Activity Report 2016

Team LARSEN

Lifelong Autonomy and interaction skills for Robots in a Sensing ENvironment

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

RESEARCH CENTER
Nancy - Grand Est

THEME
Robotics and Smart environments

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Creation of the Team: 2015 January 01

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Other Research Topics and Application Domains:

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2.5.3. - Assistance for elderly
2.8. - Sports, performance, motor skills
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1. Members

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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 [39], [50]. 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 [39], [48].

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 [47].

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 [38] 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 [57], [48]. However, current reinforcement learning algorithms require hundreds of trials/episodes to learn a single, often simplified, task [48], 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 [49], [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 [46]. 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 [55], [46], [37]).

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 [61]. Most Human-Robot Interaction (HRI) studies focus on verbal communication [56] 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 [58] and robotic co-workers [53]. 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 [43].

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) [60] 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 [45], 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 [44]. 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 [51], section 2.7.
[2] OHS (*Office d'Hygiène Sociale*) is an association managing several rehabilitation or retirement home structures.
[3] See the Robotics 2020 Multi-Annual Roadmap [51], 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

- "Prix La Recherche 2016" (mention "sciences de l'information"), to Jean-Baptiste Mouret and his co-authors (Antoine Cully, Jeff Clune, Danesh Tarapore) for the article "Robots that can adapt like animals" (Nature, 2015).
- "2016 ISAL Award for Outstanding Paper of 2015 in the field of Artificial Life", awarded by the International Society for Artificial Life to Jean-Baptiste Mouret and his co-authors (Antoine Cully, Jeff Clune, Danesh Tarapore) for the article "Robots that can adapt like animals" (Nature, 2015).

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
FUNCTIONAL DESCRIPTION

Limbo is an open-source C++11 library for 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.

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

6.2. 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/

6.3. xsensdriver

`xsens_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 a device, one can use the mtdevice.py script (or the vendor tool on Windows).

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

6.4. Platforms

6.4.1. iCub

iCub is a humanoid robot with the size of a 4 years old child. It is developed by the Italian Institute of Technology (Genoa, Italy), which is the coordinator of the EU project CoDyCo. The iCub robot was acquired thanks to the funding of this project.

Our version of iCub has a v2 head, v1 torso, v2.5 legs. It has 6 force/torque sensors, a distributed tactile skin, and inertial sensor in the head.

The robot is used in the context of the projects CoDyCo and Resibots. The software developed for the iCub is mostly published on the github page of our team:

https://github.com/inria-larsen

6.4.2. Pepper

Pepper is a humanoid mobile robot, produced by SoftBank Robotics (formerly Aldebaran). It is designed to engage humans in social interactions, entertain or communicate through gestures and visual animations on its front laptop.

The robot was acquired in the context of the CPER SCIARAT to study human-robot interaction for personal assistance.

7. New Results

7.1. Lifelong Autonomy

7.1.1. PsyPhINe: Cogito Ergo Es

Participant: Amine Boumaza.

PsyPhINe is an interdisciplinary and exploratory project (see 8.1.1) 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?

Last year, an experimental robotic device was designed and built, and an experimental campaign with human subject was conducted. The experiments consisted in recording the interactions of the subjects with the robot when realizing a task. The results of the experiments are under analysis and will partly be presented at the second 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 9.1.1.1).

7.1.2. Localisation of robots on 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 Alexis Grall (master student from Enseirb-Matmeca), we have focused on identifying localisation and tracking scenarios involving several robots and on collecting data corresponding to instantiation of these scenarios. These data originated from the sensing tiles but also from Qualisys motion capture system in order to have information about ground-truth. We have also focused on basic algorithms (for instance, Kalman filter) to tackle the issue of tracking targets, but we plan to investigate more elaborate strategies for dealing with sensor discontinuity (for example, when the robot leaves or enters a tile) and multi-traget tracking (Joint Probability Data Association Filter algorithm [52]).

With Mohammad Rami Koujan, we also started to apply deep-learning techniques on those sequential data in order to compare model-based and model-free approaches. This work included some long-term data collection with a randomized behavior in order to have enough training data.

7.1.3. Active sensing and multi-camera tracking

Participants: Olivier Buffet, 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. This is a difficult problem since the set of cameras cannot simultaneously cover the whole environment, some persons can be hidden by obstacles or by other persons, and the behavior of each person is governed by internal variables which can only be inferred (such as his motivation or his hunger).

