project.

Publications: [20]

*7.2.1.2. Generating Motions for a Humanoid Robot that Assists a Human in a Co-manipulation Task*

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

We proposed a method to make a humanoid robot adapt its motion to help a human collaborator in simulation realize a collaborative manipulation task with the robot while the robot figures out its configuration in real-time through symmetric retargeting.

Publications: [40]

*7.2.1.3. Human-to-humanoid Motion Retargeting*

**Participants:** Karim Bouyarmane, Kazuya Otani.

We continue the development of our human-to-humanoid motion retargeting method by extending it to whole-body manipulation motions based on our previously-proposed multi-robot QP paradigm. The motion retargeting system is now able to autonomously adapt the motion of the robot to dynamics parameters of the manipulated object that substantially differ from those used to provide the human demonstration.

Publications: [31]

### *7.2.2. Non-verbal Interaction*

*7.2.2.1. Multimodal Prediction of Intention via Probabilistic Movement Primitives (ProMP)*

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

We designed a method for predicting the intention of a user interacting (physically or not) with the humanoid robot iCub, and implemented an associated open-source software (cf. ProMP_iCub in the Software section). Our goal is to allow the robot to infer the intention of the human partner during collaboration, by predicting the future intended trajectory: this capability is critical to design anticipatory behaviors that are crucial in human–robot collaborative scenarios, such as in co-manipulation, cooperative assembly, or transportation. We propose an approach to endow the iCub with basic capabilities of intention recognition, based on Probabilistic Movement Primitives (ProMPs), a versatile method for representing, generalizing, and reproducing complex motor skills. The robot learns a set of motion primitives from several demonstrations, provided by the human via physical interaction. During training, we model the collaborative scenario using human demonstrations. During the reproduction of the collaborative task, we use the acquired knowledge to recognize the intention of the human partner. Using a few early observations of the state of the robot, we can not only infer the intention of the partner but also complete the movement, even if the user breaks the physical interaction with the robot. We evaluated our approach both in simulation and with the real iCub robot. We also proposed a method to exploit referential gaze and combine it with physical interaction, to improve the prediction of primitives. The software implementing our approach is open source and available on the GitHub platform. In addition, we provide tutorials and videos.

Publications: [15]

*7.2.2.2. PsyPhINe: Cogito Ergo Es*

**Participant:** Amine Boumaza.

PsyPhINe is an interdisciplinary and exploratory project (see 9.1.2) 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?

This year an experimental campaigns was organized in which around 40 test subjects where asked to solve a task in front of the moving robotic device. These interactions were recorded on video along with eye tracking data. To analyze the data, a web application was created that crowd-sources video annotation to internet users. A preliminary analysis of the data was presented at the third edition of the PsyPhINe workshop organized by the group, gathering top researchers from philosophy, anthropology, psychology and computer science to discuss and exchange on our methodology (see 10.1.1.1).

*7.2.2.3. Active Audio Source Localization*

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

*We collaborate on this subject with Emmanuel Vincent from the Multispeech team (Inria Nancy - Grand Est).*

We considered, here, the task of audio source localization using a microphone array on a mobile robot. Active localization algorithms have been proposed in the literature that can estimate the 3D position of a source by fusing the measurements taken for different poses of the robot. However, the robot movements are typically fixed or they obey heuristic strategies, such as turning the head and moving towards the source, which may be suboptimal. This work proposes an approach to control the robot movements so as to locate the source as quickly as possible using the Monte-Carlo Tree Search algorithm [30]. We represent the belief about the source using our mixture Kalman filter that explicitly includes the discrete activity of the source in the estimated state vector, alongside the continuous states such as the position of the robot or the sound source.

This work was carried through the PhD Thesis of Van Quan Nguyen under the supervision of Emmanuel Vincent and Francis Colas. This thesis was defended on the 3rd November 2017.

