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# The intelligent habitat and everyday life activity support

H. Pigot, A. Mayers & S. Giroux
*Déparetment de mathématiques et d'informatique,*
*Université de Sherbrooke, Canada.*

## Abstract

Dementia causes cognitive deficits producing functional impairments. Continuous care and monitoring are thus compulsory to keep at home elders suffering from dementia. Intelligent habitat can play a central role toward a global and integrated solution and alleviate relatives from the care burden. The general idea is twofold. On the one hand, the physical environment could supplement elder cognitive impairments by providing personalized environmental cues that assist him in achieving his tasks. On the other hand, the intelligent house could maintain a link with relatives and medical care system to inform them of the evolution of the disease and to alert them in case of emergency. This paper shows how intelligent houses can deliver such cognitive assistance to elders, prolonging the time they can remain at home. First we derive the requirements for cognitive assistance by an intelligent habitat from the impact of the Alzheimer disease in the daily living of elders. Subsequently we describe the layered computer infrastructure needed to implement a distributed intelligent house information system. The implementation of such a pervasive system raises many issues that are not trivial from a computer science perspective. In this paper, we focus on modelling issues. Finally a simple scenario is used to exemplify the interactions between the intelligent house and the elders.

## 1 Introduction

In 1991, 10.6% of the population of Canada was aged of 65 years and over. This age group is estimated to increase to 14.5% in 2011 and to 21.8% in 2031. For obvious reasons, most of the elders would prefer to stay at home as long as possible. Public administration policies also consider maintaining people at home as an efficient way to control medical costs. However dementia strikes up to 8% of the 65 and over age group. Dementia of the Alzheimer's type accounts for about 50% of all forms of dementia. It causes cognitive deficits provoking functional impairments. But technology may provide assistance. Indeed intelligent habitat can play a central role toward a global and integrated solution. The approach is twofold. On the one hand, the physical environment could supplement cognitive impairments by providing personalized environmental cues that assist the elder in achieving his tasks. On the other hand, the intelligent house could maintain a link with relatives and medical care system to inform them of the evolution of the disease and to alert them in case of emergency.

This paper shows how intelligent houses can deliver cognitive assistance to elders, prolonging the period they can remain at home. First we analyse the impact of the Alzheimer disease in the daily living of elders and we list the resulting requirements for cognitive assistance by an intelligent habitat (§2). Next we present features of the remediation systems (§3-4). Decision–making and actions for cognitive assistance are also described (§5). Then we sketch the layered computer infrastructure needed to deploy an intelligent distributed information system inside the house (§6). The implementation of such a pervasive system raises many issues that are not trivial from a computer science perspective. In this paper, we focus on modeling issues (§7). Finally a simple scenario is used to exemplify the interactions between the intelligent house and the elders (§8).

## 2 Dementia, cognitive deficits and risks

The Alzheimer disease is characterized by deterioration of the intellectual capacities. It evolves during 7 to 10 years in average. At the beginning of the disease, the elder often hides the cognitive losses by avoiding embarrassing situations. But as disease evolves, cognitive deficits become more obvious. If assistance is provided, the elder may remain at home in most cases more or less four years. Beyond this point, supervision is required. Functional performance is one criteria used to diagnose Alzheimer disease. Initially deficits impede memory, attention and planning. This is noticeable in difficulties to deal with new and complex tasks. As the disease evolves the elder is less and less able to cope with familiar tasks. Spatial orientation is also impaired. It is noticeable first when the elder is lost in new locations and then in familiar settings. Cognitive losses are graded in 7 levels in the Global Deterioration Scale (GDS) [10]. The intelligent habitat we are developing is designed for levels 3 to 5. At level 3, the elder suffering from Alzheimer disease exhibits difficulties in solving problems. Balancing budget or converting recipe ingredients are beyond his reach. At level 4, difficulties appear in preparing an unusual plate for guests. At level 5, he is no more able to plan the cooking time for two meals neither to pay attention to two meals cooking simultaneously. At levels 6 and 7, he needs supervision to eat, and physical assistance is therefore required. At home, several risks could result from Alzheimer related cognitive deficits, e.g. memory lack or judgement loss. The

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most obvious risks are fires, wounds, burns, cuts, food and medication poisoning or falls. Bad hygiene and malnutrition could as well occur. The decision to maintain or not the elder at home mainly depends on the control of these risks.

