The Praxis of Cognitive Assistance in Smart Homes

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Abstract. The current and prospective situation of cognitively impaired people entails great human, social, and economical costs. Smart homes can help to maintain at home cognitively impaired people, to improve their autonomy, and accordingly to alleviate the burden put on informal and professional caregivers. This chapter will provide a comprehensive view of the research performed at DOMUS lab. This research aims at turning the whole home into a cognitive prosthetic, especially by providing cognitive assistance. The first part of the chapter presents research on the infrastructure, both sensors networks and middleware. Research work on autonomic computing, multi-person localization, context awareness, and personalization are presented. The next part of the chapter illustrates by means of DOMUS research prototypes how cognitive assistance can help to address four kinds of cognitive deficits: initiation, attention, planning, and memory. Studies involving cognitively impaired people are also be presented. In the final part of the chapter, the role of AI, context awareness and behavior tracking are questioned. To what extend are they compulsory? Does design can provide smart and simple solutions to complex issues?

Keywords. Smart homes, pervasive computing, context awareness, cognitive deficits, design, artificial intelligence.

Introduction

Who has never searched for his keys? Who has never forgotten a pan on the stove? Considered individually, such deficits of memory and attention do not have serious consequences. But people suffering form cognitive deficits have to face them on a daily basis. People suffering from head traumas, schizophrenia, intellectual disability, or Alzheimer’s disease know all too well how such deficits may change one’s life. In many cases, they would be able to stay at home if a light assistance was provided. But resources are scarce. Oftentimes, relatives must take the initiative and responsibility of care without appropriate professional support. Smart homes can help to maintain at home cognitively impaired people, to improve their autonomy, and accordingly to alleviate the burden put on informal and professional caregivers.

This chapter presents an overview of the research performed at DOMUS lab. Cognitively impaired people are more numerous than one may think. Given the human,

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social and economic cost, means have to be found to allow them to stay in their home and live autonomously (§1). Smart homes can rely on pervasive computing and tangible user interfaces to turn the whole house into a cognitive orthosis (§2). A preliminary study involving cognitively impaired people together with natural and professional caregivers shows that cognitive assistance and tele-vigilance services have to be designed, implemented and deployed to address deficits of attention, planning, memory, and initiation (§3). However many consideration have to be taken into account—from ethic to cost—before building a true smart home (§4). The DOMUS smart home infrastructure rests on three layers: hardware and networks, middleware, and services (§5). Next a pervasive cognitive assistant for morning routine illustrates how cognitive assistance can help to address four kinds of cognitive deficits: initiation, attention, planning, and memory (§6). Then the implementation of a cognitive assistant for meal preparation is sketched and a usability study on this assistant involving people with intellectual deficiencies is detailed (§7). As a complement to pervasive cognitive assistance, mobile services are ensuring continuity of assistance and vigilance outside the home (§8). In the final part of the chapter investigates how to overcome current limitations of DOMUS cognitive assistance and tele-vigilance services (§9). First the role of AI, context awareness and behavior recognition are questioned (§10). To what extend are they compulsory? Then we explore how design can provide smart and simple solutions to complex issues (§11)

1. Cognitive Deficits Entail High Human, Social, and Economic Costs

The “World Population Ageing: 1950-2050” report of the Population Division – Department of Economic and Social Affairs (United Nations) [1] exposes how the increase in life expectancy² lead to an expected global population of 2 billion of people of 60 or over in 2050, that is more than three times the current elder population. Accordingly a tremendous rise in ageing related diseases like dementia and Alzheimer’s disease should be observed. For instance, [2] estimates that in 2005 more than 6.4 million European people were suffering of various forms of dementia (around 1.25% of the population); this number is expected to grow up to 15.9 million in 2040. So it is not surprising that current demographic trends tend to focus on elders when speaking of cognitive deficits. Unfortunately cognitive deficits are far more spread than one may think at first sight. Traumatic brain injuries (TBI), schizophrenia, intellectual deficiencies are just few examples of sources of cognitive deficits. Direct medical costs and indirect costs such as lost productivity of TBI totaled an estimated $56.3 billion in the United States in 1995 [2]. TBI people account for 6% of the SAAQ clientele but stand 28% of its costs [3]. Schizophrenia affects 1% to 2% of the population in the United States [4]. In 2002, the overall U.S. 2002 cost of schizophrenia was estimated to be $62.7 billion [5]. Mental retardation is affecting 1 to 3% of the population [6]. Therefore many young people are also affected by cognitive deficits; and they have a

² Life expectancy in 2045-2050 is expected to be 76 years old.
³ However the authors of a systematic analysis suggest that the reality is somewhat lower: “if we wish to provide the general public with a measure of the likelihood that individuals will develop schizophrenia during their lifetime, then a more accurate statement would be that about seven to eight individuals per 1,000 will be affected.” [78]
⁴ The great variation of prevalence extracted from the clinical studies is related to the definition of mental retardation used by the study, the evaluation methods and the studied populations.
long life span in front of them.

Governments try to maintain in their community people suffering from cognitive impairments (Alzheimer disease, trauma, schizophrenia...). Continuous care and monitoring are then compulsory to maintain them at home. However in many cases, they would be able to stay at home if light assistance was provided. But resources are scarce. Thus most of the time relatives take responsibility for car without access to appropriate resources. Too often this situation turns to an exhausting burden. Hence relatives and caregivers are urging for help.

2. Smart Environments, a Source of Hope

Today, networks, microprocessors, memory chips, smart sensors and actuators are faster, more powerful, cheaper and smaller than ever. Chips are all around, invading everyday objects. Wireless networks enable to easily connect them. Everyday objects can then propose innovative and unexpected interactions [7]. Clothes will transport one’s profile to reconfigure his environment according to his preferences [8]. Lamps will help him to find lost objects [9]. Interactive portraits will reflect at distance the mood and health state of his beloved people [10]. Then pervasive computing [11], cognitive orthotics [12] [13], and tangible user interfaces [7] form a promising combination for a seamless integration of assistance services in the everyday life of cognitively impaired people [14] [15]. Such smart environments will change at their root the way we conceive and use health related services: diagnosis, therapy, assistance, and vigilance.

The research at DOMUS laboratory is studying the theory and praxis of pervasive computing to create smart homes [16, 17]. Smart homes are augmented environment with embedded computers, information appliances, and multi-modal sensors. Research target is the realization of a smart home for people suffering from cognitive deficits. To enable them to perform their activities of daily living securely, the lab is developing

- **Cognitive assistants.** A home enhanced with cognitive assistance will give to people suffering from cognitive deficits the capacity to define their own life project and will foster their autonomy. The entire home then will be a cognitive orthosis able to remedy to deficits of attention, memory, planning and initiation.

- **Tele-vigilance systems.** Tele-vigilance systems will support better medical and human supervision while relieving caregivers.