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 [38] by tracking several persons with fixed camera based on particle filters and Simultaneous Tracking and Activity Recognition approach [45].

This year, we have focused on investigating the issue of solving the active sensing problem with controllable cameras. Approaches based on Monte-Carlo Tree Search algorithms (MCTS) like POMCP [54] are currently investigated for adressing the combinatorial explosion of the state space to consider (which is the space of probability distributions over all the possible states of the system).

7.1.4. 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. A typical implicit assumption in the literature is that the sound source is active, but a lot of real sound sources are actually intermittent. Systems of activity detection exist but cannot reach perfect accuracy. In this work, we propose a new 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. We take into account the imperfection of activity detection systems in order to show that we have better accuracy than the state of the art [26].

This work is led through the PhD Thesis of Van Quan Nguyen under the supervision of Emmanuel Vincent and Francis Colas.

7.1.5. Learning for damage recovery

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

In 2015, we introduced a novel algorithm that allows robots to learn by trial-and-error when they are damaged [42]. In 2016, we extended this algorithm to make it easier to deploy it in real-life situations and real systems:

- We added "safety constraints" so that the learning algorithm both maximizes the post-damage performance and minimizes the probability of breaking the robot during the learning process; we demonstrated this extension with a simulation of the iCub robot, which is a fragile and expensive robot (around 250,000 euros) for which we would like to use our learning algorithms [33].
- We proposed a novel algorithm that does not require to reset the robot to its starting position between each trial [40], which allows the damaged robots to "learn while doing". We demonstrated this algorithm on our 6-legged walking robot.
- We extended the MAP-Elites algorithm, that is, the evolutionary algorithm that we use to generate prior probability distributions for our online learning algorithm, to scale-up to high-dimensional search spaces [59]. The algorithm is based on central Voronoi tesselations (CVT). In addition, we investigated the influence of the encoding (representation of the controller) on the performance of MAP-Elites [30].

7.1.6. Interactions with biology

Participant: Jean-Baptiste Mouret.

We continued our on-going collaborations with biologists.

- *The Evolutionary Origins of Hierarchy.* Hierarchical organization—the recursive composition of sub-modules—is ubiquitous in biological networks, including neural, metabolic, ecological, and genetic regulatory networks, and in man-made systems such as large organizations and the Internet. In this contribution, we showed that the pressure to minimize the connection costs in network can explain the evolution of hierarchical and modular biological networks [21]; this result extends our previous work on the evolutionary origins of modularity in biological networks [41]. (Collaboration with Jeff Clune, University of Wyoming, USA).
- *Animal-robot interaction.* We worked with a team based in Rennes to perform preliminary experiments about animal-robot attachment (here with a gallinaceous bird) [16].

7.1.7. Learning for whole-body motions

Participants: Serena Ivaldi, Valerio Modugno.

Within the European project CoDyCo, we studied how to combine learning, dynamics, and control for redundant robots. In [25], we proposed a framework to automatically optimize the evolution in time of soft task priorities for multi-task controllers. The motivation of the work was to propose a way to automatate the manual optimization procedure of task priorities and weights, that is classically done by control experts and is time consuming. In [24], we improved the framework by using constrained stochastic optimization algorithms to optimize the task priorities while ensuring that the system constraints (robot and problem setting) are never violated. We showed the results on our robot iCub. Our master student Ugo Chervet contributed to the simulations of this paper.

7.2. Natural Interaction with Robotic Systems

7.2.1. Human Activity recognition on load-sensing floor

Participant: François Charpillet.

In the framework of a collaboration with Lebanese University and CRIStAL laboratory, Lille, we have evaluated this year the capability of the load-sensing floor that we have designed in Nancy, to adress fall detection and activity recognition for elderly people living alone at Home.

The Inria-Nancy sensing floor consists of 104 tiles (60*60 cm). Each tile is equipped with a 3-axis accelerometer in the center of the tile, and four force sensors (strain gauge load cells) positioned at each corner.

The pressure sensors measure the load forces exerted on the floor that can be used to determine, for example, the center of pressure of objects, robots or human beeing on the floor.

This year we have demonstrated that we can also determine the posture or activiy of the monitored person (walking, sitting, standing, falling, etc.) by combining the pressure amount, the pressure duration on a tile, the 3-axis acceleration using a relatively simple algorithm [10], [11].