Publication: [30]

# 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.

# 9. Partnerships and Cooperations

## 9.1. Regional Initiatives

### *9.1.1. SATELOR*

Title: SATELOR
Program: AME Region Lorraine
Duration: September 2013 - September 2017
Coordinator: Diatelic
PI for Inria: François Charpillet
The Economic Mobilisation Agency in Lorraine has launched a new project Satelor providing it with 2.5 million Euros of funding over 3 years, out of an estimated total of 4.7 million. The leader of the project is Pharmagest-Diatelic. Pharmagest, in Nancy, is the French leader in computer systems for pharmacies, with a 43.5 % share of the market, 9,800 clients and more than 700 employees. Recently, the Pharmagest Group expanded its activities into e-health and the development of telemedicine applications. The Satelor project will accompany the partners of the project in developing services for maintaining safely elderly people with loss of autonomy at home or people with a chronic illness. Larsen team will play an important role for bringing some research results such as:

- developing a low cost environmental sensor for monitoring the daily activities of elderly people at home
- developing a low cost sensor for fall detection
- developing a low cost companion robot able to interact with people and monitoring their activities while detecting emergency situations.
- developing a general toolbox for data-fusion: Bayesian approach.

Publications: [16], [18]

### 9.1.2. 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

This project gathers researchers from the following institutes: InterPsy (EA 4432), APEMAC, EPSaM (EA4360), Archives Henri-Poincaré (UMR7117), Inria Bordeaux Sud-Ouest, Loria (UMR7503). Refer to sec. 7.2.2.2 for the goals of the project.

## 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. The current approach to fault tolerance is inherited from safety-critical systems (e.g. spaceships or nuclear plants). It is inappropriate for low-cost autonomous robots because it relies on diagnostic procedures, which require expensive proprioceptive sensors, and contingency plans, which cannot cover all the possible situations that an autonomous robot can encounter. 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. We will thus shed a new light on one of the most fundamental questions of robotics: how can a robot be as adaptive as an animal? The techniques developed in this project will substantially increase the lifespan of robots without increasing their cost and open new research avenues for adaptive machines.

#### 9.2.1.2. CODYCO

Title: Whole-body Compliant Dynamical Contacts for Humanoids

Programme: FP7

Type: ICT STREP (No. 600716)

Duration: March 2013 - February 2017

Coordinator: IIT

PI for Inria: Serena Ivaldi

The aim of CoDyCo was to improve the current control and cognitive understanding about robust, goal-directed whole-body motion interaction with multiple contacts. CoDyCo went beyond traditional approaches: proposing methodologies for performing coordinated interaction tasks with complex systems; combining planning and compliance to deal with predictable and unpredictable events and contacts; validating theoretical progresses in real-world interaction scenarios. CoDyCo advanced the state-of-the-art in the way robots coordinate physical interaction and physical mobility.

*9.2.1.3. 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 Research Visitors

### *9.3.1. Visits of International Scientists*

*9.3.1.1. Internships*

- Waldez Azevedo Gomes Junior (Brazil) – from May 2017 to November 2017
- Kazuya Otani (USA, Carnegie Mellon) – from May 2017 to November 2017
- Kapil Sawant (India, BITS Pilani) – from July to December 2017
- Luigi Penco (Italy, La Sapienza University) – from October 2017 to February 2018

# 10. Dissemination

## 10.1. Promoting Scientific Activities

### *10.1.1. Scientific Events Organisation*

*10.1.1.1. General Chair, Scientific Chair*

- Co-organized an international workshop at IROS 2017 (*Micro-Data Learning: the next frontier of Robot Learning?*) [Jean-Baptiste Mouret].
- Co-organized an international workshop at ECAL'2017 (*Evolution in Physical System*) [Jean-Baptiste Mouret].
- Co-organized an international workshop at HUMANOIDS 2017 (*Human-Humanoid collaboration: the next industrial revolution?*) [Serena Ivaldi].
- Co-organized "Expressions, simulations, perceptions - Journées PsyPhINe 2017", the third workshop of the PsyPhINe project (http://poincare.univ-lorraine.fr/fr/manifestations/psyphine-2017) [Amine Boumaza].