3. Users of a Smart Home

Users of a smart home will be of course the cognitively impaired residents, but also the natural and professional caregivers. Before starting to design and build smart homes for cognitively impaired people, DOMUS have established its target population (§3.1), their needs and their requirements (§3.2).
3.1. Target Population

The global deterioration scale (GDS) for assessment of primary degenerative dementia [18] is used to assess the severity of cognitive impairments thanks to a staging system (Table 1). Although dedicated to dementia, the GDS was used to characterize the cognitive capacities of the expected typical residents of a smart home 5. We believe that stages 3, 4, and 5 were those where technology can reveal the most fruitful in maintaining cognitively impaired people at home. They delineate indeed those that would not be able to stay at home without some assistance but their health status is not too much severe so they can benefit from assistance and remote vigilance.

Table 1 The Global Deterioration Scale for Assessment of Primary Degenerative Dementia [18]

<table>
<thead>
<tr>
<th>Stage</th>
<th>Type of cognitive decline</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>No cognitive decline</td>
<td>No subjective of objective deficits</td>
</tr>
<tr>
<td>2</td>
<td>Very mild cognitive decline</td>
<td>Some subjective complaints, no objective deficits</td>
</tr>
<tr>
<td>3</td>
<td>Mild cognitive deficits</td>
<td>Mild working memory deficits (attention, concentration)</td>
</tr>
<tr>
<td>4</td>
<td>Moderate cognitive decline</td>
<td>Episodic memory deficits (memory of recent events)</td>
</tr>
<tr>
<td>5</td>
<td>Moderately severe cognitive decline</td>
<td>Explicit memory deficits (ability to accomplish usual task)</td>
</tr>
<tr>
<td>6</td>
<td>Severe cognitive decline</td>
<td>Severe memory deficits (which cause delusion)</td>
</tr>
<tr>
<td>7</td>
<td>Very severe cognitive decline</td>
<td>All verbal activities are lost</td>
</tr>
</tbody>
</table>

3.2. Requirements and needs

A study on requirements and needs of cognitively impaired people and caregivers in Quebec and in France [19] established first that a special attention should be paid to attention, initiation, memory, and planning deficits, and second two classes of applications should be privileged, namely cognitive assistance and tele-vigilance. Cognitively impaired people should be able to perform their activities of daily living while being and feeling safe at home. As a result pervasive computing and tangible user interface stand as the backbone for cognitive assistance. They enable to provide adapted and personalized ambient cues to foster the autonomy of cognitively impaired people [15] and to reduce risks and hazards. Then mobile computing and location-based services keep ensuring cognitive assistance when people are outside their home [20] [21]. Finally these technologies help relatives and caregivers to stay in touch at distance with cognitively impaired people. Besides tools for team of caregivers give means for synchronous and asynchronous collaboration [22] [23].

4. Design Principles

Though technology can be very enabling and powerful, building cognitive assistant and tele-vigilance services raises many considerations: effectiveness, costs, ethics [24]. For instance doing the actions in place of an Alzheimer patient can lead to a faster

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5 The GDS was used more as a guideline than a real assessment tool, since the residents may suffer of course of dementia, but also from other diseases as TBI.
deterioration of his cognitive capacities. Stated otherwise, it §§DOMUS lab has set the following guidelines and hypothesis:

- We don’t need to know everything to be helpful.
- Technology is not the only way to go, maybe there exists a non-technology based solution.
- Use what is already commercially available.
- The system should be as unobtrusive as possible.
- There should be as less as possible intervention; less but useful and meaningful is better.
- User owns the control and can always turn the system off.
- Advising instead of doing.
- There is always a human being at the other end of the system.

5. From Homes to Smart Homes, to Smart Care

To explore how to transform a real apartment into a smart home and to use this smart home to provide smart care, DOMUS benefits or a real apartment on the campus of the University of Sherbrooke (Figure 1). The infrastructure of this smart home has three layers. The lower layer is made of hardware, embedded processors, and networks (§5.1). Middleware is deployed on top of the hardware layer (§5.2). At upper level, smart care services are deployed (§5.3).

Prototypes will then be experimented, validated and progressively transferred to real life. In the long term, we hope that results will be applied to non-medical contexts. Indeed targeting the most difficult cases will help to better understand the needs and uses of smart homes in general.

![Figure 1](image_url)

Figure 1 The apartment at the DOMUS lab. (a) the living room. (b) the kitchen. (c) the dining room. (d) a map of the complete apartment.
5.1. Hardware, Devices and Network

A smart home is an environment augmented with heterogeneous networks, sensors networks, embedded processors in appliances, clothes, jewels, information devices, and networked communicating objects. The DOMUS laboratory provides a cutting-edge research infrastructure for pervasive computing and TUI. It consists of a standard apartment (kitchen, living room, dining hall, bedroom, and bathroom) augmented with sensors, localization systems, micros and speakers, TV, touch screens, etc. Lighting, plumbing, audio and video streams can be entirely monitored and controlled. Available networks include wired Ethernet, Wifi, Bluetooth, data communication through power line, and Crestron specialized domotic system. Currently available sensors are electromagnetics contacts, sensitive rugs, movement detectors, RFID readers and tags, ubisense localization system, Watteco, flowmeters, microphones. They are used for the localization and identification of people and objects. Processors and sensors are embedded into the stove. To provide for feedback to the user, services may use information devices such as wireless computer screen, touch screens, Icebox, PDAs, LEDs, speakers, telephones, videoconference systems, TVs, smartboards, lighting systems. Servers coupled with programmable logic controllers, provides full control over the devices, the sound and the video streams in each room of the apartment.

5.2. Middleware Layer of a Pervasive Infrastructure

Middleware links the hardware layer to the application layer. Once the hardware is installed, one needs to build a middleware layer for the pervasive infrastructure. On the one hand, middleware enables to cope with heterogeneity of devices, networks, and operating systems. On the other hand, it provides generic services useful for many applications (Figure 2). Research are done on low-level event awareness and context awareness, enabling for instance to localize user from simple sensors information [25], for transparent user friendly migration of sessions [26], autonomic computing and self-management [27], extension of OSGI for remote deployment and monitoring [28], mobile agents, multi-channel delivery of services [29], application of design patterns for security and dependability [30].

Figure 2 The middleware layer links the sensors and effectors through the various available networks. Cognitive assistance and tele-vigilance use the middleware to gathers information and to interact with users through traditional graphical user interfaces and tangible user interfaces.
5.3. Application Layer: Cognitive Assistance and Tele-Vigilance

So far applications and services are pervasive cognitive assistance for the morning routine, pervasive cognitive assistance for meal preparation, pervasive reminder systems. With respect to mobile cognitive assistance, we have built a cognitive assistant for ADLs, tele-monitoring tools, medical assessment tools, and tools for the coordination of caregivers. Finally we are also addressing pervasive space as an asynchronous collaboration medium for asynchronous coordination and collaboration of caregivers. Privacy and security are also taken into consideration in these applications. Embedding knowledge directly in the design of the artifacts is another path to assistance that is explored. Next sections will sketch some of these services.

