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Université de Bordeaux

Activity Report 2015

Project-Team PHOENIX

Programming Language Technology For Communication Services

IN COLLABORATION WITH: Laboratoire Bordelais de Recherche en Informatique (LaBRI)

RESEARCH CENTER
Bordeaux - Sud-Ouest

THEME
Distributed programming and Software engineering

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Project-Team PHOENIX

Creation of the Project-Team: 2005 September 08

Keywords:

Computer Science and Digital Science:

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1.4. - Ubiquitous Systems
2.1. - Programming Languages
2.4.2. - Verification
2.5. - Software engineering
2.6.2. - Middleware
5.1. - Human-Computer Interaction
5.11. - Smart spaces

Other Research Topics and Application Domains:

1.3.2. - Cognitive science
2.1. - Well being
2.5.2. - Cognitive disabilities
2.5.3. - Assistance for elderly
4.4. - Energy consumption
8. - Smart Cities and Territories

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2. Overall Objectives

2.1. Context

A host of networked entities (devices and services) are populating smart spaces that become prevalent (*e.g.,*, building management, personal assistance, avionics) and large scale (*e.g.,*, train station, city, highway network). These smart spaces are becoming intimately intertwined with our daily life and professional activities, raising scientific challenges that go beyond the boundaries of single field of expertise.

2.2. A Multi-Disciplinary Approach

To address these challenges, the Phoenix group conducts multi-disciplinary research that combines

1. Cognitive Science to study user needs and make a rigorous assessment of the services provided by a smart space;
2. Sensing and actuating expertise to support the user based on accurate and rich interactions with the environment;
3. Computer Science to support and guide all the development process of the services provided by a smart space.

2.3. Research Avenues

The activities of the Phoenix group revolve around two main avenues of research.

First, a design-driven software development approach that leverages programming languages principles and techniques to guide and support the development of applications orchestrating networked entities. Second, cognitive digital assistance that exploits the capabilities of smart spaces to provide services that compensate or remediate cognitive difficulties.

In practice, Phoenix has developed DiaSuite, a tool-supported methodology for both the development and verification of applications orchestrating networked entities. DiaSuite is used to propose an assisted living platform named HomeAssist. This platform is deployed in our research apartment where a variety of scenarios are explored using a range of sensing/actuating capabilities and assistive applications. Moreover, a dedicated version of HomeAssist is now deployed in the home of 24 older adults in the Bordeaux area and will be deployed in the home of adults with Intellectual Disability in 2016. Beyond the home, Phoenix studies mobile cognitive support based on tablet. In particular, we have developed cognitive assistive technology for the inclusion of children with Autism in mainstreamed environment.

3. Research Program

3.1. Design-Driven Software Development

Raising the level of abstraction beyond programming is a very active research topic involving a range of areas, including software engineering, programming languages and formal verification. The challenge is to allow design dimensions of a software system, both functional and non-functional, to be expressed in a high-level way, instead of being encoded with a programming language. Such design dimensions can then be leveraged to verify conformance properties and to generate programming support.

Our research on this topic is to take up this challenge with an approach inspired by programming languages, introducing a full-fledged language for designing software systems and processing design descriptions both for verification and code generation purposes. Our approach is also DSL-inspired in that it defines a conceptual framework to guide software development. Lastly, to make our approach practical to software developers, we introduce a methodology and a suite of tools covering the development life-cycle.

To raise the level of abstraction beyond programming, the key approaches are model-driven engineering and architecture description languages. A number of *architecture description languages* have been proposed; they are either (1) coupled with a programming language (*e.g.,* [40]), providing some level of abstraction above programming, or (2) integrated into a programming language (*e.g.,* [33], [41]), mixing levels of abstraction. Furthermore, these approaches poorly leverage architecture descriptions to support programming, they are crudely integrated into existing development environments, or they are solely used for verification purposes. *Model-driven software development* is another actively researched area. This approach often lacks code generation and verification support. Finally, most (if not all) approaches related to our research goal are *general purpose*; their universal nature provides little, if any, guidance to design a software system. This situation is a major impediment to both reasoning about a design artifact and generating programming support.

3.2. Integrating Non-Functional Concerns into Software Design

Most existing design approaches do not address non-functional concerns. When they do, they do not provide an approach to non-functional concerns that covers the entire development life-cycle. Furthermore, they usually are general purpose, impeding the use of non-functional declarations for verification and code generation. For example, the Architecture Analysis & Design Language (AADL) is a standard dedicated to real-time embedded systems [36]. AADL provides language constructs for the specification of software systems (*e.g.,* component, port) and their deployment on execution platforms (*e.g.,* thread, process, memory). Using AADL, designers specify non-functional aspects by adding properties on language constructs (*e.g.,* the period of a thread) or using language extensions such as the Error Model Annex. [1] The software design concepts of AADL are still rather general purpose and give little guidance to the designer.

Beyond offering a conceptual framework, our language-based approach provides an ideal setting to address non-functional properties (*e.g.,* performance, reliability, security, ...). Specifically, a design language can be enriched with non-functional declarations to pursue two goals: (1) expanding further the type of conformance that can be checked between the design of a software system and its implementation, and (2) enabling additional programming support and guidance.

We are investigating this idea by extending our design language with non-functional declarations. For example, we have addressed error handling [10], access conflicts to resources [38], and quality of service constraints [37].

Following our approach to paradigm-oriented software development, non-functional declarations are verified at design time, they generate support that guides and constrains programming, they produce a runtime system that preserves invariants.

[1] The Error Model Annex is a standardized AADL extension for the description of errors [42].

3.3. Human-Driven Software Design

Knowledge of the human characteristics (individual, social and organizational) allow the design of complex system and artifacts for increasing their efficacy. In our approach of assistive computing, a main challenge is the integration of facets of Human Factors in order to design technology support adapted to user needs in term of ergonomic properties (acceptability, usability, utility etc) and delivered functionalities (oriented task under user abilities contraints).

We adapt this approach to improve the independent living and self-determination of users with cognitive impairments by developing a variety of orchestration scenarios of networked objects (hardware/software) to provide a pervasive support to their activities. Human factors methodologies are adopted in our approach with the direct purpose the reliability and efficiency of the performance of digital support systems in respect of objectives of health and well-being of the person (monitoring, evaluation, and rehabilitation).

Precisely, our methodologies are based on a closed iterative loop, as described in the figure below :

- Identifying the person needs in a natural situation (*i.e.,* desired but problematic activities) according to Human Factors Models of activity (*i.e.,* environmental constraints; social support networks - caregivers and family; person's abilities)
- Designing environmental support that will assist the users to bypass their cognitive impairment (according to environmental models of cognitive compensatory mechanisms); and then implement this support in terms of technological solutions (scenarios of networked objects, hardware interface, software interface, interaction style, *etc*)
- Empirically evaluating the assistive solution based on human experimentations that includes ergonomic assessments (acceptability, usability, usefulness, *etc*) as well as longitudinal evaluations of use's efficacy in terms of activities performed by the individual, of satisfaction and well-being provided to the individual but also to his/her entourage (family and caregivers).

