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Personally Assisted Living

LSIA Pal

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1 Introduction

1.1 Motivation

The objective of this project is to create a research infrastructure that will enable experiments with technologies for improving the quality of life for persons who have suffered a loss of autonomy through age, illness or accident. In particular, the project seeks to enable development of technologies that can provide services for elderly and fragile persons, as well as their immediate family, caregivers and social groups.

The INRIA Project-Teams (IPT), see annexes 8.1 and 8.2, participating in this Large-scale initiative action *Personally Assisted Living* (LSIA Pal) – see annex 8.3, propose to work together to develop technologies and services to improve the autonomy and quality of life for elderly and fragile persons. Most of the associated project groups already address issues related to enhancing autonomy and quality of life within their work programs. This goal of this program is to unite these groups around an experimental infrastructure, designed to enable collaborative experimentation.

Working with elderly and fragile to develop new technologies currently poses a number of difficult challenges for INRIA research groups. Firstly, *elderly people* cannot be classified as a single homogeneous group with a single behavior. Their disabilities may be classified as not just physical or cognitive, motor or sensory, but can also be classified as either chronic or temporary. Moreover, this population is unaccustomed to new technologies, and can suffer from both cognitive and social inhibitions when confronted with new technologies. None-the-less, progress in this area has enormous potential for social and financial impact for both the beneficiaries and their immediate family circle.

The spectrum of possible actions in the field of elderly assistance is large. We propose to focus on challenges that have been determined through meetings with field experts (medical experts, public health responsible, sociologists, user associations...) (see 6.1.3). We have grouped these challenges into four themes: monitoring services, mobility aids, transfer and medical rehabilitation, social interaction services. These themes correspond to the scientific projects and expectations of associated INRIA projects. The safety of people, restoring their functions in daily life and promoting social cohesion are all core motivations for this initiative.

Scientific themes have been selected for their potential societal impact, for the innovative aspect of the service they offer and for the potential scientific impact of proposed solutions. The purpose of LSIA PAL is to provide an experimental infrastructure, in order to facilitate the development of models, tools, technologies and concept demonstrations. Using the skills and objectives of the involved teams, we have defined four research themes:

1. ***Assessing the degree of frailty of the elderly***
2. ***Mobility of people***
3. ***Rehabilitation, transfer and assistance in walking***
4. ***Social interaction***

The first theme ***Assessing the degree of frailty of the elderly*** aims at developing monitoring services for detecting signs to postpone the inclusion at nursery home or hospital. Note that the main reason is the loss of a sense of security perceived by the person herself/himself, and her/his social circle. It seems therefore essential to assess the state of frailty of individuals to prevent risks such as those of falls - which affect 40% of people over 65 years - or the risk of iatrogenic, malnutrition. New solutions will be explored in this issue by all teams pooling their approaches. The second theme ***Mobility of people*** responds to the problem of people motion by proposing to develop some automated mobile device: a walker, a shopping cart (caddie) and a wheelchair. The third theme ***Rehabilitation, assistance and transfer to walking*** addresses issues concerning the change in posture of persons (i.e. move from the sleeping positions to standing or sitting, etc) but is not limited to it. Indeed, a solution using cable robots, developed for this theme, may also partially address the problems of positioning people in toilets. Finally, the fourth theme ***Social interaction*** looks at *communication functions* and aims to strengthen social cohesion among family and immediate friends in order to defend against the social isolation that often results from loss of autonomy.

To effectively contribute in this area, the associated INRIA research groups require participation and guidance of experts from the domain of elderly care. Many of the individual research groups have developed collaborations with experts in the areas of gerontology, assisted living, elderly care and related areas. One of the objectives of this effort is to build on these partnerships, thereby allowing other groups to profit from such collaborations. LSIA PAL is designed to be installed with strong links between teams and with multiple experts in the associated fields, and thus to promote collaboration. The LSIA PAL is a tool to structure the exchange of emerging technologies of the future between scientists and field experts. Eventually, our services could be validated through experimental protocols developed under the guidance/control of medical experts.

An important effort within PAL is directed to support the person needs to consider all stakeholders in the field (for a description, see 6.1.3). To facilitate interaction between participants, teams want to unite around a research infrastructure that supports them in this joint venture/effort.

The role of this infrastructure is then to:

- *Coordinate communication between research teams (IPT and external) and experts in the field.* To help teams in defining and monitoring the services they offer, through the confrontation with the expertise.
- *Promote experimental common platforms.* (for a detailed description see section Platforms).

This structure should also help the teams in research funding and collaborations. The goal this time is:

- *To support the teams in their application to the scientific or local bodies of INRIA and assist teams in responding to calls for national and international tenders.*
- *To appear as a cross-team identified at international level.* We seek to foster such collaborations with prestigious foreign laboratories.

1.2 Offer useful and usable services

To be useful and usable, the services that we propose should have a number of properties. We must accommodate the prerogatives of all users: their interests to use or prescribe such services and also ensure that such use will remain in the long term.

1.2.1 Useful services

The main difficulty is that the real use or the felt use of these services is perceived differently according to different actors. Even if the various actor's priorities are difficult to conciliate, we aim to provide an organization that give an accurate solution. Namely, it should be capable to bring answers to those questions:

- How to identify a target coming from the request of an expert, a user, or to highlight a technology, that is ambitious but reasonable as a function of the state of the art and the predictable state of the technology?
- How to take into account all requirements (from the field or technological experts, in terms of safety or reliability, how to take into account human, medical or social constraints...)?
- How to ensure the validity of the proposals; how to confront them to the reality of environmental use?

It is also important to take into account the risk of the loss of existing autonomy caused by the setting of help or care services. The classic example used to illustrate this danger is the *home delivery food*. Preparing and eating a meal is a long and complex process that requires quite various cognitive and handling abilities. To describe this process briefly, one needs to elaborate a menu, to identify the ingredients, to buy them, to cook, to set the table, to eat, and finally to clear the table, to make the washing...

As soon as the person is no longer independent for at least one of these tasks, then a *home delivery food service* can be considered. However a possible consequence of using a home delivery food service is the risk that the person gradually loses her/his ability to perform the other tasks. Moreover, social and physical activities could also deteriorate. We must therefore find a compromise between compensating a lack of autonomy and preserving the existing autonomy. Additionally, the elderly and the environments where they operate are heterogeneous. It is necessary that the solutions we offer are adjustable, adaptable, and flexible, and will be able to adapt the following requirements:

- *Medical:* We should try to treat different diseases and different level of autonomy that evolve in time. We do not hesitate to adjust and limit the capacity of a system to the care goal. For example, the transfer system using wired cranes must be able to provide the just enough strength

to assist a person in its moves even if the system is able to provide enough force to perform the move completely.
- *Individual:* We must respect human freedom and integrity while preserving security. This requires adaptation to person characteristics (size, weight, age, skill, familiarity with technology...).
- *Environmental:* It is important to take into account the variability of environment by considering the uncertainties.

1.2.2 Usable services

The usefulness of a service does not guarantee that it will be used. Acceptance of our services begins with their recommendation by field experts (doctors, pharmacist, references care centre), social services, insurance ... In a second step, use and experimentation will convince a person to adopt the service. And then, if the service can adapt itself to the evolution of the autonomy of the person, it can be used on a long-term basis. Thus, even if the proven benefits of the service contribute greatly to its acceptance, it is only one component of the decision. To encourage the person to adopt and maintain the prescribed solution, we propose to emphasize the following points, which are essential according to us:
- *Interface:* It must be well adapted to the individual according to his level of autonomy, type of disability, cognitive skills, and familiarity with new technologies. It is interesting therefore to call for ergonomists and to promote modularizing the systems interface.
- *Cost:* The cost of services for the person, her/his family or the society is crucial for their distribution and deployment. It has to be compared with the cost of nursery home or hospital inclusion and the medical care. We must take this into account when designing services by promoting standard hardware, including inexpensive sensors. The scientific challenge is then to take into account the possible *low* quality of components in our models, our algorithms and our experimental developments.
- *Interaction:* Two types of interactions are distinguished:
  - The interaction between objects and people: it is here that we ensure that systems are not physically or physiologically hurting people. These people should accept that these objects are part of their everyday environment.
  - The interaction between people and their social circle (family, friends, health professionals, personal care services...). New technologies can promote these interactions, making them natural, well integrated into the environment, and perceived as non-aggressive.
- *Security:* The deployment of mobile systems in a human space must obviously require certified mechanical, electrical and computer designs. Taking into account uncertainties may again contribute to operational safety.
- *Respect for the person:* The unbearable systems at home, and unusual aspects are still unnatural and their potential to provide personal information may refrain their acceptance. Moreover, the privacy needs to be preserve. It will take time for these devices to belong to our everyday life but we should already consider how these devices can be integrated into the buildings and develop solutions accordingly. Our partners specialized in architecture will help us on this point

2 Assessing the degree of frailty of the elderly

IPT involved: Coprin, Maia, Pulsar, Prima, Trio.

2.1 Service overview

The objectives of this work are to develop and test algorithms for the automatic assessment of the frailty evolution of elderly people at home. Other goals include handling emergency situations (e.g. people falling, or taking overdose of medication), assessing the gravity level of specific diseases (e.g. Alzheimer) and the automatic detection of changes in behavior patterns of elderly.

2.2 State of the art

Healthcare technologies can enable elderly to live longer at home, to live in a familiar environment and to benefit from a maximal autonomy. Their objectives are to detect and even prevent the occurrence of critical situations for the elderly (e.g. falling down) by generating a set of alarms. These technologies are based on approaches that consist in analyzing data provided by sensors embedded in the home and/or worn by the person. Many projects are conducted on this topic of healthcare monitoring at home. They are designed to assess systems for monitoring a specific category of patients (e.g. heart failure, pulmonary failure, asthmatic, diabetic, patient with Alzheimer's disease, etc.), or for improving smart homes, or for processing sensors embedded in the home or worn by the person, or for generating social alarm systems.

We mention for example:

In France, Thomesse et al. (J. Thomesse 2002) have developed the project Tissad for monitoring kidney failure and heart failure of the elderly. Diatelic (Thomesse, et al. 2004) has developed systems for home medical monitoring of persons dialysis, where Trio and Maia have been involved, which has led to the creation of the company Diatelic in Nancy. Casper project has built intelligent tools for monitoring the communication between the elderly, families and medical staff. In particular, Casper aims at developing an innovative system that allows, from specific autonomous sensors, activity monitoring at home for the elderly or people with disabilities in order to provide solutions to help them to live in their own home by analyzing their behaviors and enabling adequate social interactions (see link Prima). The project Prosafe in France has identified abnormal behaviors of a monitored Alzheimer patient that can be interpreted as accidents, by collecting representative data on a patient's nocturnal and daily activity. The project Actidom (home actimetry) aims at measuring the activity of the frail elderly in their daily living in order to determine their frailty evolution (Noury, et al. 2004). GERHOME, CIU-sante and Sweethome projects have also addressed the problem of the automatic evaluation of the frailty degree of the elderly by using fixed cameras and environmental sensors networks (Zouba, Bremond and Thonnat 2009), (Zouba, Bremond, et al. 2009) (see link Pulsar).