## 3 Remediation by the physical environment

Continuous care and monitoring are thus compulsory to keep at home elders suffering from Alzheimer dementia. This burden is too often simply delegated to their relatives. As a result relatives frequently suffer from distress, fatigue... Since the environment significance increases when people becomes physically or cognitively impaired, physical environment strategies can lessen this burden on relatives. Environmental strategies can control inappropriate behaviours such as wandering or agitation. They can also enhance the performance of activities of daily living (ADL) [2]. Recent progress in science and technology can help deliver such aids and foster their use. Actually support technology is primarily designed to increase independence with respect to mobility and communication [8]. Nonetheless in a near future ubiquitous computing and networks will drastically transform houses. Habitats will assist people in their ADLs in an "intelligent" way. A pervasive information system will gather information from the environment, analyse it and then intervene according to people needs and preferences. Approaches ranges from distance monitoring [3] [4] and on-site automated cognitive assistance [5] [7]. Next section (§4) gives a high-level perspective on our approach that integrates both ends.

## 4 Everyday life support system

A close analysis of the hardware and software infrastructure and of the information processing needed to achieve telemonitoring and cognitive assistance reveals that, in most case, information may be acquired from the same categories of devices, then analysed by similar processes to feed akin models needed for reasoning. On the contrary, telemonitoring and cognitive assistance differ though in the course of actions they take. Telemonitoring is rather a passive process while cognitive assistance is proactive. Accordingly we are designing and implementing a pervasive distributed information system that factors common models and processes and then nourish both ways of conceiving interventions. On the one hand, telemonitoring is used to enhance security and confidence, by reporting disease evolution or by alerting the elder external supporting network of frail elders —family, caregivers, or medical staff. On the other hand, cognitive assistance is used to generate appropriate environmental cues to support or enhance the individual performance. These two approaches are active simultaneously and cooperate to provide the best of both worlds [9].

## 5 Decisions and actions in cognitive assistance

Actions done by the intelligent habitat can range from "doing nothing" to drastic operations such as shutting down electrical system. Advising stands at the

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middle of these extremes. Since the support system will be deployed in very diverse contexts, ad hoc specification of decisions and actions is neither practical nor feasible since all contexts of operations cannot be known beforehand. Hence the system must provide models to describe: what to do how to do it and when to do it. The Kitchen Task Assessment is the starting point for the first prototype [1]. The testbed ADL used is the preparation of a meal. This activity requires complex cognitive challenges such as planning, memory and attention. Home risks such as burns and cuts are also likely to happen. Moreover "preparation of a meal" is one of the canonical ADL in occupational therapy.

## 6 A layered computer infrastructure

The infrastructure is divided in three layers: hardware, middleware and application layers [9]. The hardware layer is concerned with sensors and devices. The middleware layer links all the agents of the system. The application layer contains two integrated services, one for telemonitoring, and the other for cognitive assistance to the ADLs. Figure 1 shows the interaction between all the components of the application layer. Metamodels contain generic knowledge. Their instantiations represent a given person who performs precise activities in a specific environment.

## 7 Personalization: models and actions

To make personalized interventions the cognitive assistance system needs models describing an individual performing an activity in his environment. Three models [9] are drawn from the competence model [11]. The person model contains knowledge on cognition, on physiology and on life habits and preferences. The cognitive knowledge concerns attention, planning, and memory. The physiological knowledge focus on some critical physiological data such as threshold for blood pressure or heart beat. Knowledge on life habits and preferences is used for personalization. The task model (**Figure 2**) contains successful and failed scripts of ADL to be compared to the one performed by the person. Failed scripts describe pre-selected erroneous situations due to cognitive impairments. The environment model contains generic description of devices: sensors, electrical appliances, visual and acoustic effectors and ways to connect to external resources (**Figure 3**). As an activity proceeds, isolated events are detected by sensors. Data are percolating up to the integrator. Along the percolation path, activities are inferred. The competence model establishes if the elder is in a competence or in a handicap situation. As long as the elder is in competence situation, the system remains mute. But when handicap situation occurs, messages are sent to the environment to deliver personalized interventions. Cues are generated to help the elder to achieve his activity. In case of risk, the telemonitoring system sends messages to the medical staff and the relatives.