4. Application Domains

4.1. Introduction

Building on our previous work, we are studying software development in the context of communication services, in their most general forms. That is, going beyond human-to-human interactions, and covering human-to-machine and machine-to-machine interactions. Software systems revolving around such forms of communications can be found in a number of areas, including telephony, pervasive computing, and assisted living; we view these software systems as coordinating the communication between networked entities, regardless of their nature: human, hardware or software. In this context, our three main application domains are pervasive computing, internet of things and assistive computing.

4.2. Pervasive Computing

Pervasive computing systems are being deployed in a rapidly increasing number of areas, including building automation and supply chain management. Regardless of their target area, pervasive computing systems have a typical architectural pattern. They aggregate data from a variety of distributed sources, whether sensing devices or software components, analyze a context to make decisions, and carry out decisions by invoking a range of actuators. Because pervasive computing systems are standing at the crossroads of several domains (e.g., distributed systems, multimedia, and embedded systems), they raise a number of challenges in software development:

Heterogeneity. Pervasive computing systems are made of off-the-shelf entities, that is, hardware and software building blocks. These entities run on specific platforms, feature various interaction models, and provide non-standard interfaces. This heterogeneity tends to percolate in the application code, preventing its portability and reusability, and cluttering it with low-level details.

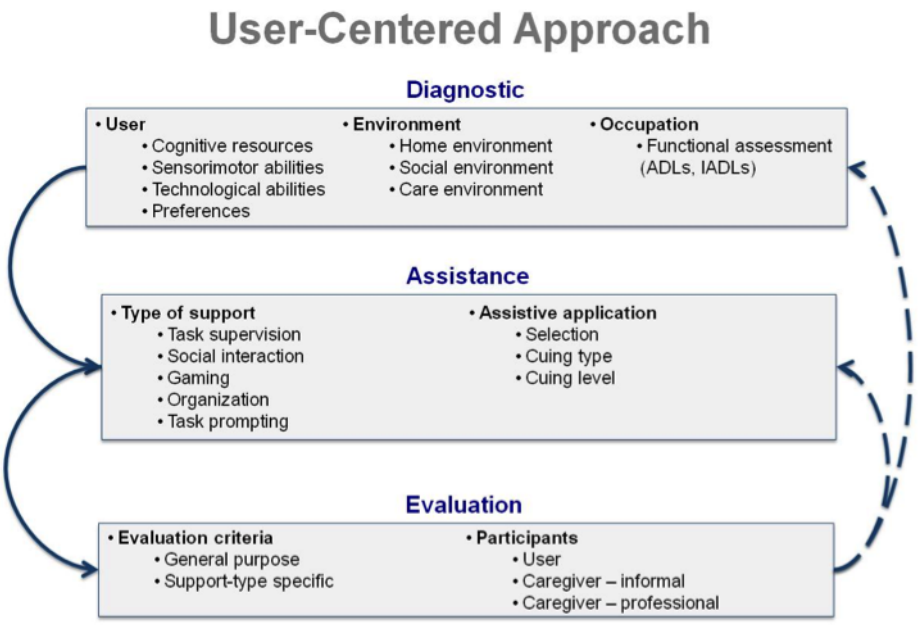

Figure 1. User-Centered Approach

Lack of structuring. Pervasive computing systems coordinate numerous, interrelated components. A lack of global structuring makes the development and evolution of such systems error-prone: component interactions may be invalid or missing.

Combination of technologies. Pervasive computing systems involve a variety of technological issues, including device intricacies, complex APIs of distributed systems technologies and middleware-specific features. Coping with this range of issues results in code bloated with special cases to glue technologies together.

Dynamicity. In a pervasive computing system, devices may either become available as they get deployed, or unavailable due to malfunction or network failure. Dealing with these issues explicitly in the implementation can quickly make the code cumbersome.

Testing. Pervasive computing systems are complicated to test. Doing so requires equipments to be acquired, tested, configured and deployed. Furthermore, some scenarios cannot be tested because of the nature of the situations involved (e.g., fire and smoke). As a result, the programmer must resort to writing specific code to achieve ad hoc testing.

4.3. Internet of Things

The Internet of Things (IoT) has become a reality with the emergence of Smart Cities, populated with large amounts of smart objects which are used to deliver a range of citizen services (e.g., security, well being, etc.) The IoT paradigm relies on the pervasive presence of smart objects or "things", which raises a number of new challenges in the software engineering domain.

We introduce a *design-driven development approach* that is dedicated to the domain of orchestration of masses of sensors. The developer declares what an application does using a domain-specific language (DSL), named DiaSwarm. Our compiler processes domain-specific declarations to generate a customized programming framework that guides and supports the programming phase.

DiaSwarm addresses the main phases of an application orchestrating masses of sensors.
Service discovery. Standard service discovery at the individual object level does not address the needs of applications orchestrating large numbers of smart objects. Instead, a high-level approach which provides constructs to specifying subsets of interest is needed. Our approach allows developers to introduce application-specific concepts (e.g., regrouping parking spaces into lots or districts) at the design time and then these can be used to express discovery operations. Following our design-driven development approach, these concepts are used to generate code to support and guide the programming phase.
Data gathering. Applications need to acquire data from a large number of objects through a variety of delivery models. For instance, air pollution sensors across a city may only push data to the relevant applications when pollution levels exceed tolerated levels. Tracking sensors, however, might determine the location of vehicles and send the acquired measurements to applications periodically (e.g., 10 min. intervals). Data delivery models need to be introduced at design time since they have a direct impact on the application's program structure. In doing so, the delivery models used by an application can be checked against sensor features early in the development process.
Data processing. Data that is generated from hundreds of thousands of objects and accumulated over a period of time calls for efficient processing strategies to ensure the required performance is attained. Our approach allows for an efficient implementation of the data processing stage by providing the developer with a framework based on the MapReduce [34] programming model which is intended for the processing of large data sets.

4.4. Assistive Computing

Cognitive impairments (memory, attention, time and space orientation, *etc.*) affect a large part of the population, including older adults, patients with brain injuries (traumatic brain injury, stroke, etc), and people exhibiting cognitive incapacities, such as Down syndrome.

The emerging industry of assistive technologies provide hardware devices dedicated to specific tasks, such as a telephone set with a keyboard picturing relatives (http://www.doro.fr), or a device for audio and video communication over the web (http://www.technosens.fr). These assistive technologies apply a traditional approach to personal assistance by providing an equipment dedicated to a single task (or a limited set of tasks), without leveraging surrounding devices. This traditional approach has fundamental limitations that must be overcome to significantly improve assistive technologies:

- They are not adaptable to one's needs. They are generally dedicated to a task and have very limited functionalities: no networking, limited computing capabilities, a limited screen and rudimentary interaction modalities. This lack of functionality may cause a proliferation of devices, complicating the end-user life. Moreover, they are rarely designed to adapt to the cognitive changes of the user. When the requirements evolve, the person must acquire a new device.
- They are often proprietary, limiting innovation. As a result, they cannot cope with the evolution of users' needs.
- They have limited or no interoperability. As a result, they cannot rely on other devices and software services to offer richer applications.