In U.S., the University of Colorado has developed the project ACHE to automatically monitor temperature, heating and lighting. The system monitors the environment, observes the actions taken by the residents on lighting and thermostats, and then builds up a model to predict their actions by using reinforcement learning based on neural networks (Mozer 1998). The projects MavHome (Das, et al. 2002) at the University of Arlington, House of Matilda House (Helal, Winkler, et al. 2003) and Gator Tech Smart House at the University of Florida (Kidd, et al. 1999), Aware Home Research (Helal, Mann, et al. 2005) of the Georgia Institute of Technology, are similar systems which aim at providing and enhancing safety for the elderly at home. Microsoft has also proposed the project EasyLiving (Brumitt, et al. 2000) for monitoring residents. The system uses video cameras combined with motion sensors fixed on the walls tracking and localizating a person by performing image processing. Finally, the project Hat (Finkelstein, O'Connor and Friedman 2001) has been developed for asthmatic patients.

In Asia, at the university of Ibaraki in Japan, an intelligent self environment (Sensorized Environment for LiFe) has been developed. The aim of this project is to monitor the health of the person, by analyzing several physiological parameters. The system records and analyzes the physiological data, and provides a daily assessment of physiological activities of the person (Nishida, et al. 2000). The systems from the University of Tokyo (Noguchi, Mori and Sato 2002) and the smart home from Osaka (Matsuoka 2004) are other examples of smart homes similar to Self in Japan. In South-Korea, the Sweehome project includes a smart home dedicated to people with reduced mobility. The goal is to assist the person to go to bed or to sit on the chair (Park and Bien 2003).

In Europe, the CarerNet system has been proposed in the United Kingdom in order to provide health services such as alarms, health-care and telemonitoring (West, Greehill and Venkatesh 2005). In the Netherlands, the Senior Citizens Technology Center is equipped with a home monitoring system for people and assistive technologies. Motion detectors measure the activity of the individual and report any suspicious inactivity and intrusion(Vermeulen and Berlo 1997). In Norway, the house called SmartBo was built specifically for the elderly. Devices and sensors can control lighting, windows, doors, locks, water pipes, and electrical outlets (Elger and Furugren 1998). In Spain, a platform for home-care has been developed to help patients suffering from specific diseases to live in their own home. The platform consists of two parts: a client application for processing data locally, and a medical assistance center (Guillen, et al. 2002). In Finland, a health automatic environment called Terva was developed to monitor simultaneously several psycho-physiological criteria using physiological measures and behaviours of persons (Korhonen, et al. 1998). The smart homes of British Telecom et Anchor Trust in England are other examples of such platforms in Europe. The goal of these system is the remote monitoring and actimetry of elderly (Barnes, et al. 1998). Rodriguez et al. (Rodriguez, et al. 1995) in Spain have developed a generic architecture of medical monitoring system under the Epic project (European Prototype for Integrated Care) and Lind et al. (Lind, Sundvall and Ahlfeldt 2001) in Sweden have developed a system for diabetics.

2.3 Description of services

The services for the objective of assessment of the health state of elderly, in this project, can be divided into four areas:

1. **Real-time risky situation detection (falls, uneasiness, weakness, etc.):** One of the crucial problems that will be addressed in this project is the prevention and detection of falls and the activity monitoring. Existing telehomecare systems cause too many false alarms and therefore became quickly unusable in a real world. Therefore a great experimental analysis and validation are needed to ensure a robust data and video analysis to detect risky situations and reduce false alarms.
2. **Automation of the Standardized Geriatric Evaluation (SGE):** The SGE as a trustworthy tool is all the more interesting in that it is reproducible as it is based on the use of scales that have all been validated to evaluate each patient in different domains, more particularly autonomy and the cognitive functions. The SGE will allow early detection of risk factors of the loss of autonomy that could compromise a satisfactory care. It is fully justified within a fragile elderly population and authorizes setting up acts of prevention. The SGE will be realized by a medical gerontologist in an interview with the patient. To do this, the basic activities of daily living or activities of daily life will be analyzed, like: using the telephone, dressing, toileting, preparing meals, cleaning, moving (e.g. bathroom to shower), taking medications and managing money. For more details, see [51]. One of the objectives of this project is SGE automation. This can be achieved using various sensors (e.g. video analysis). By doing this, the fragility level of the elderly will be measured automatically. In this context, we can model scenarios that characterize the fragility level.
3. **Behavioral profiling for pathological deviation detection:** The behavioral profile of a person can be defined as all of its activity parameters. Behavioral modeling of a person in a normal situation can be used to detect deviations from the representative profile and prevent a potentially and discrete disaster. The automatic monitoring of different activities can then detect changes in the behavior of a person (e.g. depression) and anticipate risk situations (e.g. mobility, risk of falling).
4. **Automatic analysis of behavioral disorders in patients with Alzheimer's disease**: Alzheimer's disease is a neurodegenerative disorder representing the main cause of dementia in the world. It could reach 25% of people over 65 in 2020. Patients with Alzheimer's disease show cognitive decline commonly associated with psycho-behavioral disorders (depression, agitation, apathy, aberrant motor behavior ...). It is necessary to develop tools with automatic evaluation objectives. Automatic analysis of video, as a complement, could help to develop algorithms providing such results.
   Note that this last point is a particular but important case, which leds us to separate it from point 3).

2.4 Description of tasks

To reach the objectives of the project and to remove the scientific obstacles, we consider three tasks: Monitoring using low level sensor data, Monitoring using high level data (heterogonous sensor fusion and analysis), Communication interoperability and QoS between heterogeneous sensors and actuators.

2.4.1 TASK1: Monitoring using low level sensor data

This task aims to develop fusion and combination of object tracking algorithms to improve the robustness of monitoring. In this task, the teams share data received from the sensors (low-level data). According to the type of the sensors, their functionalities and the approaches that will be used, this task can be divided into several sub-tasks.

For example, Maia and Trio will work together on video image analysis coupled with other sensors fixed or mobile. An interesting point is the use of a Smartphone for motion detection. The different functions to be accomplished in this architecture are:

- Detection of presence: By using home automation sensor this part can detect the presence of the person and localize it and turn the closest camera to the person. It turns off the camera and sensors when the person leaves the room to economize energy
- Camera controller: This part controls functionality of cameras like: Zoom and motorized change of camera orientation for the motorized cameras.

- Image transmission and filtering: In this part, we will use also a filtering algorithm (m,k)-filter proposed in TRIO team of Loria.
- Image processing: This part will use an intelligent algorithm to analyze the images and detect a fall or any other anomaly.
- Alert: This part will be used for communication and broadcasting of alerts in case of detection of a fall.
- Data base: To record the alarms.
- Flux control (Feadbaking): Transmission is made via wireless or wired network which is also shared by other applications like home automations and therefore it is important to manage the load of the network. In case of a big load in the network, images will be transmitted with a bigger delay and thus the transmission rate will change dynamically.

Maia is also working on a new device for tracking persons, which relies on a network of *intelligent tiles*. The team investigates a non-intrusive approach, which is based on a sensor/node network placed on the floor. It consists in paving the floor with connected tiles holding the network (Pepin, Simonin et Charpillet 2009). Recent works (Park et Hashimoto 2009)(Kodaka, Niwa et Sugano 2009) examine the possibility to put sensors regularly in the floor to assist the control and the localization of robots. We propose to go further by defining an active environment, able to detect events, to get measures (weight), to take decisions and to compute problem solving (as the planning and display of a path in the environment). It aims at defining a decentralized system where each tile is autonomous and only connected to its 4-neighbourings, in order to have a modular and robust network. First tests have been done with small mobile robots and an emulated tiles network (Glad, et al. 2010) and Figure 1 that show the potential of the approach.

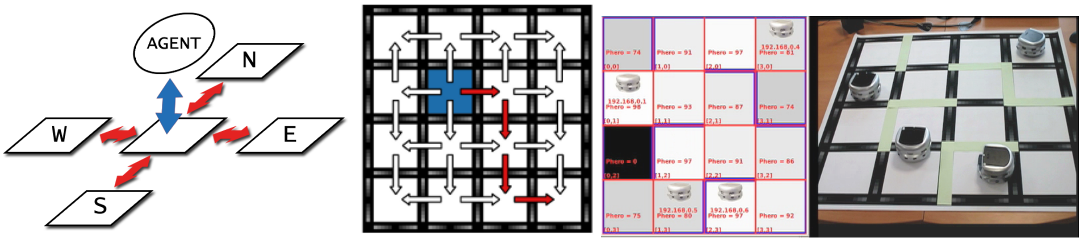

Figure 1: Tiles network as experimented by Maia

This new device composed of tiles, is under development at INRIA Nancy Grand Est, and will be used in PAL for tracking and assistance functions. These functions being mainly:

- The tracking and the recording of the person's position,
- Detection of a long suspended activity (learning person's habits),
- Measure of weight progress,
- Perception of a person or an object falling on the ground,
- Diffusion of an information in the environment, i.e. in the tiles' network,
- The communication with one or several robots.

Algorithms for these functions will be funded on distributed calculus (or multi-agent systems), where each node of the network is an autonomous process (or agent) taking decisions in function of its perceptions (sensors) and the messages received from its neighborhood (connection between tiles) (cf. work of Maia (Glad, et al. 2010)(Simonin 2005)). Algorithms will be studied and validated in simulation (an emulator is available), before to be deployed in the tiles network. The main scientific challenge is to define scalable solutions (to the number of tiles).

2.4.2 TASK2: Monitoring using high level sensor data

Another important task is the combination of data and events observed by heterogeneous sensors (video, home automation, biomedical, accelerometer, motion sensor, etc.), in order to recognize complex events.

In this task, the teams share semantic data (corresponding to higher-level events). This task is divided into several sub-tasks according to the sensors and approaches that will be used.

Particularly, Coprin team is interested in the use of non-intrusive or low intrusive sensors for monitoring. For example, in rehabilitation phase the person will be in an instrumented place, in which the sensors will give distance between points of his body and fixed points in the place or acceleration measurements of these points. The RFID tags will be used to carry out sporadic locations of the subject.

This task could be completed by visual information obtained by a webcam integrated in small mobile robots that will be deployed in specific cases (e.g. fall detection).
Coprin team is also interested in:

- **Evaluation analysis:** as part of rehabilitation, mainly physical rehabilitation. In rehabilitation period, the patient will be equipped with lightweight instruments (cable, accelerometers). The measures (haptic or others) will be served to ensure the proper execution of exercises, possibly to suggestion or corrections. This assessment / correction can be done remotely.
- **Monitoring the usage of user interfaces:** When the elderly commands a number of systems via interfaces appropriate to his motor skills / cognitive. The frequency of use of these interfaces can provide good information on the health state evolution of the person. It will be useful also for adapting or modifying the equipment and the interfaces.
- **Use of the monitoring system to feed a database that might help to early detecting the health problems**.

Pulsar team is interested in data integration from heterogeneous sensors (cameras, environmental sensors...) for elderly activities monitoring at home. This work consists of formalizing the uncertainty of treatments and modeling the complex operations using a high-level language for describing scenarios and different types of data, video (position, trajectory, 3D postures) and data from environmental sensors. In this respect, defining statistical models of its activities will create a long-term behavioral profile of a person. The objective is to detect pathological deviations (e.g. depression).
Prima team is working on compliance and business modeling to estimate the activity level, health monitoring of a person at home. The approach is to consider housing as a service provider based on the dynamic federation of digital devices that can perceive, act, communicate and interact with the occupants. These components provide information on activity level of the person.