6. Cognitive Assistance to Morning Routine

According to the caregivers four cognitive deficits elicited in the study [19] are mainly responsible of the autonomy disruption in the daily life: initiation, planning, attention and memory deficits. Autonomy could be diminished due to difficulties in remembering which activity to perform and how to do it, to difficulties in focusing on the activity in process or even to begin it. Such behaviors may impair the health and well being of the person, as the essential activities, like eating or taking medicine, could not be completed in time. Then the person needs continuous prompts from her caregiver, which could affect the relationship.

This section sketches how a pervasive cognitive assistant (PCA) can recognized these deficits during the morning routine and assisted a cognitively impaired resident in the context of a smart home. The cognitively impaired population considered when we implemented the PCA was composed of persons suffering from Alzheimer disease, head trauma, and schizophrenia.

6.1. Initiation Deficit

The initiation deficit leads to inactive periods whereas the person is supposed to perform actions [31]. For example, during breakfast time, standing in the kitchen for a long time could be attributed to an initiation deficit. The PCA detects an initiation deficit when no action is observed during a period where the occupant is supposed to be active. To diagnose it, the PCA must combine the information from three features: first the lack of actions detected by the sensors, second the period of inaction and third the occupant habits. The third feature is used to compare the actual activity with the one expected. It is essential to avoid detecting initiation deficit in a period where the occupant is usually inactive, as for example during a nap. The PCA infers a deficit of initiation when it notices that, contrary to the information stored about the occupant habits, the sensors indicate no action during a period. The aim of the assistance is to urge the person to begin the activity.

6.2. Planning Deficit

The planning is the identification and organization of the steps and elements needed to achieve a goal [32]. The planning deficit leads to the difficulty to perform an
appropriate sequence of actions in order to achieve a goal. To prepare tea, it is at least necessary to put a tea bag in a cup, to boil the water, and to pour it in the cup. The appropriate sequence requires that the third task must be performed after the two others. Performing actions in an inappropriate sequence indicates a planning deficit. Given an activity in progress, three cases are distinguished according to the current action performed:

1. The current action is related to the activity under progress, but should not occur at that time. Previous actions have to be performed before this one. For example, pouring the coffee before the water is hot.

2. The action under progress is not related to the activity. But this action takes place in the same location as the activity one. It could be inferred that the person encounters difficulties to formalize the next step that has to be completed. She then tries an action without following the goal. For example, she opens the cabin doors instead of the drawer to pick up a spoon.

3. The activity is engaged, but the current step average duration has run out. The occupant seems to be unable to perform the next step.

Time duration is involved in the third case as shown previously for the initiation deficit. But, here the activity has yet begun and the person is lost, exhibiting difficulty to find the next step, instead of waiting without beginning the activity. In the second case, the location where the non-relevant action takes place allows identifying the nature of the deficit. Outside the activity area it could be due to a stimulus leading to an attention deficit, inside the activity area it is attributed to the difficulty to find the next step. The PCA detects a planning deficit according to the three types of unfair actions presented below. To diagnose one of these cases, the PCA must combine the information from the following four features:

- the location of ADL under progress;
- the location of the current action;
- the sequence of actions in an activity;
- the average duration of a step completion.

Given the activity under progress, given the current action, the PCA diagnoses a planning deficit if the current action is not the one to be performed at that time even if performed in the same location, or if it takes too much time to perform the next action. The aim of the assistance is to recall the next step in the sequence of actions for the current activity.

6.3. Attention Deficit

The attention concept is linked to the processing of external stimuli [33]. During task completion, the person shifts her attention from the activity under progress to a stimulus causing interference. The person demonstrates difficulty to focus on the activity to be performed and as a consequence, the current activity should be forgotten and never completed. The PCA detects attention deficit when the actions performed are
not related to the current activity. To distinguish it from a planning deficit, the location of the new location is crucial. As explained before, if the current action location is different from the activity one then the PCA diagnoses an attention deficit, otherwise a planning deficit. Given the activity under progress, given the current action, the PCA diagnoses an attention deficit if the current action is not the one to be performed at that time and if it is performed in another location than the activity under progress. The aim of the assistance is to help the person continuing the current activity. It will then recall the goal of the activity to help her keeping the focus on it.

6.4. Memory Deficit

The memory processes refer to information storage and retrieval [34]. Suffering from memory deficits could lead to difficulties to remember the activity to perform, the steps of the activity or the locations of the tools and materials involved in that activity. It is inferred in this study that the person is aware of her memory deficits. She will then take the initiative to ask for assistance. The PCA diagnoses the memory deficit by the kind of demand asked by the occupant. The aim of the assistant is to provide the forgotten information.

6.5. Interacting with Users

Interactions between the PCA, residents and caregivers raise many issues. Who initiate the interactions? How users and PCA interact? Are the interactions synchronous or asynchronous?

6.5.1. Triggering Interactions

Assistive interactions can be triggered by the resident as well as by the PCA. Whenever a user feels the need for some help, he can ask explicitly for it. For instance when he is looking for the objects needed to perform a task, he can use a service dedicated to the objects localisation. When he does not know which pills he has to take, he can ask the PCA to establish a connection with his caregivers. On the contrary, when the PCA is supervising on a step by step for instance meal preparation, it can decide to highlight specific objects in the room related to the current step of the recipe. Or when the PCA detects an initiation deficit, it can prompt the resident and suggests an ADL to perform.

6.5.2. User Interaction Mode

The PCA makes use of two approaches for interaction with the resident. At one end of the spectrum, it can use traditional user interfaces, for instance a message displayed on a touch screen to suggest the next ADL to perform when an initiation deficit is recognized or display a map of the apartment to help find objects to assist user memory. Sound, recorded messages, videos can also be used to prompt the resident of attract his attention. At the other end of the spectrum, the PCA can use tangible user interfaces, for instance blinking LEDs to attract resident attention to a specific location or straightforwardly using movements of objects to control the monitoring process [14]. Nonetheless whatever the devices used, interactions should be as natural, easy and fluid as possible.
6.5.3. Synchronicity of Interactions

Most of the times, interactions will be synchronously. When a resident asks for help, he is expected to receive an answer immediately. But there are cases where asynchronous interactions are well appropriate. For instance, when the PCA detects an initiation deficit, it sends an asynchronous message to caregivers warning them that maybe this morning the resident will require more attention. So caregivers can concentrate their attention on those that may need supervision.

7. Archipel

Archipel is a context-oriented framework for cognitive assistance [15]. It has been applied to meal preparation. Its objectives are to promote ADLs completion for people with cognitive impairments, to foster their functional autonomy and their quality of life, and to exploit context-awareness and to use resources in the environment for assistance. A framework integrating four axes was implemented: knowledge representation, man-machine interfaces, ADL monitoring and ADL assistance.