To break this model, we propose to offer an assistive platform that is open-ended in terms of applications and entities. (1) An online catalog of available applications enables every user and caregiver to define personalized assistance in the form of an evolving and adapted set of applications; this catalog provides a community of developers with a mechanism to publish applications for specific daily-activity needs. (2) New types of entities (whether hardware or software) can be added to a platform description to enhance its functionalities and extend the scope of future applications.

5. Highlights of the Year

5.1. Highlights of the Year

HomeAssist 500.

We are launching a massive deployment of HomeAssist in the homes of 500 older adults. This experiment will take the form of a randomized controlled trial and will be done over a period of 12 months. More details are given in Section 8.1.2.

6. New Software and Platforms

6.1. DiaSuite: a Development Environment for Sense/Compute/Control Applications

Participants: Charles Consel [correspondent], Julien Durand, Milan Kabac, Paul Van Der Walt, Adrien Carteron.

Despite much progress, developing a pervasive computing application remains a challenge because of a lack of conceptual frameworks and supporting tools. This challenge involves coping with heterogeneous devices, overcoming the intricacies of distributed systems technologies, working out an architecture for the application, encoding it in a program, writing specific code to test the application, and finally deploying it.

DIASUITE is a suite of tools covering the development life-cycle of a pervasive computing application.
Defining an application area. First, an expert defines a catalog of entities, whether hardware or software, that are specific to a target area. These entities serve as building blocks to develop applications in this area. They are gathered in a taxonomy definition, written in the taxonomy layer of the DIASPEC language.

Designing an application. Given a taxonomy, the architect can design and structure applications. To do so, the DIASPEC language provides an application design layer [39]. This layer is dedicated to an architectural pattern commonly used in the pervasive computing domain [35]. Describing the architecture application allows to further model a pervasive computing system, making explicit its functional decomposition.
Implementing an application. We leverage the taxonomy definition and the architecture description to provide dedicated support to both the entity and the application developers. This support takes the form of a Java programming framework, generated by the DIAGEN compiler. The generated programming framework precisely guides the developer with respect to the taxonomy definition and the architecture description. It consists of high-level operations to discover entities and interact with both entities and application components. In doing so, it abstracts away from the underlying distributed technologies, providing further separation of concerns.
Testing an application.DIAGEN generates a simulation support to test pervasive computing applications before their actual deployment. An application is simulated in the DIASIM tool, without requiring any code modification. DIASIM provides an editor to define simulation scenarios and a 2D-renderer to monitor the simulated application. Furthermore, simulated and actual entities can be mixed. This hybrid simulation enables an application to migrate incrementally to an actual environment.
Deploying a system. Finally, the system administrator deploys the pervasive computing system. To this end, a distributed systems technology is selected. We have developed a back-end that currently targets the following technologies: Web Services, RMI, SIP and OSGI. This targeting is transparent for the application code. The variety of these target technologies demonstrates that our development approach separates concerns into well-defined layers.

This development cycle is summarized in the Figure 2.

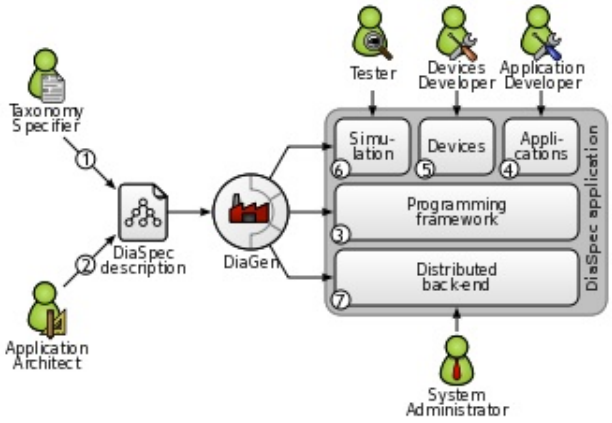

Figure 2. DIASUITE *Development Cycle*

See also the web page http://diasuite.inria.fr.

6.1.1. DiaSpec: a Domain-Specific Language for Networked Entities

The core of the DIASUITE development environment is the domain specific language called DIASPEC and its compiler DIAGEN.

DIASPEC It is composed of two layers.

The Taxonomy Layer. It allows the declaration of entities that are relevant to the target application area. An entity consists of sensing capabilities, producing data, and actuating capabilities, providing actions. Accordingly, an entity description declares a data source for each one of its sensing capabilities. As well, an actuating capability corresponds to a set of method declarations. An entity declaration also includes attributes, characterizing properties of entity instances. Entity declarations are organized hierarchically allowing entity classes to inherit attributes, sources and actions. A taxonomy allows separation of concerns in that the expert can focus on the concerns of cataloging area-specific entities. The entity developer is concerned about mapping a taxonomical description into an actual entity, and the application developer concentrates on the application logic.
The Architecture Layer. It is based on an architectural pattern commonly used in the pervasive computing domain [35]. It consists of context components fueled by sensing entities. These components process gathered data to make them amenable to the application needs. Context data are then passed to controller components that trigger actions on entities. Using an architecture description enables the key components of an application to be identified, allowing their implementation to evolve with the requirements (*e.g.,* varying light management implementations in a controller component to optimize energy consumption).

DIAGEN. It is the DIASPEC compiler that performs both static and runtime verifications over DIASPEC declarations and produces a dedicated programming framework that guides and eases the implementation of components. The generated framework is independent of the underlying distributed technology. As of today, DIAGEN supports multiple targets: Local, RMI, SIP, Web Services and OSGI.

6.2. DiaSuiteBox: an Open Orchestration Platform

Participants: Charles Consel, Julien Durand, Adrien Carteron, Milan Kabac.

The DiaSuiteBox platform runs an open-ended set of applications leveraging a range of appliances and web services. Our solution consists of a dedicated development environment, a certifying application store, and a lightweight runtime platform. This solution is based on the DIASUITE project.

The DiaSuiteBox platform can be embedded in a small plug-computer or deployed in the cloud. Thanks to the application store and the developer community, the platform is fed by a full offer of new innovative applications. During the submission process, an application is automatically analyzed and checked in order to be certified. The user is ensured the behavior of its applications are innocuous and correct with respect to the provided information. Finally, DiaSuiteBox provides an extensible software architecture. This allows the easily connect new device technologies to the platform. For example, the support for new wireless communication technologies such as Zigbee, Z-Wave or Sigfox can be easily added to the DiaSuiteBox platform.