7.2.2. Human Activity recognition with depth camera

Participants: François Charpillet, Xuan Son Nguyen.

This year, we proposed a new local descriptor for action recognition in depth images. The proposed descriptor relies on surface normals in 4D space of depth, time, spatial coordinates and higher-order partial derivatives of depth values along spatial coordinates. In order to classify actions, we follow the traditional Bag-of-words (BoW) approach, and propose two encoding methods termed Multi-Scale Fisher Vector (MSFV) and Temporal Sparse Coding based Fisher Vector Coding (TSCFVC) to form global representations of depth sequences. The high- dimensional action descriptors resulted from the two encoding methods are fed to a linear SVM for efficient action classification. Our proposed methods are evaluated on two public benchmark datasets, MSRAction3D and MSRGesture3D. The experimental result shows the effectiveness of the proposed methods on both the datasets.

7.2.3. Human Posture Recognition

Participants: François Charpillet, Abdallah Dib, Alain Filbois, Thomas Moinel.

Human pose estimation in realistic world conditions raises multiple challenges such as foreground extraction, background update and occlusion by scene objects. Most of existing approaches were demonstrated in controlled environments. In this work, we propose a framework to improve the performance of existing tracking methods to cope with these problems. To this end, a robust and scalable framework is provided composed of three main stages. In the first one, a probabilistic occupancy grid updated with a Hidden Markov Model used to maintain an up-to-date background and to extract moving persons. The second stage uses component labelling to identify and track persons in the scene. The last stage uses a hierarchical particle filter to estimate the body pose for each moving person. Occlusions are handled by querying the occupancy grid to identify hidden body parts so that they can be discarded from the pose estimation process. We provide a parallel implementation that runs on CPU and GPU at 4 frames per second. We also validate the approach on our own dataset that consists of synchronized motion capture with a single RGB-D camera data of a person performing actions in challenging situations with severe occlusions generated by scene objects. We make this dataset available online (http://www0.cs.ucl.ac.uk/staff/M.Firman/RGBDdatasets/).

7.2.4. Evaluation of control interfaces by non-experts

Participants: Serena Ivaldi, François Charpillet.

In this work, we address the question of user preference for a robotic interface by non-experts (or naive users without training in robotics), after one single evaluation of such an interface on a simple task. This refers to situations when non-experts face the decision of adopting a robot for episodic use (i.e., not a regular continuous use as workers in factories): the ease of use of an interface is crucial for the robot acceptance. We also probe the possible relation between user performance and individual factors. After a focus group study, we chose to compare the robotic arm joystick and a graphical user interface. Then, we studied the user performance and subjective evaluation of the interfaces during an experiment with the robot arm Jaco and 40 healthy adults. Our results show that the user preference for a particular interface does not seem to depend on their performance in using it: for example, many users express their preference for the joystick while they are better performing with the graphical interface. Contrary to our expectations, this result does not seem to relate to the user's individual factors that we evaluate, namely desire for control and negative attitude towards robots.

The preliminary results of this work are published in [23]. A journal paper with the complete results is in preparation. The work was conducted with the master students Sebastian Marichal and Adrien Malaisé.

7.2.5. Robot acceptance and trust

Participant: Serena Ivaldi.

We continued our collaboration with psychologists.

- *Trust as a measure of robot acceptance*: together with the research group of Elisabetta Zibetti (Université de Paris 8), we proposed trust as a main indicator of acceptance in decision-making tasks characterized by perceptual uncertainty (e.g., evaluating the weight of two objects) and socio-cognitive uncertainty (e.g., evaluating which is the most suitable item in a specific context). We measured trust by the participants' conformation to the iCub's answers to specific questions. We found that participants conformed more to the iCub's answers when their decisions were about functional issues than when they were about social issues. Moreover, the few participants conforming to the iCub's answers for social issues also conformed less for functional issues. Trust in the robot's functional knowledge does not thus seem to be a pre-requisite for trust in its social knowledge. Finally, desire for control, attitude towards social influence of robots and type of interaction scenario did not influence the trust in iCub. The results have been published in [13].
- *Acceptance of assistance robots in EHPADs by professional caregivers*: together with Sophie Nertomb (Université de Lorraine), we started a dialogue with professional caregivers to probe their acceptance and positive/negative attitude towards an assistance robot as a collaborator in an EHPAD. From the first focus group, we found that caregivers are rather positive in adopting a robot to get assistance in some daily tasks with the patients, and they would prefer a social robot such as Pepper rather than a functional robot arm, because they believe it could be more useful and would be better accepted by patients. The results of our preliminary investigation were presented in [22].