A first experimentation of the prototype has been done with 12 people with intellectual disabilities. Its protocol was presented in [35]. These persons were asked to complete two similar recipes, one with the assistant and the other without it. The familiarization with the assistant was done during an initiation recipe, completed before the experimentation. A researcher stayed with the person all the time, providing him some assistance when the person asked for. The preliminary results show a decrease of the number of cues the researcher gives when the assistant is present (Figure 3). Furthermore, cues are more abstract with the assistant, most of the time concerning the use of the orthosis. For example, instead of saying how to complete a step, the researcher invites the person to use the assistant to watch the video explaining the completion. Everyone was able to complete the recipe, even those that were not able to read.

Figure 3 We clearly observed the need for less human interventions to perform the recipe when Archipel provides assistance. Y-axis is the number of interventions by participant. For participant 1, 2, 3, 9, 12, and 6 the first value is for the experimentation without the cognitive assistant while the second value is for the experimentation with the cognitive assistant. For the participant 7, 4, 5, 11, 10, 8 the first value is for the experimentation with the cognitive assistant while the second value is for the experimentation without the cognitive assistant.
8. Mobile Cognitive Assistance

The PCA and Archipel are context-aware assistants designed for working inside the apartment of a cognitively impaired people. However if he does not have services following him anywhere, his home will soon become some sort of prison. Hence we implemented Mobus a simple mobile orthosis, as a complement to these assistants. Mobus clients are running on personal digital assistants (PDA) or smart phones. Mobus web services are accessed through wireless networks, e.g. GPRS or 3G. Mobus offers four kinds of services: activity recalls, medical assessment, requests for assistance, and contextual location-based assistance [36] [37] [38]. Each service has two facets: one for cognitively impaired people and the other for caregivers. Many usability and clinical studies of these services with real users have been made or are on-going. Results of usability studies are available in [39].

8.1. Activity Reminder

The web service for activity recalls enables a cognitively impaired person to consult at all time his activity recalls. The activity recalls are decided in collaboration between the cognitively impaired person and his caregivers. The caregiver can enter them in his own MOBUS-system. When the person completes an activity, he validates it on his MOBUS-system. The caregivers can supervise on his client the realization of the activities (consultation, creation, modification, etc.). They are notified when precise tasks (medication, meals, etc.) have been or have not been performed.

8.2. Gathering Ecological Data for Medical Assessment

Schizophrenic people usually see their psychiatrist once a month. Often answers of the patient are vague or not representative of the true situation. Furthermore medication has often harsh side-effects, and doses must be fine-tuned with care. A Mobus web service enables a patient to note facts valuable for a better cure, e.g. occurrence of symptoms and their intensity… So the psychiatrist will have real ecological values when he meets the patient. In the prototype, data are also uploaded to a database thanks to wireless networking, so the psychiatrist can adjust the dose of medication according to the observation and the intensity of side-effects.

8.3. Requests for Assistance

If the patient has a technical or personal problem he can ask for assistance to his caregivers using Mobus client.

8.4. Context-Awareness and Location-Based Assistance

Usually the smart phones or PDA used by the person is equipped with a GPS. A Mobus web service exploit GPS information to provide cues and advice related to the user location and/or the activity in his agenda. For instance when the user goes to a predefined area, MOBUS displays previously saved information related to the current activity, such as security rules, orientation help, bus schedules, etc. When they are in crisis, schizophrenes tend to follow characteristic paths or to stay in front of specific
locations, for instance churches. The GPS enables to follow the patient movements and to detect crisis. Since we know at that moment the patient location, somebody can go there and help him.

9. Towards Better and More Relevant Systems

The PCA (§6) and Archipel (§7) entangle seamlessly pervasive computing, straightforward context-awareness and tangible user interfaces into one’s home and locus of activities (morning routine and meal preparation respectively). But in both cases, reasoning capacities and adaptability are limited, ad hoc, and based on low-level information. As a consequence their behaviors may become really brittle and irrelevant. Mobus makes available useful mobile cognitive assistance services without any sophisticated computation or reasoning exploiting very few sources of contextual information. The load is put on the cognitively impaired people and their caregivers who are responsible to give explicitly the information to record and perform the interpretation of this information.

If we want to improve and personalize the services, assistants have to do activity recognition. They need better models of the users. They have to do complex reasoning on events sent by sensors and generate high-level contextual information. They have to be aware more precisely where the person and the objects are. They have to interact with users exploiting and understanding all the capacities and limitations of the devices available. Finally they have to be operative in multi-persons environments.

Obviously Artificial Intelligence (AI) appears as the silver bullet able to tackle and solve many of these issues. Next section will explore how more fundamental research at DOMUS can propose solutions, especially in relation with ontologies, activity recognition, and cognitive modeling. These works indeed address the issue of modelling and using the context in the large. Section 11 takes the opposite direction and present other researches at DOMUS that take the party of not using any contextual information to achieve effective assistance by embedding knowledge directly into the objects.

10. Artificial Intelligence and Ambient Assisted Living

Combining ambient computing with techniques from AI greatly increases the acceptance of the ambient assisted living and makes it more capable of providing a better quality of life in a non-intrusive way, where elderly people, with or without disabilities, could clearly benefit from this concept. From the computational perspective there is a natural association between them. However, research addressing smart environments has in the past largely focused on network and hardware oriented solutions. AI-based techniques (planning and action theory, ontological and temporal reasoning, etc) which promote intelligent behavior have not been examined to the same extent [40], although notable exceptions can be found in the domain of activity recognition for healthcare. Prior work has been done to use sensors to recognize the execution status of particular types of activities, such as handwashing [41], meal preparation [42], and movements around town [43]. Additionally, several projects have attempted to do more general activity recognition, using radio frequency identification (RFID) tags attached to household objects and gloves [44]. At Domus lab, we
investigate theory and praxis of plan recognition. Most theoretical and long term approaches are based on hierarchical task Markovian model [45] [35], Bayesian networks [46], and lattice-based models [47] enhanced with probabilities [48] to recognize ADLs and to anticipate erroneous behaviors classified according to cognitive errors [49].

10.1. Activity Recognition

Activity recognition aims to recognize the actions and goals of one or more agents from a series of observations on the agent’s actions and the environmental conditions [50]. Due to its many-faceted nature, different fields may refer to activity recognition as plan recognition. The problem of plan recognition has been an active research topic for a long time [51] and still remains very challenging. The keyhole, adversarial, or intended plan recognition problem refers to a fundamental question: how can we predict the behavior of an observed or communicating agent, so that this prediction can be then used for task coordination, cooperation, assistance, etc.? The theory of keyhole plan recognition, on which we are working, tries to establish a formalization of this behavioural prediction. It is usually based on a probabilistic-logical inference for the construction of hypotheses about the possible plans, and on a matching process linking the observations with some plans included in a library or a model of activities related to the application domain. This library describes the plans that the observed agent can potentially carry out. At each observation of an action occurrence, the recognition agent tries to build hypotheses based on the knowledge described in this library. Since there can be many possible plans that can explain the observations, and thus the behaviour of the observed agent, the challenge is then to disambiguate these concurrent hypotheses. The researchers at Domus lab are exploring the following representation models to attack this issue.