More details can be found on the web page http://diasuitebox.inria.fr.

The iQSpot startup uses DiaSuiteBox as a software platform to ease the management of Smart Buildings. In this project, the DiaSuiteBox platform is first used to host building management functionalities such as lighting management, heating/ventilating/air conditioning management, energy efficiency monitoring. It is also used to host software drivers that allow the building management functionalities to interact with the connected devices deployed in buildings. These devices can use wired communication technologies such LonWorks, BACNet or KNX, as well as wireless communication technologies such as Z-Wave or Zigbee.

6.3. DiaSwarm: Orchestrating masses of objects

Participants: Charles Consel [correspondent], Milan Kabac, Eugène Volanschi.

DiaSwarm provides a design language dedicated to the domain of orchestrating masses of objects. The language provides high-level, declarative constructs that allow a developer to deal with masses of objects at design time, prior to programming the application. The DiaSwarm compiler generates programming frameworks, which provide high-level support to the developer, while ensuring that programming is driven by design.

DiaSwarm consists of two main components.

- DiaSwarm Studio. It is available as an Eclipse plugin. The tool provides of a domain-specific language and a compiler dedicated to the domain of orchestrating masses of sensors.
- Runtime environment. This is a library allowing you to execute DiaSwarm applications locally. The runtime environment comprises the Apache Hadoop framework v. 1.2.1 allowing you to run MapReduce jobs locally without the need to install the framework separately.

More details can be found on a dedicated web page http://phoenix.inria.fr/software/diaswarm. In particular, an example application is provided: it is dedicated to the management of parking lots in a city. It uses presence sensors to monitor the availability of parking spaces through magnetic field variations. The application defines a few context components, which transform sensed data to determine the availability of parking lots and average occupancy of parking lots in 24 hr. Furthermore, the application suggests parking lots to drivers entering the city. Please note that the availability of parking places is computed every 30 seconds. The average occupancy of parking lots is computed every 2 minutes.

6.4. School+ Apps: Assistive tablet applications for school Inclusion

Participants: Charles Consel [correspondent], Hélène Sauzéon, Charles Fage.

School+ is a package of 7 applications. Three applications are assistive applications, guiding the child doing specific tasks. Three others are training applications made as serious games, addressing specific skills. The last application is a meta-application, comprising a link to the three training applications, with an access to statistics of their usage. For each application, data are separated from the design, meaning that every element of each application (pictures, texts, settings, etc.) can be changed at any time. Each application records a log file containing all the interactions performed by the child.

6.4.1. Assistive applications

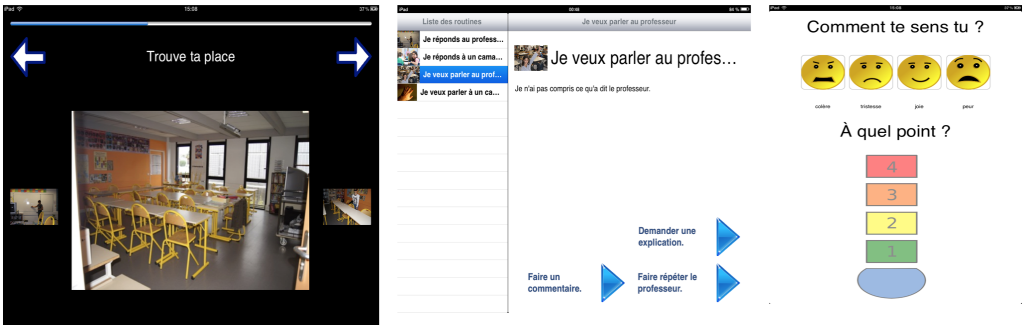

Figure 3. Assistive applications

Routines application. This application shows a list of tasks, with a short description. After clicking the starting button, a specific slideshow is shown; it decomposes a task into steps. For each step, a text and a picture can be displayed. Thumbnail of previous and next steps are also displayed. This application guides the child through classroom situations: entering classroom, taking school materials out of a backpack, writing notes, handling agenda, leaving the classroom.
Communication application. With the same design, the assistance provided by this application targets to communicating situations inside the classroom. The application covers four scenarios addressing two interaction situations (initiating and answering the interaction) and two types of interlocutors (professor and classmate). For each scenario, different slideshows guide the child, depending on the goal of the interaction.

Emotion Regulation application. This application aims to assist the child to self-regulate his/her emotions. Four simplified emoticons are proposed to the child to choose from: anger, sadness, joy and fear. Then, (s)he selects a level of intensity via a thermometer with a scale from 1 to 4. In response, the application delivers different multimedia contents according to the level selected to help the child regulate his/her emotions. Typically, a text (breathing instructions) are shown at level 1, pictures at level 2, a video at level 3 and another text at level 4.

6.4.2. Training applications

These three applications are serious games with increasing levels of difficulties, reachable after a ratio of good answers has been attained.

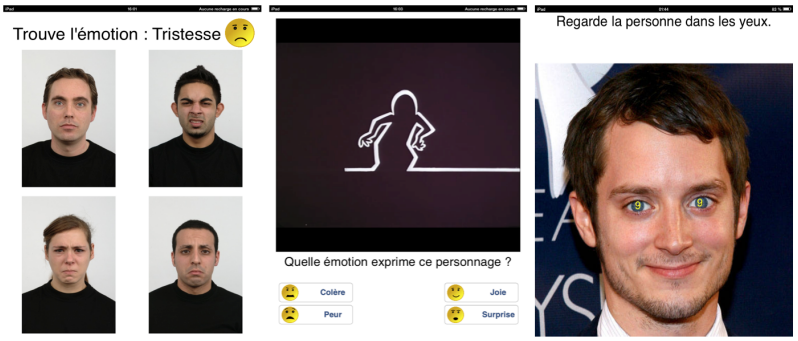

Figure 4. Training applications

Emotion Recognition application with pictures. In this application, the child is instructed to identify a specific emotion among 4 pictures showing different people exhibiting an emotion. Seven emotions are involved in this application: joy, sadness, fear, anger, surprise, disgust and neutral. The emotion to be recognized is displayed together with its simplified emoticon. The type of pictures changes with the difficulty level: level 1 contains pictures of unfamiliar people and level 2 contains pictures of friends and relatives of the child.
Emotion Recognition application with videos. In this application, the child is presented with a fragment of an animated cartoon. At some point, the video stops and the child is asked to identify the emotion of the character. Four emotions are involved in this application: joy, sadness, fear and anger. Videos are slowed down, with a speed percentage that can be changed at each level. Videos change with difficulty level: level 1 contains videos of a very basic cartoon (only one cartoon character drawn by basic form un-textured), level 2 contains a video of more sophisticated cartoons and level 3 contains movies with actors.
Attention Training. In this application, the child is presented a picture of a face and asked to make eye contact with it. Second, a symbol appears briefly in the eyes of the character. Third, the child is asked to identify the symbol shown in the previously displayed picture, to make sure he kept eye contact. The speed at which the symbol appears and disappears is changed according to the difficulty level. Types of pictures also change with the level : level 1 contains pictures of faces and level 2 contains pictures of classroom situations.