A first objective is to build a system of daily life monitoring. Variations of these observations will provide data about whether or not the person has problems such as loss of physical mobility, or any problem of cognitive impairment.

The trajectories are composed of displacements of the elderly, correspond to a distance between two positions of immobility. A trajectory can be characterized by its duration, its speed and distance. Some immobility may present a memory loss. The duration and number of immobility will be recorded in a database.
The type of the trajectory is interesting to study also. Two aspects of the trajectory will be examined:

- **Is it a normal trajectory?** That means, is it corresponded to the same trajectories that the person always uses to do to get from point A to point B?
- **Does the person have an erratic movement?** To observe and measure activity, we are working on a new form of multimodal sensor in the form of decorative object, combines a panoramic camera, a microphone and an infrared beacon. In order to gather the information of acoustic and visual activity of the elderly, these sensors will randomly place at home, and will form a wireless ad hoc network.

These sensors will be tested in the smart home platform of INRIA in Grenoble and Domus platform at Grenoble Universities. This work is conducted in cooperation with the GERHOME platform and the Pulsar team of INRIA at Sophia Antipolis. Together, we will produce a roadmap for the establishment of vivo platforms in Grenoble and Nice.

2.4.3 TASK3: Communication interoperability and QoS between heterogeneous sensors and actuators

Trio is interested in studying the interoperability and adaptive quality of service (QoS) in heterogeneous sensor and actuator networks. A telehomecare system integrates highly heterogeneous components such as biomedical and environmental sensors, cameras, robots (mobile sensors and actuators), etc. The interoperation of these heterogeneous systems is based on a communication system that must be able to communicate with various protocols (e.g. Zigbee, Ethernet/WiFi, Bleutooth, KNX...).

The first task is therefore defining and developing a multi-protocol gateway. The objective is enabling communication between heterogeneous sensors and robots without or with minimal manual configuration efforts. This task will be based on the MPIGate gateway (see 7.3), which is under development, by Trio, and also the experiences of Trio in the development of home automation based telehomecare and activity monitoring systems, especially by its collaboration with MEDETIC (using IHC of Schneider Electrics and In One of Legrand).

Quality of Service (QoS) in a network of heterogeneous sensors and actuators is another important challenge to address. Indeed, the nature of the data carried by such a network is diverse. It can include video, data from presence and movement sensors, data from biomedical sensors or alerts on critical situations (e.g. detection of a fall), etc. This variety of real-time and non-real-time data flows requires a policy of quality of service that governs the transport of these different data according to their priority. This policy is even more vital in a risky situation where excessive response time can lead to unacceptable consequences (e.g. alarm reporting).

The state of the art networking technology does not provide satisfactory solution for this challenge, especially with heterogeneous networks/protocols. In this task, we focus on the development of protocols for managing QoS and a middleware layer for self-management of QoS for reliable and optimized communication. The objective is to achieve a robust, self-organizing and self-repairing communication system (wireless mostly) integrating different protocols (ZigBee, Wi-Fi, home automation protocols...).

2.5 Challenges

The elderly monitoring services correspond to 4 scientific challenges:

- Ability for the automatic system to monitor (detect and track) a person (or more) over a long period of time and in a wide variety of environments.
- Recognition of multisensor events combining data from video cameras and other sensors (e.g. environmental).
- Recognition of complex events and activities taking into account for example the posture of the observed person.
- Automatic learning of event models, scenes, and people behavioral profiles.

Preliminary results for Maia, Prima, Pulsar and Trio have shown the importance of the automatic monitoring system to maintain elderly at home. Finer descriptions (especially on people postures and interactions with equipment) remain to be done to better characterize the frailty level of a person. Similarly, analysis in real environment over long periods is needed to measure the robustness of the detection of critical situations and to calculate significant changes in behavioral profile.

2.6 Evaluation

Two types of evaluation must be done for each task:

- **Type 1:** technical performance evaluation of the monitoring system for the elderly by using ground truth of a limited number of situations (i.e. corresponding to few representative patients) and on a short duration (less than a day).
- **Type 2:** user evaluation by gerontologists (e.g. Nice hospital) on a large number of patients.

Scheduling of Sophia teams achievements; this calendar depends on the availability of human resources:

1. Development of a multi-sensor fusion algorithm.
2. Development of an intelligent tracking algorithm.
3. Development of a multi-sensor event recognition algorithm.
4. Evaluation of the global activity recognition system.

Scheduling of Nancy teams achievements; this calendar depends on the availability of both material resources (related to CPER) and human resources:

1. Prototype realization and equipment of an intelligent apartment (in Nancy).
2. Realization of the smart tile prototype.
3. Implementation and development of an interconnecting middleware (MPIGATE).
4. Implementation of algorithms for actimetry using simulation.
5. Implementation of interactive flow control algorithms for actimetry measurement in real time.
6. Integration and evaluation of actimetry solutions.
7. Robotic assistance taking advantage of smart tiles and other smart sensors.

3 Mobility of the person

IPT involved: Arobas, Coprin, e-Motion.

3.1 Service overview

This research theme is concerned with the development of mobility assistance tools for persons with reduced or no mobility abilities. Three applications based on wheeled platforms will be considered. The first one is an automated wheelchair, the second one is an automated shopping cart and the last one is a walking aid. Because these applications share common scientific challenges, one goal is to share both hardware ressources and scientific expertise.

3.1.1 Scientific challenges

At least four major scientific challenges can be identified:

- **Control:** Mobility assistance relies on the system's capacity to move efficiently and autonomously. Different tasks can be considered, e.g. navigation (wheelchair and shopping cart), walking support (walking aid). Controlling the motion of the type of mechanisms considered remains challenging (nonholonomy issue). It is even more so since the tasks at hand requires that the system adapts itself to the user's behavior in the most inconspicuous way. It is also essential to detect risky situations, *e.g.* contact loss with the user, and quickly select adapted control strategies.
- **Motion safety:** Automated wheelchairs and shopping carts will operate in cluttered environments featuring human beings. While collisions with environmental objects should be avoided in general, it is especially important to avoid collisions with human beings. Obstacle avoidance is a long-standing problem in Robotics and many solutions have been proposed. However, obstacle avoidance strategies for which a given level of motion safety can actually be guaranteed remain an open problem in uncertain dynamic environments.
- **Motion autonomy:** The capacity for a robot to reach in an autonomous manner a given goal remains a challenging problem. While autonomous navigation in uncertain dynamic environments has already been demonstrated, *e.g.* Expo'02 or Urban Challenge'07, many difficulties remain. Coping with uncertain dynamic environments in a safe and reliable way remains a challenge. It also requires the capability to process in real-time the sensory data in order to "understand" the current situation.
- **Anthropomorphic motion:** One does not move among human beings the way one would move among, say, pieces of furniture. Inter-human motions obey a set of rules that are socially and culturally defined, *e.g.* the notion of "personal space" studied by Proxemics. Such rules must be identified and integrated inside in the navigation and tasks so that human-robot interaction be as natural as possible.

3.1.2 Experimental platforms

These applications rely on similar wheeled mobile platforms. They will be computer-controlled and equipped with various sensors depending on the task at hand. Sharing these hardware resources and the developed algorithms seems natural. For example, the walking aid and the automated shopping cart will be developed on the same platform. To that end, it is necessary to have a common and open hardware and software framework.

3.2 Automated Wheelchair

3.2.1 Presentation of the service

This service concerns people who have lost their motion autonomy (accident, disease). It will allow the user to move freely inside his/her home. It should also allow him/her to move outdoors, *e.g.* to go to the post office or to do shopping.

3.2.2 State of the Art

In the past decade, automated wheelchairs of increasing complexity have appeared, some of them demonstrating autonomous navigation capabilities. Such systems developed in the academia, *e.g.* MIT, University of Saragossa or Vienna (MOVEMENT European project), mostly focus on the Human-Machine Interaction and on the control modalities, *e.g.* vocal or ``cerebral'' commands.

Also of interest are the also mobile manipulators that have been developed to assist people at home, *e.g.* Fraunhofer's Care-O-bot or Stanford's STAIR.

However their autonomy level remains limited and they are yet to be adapted to complex dynamic environments.

3.2.3 Description of the service

The automated wheelchair is essentially a mobile robot. It is a computer-controlled wheeled platform equipped with standard proprio- and extero-ceptive sensors, *e.g.* odometry, IMU, GPS, Lidar, vision. If need be, it could also communicate with the infrastructure, *e.g.* the home information system. The primary purpose of the automated wheelchair is to transport its user wherever he/she wants to go whether indoors or outdoors.

3.2.4 Challenges

Developing an automated wheelchair that can operate autonomously in a wide range of environments (indoors, outdoors, cluttered or dynamics) remains largely an open problem with several difficulties that are to be solved.

The first challenge that needs to be addressed concerns the ``understanding'' of the current situation of the wheelchair, *i.e.* the interpretation of the data about the environment, whether it be a priori known, *e.g.* maps, or acquired on-line via the sensors. The challenge is to build a model of the environment, which is both meaningful, coherent and accurate. This interpretation must be done in real-time (processing of the sensor data) and take into account the corresponding uncertainties.

In a dynamic environment, the second challenge to solve concerns the understanding of the coming situation. Anticipating what will happen in order to build a model of the future is required for safe navigation purposes.

As far as navigation is concerned, motion safety remains an open problem in uncertain dynamic environments.

Anthropomorphic navigation is a topic that has only recently emerged in Robotics, *e.g.* (Sisbot, et al. 2007). Addressing this problem in a principled manner remains largely an open problem.

3.2.5 Evaluation

The development of the wheelchair will be carried out incrementally starting with simple environments (indoors, no moving objects), up to more complex situations (moving objects of different nature, outdoors, etc.). To begin with, the wheelchair should be able to adapt itself to the home of its user, *e.g.* learn its topology and geometry identify the different rooms and the furniture within. Then, the wheelchair should be able to navigate in a reliable, safe and anthropomorphic manner. Among other things, it should be able to cope with whatever changes that may take place, *e.g.* new/moved furniture.

3.3 Automated Shopping Cart

3.3.1 Presentation of the service

The objective is to develop and experimentally test an automated shopping cart that can assist a disabled person in doing his/her shopping (it could also be used by ordinary users). Several modes will be considered, from simple cart pushing assistance to fully automated cart motion.

3.3.2 State of the Art:

As far as we know, no such service is commercially available at this time. On the industrial side, a few projects have been reported (Thoshiba's "Guidance Robot" (Thoshiba s.d.), Aethon's "Market Mate" (Aethon s.d.)), with different levels of developments. On the academic side, besides a few students' prototypes (BOSS robotic shopping cart s.d.), more advanced solutions have been developed for blinds (Kulyukin et Gharpure 2006) with an emphasis on autonomous navigation. In the "fully automated" operating mode, all proposed solutions rely on a "follow the user" approach. Investigation of other solutions is one of the scientific goals of the present project.