10.1.1. Lattice-Based Models

The lattice plan recognition model tries to address the recognition issue by using lattice theory and Description Logics (DL) [52], which transforms the plan recognition problem into a classification issue. Description logics are a well-known family of knowledge representation formalisms that may be viewed as fragments of first-order logic. The main strength of DL is that they offer considerable expressive power going far beyond propositional logic, although reasoning is still decidable. The proposed model [47] provides an adequate basis to define algebraic tools used to formalize the inferential process of ADL recognition for Alzheimer’s patients. To summarize, our approach consists of developing a model of minimal interpretation for a set of observed actions, by building a plan lattice structure as shown in Figure 4.
In this model, the uncertainty related to the anticipated patient’s behavior is characterized by an intention schema. This schema corresponds to the lower bound of the lattice and is used to extract the anticipated incoherent plans, which are not pre-established in the knowledge base that the patient may potentially carry out as a result of the symptoms of his disease. However, it is not sufficient to be able to disambiguate the relevant hypotheses. Therefore, the addition of a probabilistic quantification on the lattice structure [53] is an interesting and effective alternative, in the sense that it makes it possible to combine the symbolic approach for hypothesis construction with a probabilistic inferential process. The symbolic recognition agent filters the hypotheses by passing only a bounded lattice recognition space to the probabilistic inference engine, instead of considering the whole set of plans included in the library, as the classical probabilistic approaches usually do. The probabilistic quantification that we propose is based on samples of observation frequencies obtained at the end of a training period while the system learns the usual routines of the patient. This knowledge allows us to create a profile of the patient that offers a relevant basis to accurately estimate the probabilities of possible ongoing plans. This approach was implemented and tested in the Domus experimental infrastructures, where we have simulated different scenarios based on 40 low-level actions and 10 activities of daily living. Each of these activities corresponds to a common kitchen task (cooking cake, cooking pasta, making tea, etc.) sharing several actions with some other activities, in order to create a realistic context where plans can be interleaved and can lead to many different kinds of planning errors (realization, initiation, sequence, completion, etc.). The observation’s frequencies of the erroneous and coherent behaviours are based on the frequencies described in the study of Giovannetti et al. [54], done on 51 patients suffering from neurodegenerative diseases, which include the Alzheimer’s disease. The results clearly show that the model recognizes all of the interleaved plans and realization type errors, and 70% of the sequence type errors. These results are
promising, as all these recognized hypotheses were not pre-established in the knowledge base; they were dynamically generated in the recognition space, according to the initial identified possible plans set. However, our approach is limited by the fact that the first observed action is assumed to be correct (no errors) and coherent with the patient’s goal. The problem is that in some scenarios that we simulated, the patient started by performing an action that he was only supposed to carry out in a later stage. This limitation explains the 30% of unpredicted sequence errors and also explains why our system has trouble predicting initiation errors. In another hand, we have also experimented the approach in concrete case by extending the system named COACH [49] [41], a cognitive aide for Alzheimer’s patients that actively monitors a user attempting a handwashing task and offers assistance in the form of task guidance (e.g., prompts or reminders) when it is most appropriate. When an Alzheimer’s patient is performing the handwashing activity, the system gets as observations a set of state variables obtained using cameras, such as the patient’s hand location, the tap position (open or closed), etc., in order to determine the completion status of the task according to a previously handcrafted model. If the completion status of the task regresses or does not evolve for a certain period of time, the system will compute the best possible solution to achieve the task and will try to guide the person until the next activity step.

10.1.2. Hierarchical Markovian Task Model

Over the last decade, there has been significant research and development on Hidden Markov Models (HMM) formalism [55] as the predictive core model of many systems. Several investigators have highlighted the importance on representing hierarchically structured complex activities with this dynamic probabilistic model. For instance, in Pigot et al. [35] and Bauchet et al. [45], the recognition process is based on a model of activities where tasks are described using hierarchical structure as shown in Figure 5.

![Image of a diagram showing a hierarchical model of activities.](image)

Figure 5 ADL recognition process is based on a hierarchical model of activities.

The model includes two types of task’s nodes: goal of the occupant and the method to complete it. Leaves are methods of terminal tasks, which mean an atomic way to realize a concrete goal. Similar approaches can be found in hierarchical task network planning. However, this hierarchical model does not consider the set of subtasks as a predefined sequence, since there are numerous ways to realize an activity for a given
method. Instead of generating all plausible sequences, rules are defined to generalize, for a given method, the criteria of integration of subtasks: partial or total sequence, repetition and/or necessity constraint. Breaking those rules should be considered as an improper activity completion. To monitor the proper completion of activities, temporal information is introduced for tasks nodes. This deals with the average time needed to realize the task, and the time slot of completion. The validation of these constraints during task realization is done according to the Epitalk approach, a tutoring architecture used for generating advisor agents [56]. Each adviser manages a local model of the activity based on a hierarchical Markov model of the patient’s habits by using an episodic memory. The activity is considered as an episode incorporating information on the method used for task completion, on right time slots, locations, sequences of subepisodes, frequencies of the observed activities, and so on. Hence, the adviser agent is both responsible to recognize a precise subtask and to provide for assistance related to this task. The leaves of the model are connected to the IO events server and are fed by low-level events triggered by the sensors. A bottom-up traversal of the hierarchy aggregates information to provide for a larger view of what is going on. The main characteristics of this model are that the plan recognition and the production of pieces of advice are combined into a single walk through the adviser tree. The principle is simple: each time a sensor triggers an event, it sends it to the corresponding terminal advisers. Then a bottom-up spreading is activated as follows: (i) each adviser (terminal or non-terminal) processes the information, either to issue local advice or to update a local model of the activity being observed, (ii) the adviser transmits to its direct father any information it considers relevant. This scheme is applied recursively for all advisers of the tree, terminal or non-terminal, until the root adviser is reached. Terminal advisers receive information directly from the host system, in particular sensors, whereas non-terminal advisers receive information from advisers below them in the hierarchy. This model, compared to previous works, allows a more effective description of ADLs for cognitive assistance. Despite the good results that has shown in real case assistance scenarios, the system appears to be somewhat limited owing to the fact that it is only able to monitor one specific ADL and the assistance agent react after the user error. This model constitute the base component of the Archipel system described above in section 5.2