*10.1.1.2. Member of the Organizing Committees*

- Serena Ivaldi was Publicity Chair of the international conferences HUMANOIDS 2017 (IEEE/RSJ International Conference on Humanoid Robots) and of ICDL 2017 (IEEE Conference on Development and Learning)

### *10.1.2. Scientific Events Selection*

*10.1.2.1. Member of Conference Program Committees*

- CEC 2017 (Congress on Evolutionary computation) [Amine Boumaza]
- CoRL (Conference on Robot Learning) [Serena Ivaldi, Jean-Baptiste Mouret]
- ECAL 2017 (European Conference on Artificial Life) [Amine Boumaza, Jean-Baptiste Mouret]
- EVO* 2017 (EvoStar) [Jean-Baptiste Mouret]
- GECCO2017 (Genetic and Evolutionary Computation Conference) [Amine Boumaza, Jean-Baptiste Mouret]
- HFR 2017 (Human-Friendly Robotics Conference) [Serena Ivaldi]
- HUMANOIDS 2017 (IEEE/RSJ International Conference on Humanoid Robots) [Serena Ivaldi, associate editor]
- ICRA 2017 & ICRA 2018 (IEEE International Conference on Robotics and Automation) [Serena Ivaldi, associate editor]
- IROS 2017 (IEEE/RSJ International Conference on Intelligent Robots and Systems) [Serena Ivaldi, associate editor]
- JFPDA 2017 (Journée Francophones sur la Planification, la Décision et l'Apprentissage pour la conduite de systèmes) [Vincent Thomas]
- NIPS Bayesian Optimization Workshop [Jean-Baptiste Mouret]

*10.1.2.2. Reviewer for Peer-reviewed Conferences*

- ICRA 2018 (2018 IEEE International Conference on Robotics and Automation) [Karim Bouyarmane, Francis Colas, Serena Ivaldi, Jean-Baptiste Mouret]
- IROS 2017 (IEEE/RSJ International Conference on Intelligent Robots and Systems) [Karim Bouyarmane, Francis Colas, Jean-Baptiste Mouret]
- HUMANOIDS 2017 (IEEE/RSJ International Conference on Humanoid Robots) [Jean-Baptiste Mouret, Karim Bouyarmane]
- ICDL-EPIROB 2017 (EEE International Conference on Development and Learning and on Epigenetic Robotics) [Francis Colas]

### *10.1.3. Journal*

*10.1.3.1. Member of the Editorial Boards*

- Jean-Baptiste Mouret co-edited a special issue of the Artificial Life journal (MIT Press), called "Evolution in Physical Systems" [19]

- Serena Ivaldi was an Associate Editor of IEEE Robotics and Automation Letters (RAL) and an Editorial Board member for the Springer Journal of Intelligent Service Robotics

*10.1.3.2. Reviewer - Reviewing Activities*

- Frontiers in AI and Robotics [Amine Boumaza, Serena Ivaldi, Jean-Baptiste Mouret]
- Robotics and Automation Letters [Karim Bouyarmane, Francis Colas, Jean-Baptiste Mouret]
- Autonomous Robots [Francis Colas]
- IEEE Transactions on Robotics [Karim Bouyarmane, Serena Ivaldi]
- International Journal of Robotics Research [Karim Bouyarmane]
- IEEE Transactions on Systems, Man and Cybernetics [Karim Bouyarmane]

### *10.1.4. Invited Talks*

- Jean-Baptiste Mouret was invited to talk at as the Centre for BioRobotics – University of Southern Denmark (distinguished speaker), at the LIRIS (CNRS / Univ. Lyon) at the "Evolution in Cognition Workshop" (GECCO 2017), and at the GT8 (Robotique et Neurosciences) meeting of the GDR Robotique (CNRS).
- Serena Ivaldi was invited to talk at XEROX Research in Grenoble, at IHEST in Paris, at the GT Robotique Humanoide in Montpellier, at the IEEE ICDL 2017 Workshop on Perception of Self, and at the the GT8 (Robotique et Neurosciences) meeting of the GDR Robotique (CNRS).
- Karim Bouyarmane was invited to give a presentation at the Seminaire Francilien de Geometrie Algorithmique et Combinatoire at Institut Henri Poincarre in Paris.

### *10.1.5. Leadership within the Scientific Community*

- Jean-Baptiste Mouret is the chair of the "evo-devo-robot" task force of the IEEE technical committee "Developmental and Cognitive Systems".
- Serena Ivaldi is the co-chair of the web task force of the IEEE technical committee "Developmental and Cognitive Systems".