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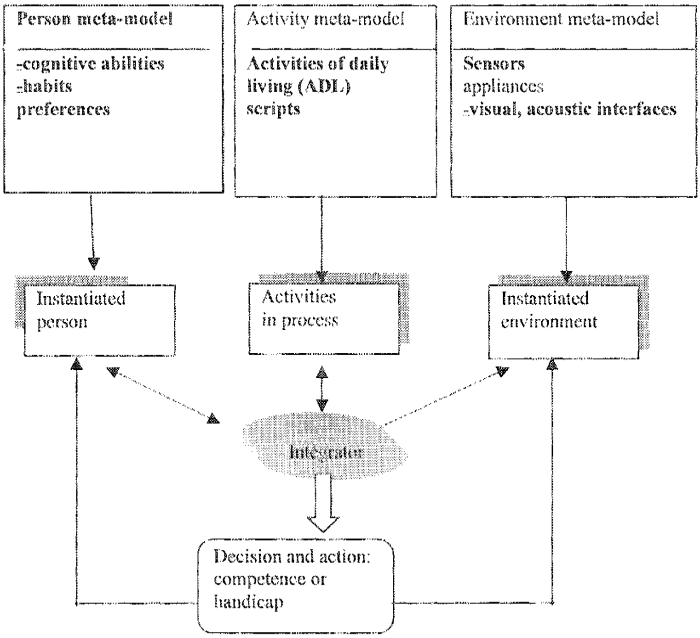


Figure 1: The ADLs support system.

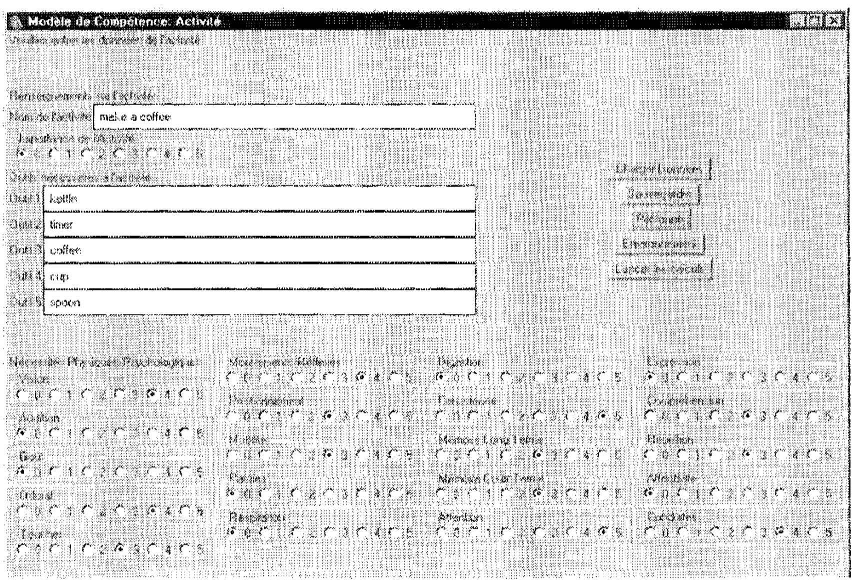


Figure 2: The instantiated model of the activity.