6.5. HomeAssist: A Platform for Assistive Living

Participants: Charles Consel [correspondent], Adrien Carteron, Julien Durand, Lucile Dupuy, Hélène Sauzéon.

The HomeAssist platform proposes a systemic approach to introducing an assistive technological platform for older people. To do so, we formed a trans-disciplinary team that allows (1) to identify the user needs from a gerontological and psychological viewpoint; (2) to propose assistive applications designed by human factors and HCI experts, in collaboration with caregivers and users; (3) to develop and test applications by software engineers; (4) to conduct a field study for assessing the benefits of the platform and assistive applications, in collaboration with caregivers, by deploying the system at the actual home of older adults.

The HomeAssist platform is implemented on top of the DiaSuiteBox platform, using a suite of tools, namely DiaSuite, that have been designed, developed and tested by our research group at Inria. The DiaSuite tools include a dedicated integrated development environment that enables applications to be developed quickly and safely. This technology has been successfully applied to a variety of domains where environments consist of networked objects that need to be orchestrated.

6.5.1. Applications

HomeAssist offers an online catalog of applications. Using this catalog, the user and the caregiver determine what and how activities should be assisted by selecting the appropriate assistive applications and configuring them with respect to the user's requirements and preferences. The resulting set of applications forms a personalized assistive support. Additionally, to respond to evolving needs, our platform allows to stop/remove applications easily and to install new ones from the online catalog.

This platform proposes many applications in three domains of everyday life.

- Daily activities: including activity monitoring, light path, and a reminder.
- Home or personal safety: including entrance monitoring, stove monitoring, and warning if no movements are detected after a certain amount of time.
- Communications and social activities: including collaborative games, videoconference, information about local events, TV programming, *etc*.

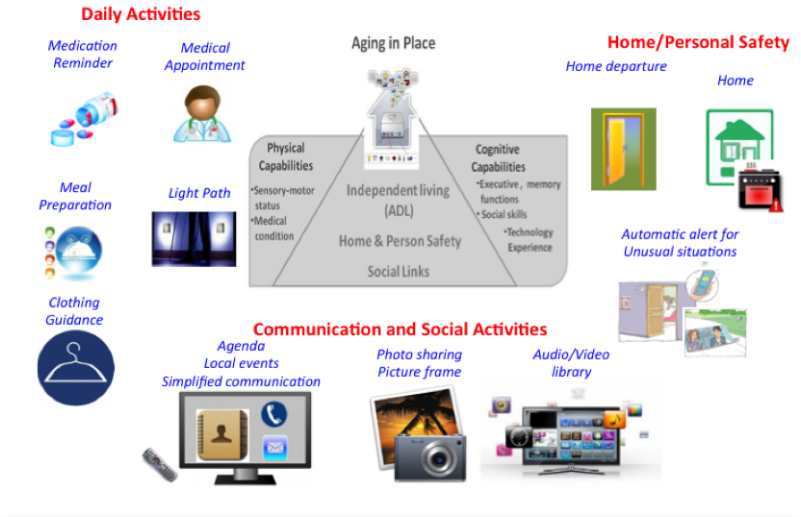

Figure 5. The HomeAssist platform and applications

For video presentations of HomeAssist, see the following:

- http://videotheque.inria.fr/videotheque/media/23705. Title: "DiaSuiteBox", 2013.
- http://videotheque.inria.fr/videotheque/media/29998. Title: "DomAssist : L'assistance numérique à la personne", 2014.

6.5.2. Devices

Several entities have been identified to deliver an assistive support. These entities include (1) technological devices: wireless sensors (motion detectors, contact sensors and smart electric switches), and two tablets, and (2) software services (agenda, address book, mail agent, and photo agent) to monitor everyday activities and propose assistive applications. Sensors are placed in relevant rooms in the house: kitchen, bedroom, bathroom, and around the entrance.

Figure 6. HomeAssist devices

6.5.3. Experimental validation

A field study is currently being conducted with elderly people. The major purpose of this study is to identify the benefits of using HomeAssist for this population in an ecological framework. We selected 24 elderly people with different levels of autonomy (GIR scores). The HomeAssist technology has been installed in their house during 9 months. Twenty-four non-equipped older adults were also selected to participate to the study, as control participants.

The expected impact of HomeAssist reflects the trans-disciplinary nature of the project. We aim to deliver results in the domain of (1) elderly care, (2) ergonomics and human factors, and (3) pervasive computing.

The major expected results are that HomeAssist (1) prolongs ageing in place, improves well-being of the users, and improves the efficiency of the caregiving environment; (2) is a cognitively low-cost assistive technology, and is well accepted and perceived as useful and usable by the users; (3) is technologically robust, and is a validated assistive platform.

The preliminary results of this field study show that the platform is well adopted (highly accessible and usable) by the older users and their families or caregivers.

Additionally, these results support our claim that DiaSuiteBox is effective in terms of:

1. autonomy and well-being of older adults, comparing pre- vs. post-deployment, as well as not-equipped, control participants;
2. gains pre- vs. post deployment in management and load of caregiving tasks, and
3. longitudinal efficacy (gains unchanged at 6 vs. 9 months of use).

Most notably, this pilot project also uses a systemic approach to assistive living as illustrated by (1) its funding sources involving key stakeholders of the caregiving domain, including a territorial agency of Gironde dedicated to ageing, as well as the regional branch of the national public retirement organization (*i.e.,* CARSAT of Aquitaine), (2) their partners operating caregiving services (UDCCAS Gironde), and (3) The regional Chamber of Trades and Crafts to assist the older adults in installing and positioning the devices.

Final results are expected in March 2016.

6.5.4. External Partners

The HomeAssist platform is being developed with support from the following partners:

- Équipe "Handicap et Système Nerveux" (EA 4136), Bordeaux University
- Chaire TSA, Université du Québec Trois-Rivières
- CRIUGM, Université de Montréal
- UDCCAS Gironde
- CARSAT Aquitaine
- Conseil Général 33
- Conseil Régional d'Aquitaine

7. New Results

7.1. Tablet-Based Activity Schedule in Mainstream Environment for Children with Autism and Children with ID

Including children with Autism Spectrum Disorders (ASD) in mainstreamed environments creates a need for new interventions whose efficacy must be assessed in situ. We present a tablet-based application for activity schedules that has been designed following a participatory design approach involving mainstream teachers, special-education teachers and school aides. This applications addresses two domains of activities: classroom routines and verbal communications. We assessed the efficiency of our application with two overlapping user-studies in mainstream inclusion, sharing a group of children with ASD. The first experiment involved 10 children with ASD, where 5 children were equipped with our tabled-based application and 5 were not equipped. We show that (1) the use of the application is rapidly self-initiated (after two months for almost all the participants) and that (2) the tablet-supported routines are better performed after three months of intervention. The second experiment involved 10 children equipped with our application; it shared the data collected for the 5 children with ASD and compared them with data collected for 5 children with Intellectual Disabilities – ID. We show that (1) children with ID are not autonomous in the use of the application at the end of the intervention; (2) both groups exhibited the same benefits on classroom routines; and, (3) children with ID improve significantly less their performance on verbal communication routines. These results are discussed in relation with our design principles. Importantly, the inclusion of a group with another neurodevelopmen- tal condition provided insights about the applicability of these principles beyond the target population of children with ASD.