10.1.3. Bayesian Networks

In general, Bayesian networks are the principal technology used for performing activity recognition [57]. A typical approach is that taken in the Barista system [58], which is a fine-grained ADL recognition system that uses object IDs to determine which activities are currently executed. It uses radiofrequency identification (RFID) tags on objects and two RFID gloves that the user wears in order to recognize activities in a smart home. The system is composed of a set of sensors (RFID tags and gloves) that detects object interactions, a probabilistic engine that infers activities with observations from the sensors, and a model creator that allows creating probabilistic models of activities from, for instance, written recipes. The activities are represented as sequences of activity stages. Each stage is composed of the objects involved, the probability of their involvement, and, optionally, a time to completion modeled as a Gaussian probability distribution. The activities are converted into Dynamic Bayesian Networks (DBN) by the probabilistic engine. By using the current sub-activity as a hidden variable and the set of objects seen and time elapsed as observed variables, the engine is able to
probabilistically estimate the activities from sensor data. The engine was also tested with hidden Markov models (HMM) in order to evaluate the accuracy precision of activity recognition. These models were trained with a set of examples where a user performs a set of interleaved activities. However, some HMM models perform poorly, and the DBN model was able to identify the specific on-going activity with a recognition accuracy higher than 80%, which is very impressive. This approach is able to identify the currently carried out ADL in a context where activities can be interleaved. However, this approach does not take into account the erroneous realization of activities, because the result of the activity recognition is the most plausible on-going ADLs.

10.2. User Modeling

In the past, user modeling was focusing on developing domain-dependent software architectures for user models. These artificial representations have been studied by the Human-Computer Interaction and Intelligent-Tutoring Systems communities for years. However, developing applications in ambient living environments poses the challenge of continuously updating user models and, what is more important, this implies to be able to deal with not only the ongoing technological developments (e.g. pervasive computing, wearable devices, sensor networks, etc.), but also with any type of the objective, subjective or emotional user feature. Mostly, the user models proposed are based on learning process of user's preferences such as in Lin's work [59] which build a system to learn a dependency between user's services and sensor observations. On other hand, in order to contribute to this kind of future ambient user model, Casas et al. [60], use the persona concept to build a user model based on the persona’s aptitudes, with the intention of creating an accurate, parameterized user profile that could be adjusted to resolve the User Interface (UI) features of what could be the most appropriate for a specific user at any time. They defined ten data-driven fictional characters, based on age, education, work, family situation, impairments, and technology background. For instance, to correct visual impairment of elders, they develop an adaptive glass magnifier agent for checking emails according to the user’s disabilities evolution. This work has argued the importance of user-modeling involvement in the development of an ambient assisted living.

10.3. Cognitive Modeling Based on Episodic Memory

The ability to remember where you have been, what you have sensed and what actions you have taken in various situations provides a knowledge base of information that is invaluable for acting in the present. Knowing this episodic memory facilitates your ability to use several cognitive skills in the context of sensing, reasoning and learning [61]. Serna et al. [62] have conducted an investigation to explore how such an episodic memory system based on ACT-R [63] cognitive architecture, can be exploited for assisting Alzheimer’s patients in a smart home context, in order to know from life habits, for example, how one cognitively and usually performs an activity. Like the SOAR system [64], which is used to build intelligent decision making agents, ACT-R has been inspired by the work of Allen Newell on unified theories of cognition [65]. The knowledge is stored in episodic memory as component of declarative memory subsystem, in form of memory chunks, each of which has a base level of activation that decays according to a power law of forgetting, and increases through rehearsal.
Specifically, Serna’s work attempted to investigate whether episodic memory is sufficient to support cognitive capabilities across a range of tasks. They created a model of an Alzheimer’s patient completing a cooking task, based on study of mistaken behavior during the Kitchen Task Assessment (KTA) developed by occupational therapist [66]. They incorporate in the model the type of errors observed during the KTA as a production rules and the chunks generated automatically during the execution of the system as means to model cognitive phenomena such as memory loss according to the increase of the number of errors committed over the course of disease’s progression. This model has been developed at the Domus lab as part of the project on home support for people suffering form cognitive disorders. The result of this research demonstrates the effectiveness of computational cognitive modeling of daily activities for ambient assisted living technologies. These technologies should be based on better understanding of the people they seek to assist. Therefore, the cognitive modeling is an important step for designing cognitive assistive devices. Unfortunately, up to our knowledge, not many technology-based solutions have focused on building a computational cognitive model for the person’s living environment.

10.4. What Are the AI Techniques Needed for Better Systems

The new development towards ambient computing will stimulate the research in many field of artificial intelligence, such as multi-agent approach as development paradigm for this open and hardly dynamic environment [67] [68]. Since forty years, artificial intelligence has not ceased to being used on a large scale through expert system applications, web search agent, etc. If the internet devoted the advent of the conventional planetary networks, the next evolution, that will support the development of the artificial intelligence, relates to new challenging issues concerning how a network of ambient agents will be deployed within our natural living environment, and how each of these artificial agents, in the sense of multi-agent systems [69], will be represented according to the following ambient capacities: (i) ubiquity which means that the agent must be able to interact with an embarked heterogeneous electronic devices within the assisted-living by using the pervasive computing technology, (ii) context-awareness based on ontological reasoning to detect the localization and the implication of objects and inhabitants in daily activities, (iii) natural interaction for communicating intuitively with occupant through a personalized multimodal interface, and finally (iv) intelligence based on activity recognition and machine learning in order to predict the behaviour of the inhabitant allowing cognitive assistance and as well as stimulation for avoiding the rejection of such ambient technology. Hence, the question concerns the integration of these four characteristics of ambient agents within any object of everyday life. For instance, if the door of the refrigerator is open, the associated ambient agent must be able to have an idea on the behaviour of the person, such as this opening is under the context of meal preparation while it communicates in an opportunistic way with other objects of the habitat, for example, the cooker’s ambient agent. The stimulation for closing the door because of memory loss can be done through an intuitive interaction (game) between the refrigerator’s ambient agent and the occupant with disabilities, explaining the concept of the door closed. This new concept of ambient agent will ineluctably impose a capital evolution in the assisted living.
11. Design and Ambient Assisted Living

Previous section explored extensively how AI can enhance cognitive assistants to render them less brittle and more relevant. But information and communication technology (ICT) is not necessarily THE solution. Using design to embed knowledge into objects does not require artificial intelligence whilst it may dramatically improves and simplifies technology-based solutions. This section describes the philosophy and examples of this research direction at DOMUS towards assistance and well-being for cognitively impaired people.

11.1. Technology and their Impact on User Behavior

What distinguishes Intelligent living environments from ordinary living spaces is their ability to sense and register information and to provide feedback and assist the habitants. A communication process takes place between the user and its physical surrounding via ICT and intelligent devices such as computer systems, TVs, cell phones, etc. Many of these devices and their services have easily found their place in people’s daily lives and contributed to the transformation of social dynamics. Some suggest that their ubiquity not only provides instant access to communication and information, but more significantly, it contributes to the emergence and structure of new social cultures and changes the meaning of the concept of presence (physical, virtual, or geographic, etc.). Intelligent products have not only the ability to facilitate communication and social interaction, they also have semiotic qualities and rhetoric abilities of their own. A cell phone in plain site, for instance, suggests the presence of a third party, while its ringing not only announces a number of possibilities (a social event, an emergency or a pleasant conversation with a loved-one) but also imposes itself in people’s life by interrupting and obliging the user to take immediate action.