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3.3.3 Description of the service

Experimental tests will be conducted on the walking aid (the mechanical structure of which is very similar to a shopping cart). Specific telemetry sensors will be mounted on the platform to locate the user in the case of contactless operating modes. In the following, we consider that such a sensor is a camera. Different operating modes will be addressed.

1. Operating mode with contact: this mode is based on a tactile contact of the user with the cart. Force sensors are used to measure the user's pressure on the cart's handle and to provide pushing assistance through the wheels' motors. This mode is simple, user-friendly, and psychologically reassuring.
2. Contactless mode with instrumented user: in this mode the user wears a device that allows to locate him/her easily *w.r.t.* the cart. It can be something light and inconspicuous, *e.g.* LEDs fixed to the user's belt, from which the user's position and orientation can easily be estimated via the camera data. A feedback controller allows to maintain a fixed distance between the user and the cart. At any time, the user can take the lead and go back to the mode with contact.
3. Contactless mode with un-instrumented user: similar to the precedent mode but without any device attached to the user. The estimation of his/her position and orientation is done using visual data only.

3.3.4 Challenges

The first challenge is an accurate estimation of the user position and orientation *w.r.t.* the cart. This is instrumental in controlling the cart motion *w.r.t.* the user. This is particularly challenging when the user is not instrumented. Obstacle avoidance is also a permanent challenge. Collisions with the user or other users in the shop have to be avoided. Fixed obstacles are also omnipresent. Finally, task transitions and unexpected events have to be dealt with.

3.3.5 Evaluation:

It will be incremental, from simple modes to most elaborated ones. First, the operating mode with contact will be considered. Simple from a control point of view, it will allow validating the hardware and software architecture of the shopping cart. Then, the contactless mode with instrumented user and without obstacles will be addressed. Here the goal is to develop and validate a motion strategy that avoids collisions with the user. The third step is the contactless mode with instrumented user and obstacles. Finally the ultimate goal is the contactless mode with un-instrumented user and obstacles.

3.4 Walking Aid

3.4.1 Presentation of the service

A walking aid is an engine, which helps people with limited mobility, though not in a wheelchair. Generally its mechanical structure is similar to that of a shopping cart: two caster wheels and two fixed ones. The aim of this service is to instrument/motorize a walking aid in order to provide help with mobility but also some other assisting functions such as fall prevention (and assistance management in case of fall), a help with physiotherapy, a monitoring of usual moves which can anticipate difficulties with the use of the interface or physiological ones.

3.4.2 State of the Art:

Two types of walking aids are identified: passive or active. In the first case, the only effector available is the wheel brake. In the second one, the wheels are powered. As for the passive walking aids, let us mention the RT-Walker from Hirata Hirata (Hirata, Komatsuda et Kosuge 2008) (fall prevention oriented with a navigation assistance), and the COOL Aide from Virginia University (Alwan et others 2005). As for the active walking aids, the most famous ones are: NURSEBOT from CMU (Rentschler, et al. 2003), Stanford's Walker (Glover et others 2003), Fraunhofer's Care-O-bot (Graf, An adaptive guidance system for robotic walking aids 2009), Monimad from ISIR (Médéric, et al. 2003), (Chugo et others 2008) (lower limbs physiotherapy oriented), and the PAM-AID from Trinity College of Dublin (Lacey et MacNamara, User involvement in the design and evaluation of a smartmobility aid 2000) (commercially available under the name of Guido).

Various reasons can explain the relative unsuccessful of those walking aids:

- Some of them are quite imposing: the CARE-O-ROBOT weighs 180Kg and is higher than most users.
- An excessive price for some of them (higher than the price of an upper-range wheelchair).
- Interfaces not really suitable.

3.4.3 Description of the service

The aim of this service is on one hand the motorization of the two fixed wheels of the walking aid and on the other hand its instrumentation. Two basic functioning ways are planned: one free mode where the motors are not engaged (but the wheels rotation is measured though), or a power mode with motors engaged. Those two modes come then with various functionalities like *detection and prevention of fall*, *help with physiotherapy* or *help with location/navigation*. The walking aid will be a smart object able to communicate its status and some warnings. It takes part of the services that give information about the state of the user evolution, for instance by recording movements on specific routes repeated daily. The experiences will use a platform currently in working progress based on a commercial walking aid. It will carry encoders on its wheels, distance IR and ultrasound sensors, an electronic compass, a GPS receiver, a RFID receiver and a WiFi connection.

3.4.4 Challenges

They are similar to the ones identified for the wheelchair such as control, steer clear of obstacles and navigation, monitoring of the user in space and time, maintenance interface. One major technological challenge is to keep the cost of the walking aid lower than that of a mid-range wheelchair.

3.4.5 Evaluation:

Some functionalities like autonomous navigation could be the subject of an objective evaluation without the presence of aged users. Some monitoring will need a significant sample group but could be held at INRIA whereas some functionalities such as walking physiotherapy must be evaluated in a specialized structure.

4 Rehabilitation, transfer and walking assistance

IPT involved: Coprin, Demar, possible assistance of Lagadic for the gripping ability aspect.

4.1 Transfer and walking assistance

4.1.1 Presentation of the service

A transfer should achieve an assisted change of posture (for example to go from lying down to stand up position). The walking assistance has already been discussed in the Mobility section with the smart walking aid. We focus on an indoor transfer device with added functionalities such as walking assistance and some limited manipulation possibilities. The offered device is a wire-driven parallel robot with a very little intrusion and a limited cost.

4.1.2 State of the Art

The existing transfer machines are mainly frames on wheel equipped with a hydraulic or electric elevating system, which is strapped with specific harnesses in order to operate the transfer. They are mainly in use in hospitals, quite expensive and inappropriate for a use at home (see Handbook of Human Factors and Ergonomics in Health Care and Patient Safety, Pascale Carayon, published by Routledge, 2006)

4.1.3 Description of the service

A transfer is about making a person to go from one position to another : lie down, seat, stand. Obviously this problem is crucial in everyday life (getting off bed, lunchtime, wash). This is why we offer the use of a wired parallel robot with a crane layout, the actuators being located on the room's ceiling. When not in use this service will be hidden and will only come out on request for partial or complete assistance.

This kind of service is not limited to transfer; it can help as an indoor walking assistance device too, instead of the use of a walking aid. Moreover, it can be used as a manipulation system in order to grasp an object, to help in physiotherapy, first assistance engine (stand up help in case of fall). In addition this service could be used for tracking people movement so as to provide information about everyday walking movements and evaluation of needs.

From a hardware point of view, a prototype is already under construction and should be installed in the Coprin apartment.

4.1.4 Challenges

Here is a list of problematics linked with this service:

- Determine the robot geometry, which could allow the transfer in the major part of a room with a given shape. One should take into account some uncertainty in the physical realization of the geometry;
- Command: problems linked with the use of wires only acting when under tension. In a crane structure the mechanical balance may lead to slack wires and therefore not all degrees of freedom of the system may be controlled simultaneously. The command should insure that in spite of this limit the system remains globally operational;
- Cost : the mechatronic part of the system should have a reduced cost in order to keep it affordable for the largest majority of users;
- Fitting: besides the fitting of the component realized during the phase of dimensional synthesis one should offer and allow changes on the robot final organ according to the user and the tasks assigned to the robot;
- Adequate interfaces.

4.1.5 Evaluation

There are two distinct types of evaluation for this service: on one hand performance evaluation of the transfer and walking assistance tasks (the physiotherapy and handling tasks evaluation is treated in a section apart), on the other hand the interfaces evaluation. The transfer part can be done with dummies in the first place, then locally with volunteers. However a complete evaluation should only take place in a specialized structure.
A technological transfer towards medical equipment providers could be considered in the medium term.

4.2 At home rehabilitation

4.2.1 Presentation of the service

The purpose of this service is to instruments classical training devices available at home for monitoring rehabilitation sessions (passive mode), for reducing fatigue of muscles that are not essential for the rehabilitation (semi-active mode) and for applying corrective forces if needed for improving the rehabilitation process (active mode).

4.2.2 State of the art

There are many works in this domain and references are provided in the Annex.

4.2.3 Description of the service

The aim of this service is first to provide measurements of specific human movements during a rehabilitation session. The nature of these measurements has to be adapted according to the rehabilitation objectives and to the involved joints but we may mention distance sensors and accelerometers. The purpose is to allow a doctor to download the measurements in order to verify if the exercises have been correctly executed, to measure the progress of the rehabilitation and possibly to detect in advance symptoms that are characteristic of a new pathology. In a second step wire-driven actuators will be used, providing additional distance data, but also allowing to exert forces in specific directions. These forces may be used to reduce muscular fatigue (for example decrease the impact of gravity for an exercise where the patient has to extend his arm for a long time) and/or to exert corrective forces. On the long term the Demar team may also propose systems combining robotized rehabilitation and electrostimulation.

4.2.4 Challenges

We have identified the following Challenges:

- Determination of the optimal location of the sensors/actuators for a given pathology and given patient. An associated problem is the calibration of the resulting system;
- Identification: a large number of measurements will be obtained, not all of them having the same accuracy or the same importance for identifying the important joint motion.

4.2.5 Evaluation

Evaluation/development of this system can only be done under the control of doctors. The clinical contact and the experience of the Demar team in clinical experiments will be essential components of the evaluation.

5 Services for social interaction

IPT involved: Prima.

We propose to create a networked family of affective devices that sense and react to the presence and monitor the activities of persons. The CuPID device family will consist of an affective mother stations, assisted by a number of remote satellite sensors for specialised sensing services. The mother station and sensor form an ad-hoc wireless sensor network that uses machine-learning technique to construct and maintain a model of daily activity. The devices will use "ambient" communication technologies (lights, sounds, movements, vibration) to interact "affectively" and to communicate a sense of presence between the device owner, family and health care service providers.

5.1 State of the Art

Technologies and theoretical foundations for computer vision, acoustic scene analysis and machine learning have all made substantial progress over the last decade (Crowley and Piater 2004). As a result, a commercially viable technologies have lead to rapid market growth for application sectors such as Video Surveillance for security and commercial services (Hall 2005), speech recognition for telephone based services, and machine learning for data mining. Laboratory experiments have demonstrated the feasibility of many other high volume applications in areas as diverse as use of vision and acoustic sensing for video communications and video conferencing (Schwerdt and Crowley 2000), perceptual user interfaces (Crowley et Al 2000), autonomous vehicles, and new classes meeting services based on observation of human activity (Brdiczka, Reignier and Crowley 2005).

This work will build on results of several recently completed National and European Projects in the areas of Context Aware Vision for Surveillance and Monitoring (IST CAVIAR) (Hall et Al 05), Extraction of information for Broadcast Video (IST DETECT) (Hall et Al 2004), Multi-modal interaction and communications (IST FAME) (Metze et Al 2005) and Multi-modal observation of activity for meeting services (IST CHIL) (Brdiczka, Regnier and Crowley 2005), (Brdiczka et Al 2005). This series of ICT projects has provided a technological foundation that can be directly applied to monitoring and interaction for the CuPID projet. The PRIMA group has recently completed a National ANR project, CASPER, on the design of self-configuring visual sensors for monitoring elderly activity. We will also adopt techniques for embedded computer vision developed in the OSEO MinImage project.