7.2. Age and active navigation effects on episodic memory: A virtual reality study

We investigated the navigation-related age effects on learning, proactive interference semantic clustering, recognition hits, and false recognitions in a naturalistic situation using a virtual apartment-based task. We also examined the neuropsychological correlates (executive functioning [EF] and episodic memory) of navigation-related age effects on memory. Younger and older adults either actively navigated or passively followed the computer-guided tour of an apartment. The results indicated that active navigation increased recognition

hits compared with passive navigation, but it did not influence other memory measures (learning, proactive interference, and semantic clustering) to a similar extent in either age group. Furthermore, active navigation helped to reduce false recognitions in younger adults but increased those made by older adults. This differential effect of active navigation for younger and older adults was accounted for by EF score. Like for the subject-performed task effects, the effects from the navigation manipulation were well accounted for by item-specific/relational processing distinction, and they were also consistent with a source monitoring deficit in older adults.

7.3. Constraining application behaviour by generating languages

Writing a platform for reactive applications which enforces operational constraints is difficult, and has been approached in various ways. In this experience report, we detail an approach using an embedded DSL which can be used to specify the structure and permissions of a program in a given application domain. Once the developer has specified which components an application will consist of, and which permissions each one needs, the specification itself evaluates to a new, tailored, language. The final implementation of the application is then written in this specialised environment where precisely the API calls associated with the permissions which have been granted, are made available. Our prototype platform targets the domain of mobile computing , and is implemented using Racket. It demonstrates resource access control (e.g., camera, address book, etc.) and tries to prevent leaking of private data. Racket is shown to be an extremely effective platform for designing new programming languages and their run-time libraries. We demonstrate that this approach allows reuse of an inter-component communication layer, is convenient for the application developer because it provides high-level building blocks to structure the application, and provides increased control to the platform owner, preventing certain classes of errors by the developer.

7.4. A Unifying Notification System To Scale Up Assistive Services

Aging creates needs for assistive technology to support all activities of daily living (meal preparation, dressing, social participation, stove monitoring, *etc.*). These needs are mostly addressed by a silo-based approach that requires a new assistive service (*e.g.*, a reminder system, a pill prompter) to be acquired for every activity to be supported. In practice, these services manifest their silo-based nature in their user interactions , and more specifically, in the heterogeneity of their notification system. This heterogeneity incurs a cognitive cost that prevents scaling up assistive services and compromises adoption by older adults. We present an approach to scaling up the combination of technology-based, assistive services by proposing a unifying notification system. To do so, (1) we propose a decomposition of assistive services to expose their needs in notification; (2) we introduce a notification framework, allowing heterogeneous assistive services to homogeneously notify users; (3) we present how this notification framework is carried out in practice for an assisted living platform. We successfully applied our approach to a range of existing and new assistive services. We used our notification framework to implement an assistive platform that combines a variety of assistive services. This platform has been deployed and used 24/7 in the home of 15 older adults for up to 6 months. This study provides empirical evidence of the effectiveness and learnability of the notification system of our platform, irrespective of the cognitive and sensory resources of the user. Additional results show that our assisted living platform achieved high user acceptance and satisfaction.

7.5. Orchestrating Masses of Sensors: A Design-Driven Development Approach

We propose a design-driven development approach that is dedicated to the domain of orchestration of masses of sensors. The developer declares what an application does using a domain-specific language (DSL). Our compiler processes domain-specific declarations to generate a customized programming framework that guides and supports the programming phase.

7.6. Analysis of How People with Intellectual Disabilities Organize Information Using Computerized Guidance

Access to residential settings for people with intellectual disabilities (ID) contributes to their social participation, but presents particular challenges. Assistive technologies can help people perform activities of daily living. However, the majority of the computerized solutions offered use guidance modes with a fixed, unchanging sequencing that leaves little room for self-determination to emerge. The objective of the project was to develop a flexible guidance mode and to test it with participants, to describe their information organization methods. This research used a descriptive exploratory design and conducted a comparison between five participants with ID and five participants with no ID. The results showed a difference in the information organization methods for both categories of participants. The people with ID used more diversified organization methods (categorical, schematic, action-directed) than the neurotypical participants (visual, action-directed). These organization methods varied depending on the people, but also on the characteristics of the requested task. Furthermore, several people with ID presented difficulties when switching from virtual to real mode. These results demonstrate the importance of developing flexible guidance modes adapted to the users' cognitive strategies, to maximize their benefits. Studies using experimental designs will have to be conducted to determine the impacts of more-flexible guidance modes.

8. Partnerships and Cooperations

8.1. Regional Initiatives

8.1.1. HomeAssist: Platform for Assisted Living

The objective of this project is to provide an open platform of digital assistance dedicated to aging in place. This project is in collaboration with researchers in Cognitive Science (Bordeaux University) and the UDCCAS Gironde (Union Départementale des Centres Communaux d'Action Sociale) managing elderly care. This project includes a need analysis, the development of assistive applications and their experimental validation.

This work is funded by CARSAT Aquitaine ("Caisse d'Assurance Retraite et de la Santé au Travail"), Aquitaine Region and Conseil Général de la Gironde.

8.1.2. HomeAssist 500 – Populational Study

HomeAssist is an assisted living platform developed by the Phoenix research group at Inria. This platform has been applied to the domain of assisted living for the past two years. From the start, computer scientists and researchers in Ageing and Occupational Therapy have conducted this research effort in close collaboration with the stakeholders of aging in place. An initial set of applications has been developed, relying on a basic set of entities (sensors, actuators and web services). HomeAssist has been deployed in the homes of 24 older adults (matched with 24 control counterparts not equipped) and is currently being assessed. Although ongoing, the preliminary results of this field study show that the platform is well adopted (highly accepted and usable) by the older adults and their families or caregivers. Additionally, benefits from HomeAssist intervention have been demonstrated in terms of well-being, autonomy as well as quality of life (psychological health).