7.2.6. Individual factors and social/physical signals

Participant: Serena Ivaldi.

We finalized our study about the influence of individual factors in the production of social signals during human-humanoid interaction on a collaborative assembly task. We found that the more people are extrovert, the more and longer they tend to talk with the robot, and the more people have a negative attitude towards robots, the less they will look at the robot face and the more they will look at the robot hands where the assembly and the contacts occur. Our results confirm and provide evidence that the engagement models classically used in human-robot interaction should take into account attitudes and personality traits. The results are published in [15].

We started to study the influence of individual factors on physical signals and collaborative movement. We made interesting observations, for example the influence of age and negative attitude towards robots in the amount of exchanged forces. Part of the analysis was performed by the master student Anthony Voilqué. A paper describing our findings is in preparation.

7.2.7. *Learning gait models with cheap sensors for applications in EHPADs*

Participants: Serena Ivaldi, François Charpillet, Olivier Rochel.

Thanks to the MITACS-Inria grant, we started a collaboration with Prof. Dana Kulic in University of Waterloo on the topic of learning gait models with cheap sensors. Jamie Waugh, master student, visited us for 3 months to start a data collection protocol where several sensors are used to monitor the human gait under different conditions. The aim is to learn gait parameters with different sensors, such as IMUs and Kinect cameras, and to provide quantitative comparison of the accuracy of the estimation provided by the different sensors. As ground truth, the Qualisys motion capture and the Gaitrite walking mat are used. The final goal of the project is to be able to deliver algorithms for estimating gait based on cheap sensors that could be used on a daily basis in healthcare facilities such as EHPADs.

8. Partnerships and Cooperations

8.1. Regional Initiatives

8.1.1. *Project PsyPhINe: Cogitamus ergo sumus*

Participant: Amine Boumaza.

This project is financed for two years by the MSH Lorraine (USR3261) gathering researchers from the following institutes: , InterPsy (EA 4432), APEMAC, EPSaM (EA4360), Archives Henri-Poincaré (UMR7117), Inria Bordeaux Sud-Ouest, Loria (UMR7503). Refer to sec. 7.1.1 for further information.

8.1.2. *AME Satelor*

Participants: François Charpillet, Xuan Son Nguyen, Thomas Moinel, Mélanie Lelaure.

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.

8.2. National Initiatives

8.2.1. *PIA LAR Living Assistant Robot*

Participants: François Charpillet, Abdallah Dib.

Partners : Crédit Agricole, Diatelic, Robosoft
The LAR project has the objective to design an assistant robot to improve the autonomy and quality of life for elderly and fragile persons. The project started at the beginning of 2015. The role of the Larsen Team is to develop a simultaneous localisation and mapping algorithm using a RGB-D camera. The main issue is to develop an algorithm able to deal with a dynamic environment. Another issue is for the robot to be able to behave with acceptable social skills.

8.3. European Initiatives

8.3.1. FP7 & H2020 Projects

8.3.1.1. RESIBOTS

Title: Robots with animal-like resilience

Programm: 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 damage 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 or 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 will open new research avenues for adaptive machines.

8.3.1.2. CoDyCo

Participants: Serena Ivaldi, Valerio Modugno, Oriane Dermy.

Title: Whole-body Compliant Dynamical Contacts in Cognitive Humanoids

Program: FP7

Instrument: STREP

Objective: Cognitive Systems and Robotics (b)

Duration: March 2013 - February 2017 (4 years)

Coordinator: Francesco Nori (Italian Institute of Technology)

Partners: TU Darmstadt (Germany), Université Pierre et Marie Curie (France), Josef Stefan Institue (Slovenia), University of Birmingham (UK)