Tracking is fundamental to observing human activity (Crowley 2003a). Robust, real time perceptual components for visual detection and tracking have been developed and demonstrated in the IST projects FAME (Caporossi et Al 2004), (Crowley 2002) and CAVIAR projects (Hall et Al 2005). These components operate as cyclic process managed by a process supervisor (Crowley et Al 2002). In each cycle, a list of currently tracked targets is used to predict regions of interest for detection and observation. Pixel level image analysis procedures are applied to the predicted target region to detect and update information about the target. Available image analysis procedures include Color statistics (Schwerdt and Crowley 2000), motion (Chomat 1999), adaptive Background subtraction (Piater 2001), natural interest points and lines (Tran 2006), and scale normalised receptive field histograms (Schiele 2000), (Hall 2004). After each target has been updated, procedures are used detect possible new targets that may have entered the field of view. The list of targets are then analysed using probabilistic recognition (Chomat 2000), (Gourier 2004) to provide an interpretation. Robust processing in the presence of natural variations in illumination is provided by incorporating self-monitoring and automatic parameter regulation in each perceptual component (Hall 2005).

Acoustic activity recognition will be based perceptual components developed for the IST FAME and IST CHIL projects. Both the mother station will be equipped with an array of microphones for stereo detection and localisation of acoustic events. Satellite sensors will be equipped with one or more microphones, depending on their target domains.

Acoustic energy recorded by either a microphone array or individual microphone may classified into speech or non-speech in order to provide clean signals to the speech localization and topic spotting processes (Zot 2001). Probabilistic classification is used to classify signals based on a spectrogram provided by a Fast Fourier Transform. The recognition of acoustic signals is provided by a series of statistical tests applied to the spectrogram. Classifiers are trained on samples of the target acoustic signals.

The tracking system provides information about users' behaviours that can be used for recognition of users and their activities. Perceptual components for detection and recognition of faces have been developed in recent EU projects. Identification of individuals from a small set of people including the owner, family, friends, and frequent visitors can be based on both face recognition and voice recognition. Face recognition using simple techniques such as principle components analysis (Turk 1999) is feasible for small groups, provided that facial features can be precisely located for normalisation (Gourier 1994). Similar methods have been demonstrated for detecting interest, pleasure and displeasure based on face expressions from localised, normalised face images (Schwerdt et Al 2000).

Observation for heath and well being involves interpreting users appearance and activities. Appearance information, based on statistical classification using colored receptive fields (Hall 2000), spatio-temporal receptive fields (Chomat 2000), and situation modelling (Crowley 2003). Statistical classification of appearance can be used to classify such information as whether the owner has changed clothes. Spatio temporal information can be used to classify activity states (such as agitation or lethargy) as well as to detect information about movement and posture, and to recognize actions such as sitting, standing or falling (Chomat 1999). Such techniques can also be adapted to observing people to aid in communication of presence information.

5.2 Description of the service

Devices will be designed as cute "ambient" devices that sense and respond to human attention with affective interaction using vision, touch, vibration and voice. The challenge is program such devices with abilities to recognize attention, as well as relevant emotions such as pleasure, curiosity, frustration, and sadness in the owner. Machine learning techniques will be used to refine these abilities through interaction as well as to learn reactions that most please or endear the device to the owner. Affective interaction will be used to attract the owner in order to allow sensors to acquire biophysical information such as heart rate, body temperature and whether the person has dressed for the day. It will also be used to communicate a sense of presence between the owner and family or friends, by copying interactions to a remote devices located at the home of family or friends.

An important challenge is to provide devices will require absolutely no set up by users. The mother stations and her satellite children must work "out of the box" (Plug and play), requiring only that they be placed at different parts of the domestic environment to be monitored. They will be pre-programmed with minimal abilities that will be refined in place through monitoring and machine learning. They will form an ad-hoc sensor network to cover the environment and record activity in different locations. The mother station and devices will form an ad-hoc sensor network to cover the environment and record activity in different locations. Machine learning will be used throughout the system to adapt sensing and perception, learn affective interaction, learn to recognize classes of daily events, and model daily cycles of activity.

5.3 Challenges

Visual Observation of activity The first task for the device will be to organise an approximate map of places where activity is observed to occur. The mother station is assumed to be placed in a central location in the residence. A vertically oriented panoramic camera presents an image in the form of a disc, with the center point indicating vertical. In such an image, the direction to an object is indicated by the angle, while distance is indicated by distance from the center-point, using a highly non-linear relation. This allows a simple site-map to be composed in polar coordinates with the mother station at the origin. Simple pixel based detection based on adaptive background subtraction will be used to detect human motion. Moment based grouping and tracking will be used to detect and follow human activity. A map of regions on the horizon will be composed to provide a basis for activity monitoring. Activities will be monitored using robust tracking processes developed in previous EU projects. Perceptual components for classification of appearance and spatio-temporal activity patterns will be implemented based on previously demonstrated techniques.

Acoustic Observation of activity The mother station will also contain a number of acoustic sensors (directional microphones), providing information about the direction and amplitude of acoustic energy, as well as possibility of recognizing acoustic sources. Acoustic and visual activity will be correlated in order to determine entity classes that are mobile (people, pets) and stationary (appliances, entertainment devices).

Recognizing the owner(s). The system will learn to discriminate between the owner and other people based on visual and acoustic features. Despite the difficulty of unconstrained face recognition, facial features constitute important source of identity recognition. The identification problem in this context can be greatly simplified by reducing it to a binary discrimination problem (owner/not-owner). Face detection algorithms, such as AdaBoost (Viola and Jones 2001), can be used to first detect when a face is present in the image, and then to discriminate whether the observed face is that of the owner. We will compare this solution with several alternative approaches that have recently been proposed. Face recognition will use appearance based techniques such as Principle Components of normalised face imagettes, combined with probabilistic classification using an incremental algorithm.

Identity can also be determined from the acoustic signature of voice. As with vision, acoustic recognition in this context can be reduced to a two class discrimination problem. Combining vision and acoustic identity recognition should improve recognitions rates. Further improvement is provided by tracking. Tracking allows sequential evidence to be accumulated and associated with a moving target. Multiple owners can be accommodated by a fixed number of such discriminative tests. A similar approach can be used to learn a class of frequent visitors.

Perception for Communication and Interaction Interaction between the owner and the base station requires detecting and recognizing the presence of the owner, as well as detecting interest and a desire to engage in interaction. We proposed to develop techniques to detect interest, pleasure, displeasure, confusion, and frustration by combining information from face expressions and acoustic recognition of prosody. Interest and desire to engage in interaction are manifested by approaching the base station followed by caressing or talking to it. Visual attention will be detected by localising the face and estimating head pose. Facial expression of emotional state will be recognized based on trajectories in an incrementally acquired appearance space such as acquired by a Widrow-Hoff learning rule or principal components analysis. Acoustic recognition of emotional state will use prosody classification and spotting of a small vocabulary of speech utterances.

Learning to recognize attention and affect The challenge here is to learn to recognize individual specific indications of affect from facial expressions and acoustic events, together with tactile information from a touch sensitive pad. Users will be instructected to caress the mother station when they are pleased in order to train its behaviour. Caressing, along with some limited speech recognition, will provide positive feedback for both reinforcement learning and for semi-supervised statistical learning for signal classification. In this way the user will train the device to recognize pleasure, displeasure, frustration, and confusion from individual specific face expressions, body movements and vocal utterances. A number of competing existing solutions will be investigated for dealing separately with the face, prosody, speech and caressing.

Learning to evoke interest, pleasure and affection. The objective of this task is to provide the artificial agent with the means to learn the most successful visual and acoustic expressions for evoking interest and pleasure. We will use reinforcement learning to learn to please from repeated interactions with the owner. A vocabulary of preprogrammed luminous displays, musical sounds and spoken utterances (text to speech) will provide an initial pre-programmed expressive vocabulary. We will use simple, off-the-shelf text to speech with prosodic mark-up to generate linguistic messages. This vocabulary of luminous, musical and linguistic expressions will be periodically extended by adding new randomly generated visual and audio expressions. Luminous displays, musical sounds, and speech will be correlated with user affective state and their ability to evoke interest or pleasure. In this way the device and the owner will mutually train each other for affective interaction.

5.4 Evaluation

Evaluations for component technologies will be carried out in experiments at the smart environments lab at INRIA Grenoble Rhône Alpes research center. Evaluation of affective interaction and social communications services will be performed in experiments in association with the Multi-com facility at the Universtiy of Grenoble.

6 Project Organization

6.1 Structure of the consortium

6.1.1 Management

A scientific council is composed of all heads of IPT involved permanently and of the coordinator. This advising board can get help from outside members: end-users association, as well as industrial or institutional representatives. It sets scientific policy, decides the budgetary requests and their sharing, and decides on the integration of a new team within consortium. The Scientific Council also serves as the supervisory committee and ensures:

- The progression of scientific and experimental works.
- The convergence and coherence of researches
- The collaboration between IPT and field experts.
- The promotion of the LSIA results

A technical council is composed of a set of technical correspondents representing an INRIA research unit, an experimental platform or a team. Its missions are:

- To map services developed or under development,
- To coordinate funding requests
- To ensure that technologies and software are shared,
- To manage the integration of different services within the common platforms.

The corresponding techniques maintain a "laboratory logbook" that is a collaborative space containing a description of scientific advances, experimental results, achievements hardware and software available to the community. This space will be a tool used for technical collaborations as well as an instrument of scientific dissemination.

6.1.2 Scientific Partners

All the teams involved are *INRIA's project-teams*. However, the LSIA PAL is opened to the external teams that can complete expertise. The IPT expertise is given in Annexes. 8.2.

The Figure 2 describes the geographical location of the teams whereas the Figure 3 describes their thematic organization.

Figure 2: Geographic Organization

Arobas, (Pascal Morin).
Areas of Expertise: Automatic control for wheeled mobile robots, state estimation, simultaneous localization and mapping (SLAM).

Coprin, (Jean-Pierre Merlet).
Areas of Expertise: Areas of Expertise: Innovative robot mechanical structure, especially parallel robots with rigid or wire-driven legs. Coprin is specialized in the analysis and design of mechanical structure, including calibration and uncertainty modeling.

e-Motion, (Thierry Fraichard).
Areas of Expertise: Modeling and planning in environments composed of multiple moving objects. The group includes expertise in detection and tracking, prediction, motion planning, navigation in open environments, and safe movements.

Maia, (François Charpillet).
Areas of Expertise: Probabilistic modeling, and in particular, applications for the capture of movement and the monitoring, distributed problem solving and collective robotics.

Pulsar, (François Brémond).
Areas of Expertise: Video sequence analysis, multi-sensor scene interpretation, activity recognition, automatic synthesis of vision systems, machine learning.

Prima, (James L. Crowley).
Areas of Expertise: Technologies for smart environments, capable of perception, action, communication and interaction; Architectures for robust multi-modal perception, Situation modeling, Modeling of human activity, new forms of man-machine interaction using machine perception.

Trio, (Ye-Qiong Song).
Areas of Expertise: Quality of service for sensor networks, modeling and design of surveillance systems.

Demar, (David Guiraud and Christine Azevedo-Coste).
Areas of Expertise; sensing and reconstruction of motion, modeling and identification of skeletal and muscular systems, control of posture, clinical experimental procedures, functional reeducation.