### *10.1.6. Scientific Expertise*

- Serena Ivaldi was vice-president of the CES33 committee for evaluation of national projects for the ANR
- Francis Colas was member of the CES33 committee for evaluation of national projects for the ANR
- Serena Ivaldi is a member of the scientific experts committee for the upcoming Robots exhibition at the Cite de la Science in Paris.
- François Charpillet was member of the hiring committees:
  - CR2 Inria: Committee member (Bordeaux)
  - Maitre de conferences: Committee member for jury (UTT)
  - Professeur des Universités: Committee member for jury PR 4036 "Traitement du signal, conception de méthodes de décision, fusion de données" (UTT)

### *10.1.7. Research Administration*

- Amine Boumaza is a board member of the Évolution Artificielle association.

## 10.2. Teaching - Supervision - Juries

### *10.2.1. Teaching*

Master [Vincent Thomas]

- "Modèles probabilistes et Apprentissage par renforcement", 15h eq. TD, M2 "Informatique - Image Perception Raisonnement Cognition", Univ. Lorraine, France.

- “Optimisation et méta-heuristiques”, 15h eq. TD, M1 “Informatique”, Univ. Lorraine, France.
- ‘Game Design”, 20h eq. TD, M1 “Sciences Cognitives”, Univ. Lorraine, France.
- “Agent intelligents et collectifs”, 20h eq. TD, M1 “Sciences Cognitives”, Univ. Lorraine, France.
- “Serious Game”, 12h eq. TD, M2 “Sciences Cognitives”, Univ. Lorraine, France.
- “Robotique Autonome”, 18h eq. TD, M2 “Systèmes Interactifs et Robotiques”, Centrale-Supélec, France.

Formation IHEST [Serena Ivaldi] “Robotique collaborative”, 2h.

Tutorial in an international conference [Jean-Baptiste Mouret] “Evolutionary Robotics”, GECCO 2017, Berlin, Germany [1h].

Engineering School [Karim Bouyarmane]:

- “Programmation et algorithmique Java”, Polytech Nancy School of Engineering
- Engineering school: Karim Bouyarmane, “Langages C et C++”, Polytech Nancy School of engineering
- Engineering school: Karim Bouyarmane, “Introduction to Computer Science”, Polytech Nancy School of engineering
- Engineering school: Karim Bouyarmane, “Operating Systems”, Polytech Nancy School of engineering

### 10.2.2. Supervision

- HDR: Francis Colas, “*Modélisation bayésienne et robotique*”, 17 May 2017 [7].
- PhD: Van Quan Nguyen, “*Mapping of a sound environment by a mobile robot*”, 3 Nov. 2017, Emmanuel Vincent (advisor), Francis Colas, François Charpillet.
- PhD: Nassim Kaldé, “*Exploration et reconstruction d’un environnement inconnu par une flottille de robots*”, 12 Dec. 2017, François Charpillet (advisor), Olivier Simonin.
- PhD: Iñaki Fernández Pérez, “*Apprentissage incrémental évolutionnaire*”, 19 Dec. 2017, F. Charpillet (advisor), Amine Boumaza.
- PhD: Vincent Samy, “*Humanoid fall control by postural reshaping and adaptive compliance*”, 13 Nov. 2017, Abderrahmane Kheddar (advisor), Karim Bouyarmane.
- PhD in progress: Yassine El Khadiri, “Apprentissage automatique pour l’assistance à l’autonomie à domicile”, started in June 2017, François Charpillet (advisor).
- PhD in progress: Adrien Malaisé, “*Capteurs porte´s dans la robotique collaborative : de l’apprentissage du mouvement humain a` l’acceptabilite´ de cette technologie*”, started in January 2017, Francis Colas (advisor), Serena Ivaldi
- 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: Rituraj Kaushik, “Fast adaptation to damage by exploiting trajectory data”, started in Oct. 2016, Jean-Baptiste Mouret (advisor).
- PhD in progress: Konstantinos Chatzilygeroudis, “*Diagnosis-free Damage Recovery in Robotics with Machine Learning*”, started in Oct. 2015, Jean-Baptiste Mouret (advisor).
- PhD in progress: Oriane Dermy, “*Learning to control the physical interaction of a humanoid robot with humans*”, started in Nov. 2015, François Charpillet (advisor), Serena Ivaldi.
- PhD in progress: Adrian Bourgaud, “*Multi-sensor Fusion and Active Sensing*”, started in Jul. 2015, François Charpillet (advisor).