Inria contact: Serena Ivaldi

Abstract: The aim of CoDyCo is to advance the current control and cognitive understanding of robust, goal-directed whole-body motion interaction with multiple contacts. CoDyCo will go beyond traditional approaches by: (1) proposing methodologies for performing coordinated interaction tasks with complex systems; (2) combining planning and compliance to deal with predictable and unpredictable events and contacts; (3) validating theoretical advances in real-world interaction scenarios. First, CoDyCo will advance the state-of-the-art in the way robots coordinate physical interaction and physical mobility. Traditional industrial applications involve robots with limited mobility. Consequently, interaction (e.g., manipulation) has been treated separately from whole-body posture (e.g., balancing), assuming the robot firmly connected to the ground. Foreseen applications involve robots with augmented autonomy and physical mobility. Within this novel context, physical interaction influences stability and balance. To allow robots to surpass barriers between interaction and posture control, CoDyCo will be grounded in principles governing whole-body coordination with contact dynamics. Second, CoDyCo will go beyond traditional approaches in dealing with all perceptual and motor aspects of physical interaction, unpredictability included. Recent developments in compliant actuation and touch sensing allow safe and robust physical interaction from unexpected contact including humans. The next advancement for cognitive robots, however, is the ability not only to cope with unpredictable contact, but also to exploit predictable contact in ways that will assist in goal achievement. Third, the achievement of the project objectives will be validated in real-world scenarios with the iCub humanoid robot engaged in whole-body goal-directed tasks. The evaluations will show the iCub exploiting rigid supportive contacts, learning to compensate for compliant contacts, and utilizing assistive physical interaction.

8.4. International Initiatives

8.4.1. Participation in Other International Programs

Serena Ivaldi, in collaboration with Prof. Dana Kulic of University of Waterloo, obtained a MITACS-Inria grant for the master student Jamie Waugh for the project "learning gait models".

8.5. International Research Visitors

8.5.1. Visits of International Scientists

- Francesco Nori, researcher at the Italian Institute of Technology, and coordinator of the European Project CoDyCo (where we are partners), visited our team for one month. During this visit, we wrote together a proposal for a H2020 project that was submitted in April 2016 and was subsequently accepted: the project, AnDy, will start in January 2017.
- John Rieffel, Associate Professor at Union College (NY, USA), visited our team for a month. During his visit, we used Bayesian optimization to learn gaits for a soft tensegrity robot. A paper has been submitted.

8.5.1.1. Internships

- Jamie Waugh, master student of University of Waterloo, visited our team for 3 months (from September to December) thanks to a MITACS-Inria grant.

9. Dissemination

9.1. Promoting Scientific Activities

9.1.1. Scientific Events Organisation

9.1.1.1. Member of the Organizing Committees

- Amine Boumaza co-organized "Projections, Interactions, Emotions - Journées PsyPhINe 2016", the second workshop of the PsyPhINe project (http://poincare.univ-lorraine.fr/fr/manifestations/psyphine-2016).
- François Charpillet co-organized and co-chaired the Workshop on On-line decision-making in multi-robot coordination, June 19, 2016, Ann Arbor, Michigan, USA, organized in conjuction of the 2016 Robotics: Science and Systems Conference (RSS 2016).
- Serena Ivaldi co-organized the Workshop "Human-Robot collaboration: towards co-adaptive learning though semi-autonomy and shared control" at IROS 2016 (http://www.ausy.tu-darmstadt.de/Workshops/IROS2016).

9.1.2. Scientific Events Selection

9.1.2.1. Member of the Conference Program Committees

- Amine Boumaza was a PC member of GECCO'2016 (Genetic and Evolutionary Computation Conference), ALIFE'2016 (International Conference on the Synthesis and Simulation of Living Systems), CEC'2016 (Congress on Evolutionary computation).
- Francis Colas was a Technical PC member for the EAI International Conference Track on Smart Cities and the Future Internet (SCiFI).
- Serena Ivaldi was an Associate Editor for the 2016 IEEE/RAS International Conference on Robotics and Automation (ICRA), the 2016 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS), the 2016 IEEE/RAS International Conference on Humanoid Robots (HUMANOIDS), the 2016 IEEE International Conference on Development and Learning (ICDL).
- Jean-Baptiste Mouret was a PC member of GECCO'2016 (Genetic and Evolutionary Computation Conference), ALIFE'2016 (International Conference on the Synthesis and Simulation of Living Systems), EVO*2016 (EvoStar), SAB'2016 (Conference on System and Adaptive Behaviors – from animals to animats).
- Vincent Thomas was a member of the program committee for "Journées Francophones sur la Planification la Décision et l'Apprentissage pour la conduite de systèmes 2016" (JFPDA 2016).