Lagadic, (François Chaumette).
Areas of Expertise: Assistance for mobility and manipulation of objects, visual servoing, 3D position estimation.

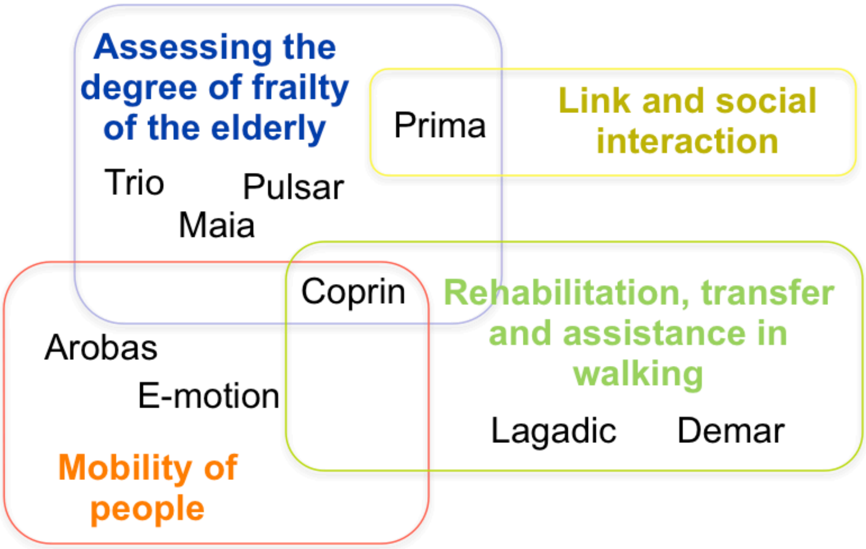

Figure 3: Thematic organization of teams

6.1.3 Field experts

The actors for assistance to the elderly are numerous:

- The users: the elderly represented by their associations, their family, caregivers
- The medical and social: physiotherapist, nurse, care assistant, hospital or public health doctor, social workers...
- The financial actors and coordinators: public utility, solidarity funds, and pension funds, national health insurance office, mutual insurance….
- The economic actors: personal care companies, the medical devices industry…
- The technological actors: the research and innovation organizations, university hospital centers.

We looked for some external partners thanks to their expertise, will help us in our specifications, monitoring experimentation and labeling of our services. The following external partners are informed of our action and ready (or have already) to work with us.

Two national organizations are in charge of the coordination the gerontechnology actors. Their roles will be to assist the LSIA in their services specifications and to monitor the experiments.
The aim of the **National Reference Center Health at Home and Autonomy**, localized in Nice, is to assist in the development and the proper use of solutions to support health and maintain people at home. It coordinates missions of collective interest and services at every level for all actors. The Reference Center is structured as an innovation network to ensure effective coordination of activities at the national level.
The main objectives of the Reference Centre include:

- The emergence of new organizations and innovative solutions associated
- The development of the competitiveness of the sector
- Improved quality of life of citizens and patients

The **Center for Innovation and Uses Health**, localized in Nice, is a resource and skills center and for healthcare professionals and industrials to design, test and evaluate ICT solutions in the field of health. Its missions are:

- To help in the development and the proper use of ICT.
- To ensure missions of collective interest and business.
- To have a technological means (integration and testing platform) and a methodology in order to carry out demonstrations and the setting technological showcases.
- To act as a referring point in e-health activities taking place in France and abroad.

The **CSTB**, see their web site, offers its expertise and knowledge in intelligent building (engineering, architecture, network sensors ...). They are ready to invest in our experiments, particularly within a common platform with INRIA, named Gerhome.

The IPT involved have strong links with three **CHU** (University Hospital Center) (Montpellier, Nancy, Nice). Their role will be to provide medical expertise and to organize **CPP** experimentations (Medical experimentations submitted to an ethical protocol).

6.2 Sharing resources

We presented four themes that we will develop. We hoped that, taken separately, they are relevant, adaptable, and their costs are under control. We can then offer a set of modular services, well adapted to meet the various needs in terms of personal assistance. However, in a second part of LSIA PAL, it will be interesting to interact with these services and integrate them into a common platform, because they are naturally complementary and intend to interact by sharing information. For example, systems that measure the condition of frailty can provide valuable information in order to adapt the rehabilitation session protocol. On the other hand, physical measurements collected during these sessions may update or correct information about the status of the person. Similarly watching systems can manage the reactions of mobile robots to perform security checks or to assist the person.

One difficulty is the LSIA integration of different services into common platforms. Each service is based on a set of software, sensors and actuators that provide information about the status of the person, her/his environment, actions, we aim that this information is possibly shared between services. The difficulty of integration is due to heterogeneous services (robotics, monitoring, social interaction...), with the specific software programs (real-time for the control, quality of service for wired/wireless communication, with low dynamics for monitoring, high for computing…), with again the want to control the cost of development.

Our integration strategy is supposed to be pragmatic, taking place at three levels:

- At services level: It is unrealistic and even undesirable to expect the uniqueness of development platforms at this level. However it is necessary to provide the possibility of adding sensors, interactions with communication systems and actuators. For this integration, the correspondent will be name in each team. Her/his role at this level will ensure the existence of gateways and ensure the maintenance of consistent documentation for both hardware and software.
- At themes level: we have chosen to cut our action in scientific themes that share a common theoretical base. Within these themes, the teams can compare their experiences and solutions in hardware and software integration. We expect after tests in different teams that a limited number of solutions will emerge: it will become a standard.
- At experimental platforms level: At this stage it is essential to consider that the services are seen as communicating objects. We must therefore agree on a common communication protocol that enables communication between all services offered by IPT. These solutions will be kept to enable the integration of a small number of scenarios constructed to demonstrate how our services can communicate together in a single structure.

This strategy will be implemented throughout the LSIA. For this, the council of the technical correspondent will gather a working group to think about solutions to be adopted during the maturation of services. This task will be shared with partners, IPT or externals and will require skills in several areas, for example on network. In this context, we will bring another LSIA (Sensas, E. fleury). This initiative focuses on networks of sensors / actuators and wants to open the application areas such as robotics and health. We believe that our two actions are perfectly complementary and it would be interesting to build strong bridges between them.

Experimental Platforms

PRAM Platform for Regional Analysis of Movement	Analysis of human movement.	Montpellier	The vocation of the PRAM is to bring together a coherent set of tools for the analysis of human motor performance. These tools allow for a multi-methodological work and encourage inter-team and multi-disciplinary research. Multidisciplinarity of participating teams, whose field of research is at least in part linked Human Movement Science, centers around the analysis of determinants of human motor performance. The technical platform comprises a set of non-invasive tools for the registration of kinematics and dynamics of human movement (VICON, LABVIEW, BIOPAC, force platforms ...). The PRAM comprises also more easily moveable systems to sport fields or for other research platforms, such as tools mainly dedicated to the study of muscle function (EMG NIRS ...).

Smart Home INRIA, LORIA, CPER MISN Lorraine, CHU Nancy	Apartment (under construction)	Nancy	A platform of "smart home" is under construction to test and to develop solutions for the communication network of sensors and robotic assistance. This platform includes home automation installations completed by environmental and biomedical wireless sensors, tiles, cameras, robots and computers. A major effort is focused on the integration of heterogeneous hardware and software.

Gerhome CSTB, INRIA, CHU Nice, PACA, CG06, UNSA See Figure 4	Apartment - 2 rooms, - 1 kitchen, - 1 bathroom	Sophia Antipolis	The objective of GERHOME project is to develop, try out and certify technical solutions supporting the assistance services for enhancing independence of the elderly at home, by using intelligent technologies for house automations to ensure autonomy, comfort of life, security, monitoring and assistance to place of residence. One of the main concerns of this project is to make technology “invisible”. These services will allow: - to reduce the risks of accidents at home (risks of falls, burns, etc) and other risks (heat wave, etc) - to keep the bond with the members of the family, the social circle, the doctor - to adapt the habitat in order to follow and preserve the autonomy of the growing old people - to offer some other services such as the medical follow-up (drugs absorption, real-time monitoring, etc), the management of the urgency, and the assistance to place of residence.
Coprin apartment INRIA	Apartment 15 m^2 - 1 bed room, - 1Kitchen, -1 toilet	Sophia Antipolis	The aim of this apartment is to allow the introduction of robotic assistance in various everyday life scenarios, especially during the morning: making meals, toilet, and rehabilitation. It will also be used to test the role of interfaces provided for the user and allow monitoring to anticipate adaptation and health problems.

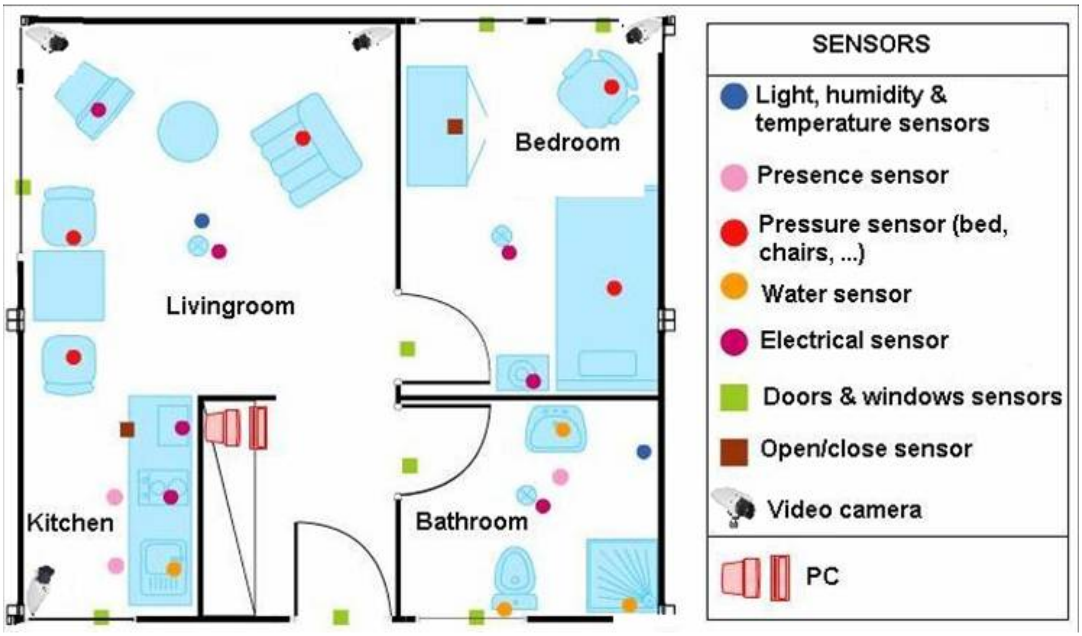

Figure 4: Gerhome

Domus CNRS, INPG, J. Fourrier Univ., INRIA, Région Rhone-Alpes See Figure 5	Hotel Suite 40 m^2 -1 bed room -1 office -1 kitchen	Grenoble	DOMUS is a working tool for researchers. Designed to be scalable, the platform has several objectives: - To collect in one place all the resources, standards, systems available to innovate in an environmental context realistic and complex, - To validate concepts, evaluate models and prototypes, conduct demos, - To develop and professionalize the research partnership for the benefit of socio-economic actors (firms, industry, local authorities)
Smart Home INRIA See Figure 6	Apartment 30 m^2 -1 bed room, -1 kitchen, -1 office	Grenoble	SmartHome is an open platform that can be used by partners as a means of testing situations for services.