8.1.2.1. A Randomized Controlled Trial (RCT) of HomeAssist

This RTC will be conducted with older adults, ranging from autonomous to mildly cognitively impaired (e.g., cognitive or physical frailty) Alzheimer disease (AD) in its early stage). The RCT is considered as the gold standard of a true experimental design. Furthermore, it provides strong evidence for causal relationships, as well as the ability to generalize the results to people outside the study's sample. The study design will thus be a single-blinded RCT. It will include up to 500 participants, matched with non-equipped participants. The HomeAssist intervention will involve monitoring as well as compensation services to support independent living in place. The duration of the HomeAssist intervention is of 12 months.

8.1.2.2. Expected Impact on Elderly Care

Prolonging ageing in place. Our 12-month field study of a large group of participants, combined with a control group, will give a statistical basis to assess the efficacy of our platform to prolong ageing in place for a range of older adults, including participants with mild cognitive impairment. Functional status and nursing needs will be assessed through statistical analyses over the duration of the field study. Subjective and objective measures will be done using such tools as the Multilevel Assessment Instrument or Lawton Scale and the Time-Based IADL. These traditional assessments will be completed by longitudinal in situ actimetric data recorded at home via HomeAssist, for measuring the actual IADL performance.

Secondary criteria of technology efficacy will also be studied, including general cognitive status, memory and executive functioning.

Improving well-being. Socialization activities have proven to be a key factor in well-being. To promote socialization activities, our platform offers a variety of services ranging from the main tablet, running a digital picture frame connected to online albums, to a simplified email client, allowing responses to be voice-recorded, instead of typed on a keyboard. Our platform also supports autonomous realization of daily tasks, which is known to be related to older adult well-being. Additionally, to improve well-being, applications support self-regulation and self-determination in helping the users to conform to their own daily routines via sensor-based activity monitoring and assistive supports (e.g., activity reminders or prompters). Specific assessment tools will be used to measure the well-being and the self-efficacy of the participants over the duration of the study.

Improving the efficiency of the caregiving environment. The actions of the caregiving environment are often limited or impeded by the lack of a proxy at the older adult's home. Such a proxy is needed for a number of actions, including mutualizing the planning of care services, gathering information on older adult activities, reminding of activities and appointments, monitoring potentially unsafe activities and situations. Our online catalog already offers applications materializing a caregiving proxy; the HomeAssist project will expand this catalog with an emphasis on older adults with cognitive impairment. Questionnaires will be administered to caregivers to assess the reassurance impact of our platform in their daily delivery of services (e.g., feeling of burden assessment, Psychological health of caregivers).

8.1.2.3. Expected Impact on Pervasive Computing

Robustness. The DiaSuiteBox platform will be deployed at a large scale, serving 500 users. This deployment will allow to further test the robustness of DiaSuiteBox beyond the current 24 users in Bordeaux. Various runtime logs will be collected to measure the performance and the behavior of DiaSuiteBox.

Development of assistive applications. Our existing experience in developing assistive applications will be significantly expanded by considering users with cognitive impairment. This situation will result in taking into account additional parameters in the user interactions. We will formalize and report on a methodology to assess users' need and develop assistive applications, leveraging our current experience and the one of HomeAssist.

A validated assistive platform. An outcome of the HomeAssist project is the validation of the DiaSuiteBox technology as a platform for assisted living. The project will provide a solid basis on which a technology transfer can be achieved. In particular, the following factors will be key measures of the readiness and potential of DiaSuiteBox: diversity of users participating in our field study, the range of applications developed, the variety of devices utilized. The questionnaires administered to the participants will be valuable information for elaborating marketing strategies of the DiaSuiteBox technology.

8.1.2.4. Technology Transfer

An outcome of the HomeAssist-500 project is the validation of the DiaSuiteBox technology as a platform for assisted living. The project will provide a solid basis for the creation of a startup to market the technology. In particular, the following factors will be key measures of the readiness and potential of DiaSuiteBox: diversity of users participating in our field study, range of applications developed, variety of devices utilized, deployment in 500 homes for a period of 12 months. The questionnaires administered to the participants will be valuable information for elaborating marketing strategies for the DiaSuiteBox technology. Inria, which owns the intellectual property of DiaSuiteBox, is committed to providing the Inria Phoenix group with support to turn this technology into a marketable product.

This work is funded by European Regional Development Funds, CARSAT Aquitaine, (ERDF), Aquitaine Region, Réunica, Conseil Département de Gironde, RPDAD / UDCCAS Gironde, CNSA.

8.1.3. ANDDI

Five percent of the population have Intellectual Disabilities (ID). Individuals with ID have significant socio-adaptive limitations in a variety of daily activities, at home (task planification and execution, medication, home safety, etc.) as well as outside (route planning, itinerary in public transportation, etc.). Individuals with ID, their families, health institutions, caregiving services, and dedicated organizations strive to find ways in which these individuals can live as independently as possible, while promoting their social inclusion in every respect of their life (housing, professional training, employment, leisure, culture, etc.).

The research project ANDDI leverages the abilities of individuals with ID and the recent technological advances to develop a variety of assistive services addressing their daily needs. These services draw on our expertise in cognitive science and computer science, dedicated to assisting users with technologies. In particular, we use our platform, named HomeAssist, dedicated to the independently living of older adults. This platform relies on DiaSuite, our suite of tools for developing applications that orchestrate networked objects, and DiaSuiteBox, our platform that runs an open-ended set of applications, sensors, actuators and web services.

ANDDI addresses users with Down syndrome aiming to live independently; it pursues the following goals:

1. determining the key obstacles to perform daily activities autonomously and collecting the needs in assistive support expressed by individuals with ID and their family and caregivers;
2. developing and adapting assistive services available in HomeAssist across an iterative assessment (period of 6 months) of experiences of each individual;
3. evaluating the efficacy of our developed assistive services across the stages experienced by individuals progressively becoming independent in their daily life (pre-post comparison after 12 months of HomAssist intervention).

This project is the outcome of the OPALI project, described in Section 8.3.1.1, and is funded by the Aquitaine Region and “Trisomie 21 France” .

8.1.4. Certification of an open platform

The purpose of this project is to define concepts and tools for developing certifying open platforms. This certification process must ensure a set of critical properties (e.g., safety, confidentiality, security) by certifying each tier application. These guarantees are essential to ensure that openness does not come at the expense of the user’s well-being. To preserve the innovation model of open platforms, this certification process should also be as automatic as possible. Indeed, the success of open platforms is mainly due to the low development cost of a new application. The case study of this thesis will be the domain of home automation. The results of this thesis will be put into practice in the DiaSuiteBox open platform.

This project is funded by Aquitaine Region.

8.2. National Initiatives

8.2.1. Objects’ World: design-driven development of large-scale smart spaces

There are an abundance of research and industry initiatives that have been undertaken with the aim of promoting the emergence of Internet of Things. In line with this goal, the Object’s World project brings together stakeholders from different domains to build and support the emergence of an IoT sector in France and beyond. The project is lead by SIGFOX, the world’s first cellular network operator dedicated to low-bandwidth wireless objects. The cooperation between industry and research partners (e.g., sensor manufacturers, computer science and electrical engineering research labs) is of uttermost importance in overcoming technological barriers. This issue is currently hindering the development of an IoT sector. The main objectives of this project are the development of

- expertise in the low-bandwidth network sector,
- low-cost transmitter/receiver chips,
- low-energy autonomous sensors, and
- software frameworks which cover the entire lifecycle of IoT applications.