9.1.2.2. Reviewer

- François Charpillet was a reviewer for the 2016 IEEE International Conference on Robotics and Automation (ICRA), The 2016 europeen conference on artificial intelligence (ECAI), Rob&IA2016, RFP-IA 2016, WACAI2016, DEMUR, and the 2016 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS).
- Francis Colas was a reviewer for the 2016 IEEE International Conference on Robotics and Automation (ICRA), the EAI International Conference on Smart Cities and the Future Internet (SCiFI), and the 2016 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS).
- Serena Ivaldi was a reviewer for the ACM International Conference on Human-Robot Interaction (HRI), the IEEE International Conference on Human-Robot Communication (RO-MAN), the International Conference Robotics: Science and Systems (RSS).
- Jean-Baptiste Mouret was a reviewer for the 2016 IEEE International Conference on Robotics and Automation (ICRA), and the 2016 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS).
- Vincent Thomas was a reviewer for "Journées Francophones sur la Planification la Décision et l'Apprentissage pour la conduite de systèmes 2016" (JFPDA 2016).

9.1.3. Journal

9.1.3.1. Member of the Editorial Boards

- Serena Ivaldi is an editorial board member for the Journal "Intelligent Service Robotics", Springer. She was also Guest Editor for Springer Autonomous Robots for the Special Issue "Whole-body control of contacts and dynamics for humanoid robots".

9.1.3.2. Reviewer - Reviewing Activities

- Amine Boumaza is a Review Editor for Frontiers in AI and Robotics.
- Francis Colas was a reviewer for the Journal of Field Robotics, and the IEEE Transactions on Automation Science and Engineering.
- Serena Ivaldi was a Review Editor and reviewer for Frontiers in AI and Robotics, and a reviewer for IEEE Transactions on Cognitive and Developmental Systems.
- Jean-Baptiste Mouret is Review Editor for Frontiers in AI and Robotics. He was a reviewer for Nature Communications, Frontiers in Neurobotics, Artificial Life.
- Vincent Thomas was a reviewer for the IEEE Transactions on Cybernetics.

9.1.4. Invited Talks

- Jean-Baptiste Mouret was invited to talk at:
The Origins Workshop (Arizona State University, USA),
The cross-disciplinary symposium on Machine Learning and Architecture (Copenhague, Danemark),
9th SIG on Design Theory of the International Design Society (Keynote, Paris, France),
Journée des Jeunes Chercheuses et Chercheurs organisée de l'ANR (Paris, France),
Ministère des finances (Conseil Général de l'Economie / mission de réflexion sur les armes autonomes, Paris, France),
Journée "Apprentissage et IA" organized by CERNA (Commission de réflexion sur l'Éthique de la Recherche en sciences et technologies du Numérique d'Allistene),
Journée Scientifiques Inria (Rennes, France),
Journée Intelligence Artificielle et Voiture Autonomes (Institut VEDECOM, Versailles, France),
HLR 2016 (German-French Winter School on Humanoids and Legged robots).
- Serena Ivaldi gave the following invited talks:
06/2016: *Humanoid robotics and human-robot interaction*. Invited talk at Journée Robotique et IA, RFIA 2016, by Olivier Simonin.
10/2016: *Grasping, vision and interaction for object manipulation with iCub*. Invited talk at IEEE-RAS IROS 2016 Workshop on Grasping and Manipulation, by Yasemin Bekiroglu.
11/2016: *Exploiting tactile information for whole-body dynamics, learning and human-robot interaction*. Invited talk at IEEE-RAS Humanoids 2016 Workshop on Tactile Manipulation, by Qiang Li.
11/2016: *Studying human behavior during human-robot collaborative tasks*. Invited talk at IEEE-RAS Humanoids 2016 Workshop on Human Movement Understanding, by Emel Demircan.
11/2016: *Les robots humanoides: de l'acceptabilité à l'interaction*. Invited talk at the Forum de Sciences Cognitives, Nancy, by Christine Bourjot.
12/2016: *Learning and interaction with iCub*. Invited talk at the German-French Conference on Humanoid and Legged Robots 2016, by Olivier Stasse.

9.1.5. 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".

9.1.6. Scientific Expertise

- Serena Ivaldi was appointed vice-president of the CES 33 panel Interaction and Robotics of the ANR. She was an invited member of the CNRS for the "Groupe de Discussion pour le renouvellement de la liste des candidats" section 07 CNRS (Specif Campus, GRETSI & Club EEA) - invited by Specif Campus, 2016.