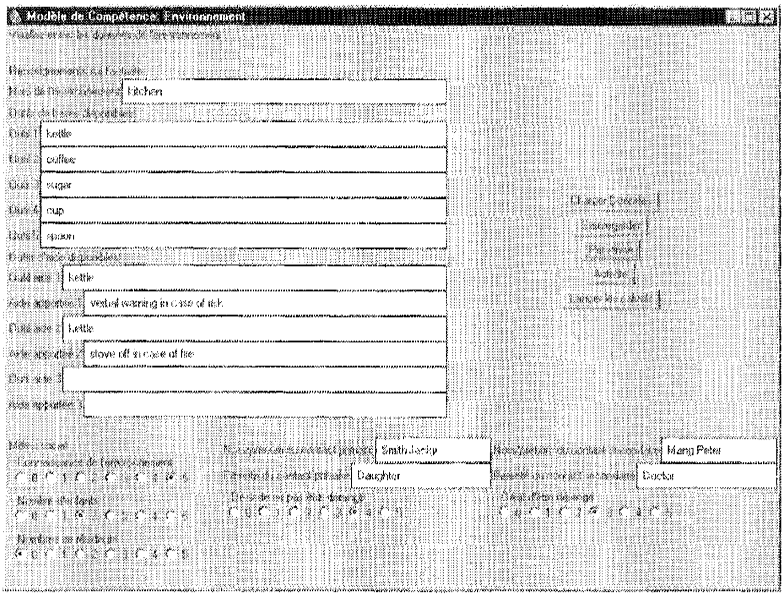


Figure 3: The instantiated environment model of Mrs Smith's house.

# 8 Scenario

Let's take a scenario to highlight the reasoning of the cognitive assistance system. As autumn is on, afternoons are colder and darkness is falling early. Mrs. Smith enjoys to take coffee at 4.00 p.m. Mrs Smith is a 73 years old female with Alzheimer disease and osteoporosis. She lives alone. Her cognitive abilities range from mild to severe deficits. On Friday afternoon as usual Mrs. Smith decides to cook a veal stew. Water is boiling for coffee and veal stew is simmering when the phone rings. After her phone call Mrs Smith feels tired. She decides to rest for a while in her bedroom. Suddenly the fire alarm of the cognitive assistance system's is triggered... Mrs Smith's house is equipped with sensors to detect presence in most rooms : kitchen, lounge, bathroom and bedroom. Her stove is a high-tech device enhanced with a small screen and audio. The stove could be turned off automatically. Each heating element has also its own security switch. Derived from sensor information, two meal preparation activities are in process at 4.00 p.m. : veal stew activity and coffee activity. A third activity starts when the phone rings. Ten minutes later, the phone activity is completed as Mrs Smith hangs up. The two meal preparation activities are still in process. A fourth activity is inferred as the bedroom sensor detects Mrs's Smith presence. At 4.00 p.m. the supervisor diagnoses handicap situation based on three facts. Three activities are in process. Mrs Smith's attention is overloaded beyond two activities. Meal preparation activities are at risk of fire. The supervisor decides not to intervene but keeps an eye on the situation. The supervisor is even more in alert when Mrs Smith goes to her

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bedroom without checking the meals. But the activities are still in control and the supervisor decides to wait again. As soon as internal fire alarm of the cognitive assistance systems is triggered, the stove is turned off. The decision is taken locally at the stove level. Such a locality of decision is implemented to guarantee security. No matter how long it takes for the supervisor to intervene Mrs Smith and her the house are at least protected against fire. Moreover if network is down, Mrs Smith security is not compromised. Simultaneously, the hardware layer send upward two messages : 1) the fire alarm is triggered, 2) the stove is turned off. The supervisor receives this information and faces a handicap situation. Intervention may be necessary and must be personalized. If a prompt is enough to help Mrs Smith remembering her cooking activities, the stove is turned on. The prompt is done using music since Mrs Smith prefers to wake up in music. The supervisor continues to watch the stove to be sure Mrs Smith turns it off. The intervention has followed the minimal intervention rule. If a prompt is not enough to remember to Mrs Smith she was preparing coffee before the phone call, then the supervisor turns on the stove element used for the veal stew preparation while the element used for the coffee remains off. This intervention respects the security and the personalization principle taking into account Mrs Smith life habits. If Mrs Smith presents too severe deficits to remember the two cooking activities the supervisor decides to let the stove off. In all cases information is transmitted to the person model in order to built history for further interventions and to warn caregivers if cognitive deficits related to the Alzheimer disease have increased. An analogy could be drawn between the withdrawal reflex and the local and supervisor decisions. When a hand feels heat source, immediately it withdraws. Further when information reaches the cerebral cortex by ascending pathways conscious movements could be directed to let the hand off the heat source or not, like the supervisor decisions.

## 9 Implementation

The implementation of the simulation environment is made in Java (**Figure 4**). It enables to model and simulate devices (stove, oven, fridge, freezer, cabin) and activities (recipes and cooking steps –General Dish Simulator). The simulation may be run either on a script basis, —all simulated steps are performed as a batch operation— or on a step by step mode —each actions is triggered through graphical user interfaces and menus. A trace of actions, alarms and pieces of advice is outputted on the console.