Even though, it is the designers and engineers who determine the product features and interface, once in use, “intelligent products take on a relative autonomy on their own: the ability to affect the user, his actions and to alter his behavior.” Caron stresses: “it is the role of society to rethink, rectify, reinvent or legitimize behavior and practices of social interaction to instate rule of engagement that can be accepted and shared by all.” [70].

Without the introduction of ICT a whole range of services has been adopted (e-commerce, e-banking, e-health, intelligent environments), changing the way people work, access information, manage their daily lives and transforming society as a whole. Many welcomed and embraced these communication technologies without hesitation, while others apprehend, fear or even reject them. Those who most apprehend them are often seniors and neophytes, those who feel oppressed by its ubiquity, those who feel overrun by technology and inapt to cope with their perpetual changing nature, and those who are worried of losing control over their lives. Such inaccessibility or rejection led to new social phenomena, such as digital exclusion - a subject of numerous studies. Therefore many disciplines, including designers, have adopted human-centered approaches in order to propose user-friendly and inclusive design solutions.
11.2. Interdisciplinary Approaches Towards Inclusive Design

When designing intelligent living environments for the aging population and people with reduced physical and cognitive capacities, one needs to look at the problem from a larger perspective and study the contextual environment at large. It is especially important to understand this particular type of user, his real challenges, what is meaningful to him, how he feels about himself, etc. Obviously, this task cannot be affronted from a single disciplinary perspective. This requires expert’s input, interdisciplinary approaches and transdisciplinary thinking.

Therefore, designers have joined the DOMUS team in their interdisciplinary research on ambient assisted living, which seeks to promote autonomy and auto determination and enable the user through pervasive technologies. By merging knowledge bases, designers were able to study the specific contextual environment of use, identified user’s challenges and integrated expert knowledge in the process of creative problem solving. As part of the design research designers tackled the following questions:

1. How to assist in completing a complex task (example preparing a meal)
2. How to assist in locating objects
3. How to motivate, incite and engage in activities of daily living

The design research was studying the environment of use, the context of use, the actors involved, challenges they face and ultimately identified design opportunities and design concepts that are susceptible to address the needs and further the research.

In order to assess the complexity of a task and identify design opportunities, analytical scenarios have been developed. This method involved a step-by-step photo documentation and analysis of a task (ex. preparing a meal) and all its variables, followed by a categorization process which allowed the grouping of individual steps in structural phases: motivation, initiation, preparation, realization, etc. Other techniques involved the creation of personas or the generation of contextual user scenarios, which includes all actors (the user, his family and friends, health professionals, neighbors, community).

Various challenging elements have been identified during this assessment process:
- inadequate living environment (kitchen configuration, too many cabinets, non-disclosure of their content, etc.)
- complexity of various appliances and interfaces (microwave oven, dishwasher, cook top, etc)
- complexity of the task itself (too many steps involved, complex recipe)
- complexity of produce and their packaging, (recognition of ingredient or its packaging, changing packaging design, overload of information)

11.3. Complexity of Intelligent Products

For many seniors or people who suffer from reduced cognitive and intellectual capacity, the complexity of user interfaces, their logic and configuration appear to be the biggest
challenge. Many designers and manufacturers still overlook these problems. Therefore, simplifying user interfaces should be a designer’s and software engineer’s main focus.

Technological progress in the last years has already significantly contributed to simplifying interfaces. Intelligent devices such as the iPod, the Wii interface, dual touch screens, and projection technologies, are only a few of those that proliferated with great success among the young and old. These technological advances have made other applications possible. However, technological features such as digital displays, touch-sensitive screens, numeric keys, light emitting diodes, captors, etc. have become so inexpensive that manufactures keep adding them mindlessly wherever they can. Evidently, issues such as complexities, legibility, compatibility, feature redundancies, information overload or (coexistence with other equipment) are barely taken into account. As a result, many devices remain complex and unsuitable for many elderly and people with intellectual disability. Either the interfaces are too intricate, push buttons too small, typeface illegible or pictograms incomprehensible.

Such misfit mainly arises when designers or engineers unconsciously transpose their cognitive model onto the products, without taking into consideration the cognitive model of the end user. Indeed, simple or intuitive can be interpreted quite differently by the designer or user. Thus, before engaging in the process of designing intelligent living spaces, it is critical to comprehend how users perceive, interact and experience their environment or products, and how they infer meaning.

11.4. Universal Design

Universal design is a term, which refers to accessible, comprehensible and intuitive design solutions for all, regardless of age, ability, or status, but also solutions that avoid stigmatization and digital exclusion. Today more than ever, designers are sensitive to the need for simple and meaningful products, especially considering the complexity and continuously changing nature of digital products and devices. Physical or psychological barriers can be reduced if user interfaces are intuitive and decipherable. Some principles for universal design developed by the Center for Universal design, State University of NC are [71] [72]:

Flexibility - Space configuration, interface options, mode of communication (visual, acoustic, tactile, feedback) need to be flexible enough to adjust to user preferences and potentially evolving cognitive ability.

Tolerance – User interface should be able to anticipate and tolerate missteps, unintended use, input errors, etc. and propose corrective measures or alternatives.

Minimize physical and cognitive effort - (Unless desired, e.g. to stimulate mental function) cognitive and physical effort should be reduced.

Intuitive use - Interface should be obvious, features easily identifiable, its purpose recognizable allowing the user to anticipate actions and consequences.

Perceptible – Essential information (all modes: visual, acoustic, etc) needs to be made available in a comprehensible and legible way to ensure effective communication. Message has to be distinguishable and meaning decipherable from its surrounding context.
• purpose is easily identifiable
• essential information is perceptible (variety of modes: acoustic, tactile, symbolic)
• action can be anticipated
• interface is obvious, signs (symbols, icons, pictograms, index) comprehensible.

11.5. Low-Tech and Non-Tech Modes of Communication

11.5.1. The Role of Light

Light has an affect on a person’s mental and physical health and is considered a regulator of the human biological cycle, influencing sleep patterns, body temperature, hunger, energy level, mental alertness, emotion, etc. Disturbances in circadian rhythms can trigger a number of health problems, such as irritability, loss of appetite, sleeping disorders, depression or seasonal affective disorders [73]. As an example, appropriate lighting can improve sleep patterns and brain activity [74], and stimulate a person during his or her morning routine. While dimmed lighting, on the other hand, can reduce visual strain and produce calming effects.