Network infrastructures that support huge numbers of objects open up a range of opportunities for innovative services. Critically, these new opportunities rely on the ability to address the software engineering challenges of this new sector. We promote an approach that revolves around software frameworks. In areas such as mobile and web development, this approach has already been shown to facilitate software development by abstracting over implementation details and guiding the programmer.

Our objective is to propose concepts and tools for developing reliable applications orchestrating large-scale smart spaces of networked entities. The industrial partners of the Objects' World project will provide us with real-size case studies in various application domains (e.g., smart cities, tracking of vehicles, healthcare, energy management).

This work is funded by the OSEO national agency.

8.2.2. School Inclusion for Children with Autism

The objective of this project is to provide children with assistive technologies dedicated to the school routines. This project is in collaboration with the "Handicap et Système Nerveux" research group (EA 4136, Bordeaux University), the PsyCLÉ research center (EA 3273, Provence Aix-Marseille University) and the "Parole et Langage" research laboratory (CNRS, Provence Aix-Marseille University).

This work is funded by the French Ministry of National Education and Orange Foundation.

8.3. International Initiatives

8.3.1. Inria Associate Teams not involved in an Inria International Labs

8.3.1.1. OPALI

Title: OPen Assistive-technology platform for independent LIving

International Partner (Institution - Laboratory - Researcher):

Université du Québec à Trois Rivières (Canada) - Self-Determination Assistive Technologies Research Chair (TSA Chair) - Dany Lussier-Desrochers

Start year: 2013

See also: http://phoenix.inria.fr/opali

The goal of the OPALI project is to develop an Open Platform for Assisted Living targeting users with cognitive disabilities. It is a cross-disciplinary project combining expertise in (1) Computer Science focusing in development of applications orchestrating networked devices and (2) Psychology focusing in assistive technologies for users with cognitive disabilities. Furthermore, this project will leverage a unique research vehicle created by the University of Trois-Rivières consisting of a full-fledged apartment equipped with a range of networked devices and dedicated to experimental studies. The outcome of the project will include a large catalog of assistive applications allowing to match each user's project life.

8.4. International Research Visitors

8.4.1. Visits of International Scientists

Faustina HWang visited in June 2015. She is a professor at Reading University (UK). Her research interests concern assistive technologies, mainly for older adults and people with learning disabilities.

Matthew Goodwin visited in July 2015. He is a founding and key faculty member of a new doctoral program in Personal Health Informatics (PHI) and Director of the Computational Behavioral Science Laboratory (CBSL) at Northeastern University.

Myra Fernandes visited in September 2015. She is a professor at Waterloo University. Her research interests incude memory, aging, Parkison disorder, and virtual reality.

9. Dissemination

9.1. Promoting Scientific Activities

9.1.1. Scientific events selection

9.1.1.1. Member of the conference program committees

Charles Consel

- ESOP 2015, the 24th European Symposium on Programming. April 11-15, 2015 London, United Kingdom.

9.1.2. Invited talks

- C. Consel: HomeAssist: An Assisted Living Platform for Aging in Place Based on A Multidisciplinary Approach. Presentation at Washingon State University, July 7, 2015.

9.2. Teaching - Supervision - Juries

9.2.1. Teaching

Licence: Hélène Sauzéon, "General Cognitive Psychology", 36h, L2/L3, University of Bordeaux, France
Licence: Hélène Sauzéon, "Cognitive Neuropsychology", 14h, DU, University of Bordeaux, France
Master: Hélène Sauzéon, "Cognitive Science of Language", "Technologies For Cognitive Disabilities", "Human Factors and HCI", 120h, M1/M2, University of Bordeaux, France
Master: Charles Consel, "Telephony Over IP", 43h, M2, Bordeaux INP, France.
Master: Charles Consel, "Software Engineering for Smart Spaces", 10h, M2, Bordeaux INP, France.
Master: Charles Consel, "Ubiquitous Computing", 10h, M2, Bordeaux INP, France.

9.2.2. Supervision

PhD: Paul van der Walt, “Certification d’une plateforme ouverte”, completed in December 2015, supervised by Charles Consel
PhD in progress: Milan Kabac, “Orchestration à grande échelle d’objets communicants”, started in September 2012, supervised by Charles Consel
PhD in progress: Charles Fage, “Validation expérimentale d’un assistant numérique d’inclusion scolaire d’élèves collègiens porteurs d’autisme”, started in September 2012, supervised by Hélène Sauzéon
PhD in progress: Lucile Dupuy, “DomAssist: Assistance domiciliaire pour la personne âgée et son aidant formel basée sur la technologie DiaSuiteBox”, started in September 2013, supervised by Hélène Sauzéon and Charles Consel
PhD in progress: Adrien Carteron, "A development environment dedicated to assistive application", started in October 2014, supervised by Charles Consel.
PhD in progress: Cécile Magnier, "Customized technology for autonomous schooling: on longitudinal effects for students with an autism spectrum disorder", started in November 2014, supervised by Hélène Sauzéon and Charles Consel.
PhD in progress: Quentin Chisin, "Digital home assistance for young adults with Down syndrome", started in December 2014, supervised by Bernard N’Kaoua and Charles Consel.

9.2.3. Juries

Charles Consel participated in the following jury:

- Thesis defense committee for A. Capra, Université de Bordeaux, december 2015.

Hélène Sauzéon participated in the following juries:

- Thesis defense committee for S. Gombart, Université de Tours, december 2015
- Thesis defense committee for B. Chateau, Université de Poitiers, december 2015

9.3. Popularization

- Hélène Sauzéon. " Assistance numérique pour soutenir les activités quotidiennes des personnes âgées et/ou avec handicap cognitif." Journée de Lancement du Living Lab e-santé Aquitain. March 5, 2015, Bordeaux.
- Hélène Sauzéon. " Quels outils numériques pour les élèves avec handicap cognitif ?" Congrès FNAREN. June 24-27, 2015, Cenon.
- Hélène Sauzéon. "DomAssist : pesrpectives d'application en EPHAD." Congrès EHPAD et Innovations. July 2, 2015, Bordeaux.
- Phoenix members. Présentation de DomAssist et College+. Les rencontres Inria-Industrie sur le thème de la santé. Novembre 13, 2015, Bordeaux.
- Benjamin Bertran. Présentation de DomAssist. Colloque sur la Silver Economy. October 19, 2015, Bordeaux (200 personnes).
- Benjamin Bertran. Présentation de DomAssist / HomeAttendant, Rencontre médico-social. October 1, Limoges (80 personnes).

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