### 10.2.3. Juries

- Jean-Baptiste Mouret was:
  - a reviewer of the PhD of Valerio Modugno (Univ. Sapienza, Rome, Italy);
  - the president of the jury for the PhD of Charles Rocabert (Univ. Lyon / Inria).
- Serena Ivaldi was
  - an examiner of the PhD of Ganna Pugach (Univ. Cergy-Pontoise);
  - a reviewer of the PhD of Oskar Palinko (IIT & Univ. Genoa, Italy);
  - an external reviewer in the VIVA / PhD exam of Valerio Ortenzi (Univ. of Birmingham, UK).
- François Charpillet was:
  - a reviewer of the PhD of Kabalan Chaccour (Tech. Univ. Belfort-Montbéliard);
  - a reviewer of the PhD of Alexis Brenon (Univ. Grenoble Alpes);
  - a reviewer of the PhD of Chu Xing (Ecole Centrale Lille);
  - a reviewer of the PhD of Viet-Cuong Ta (Univ. Grenoble Alpes);
  - an examiner of the HDR of Olivier Buffet (Univ. Lorraine).

## 10.3. Popularization

One of the main general audience event of the team has been the “Fête de la Science” on the 13th and 14th of October, 2017. The team hosted about 10 groups of 15-20 persons (150 to 200 visitors) over two days, with the following demonstrations:

- “smart appartment”, with the “smart tiles” and the Pepper Robot;
- AnDy project: activity recognition with the “inertial” motion capture suit, muscle sensing with EMG sensors;
- iCub robot: performing squats with the iCub robot and a whole-body motion controller; interactive demonstrations of iCub following a red-ball (given to a child) with the gaze and the head;
- ResiBots project: damage recovery with a damaged 6-legged robot.

The team also presented numerous videos of additional results with the robots. Involved members of the team: François Charpillet, Konstantinos Chatzilygeroudis, Brice Clément, Francis Colas, Oriane Dermy, Dorian Goepp, Waldez Gomes, Aurore Husson, Serena Ivaldi, Yassine El Khadiri, and Adrian Bourgaud, Adrien Malaisé, Jean-Baptiste Mouret, Kazu Otani and Olivier Rochel.

In addition:

- Vincent Thomas gave tutorials on “physics simulation” and “stochastic decision making” for teachers during “journées ISN-EPI” (30th of Mars 2017).
- Vincent Thomas participated in the preparation and reviewing of “Computer Science Exporoute” (conducted by Inria Nancy Grand-Est) presented in 2017.
- Vincent Thomas animated discussions and tutorials on “planning in mazes” for students from 6 to 20 years old during “fetes de la sciences” organized by Univ. Lorraine (13th of October 2017).
- Vincent Thomas presented “Bayesian reasonning” during “journées portes ouvertes” organized by Inria Nancy-Grand Est (14th of October 2017).
- Vincent Thomas accompanied computer science DUT students during the “Nancy acceuille Google” event (20th of October 2017).
- Serena Ivaldi was panelist in public conferences/debates in Futur en Seine and 50 ans of Inria, both in Paris.
- Amine Boumaza is a member of the editorial board of “Interstice”.
- Karim Bouyarmane was the academic advisor for the Polytech School of Engineering students team of robotics that particpated to the 2017 Coupe de France de Robotique.
- Francis Colas participated in a Sciences en Lumières event “Visages de la robotique” at RTE (14th of December 2017).

# 11. Bibliography

## Major publications by the team in recent years

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[8] V. Q. NGUYEN. *Mapping of a sound environment by a mobile robot*, University of Lorraine, November 2017, https://hal.archives-ouvertes.fr/tel-01664540

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A. GAIER, A. ASTEROTH, J.-B. MOURET. *Data-Efficient Exploration, Optimization, and Modeling of Diverse Designs through Surrogate-Assisted Illumination*, in "Genetic and Evolutionary Computation Conference (GECCO 2017)", Berlin, Germany, 2017, https://arxiv.org/abs/1702.03713 [*DOI :* 10.1145/3071178.3071282], https://hal.inria.fr/hal-01518698.

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