## 10 Conclusion

Two kinds of interventions are provided to assist the elders suffering from Alzheimer disease and to lessen the burden caregivers. The first one operates inside the home. It helps the elder to complete an ADL failed due to cognitive deficits. The second type of interventions sends messages to external caregivers, the medical team or the family. It warns in case of risks and to inform about disease evolution. We showed that to provide appropriate interventions it is

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necessary to model the relationship between the person, the activities and the environment. Distributed architecture is also needed as data come from several sensors spread around the house. Data is percolating up to the cognitive assistance application. Like a withdrawal reflex, decisions could be drawn locally and then controlled by the central supervisor. Actually one ADL is understudy, the meal preparation activity. But as the system evolves more ADLs will be supported in order to increase the elder autonomy.

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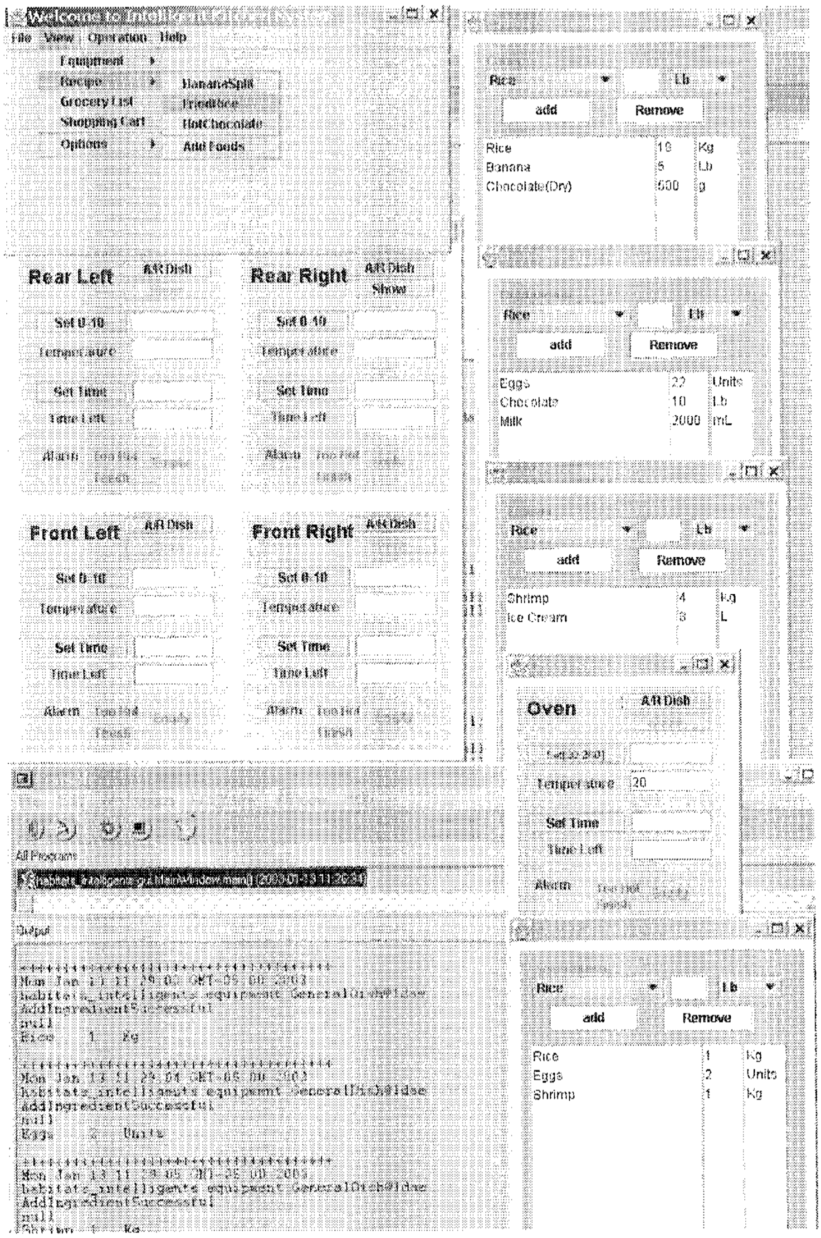


Figure 4: Kitchen simulation environment for meal preparation.

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