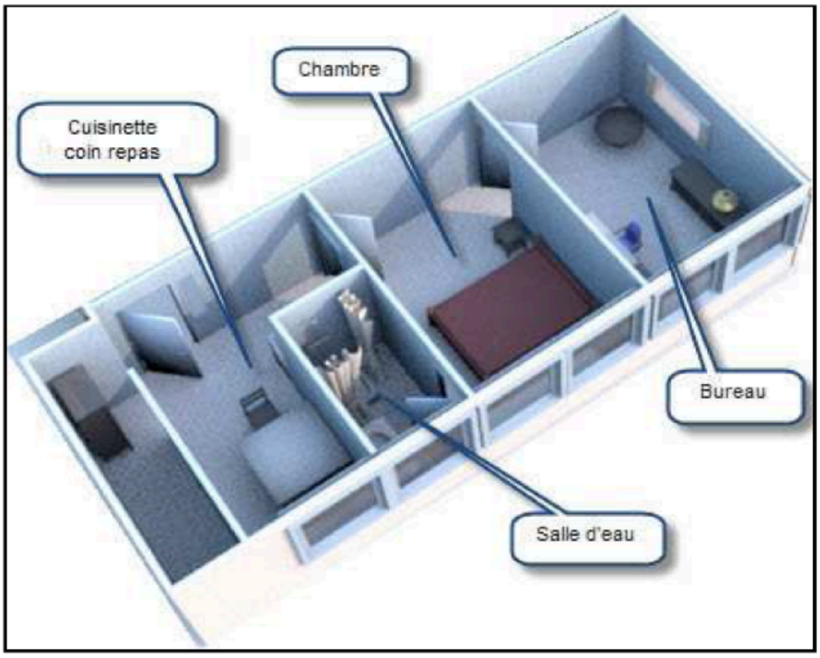

Plate-forme Domus (équipe MultiCom du LIG)
image fournie par J Caelen et F. Jambon

Figure 5: Domus

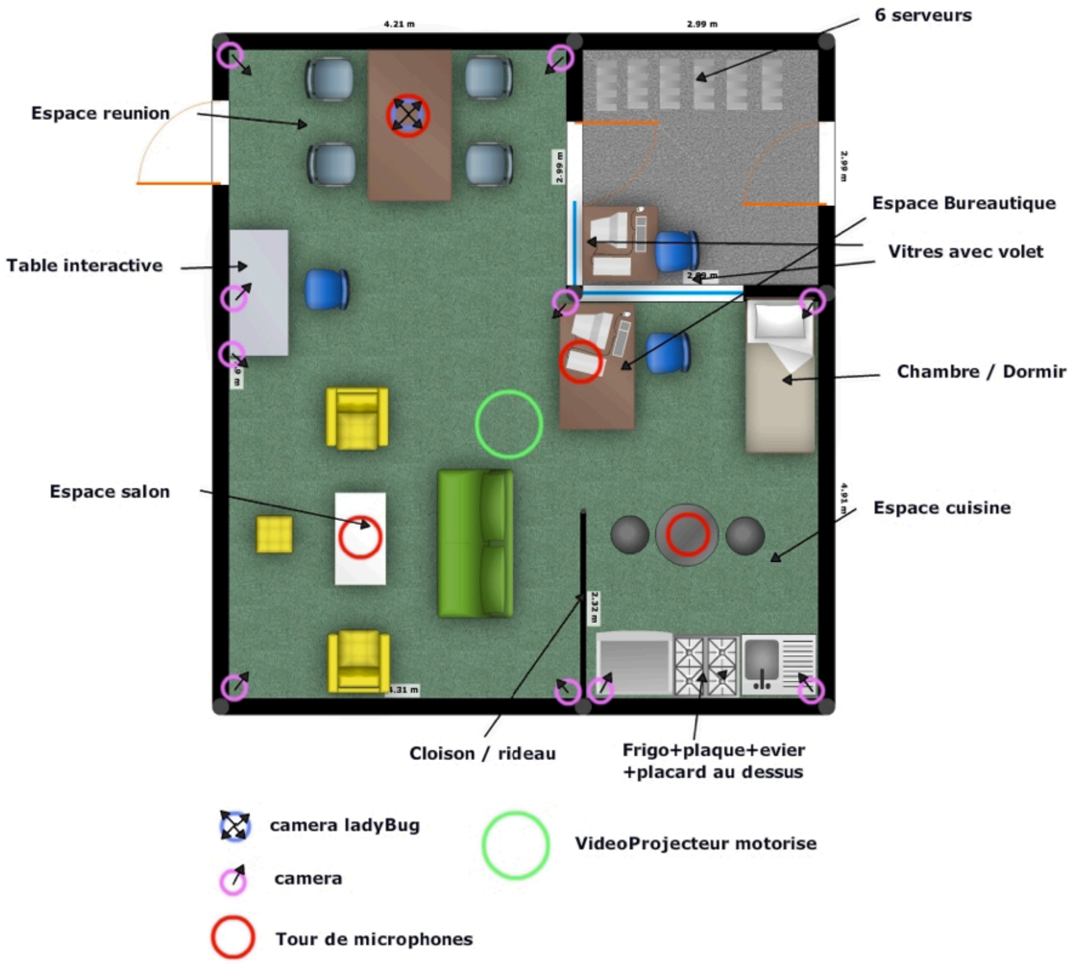

Figure 6: Smart Home

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8 Annex

8.1 INRIA's "Project-team" model

From the very outset, INRIA's activities have been organised around an original research model built on a basic structural element, known as the PROJECT-TEAM. Each team comprises around twenty members, headed by a scientific "leader", devoted to a research project approved by the Institute.

A team on a HUMAN scale The INRIA project-team (abbreviated to EPI within the organisation) brings together a group of researchers, research lecturers, PhD students and engineers, under the leadership of an experienced scientist. Their common goal is to take up a particular scientific and technological challenge in one of the key research areas defined in the strategic plan.

A clearly defined LIFE cycle Before it can be granted "EPI" status, the research project-team must be approved by an evaluation committee particularly qualified in the scientific field concerned. Once it has acquired its EPI status, the project-team has four years in which to successfully complete its research programme and reach its goals. It is given its own resources to achieve this. After four years, the EPI undergoes another scientific evaluation. At this point, it may be decided to continue or discontinue its activity. EPIs can only be granted a new period of activity twice, so they have a maximum life of 12 years, with 8 years being the average.

Management AUTONOMY Each INRIA project-team enjoys organisational and management autonomy. It decides what use to make of its own financial resources. It can also draw on the resources made available by the "research support" services of INRIA's eight regional centres (development and transfer, human resources, funding, information technology, communication, etc.) The Institute promotes exchange and collaboration among the project-teams of its eight centres. It also encourages them to cooperate with their counterparts in other countries.

Science & transfer – twin OBJECTIVES Each INRIA project-team pursues two objectives. The first is to make its scientific results widely known through its publications and by taking part in major conferences and seminars. The second is to play an active part in transferring the knowledge and technology acquired to industry or a large community of users. This transfer can take various forms – training, patents, licensing agreements, strategic partnerships with large groups, setting up technology platforms for SMEs or creating new businesses.

A PARTNER in essence Information science is "partnership-based" in essence. Three out of four INRIA project-teams are joint teams set up with the Institute's various partners. INRIA's often composite project-teams are sometimes based in a joint laboratory or on a partner's site: grande école, university, other research organisation, university hospital, etc. Collaborative activities are based on co-ownership of results, determined in proportion to the resources allocated by each party, and a shared workload, which optimises the impact of research.

8.2 INRIA's "Project-team" involved

8.2.1 Arobas

Web site: Arobas, Contact person: Pascal Morin.

The project-team activity is focused on the study of mobile robotic systems destined to accomplish complex tasks involving strong interactions with the system's environment. The underlying spectrum of research is vast due to the variety of devices amenable to automatization (ground, underwater and aerial vehicles...), of environments in which these devices are vowed to operate (structured/natural, known/unknown, static/dynamic...), and of applications for which they have been designed (assistance to handicapped people, environmental monitoring, rescue deployment after natural disasters, observation and tactical support...).

A fundamental issue in autonomous mobile robotics is to build consistent representations of the environment that can be used to trigger and execute the robot's actions. In its broadest sense, perception requires detecting, recognizing, and localizing elements of the environment, given the limited sensing and computational resources of the robot. The performance of a mobile robotic system crucially depends on its ability to process sensory data in order to achieve these objectives in real-time. Perception is a fundamental issue for both the implementation of reactive behaviors (based on feedback control loops) and the construction of the representations which are used at the task level. Among the sensory modalities, artificial vision and range finder are of particular importance and interest due to their availability and extended range of applicability. They are used for the perception and modeling of the robot's environment, and also for the control of the robot itself. Sensor-based control refers to the methods and techniques dedicated to the use of sensor data and information in automatic control loops. Its mastering is essential to the development of many (existing and future) robotic applications and a corner-stone of the research on autonomous robotics.

Most tasks performed by robots rely on the control of their displacements. Research on robot motion control largely stems from the fact that the equations relating the actuators outputs to the displacements of the robot's constitutive bodies are nonlinear. The extent of the difficulties induced by nonlinearity varies from one type of mechanism to another. Whereas the control of classical holonomic manipulator arms has been addressed very early by roboticists, and may now be considered as a well investigated issue, studies on the control of nonholonomic mobile robots are more recent. They also involve more sophisticated control techniques whose development participates in the extension of Control Theory. Another source of difficulty is underactuation, i.e. when the number of independent means of actuation is smaller than the number of degrees of freedom of the robotic mechanism. Most marine and aerial vehicles are underactuated. A particularly challenging case is when underactuation renders all classical control techniques, either linear or nonlinear, inoperative because it yields a system of linearized motion equations which, unlike the original nonlinear system, is not controllable. Such systems are sometimes called critical . Research in this area of automatic control is still largely open.

ARobAS genuinely tries to balance and confront theoretical developments and application-oriented challenges. In this respect, validation and testing on physical systems is essential, not only as a means to bring together all aspects of the research done in ARobAS –and thus maintain the coherence and unity of the project-team–, but also to understand the core of the problems on which research efforts should focus in priority. To this aim, a significant part of our resources is devoted to the development of experimentation facilities that are proper to the project and constitute an experimental workbench for the research done in the project. In parallel, we try to develop other means of experimentation in partnership research programs, for example with the Ifremer concerning underwater robotics, and with the CenPRA of Campinas (Brazil), I.S.T. of Lisboa (Portugal), and Bertin Tech. Inc. for the control of unmanned aerial vehicles (blimps and drones).

8.2.2 Coprin

Web site Coprin, Contact person: Jean-Pierre Merlet.

The COPRIN team scientific objective is to develop and implement systems solving algorithms based on constraints propagation methods, interval analysis and symbolic computation, with interval arithmetic as the primary tool. The academic goals of these algorithms is to provide certified solutions to generic problems (e.g. to calculate all solutions of a system of equations within a search space) or to manage the uncertainties of the problems (e.g. to provide an enclosure of all solutions of a system of equations whose coefficients are intervals). These academic goals may also be declined in applicative goals.