9.1.7. Research Administration

- Amine Boumaza is a board member of the Évolution Artificielle association.
- Serena Ivaldi was member of the hiring committees:
  - CNRS: Committee member for jury n.29 - IR2 - BAP, sept.-oct. 2016.
  - Maitre de conference: Committee member for jury 27MCF1744 (4335) at UPMC, Paris, apr.-may 2016.
- Francis Colas was member of the hiring committee 27-MCF-0762 at ESSTIN, Université de Lorraine.

9.2. Teaching - Supervision - Juries

9.2.1. Teaching

- Master: Karim Bouyarmane, “Programmation C/C++”, 20h eq. TD, M1/M2, ESSTIN, France.
- Master: Francis Colas, “Robotique Autonome”, 18h eq. TD, M2 “Systèmes Interactifs et Robotiques”, CentraleSupélec, France.
- Master: Francis Colas, “Introduction à ROS”, 6h eq. TD, M1, Mines de Nancy, France.
- Master: Serena Ivaldi, “Analyse du comportement”, 15h eq. TD, M2 “Science Cognitive”, Université de Lorraine, France.
- Master: Jean-Baptiste Mouret, “Disruptive technologies: Robotics”, 3h eq. TD, M2 (School of Public Affairs), Sciences Po Paris, France.
- Master: Vincent Thomas, “Modèles probabilistes et Apprentissage par renforcement”, 15h eq. TD, M2 “Informatique - Image Perception Raisonnement Cognition”, Univ. Lorraine, France.
- Master: Vincent Thomas, “Game Design”, 20h eq. TD, M1 “Sciences Cognitives”, Univ. Lorraine, France.
- Master: Vincent Thomas, “Agent intelligents et collectifs”, 20h eq. TD, M1 “Sciences Cognitives”, Univ. Lorraine, France.
- Master: Vincent Thomas, “Serious Game”, 12h eq. TD, M2 “Sciences Cognitives”, Univ. Lorraine, France.

9.2.2. Supervision

- PhD: Abdallah Dib, “*Assistance à la personne en perte d'autonomie : étude de l'apport d'un robot compagnon*”, 24 May 2016, François Charpillet (advisor).
- PhD in progress: Adrian Bourgaud, “*Multi-sensor Fusion and Active Sensing*”, started in Jul. 2015, François Charpillet (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: Yassine El Khadiri, “Apprentissage automatique pour l'assistance à l'autonomie à domicile”, started in Nov. 2016, François Charpillet (advisor).
- PhD in progress: Iñaki Fernández Pérez, “*Apprentissage incrémental évolutionnaire*”, started in Oct. 2013, F. Charpillet (advisor), Amine Boumaza.
- PhD in progress: Nassim Kaldé, “*Exploration et reconstruction d'un environnement inconnu par une flottille de robots*”, started in Oct. 2012, François Charpillet (advisor), Olivier Simonin.
- PhD in progress: Rituraj Kaushik, “Fast adaptation to damage by exploiting trajectory data”, started in Oct. 2016, Jean-Baptiste Mouret (advisor).
- PhD in progress: Van Quan Nguyen, “Mapping of a sound environment by a mobile robot”, started in Dec. 2014, Emmanuel Vincent (advisor), Francis Colas, François Charpillet.

9.2.3. Juries

- François Charpillet was reviewer and member of the PhD committee of :
  - Hendry Ferreira Chame, “Egocentric Representations for Autonomous Navigation of Humanoïd Robots”, école centrale de Nantes, IRCCYN.
  - Patrick Béchon, “Planification multi-robot pour des missions de surveillance avec contraintes de communication”, Université de Toulouse, ISAE, LAAS, ONERA.
  - Raphael Lallemand, “Symbolic and Geometric Planning for teams of Robots and Humans”, Université de Toulouse, INSA Toulouse, LAAS.
  - Loïc Sevrin, “Mesure et suivi d'activité de plusieurs personnes dans un Living Lab en vue de l'extraction d'indicateurs de santé et de bien être”, Université de Claude Bernard Lyon 1, Institut des nanotechnologies de Lyon;