However, light also provides critical information and visual feedback about the surrounding. About 85% of all sensory information is absorbed through the visual system. Designers exploit the advantages of both the natural and artificial light sources, while creating modern living spaces. They distinguish direct and indirect lighting, task lighting, ambient lighting, accent lighting, decorative lighting, etc. The size of a lit area, the light source, the light intensity, the color of the light, direct light or indirect are all attributes that not only contribute to the way someone perceives the built environment, but also significantly affect a person’s mood. Orange lighting, for instance, is supposed to set an intimate mood and lessen depression, but could have undesirable effects on people suffering from insomnia. Blue tints, on the other hand, tend to be calming and facilitate sleep [75]. Red lights, for instance, are often associated with danger and action, and are therefore largely used as limitation indicators in user interface design.

When lighting spaces, reflective surfaces ought to be carefully chosen since they tend to produce glare that contributes to visual fatigue. In severe circumstances or long-term exposure, glare can lead to visual impairment. Strong contrast between light source and the surrounding light conditions, or heavy contrasts in color, should be carefully waged since they too can trigger visual stress.

11.5.2. Communication Between a User and his Surrounding

Information can be transmitted and perceived by people in a number of ways and designers and software engineers should not neglect a human’s unique ability to perceive information through his sensory organs, which enable him to see, to hear, to touch, to taste and to smell.

Interface solutions don’t have to be always technological. And technological solutions don’t always require a digital interface, a monitor or numeric controls. Some low-tech form of communication can be sufficient, such as the use of signs (symbols, icons, index) that are more or less invasive and able to assist a person in locating an object, for instance. Activated by captors of various types (light, weight, temperature, sound, movement), the intelligent environment can be programmed to sense and intervene if desired.
Visual indicators, which are typically used are LED, light signals, labels, projected symbols or icons,… (Figure 6). Acoustic indicators can produce sounds such as a jingle, a tune, a bell, or speech, activated or deactivated in multiple ways

More or less explicit information can be diffused through light. An illuminated area (activated by motion sensors) can indicate the presence of a person. The changes from non-lit to a lit state can, too, attract the attention of a person. Changing light intensity can act as an attention seeker. The intelligent built living space can assist its user in locating an object by simply illuminating a localized area, a drawer, or a cupboard, thus revealing its content.

Non-technological form of communication, for example, is the configuration of a product or space in itself. A specific kitchen layout (sink, work surface, appliances, utensil storage) can be suggestive in terms of procedural sequence of a certain task. Figure 7 illustrates the concept of a kitchen workstation that, through its linear configuration, suggests:

1. washing and preparing produce,
2. gathering and preparing ingredients,
3. cooking,
4. enjoying the meal.

In this, design concept technology intervenes progressively and only if desired. In the process of realizing a task, additional assistance can be provided on demand, since the weight-sensitive flooring can detect a person’s position in space and offer a touch-sensitive interface whenever needed, thus activating, for example, the projection of a demonstration video “how to….” on a desired surface (wall, screen, cabinet door, work surface,…). Such solutions are sensitive to the user context and flexible enough to accommodate different type of users and avoid stigmatization.
11.5.3. Communicating with Sound

Information and communication technologies make mainly use of human’s audio-visual capacities and sound is being more consciously employed as a command feature. Voice activated devices and interfaces become, indeed increasingly popular even though some still lack precision and reliability. Sound experts have been especial involved in developing new sound indicators (positive, negative, reassuring, alerting) for technological products and environments. This is a new avenue, which is being explored by many sound designers.

Interior design trends show that hard surfaces (glass, concrete, stone, stainless steel, ceramic, hardwood) are increasingly popular. These surfaces unfortunately become a source of reverberation and undesirable noise-production. Appliances and technical equipment generate sounds, either unintentional (example due to vibration) or intentional as a new form of communication to signal a certain state of the equipment: a toaster that finished toasting, an oven requiring attention, etc. The burgeoning of sound producing equipment in home environments can have negative effects such as difficulties to distinguish a voices or a ringing phone for example. According to Kopec, “slight but continual noise can lead to reduced mental alertness, annoyance, irritability and can have extremely negative affect on the psychological and physical wellbeing”. He also suggests that unpleasant sounds can trigger physical reactions such as increase in blood pressure and muscular tension and the release of stress hormones where as pleasant sounds, are capable of stimulating people and incite immediate action [76].

To control noise level and achieve a well-balanced atmosphere, interior designers can make use of sound-absorbing materials on ceilings or walls, windows and floors. Nonetheless,

Nevertheless, if managed appropriately, sound can be a highly desirable mode of communication, capable of creating stimulating or calming atmosphere in a living environment.

11.5.4. Design Implication

Overall design needs to consider the aging process and the gradual changes a human body experiences over time. Among others, these changes include a deterioration of the perceptive system and may result in reduced touch sensitivity, visual capacity, hearing difficulties and/or memory loss.
Design solutions need to be responsive to such biological, physical and psychological changes. They should also include solutions that provide appropriate lighting and manage its level of intensity, color, glare, etc., in addition to also assuring legibility of user interfaces by carefully waging the use of signs, and testing the legibility (size, color, contrast, detailing) and comprehension of information.

12. Conclusion

The population of cognitively impaired people is not just restricted to dementia and Alzheimer disease. Schizophrenia, traumatic brain injury, or intellectual disability strike also a significant part of the population. Therefore cognitive deficits entail high human, social, and economic costs. Cognitively impaired people would prefer to stay at home and live autonomously. For many of them it would be possible if assistance was provided. But resources are scarce and relatives have to take this load. Fortunately current advances in technology could give a helping hand.

At Domus lab, research on smart homes, cognitive assistance, and telé-vigilance has produces promising prototypes of pervasive cognitive assistance for the morning routine and meal preparation inside one’s home. Pervasive computing, artificial intelligence and tangible user interfaces are the key field. Cognitive assistants do activity recognition, personalisation thanks to user models, reason on low-level events sent by sensors, use contextual information and localization, understand devices capabilities, and finally interact with the resident. Interactions can be triggered on the user request or on the assistant initiative. Traditional graphical user interface may be used, but also tangible user interfaces are investigated to provide for a seamless integration in the resident activities. Indeed the whole home itself becomes the interface and acts as a cognitive orthosis. In complement to pervasive assistants, a mobile assistant was also presented enabling the resident to go outside while still benefiting of cognitive assistance.

These prototypes showed a lack of flexibility and adaptability, though they revealed useful and relevant in specific context during usability studies involving cognitively impaired people. Therefore Domus current research is based on AI, representation and context-awareness to overcome these limitations in pervasive environment. It seems a very promising avenue. Nonetheless for the sake of assistance and well being of cognitive impaired people, Domus is also conducting research in design in search for non-technical solution to hard problems. To paraphrase the famous sentence of Rodney Brooks “intelligence without representation” [77], this last avenue raised the question of

“pervasive computing without context”?

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