The study of robotics problems is a major focus point of the COPRIN project. In this field our objectives are:

- To develop methods for the analysis of existing robots, taking into account uncertainties in their modeling that are inherent to such mechatronic devices
- To propose innovative robotic systems
- To develop a design methodology for complex robotic systems that guarantee a required level of performance for the **real** robot. Our methodology aims at providing not a single design solution but a set of solutions offering various compromises among the performances. Furthermore the solutions will be robust with respect to errors in the realization of the real robot (e.g. due to manufacturing tolerances and control errors)

Experimental work and the development of our own prototypes are strategic for the project as they allow us to validate our theoretical work and discover new problems that will feed on the long term the theoretical analysis developed by the team members.

We have started since two years a strategic move toward **assistance robots**. Our long term goal will be to provide robotized devices for assistance, including smart objects, that may help disabled, elderly and handicapped people in their personal life. Our goals for these devices are that they can be adapted to the end-user and to its everyday environment they should be affordable they may be controlled through a large variety of simple interfaces In summary COPRIN has two major research axes, interval analysis and robotics. The coherence of these axis is that interval analysis is a major tool to manage the uncertainties that are inherent to a robotized device while robotics provides realistic problems which allow us to develop, test and improve interval analysis algorithms.

8.2.3 e-Motion

Web site : e-Motion, Contact person : Thierry Fraichard

The **e-Motion** team aims at developing models and algorithms allowing us to build artificial systems including advanced sensori-motors loops, and exhibiting sufficiently efficient and robust behaviors for being able to operate in open and dynamic environments (i.e. in partially known environments, where time and dynamics play a major role), while leading to various types of interaction with humans. Recent technological progresses on embedded computational power, on sensor technologies, and on miniaturised mechatronics systems, make the required technological breakthroughs potentially possible (including from the scalability point of view). In order to try to reach the previous objective, we combine the respective advantages of computational geometry and of the theory of probabilities. We are also working in cooperation with neurophysiologists on sensory-motor systems, for trying to apply and experiment some biological models. This approach leads us to study, under these different points of view, four strongly correlated fundamental research themes: **Perception and multimodal**, **Perception based navigation and SLAM**, **Motion planning and autonomous navigation in the physical world**, and **Learning, decision and probabilistic inference.**

8.2.4 Maia

Web site: Maia, Contact person: François Charpillet.

The issues we are concerned with belong to the field of artificial intelligence (A.I.). We approach our objectives according to the two complementary approaches of A.I.-imitating the intelligent aspects of the behavior of biological entities, or designing models that can endow one or several agent with capabilities usually attributed to intelligence, without necessarily trying to draw inspiration from the underlying cognitive processes. Our work in this context concerns the design of computer agents capable of perceiving their surroundings, interpreting it and taking action in a relatively autonomous fashion.

Research themes:

- Distributed artificial intelligence. Study of interaction and organization phenomena, algorithm and interpretation agent steering, simulation, problem solving.
- Solving problems with resource constraints. Design, modeling and steering of "anytime" algorithms.

- Stochastic decision models for planning and perception. Markovian decision processes (MDP), partially observable Markovian decision processes (POMDP).
- Interpretation of industrial and medical signals.

8.2.5 Pulsar

Web site Pulsar, Contact person: François Brémond.

The research project-team is focused on Activity Recognition. More precisely we are interested in the real-time semantic interpretation of dynamic scenes observed by sensors. We study long-term spatio-temporal activities performed by human beings, animals or vehicles in the physical world. The major issue in semantic interpretation of dynamic scenes is the gap between the subjective interpretation of data and the objective measures provided by the sensors. Our approach in order to address this problem is to keep a clear boundary between the application dependent subjective interpretations and the objective general analysis of the videos. Pulsar proposes new techniques in the field of cognitive vision and cognitive systems for physical object recognition, activity understanding, activity learning, system design and evaluation. Pulsar focuses on two main application domains: safety/security and healthcare monitoring.
Research themes We have two main research themes:

- Scene understanding for activity recognition: scene understanding aims at solving the complete interpretation problem ranging from low level signal analysis to semantic description of what is happening in the scene viewed by video cameras and possibly other sensors. We work more particularly on perception, understanding and learning.
- Software architecture for activity recognition: this research direction consists in studying generic systems for activity recognition and in elaborating a methodology for their design. We wish to ensure genericity, modularity, re usability, extensibility, dependability, and maintainability. We work more particularly on models, platform architecture, and system safeness.

8.2.6 Prima

Web site: Prima, Contact person: James L. Crowley.

The overall goal of the PRIMA project-team is the elaboration of a scientific foundation for interactive environments. An interactive environment requires the capabilities of perception, action and communication. An environment is said to be perceptive if it is capable of maintaining a model of its occupants and their activities. Such may a model includes the identity of individuals, an estimation of their position, their recent trajectory, as well as recognition of the activities of individuals and groups. An environment becomes active when it is capable of action. Actions may include presentation of information. They may also include the capability to manage visual and acoustic communications, as well as the capability to transport documents and material. Controlling an environment that is perceptive and active requires a capability to interact. This capability may rely on speech recognition, gesture interpretation, interpretation of the manipulation of object and observation of the interaction of people. The PRIMA project-team has as its mission to develop and integrate these three capabilities.

- The capacity to perceive and model the environment and its contents.
- The capacity to act by presenting information or service, or by transporting materials
- The capactive to communicate and interact with occupants.

Research themes The PRIMA project-team concerns the development of techniques for machine perception of people and their activities. The research is organized along four axes:

- Multi-modal observation and tracking of people
- Integration and control of perceptual processes
- New forms of man-machine interaction
- Recognition and learning guided by the context of interaction

8.2.7 Trio

Web site: Trio, Contact: Ye-Qiong Song.

The objective of the TRIO team is to provide a set of methods, tools and techniques to assist the designer in building, validating and scaling distributed real time applications. The studies are based on formally modeling and verifying interoperability properties. They can be applied both to communication networks and to distributed systems.

Research themes

- Specification of on-line mechanisms : the provided mechanisms allow applications to respect the specified time constraints, and/or to realize temporal fault tolerant algorithms,
- Operational architecture modeling process the objective is to exhibit reference models according in one hand to application domains and on the other hand to the particular properties to be proved,
- Techniques of temporal properties verification : Timed Automata, Petri Nets, Queueing Systems.

8.2.8 Demar

Web site: Demar, Contact person: David Guiraud.

Functional Electrical Stimulation (FES) has been used for about 30 years in order to restore deficient physiological functions. At the beginning, only surface stimulation was possible and thus only used in a clinical context due to the low reliability of electrode placements. In the early eighties, implanted FES appeared through well-known applications: pacemaker, Brindley bladder control, cochlear implant, and more recently deep brain stimulation (DBS).

Currently, FES is the only way to restore motor function even though biological solutions are studied, but not yet successfully tested on humans. Few teams carry out researches on implanted FES and the functional results remain poor. Nevertheless, the technique has proved to be useable and needs enhancements that we partly address in DEMAR. Regarding technology, complex electrode geometries associated with complex stimulus waveforms provide a way to perform fibre type selectivity and spatial localization of the stimuli in the nerves. These features are not yet implemented and demand new hardware and software architectures. Several teams Denmark (SMI U. Aalborg), Germany (IBMT Franhaufer Institute), England (U. College of London), Belgium (U. Catholique de Louvain), United States (Cleveland FES centre), and Canada (Ecole Polytechnique de Montréal), work on multi-polar neural stimulation but mainly on electrode aspect, except Polytsim Lab of Montréal.

Such a complex system needs advanced control theory tools coupled with a deep understanding of the underlying neurophysiological processes. This major area of research will be also an important part of the DEMAR objectives.

Besides, experiments are necessary to: improve neurophysiology knowledge, validate and identify models, evaluate control strategies or test neuroprostheses. Our experiments are carried on valid and non-valid individuals in clinical environment, but also on animals. They are particularly difficult to manage and highly time demanding to prepare, realize and analyze data. Nevertheless, it really worth the effort in order to bring theory to useable systems.

Finally, industrial transfer is mandatory since we aim at proposing effective solutions to patients. Thus we try to prototype all our findings in order to validate and transfer efficiently our concepts. To be useable in clinical or private environments by the patients themselves, systems need to be certified as an industrial Medical Device.

Demar research is organized as follows:

- Modeling and identification of the human sensory-motor system.
- Synthesis and control of functions.
- Interfacing artificial and natural parts through neuroprosthetic devices: both stimulation and recording.

The main applied research fields are then:

- Quantitative characterization of the human sensory-motor system firstly for motor disorders diagnosis and objective quantification, and secondly in order to help the design and the control of neuroprosthetic devices.
- Restoring motor and sensitive functions through implanted FES and neural signals sensing such as lower limb movement synthesis and control for spinal cord injured patients, synergetic control of the deficient limb for hemiplegic patients, bladder control, pain relief...
- Improving surface stimulation for therapy such as active verticalization of paraplegic patients, reduction of tremor, reeducation of hemiplegic post-stroke patients...

8.2.9 Lagadic

Web site: Lagadic, Contact person: François Chaumette.

Research activities of the Lagadic team are concerned with visual servoing and active vision. Visual servoing consists in using the information provided by a vision sensor to control the movements of a dynamic system. This system can be real within the framework of robotics, or virtual within the framework of computer animation or augmented reality. This research topic is at the intersection of the fields of robotics, automatic control, and computer vision. These fields are the subject of profitable research since many years and are particularly interesting by their very broad scientific and application spectrum. Within this spectrum, we focus ourselves on the interaction between visual perception and action. This topic is significant because it provides an alternative to the traditional Perception-Decision-Action cycle. It is indeed possible to link more closely the perception and action aspects, by directly integrating the measurements provided by a vision sensor in closed loop control laws.

This set of themes of visual servoing is the central scientific topic of the Lagadic group. More generally, our objective is to design strategies of coupling perception and action from images for applications in robotics, computer vision, virtual reality and augmented reality.

This objective is significant, first of all because of the variety and the great number of potential applications to which can lead our work. Secondly, it is also significant to be able to raise the scientific aspects associated with these problems, namely modeling of visual features representing in an optimal way the interaction between action and perception, taking into account of complex environments and the specification of high level tasks. We also work to treat new problems provided by imagery systems such as those resulting from an omnidirectional vision sensor or echographic probes. We are finally interested in revisiting traditional problems in computer vision (3D localization, structure and motion) through the visual servoing approach.

8.3 Large-scale Initiative Actions

The aim of the Large-scale Initiative Actions Program is to achieve a specific level of scale for a research subject identified by the Institute with a direct link to its strategic plan and the defined milestones. The intention is to achieve the most effective application of the expertise of INRIA in specific fields.

An large-scale initiative action brings together researchers from INRIA project-teams to work on a multidisciplinary initiative. It ensures the coordination and involvement of research teams from different subject focuses, and includes collaboration not only between INRIA teams but also with outside partners, both academic and industrial.

There will only be a small number of large-scale initiative actions, each with a specified duration and with precise objectives and significant resources. The deliverables will be clearly defined in each proposal.

Table des matières