  - Vishnu Karakkat Narayanan, “Characterizing assistive shared control through vision-based and human-aware designs for wheelchair navigation assistance”, Université Bretagne Loire, INSA Rennes, Team Project Lagatic and Chroma.
  - Haïfa Rabai, “Réseau dynamique d’applications chaotiques couplées pour l’étude de la mobilité urbaine”, Université du Havre.
- François Charpillet was member and chair of the PhD committee of :
  - Coralie Angeletti, “Stratégie de Perception Active pour l’Interprétation de Scènes”, University Blaise Pascal, Clermont Ferrand.
  - Kevin Roussel, “Évaluation et amélioration des plates-formes logicielles pour réseaux de capteurs sans-fil, pour optimiser la qualité de service et l’énergie”, Université de Lorraine.
- François Charpillet was member of the Phd committee of :
  - Abdallah Dib, “Vers un système de capture du mouvement humain en 3D pour un robot mobile évoluant dans un environnement encombré”, Lorraine University.
  - Seifallah Ben Saad, “Conception d’un algorithme de coordination hybride de groupes de robots sous-marins communicants Application : acquisition optique systématique et détaillée des fonds marins”, Université de bretagne occidentale, ENSTA Bretagne.

9.3. Popularization

- Amine Boumaza is a member of the editorial board of “Interstice”.
- Vincent Thomas gave proposed tutorials on “physics simulation” and “reinforcement learning” during “journées ISN-EPI” (24th of Mars 2016).
- Vincent Thomas participated in the preparation of “Computer Science Exporoute” (conducted by Inria Nancy Grand-Est) planned for 2017.
- Jean-Baptiste Mouret wrote an article for “Interstices” (“ Des robots qui s’adaptent aux dommages en seulement quelques minutes”).
- Jean-Baptiste Mouret helped Pierre Vandeginste (journalist) to write an article about his work in “La Recherche” (Dec. 2016); he also appeared in Science et Avenir, Arte Future Mag, Socialter, Telerama.
- Serena Ivaldi appeared in the following articles / gave the following interviews:
  07/2016: Humanité Dimanche, Homme/robot. Le trouble au rendez-vous. http://www.humanite.fr/hommerobot-le-trouble-au-rendez-vous-612149
  06/2016: Inriality, Robots humanoides : une inquiétante étrangeté. http://www.inriality.fr/culture-loisirs/relations-homme-robot/robophobie/robots-humanoides-une/
  06/2016: Les Inrockuptibles, n.1070, Comment les robots ont conquis nos coeurs. http://www.lesinrocks.com/2016/06/01/actualite/dossier-high-tech-androides-ont-conquis-coeurs-11832819/
  03/2016: Interstices, Des robots au service de l’homme. https://interstices.info/jcms/p_88305/des-robots-au-service-des-hommes
  03/2016: La semaine, Têtes chercheuses. http://www.lasemaine.fr/2016/03/17/tetes-chercheuses
  03/2016: Pour la science, Quels obstacles à l’insertion des robots en société ? https://pbs.twimg.com/media/CceuEH3W4AEoNx-.jpg:large

10. Bibliography

Major publications by the team in recent years

[1] 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

[2] 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

[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, to appear (provisional acceptance), http://arxiv.org/abs/1508.04603

[4] F. POMERLEAU, F. COLAS, R. SIEGWART. *A Review of Point Cloud Registration Algorithms for Mobile Robotics*, in "Foundations and Trends in Robotics (FnTROB)", 2015, vol. 4, n^o 1, pp. 1–104 [*DOI :* 10.1561/2300000035], https://hal.archives-ouvertes.fr/hal-01178661

[5] O. SIMONIN, F. CHARPILLET, E. THIERRY. *Revisiting wavefront construction with collective agents: an approach to foraging*, in "Swarm Intelligence", June 2014, vol. 8, n^o 2, pp. 113-138 [*DOI :* 10.1007/S11721-014-0093-3], https://hal.inria.fr/hal-00974068

Publications of the year

Doctoral Dissertations and Habilitation Theses

[6] A. DIB. *Toward a motion capture system in 3D for a mobile robot moving in a cluttered environment*, Université de Lorraine, May 2016, https://hal.inria.fr/tel-01333772

Articles in International Peer-Reviewed Journals

[7] M. AMBLARD, A. BOUMAZA. *Human Robots, Are You Real Then?*, in "Iride", 2016, vol. XXIX, n^o 2, pp. 287-298 [*DOI :* 10.1414/84251], https://hal.inria.fr/hal-01391754

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