A Multiagent Approach to Personalization and Assistance to Multiple Persons in a Smart Home

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Abstract

Localization, personalization, activity recognition, and cognitive assistance are key issues in research on smart homes for cognitively impaired people. Most of the current solutions rely on the presence of solely one person in the residence. To actively consider the interaction of the smart home inhabitant with their caregivers, nurses, doctors and people sharing their home, this paper proposes a multi-agent approach to transparently locate, identify, and ease the collaboration between distributed personalization and assistance services. Based on Bayesian filtering localization using anonymous sensors, the multi-person localization process provides information on each occupant presence, either incoming or outgoing. This information is then used for personalization and assistance.

Introduction

The growing population of elderly people all over the world compels for a new vision of assistance at home. But this new vision can benefit to other categories of cognitively impaired people, for instance, people suffering from traumatic brain injuries, schizophrenia, or intellectual deficiencies. Of course, relatives and professional caregivers sharing the space with the occupant will still provide assistance (Farran et al. 2004). But technology can also give a helpful hand. A smart home can ensure personalized assistance, contextual help and adaptation of the environment. In particular, smart homes can provide a familiar while safe environment to cognitively impaired people (Rialle et al. 2003) (Rialle et al. 2002) (Pigot et al. 2003). Since in a realistic setting many persons may evolve in an apartment, a system must be able to manage the interpretation of sensors data and personal assistance in a multi-person context to claim for ensuring continuous pervasive cognitive assistance and security to the occupant (Woolham 2005).

In this paper we present a multi-agent infrastructure that enables agents to follow each person in a smart home. Localization agents, environment agents, and personal agents collaborate to personalize cognitive assistance locally, dynamically and contextually in each room. The resulting multilayer multi-agent system hence provides transparent assistance adapted to the needs of all the people living in (or visiting) the smart home. It addresses personalization and assistance while taking into account conflicts that may emerge in a multi-person environment. To illustrate this distributed approach over space, a prototype has been implemented and validated against five scenarios.

Localization Agents

To monitor and assist many people simultaneously in a personalized smart environment, a robust localization system is mandatory. Domino is a Bayesian filtering approach (Fox 2003) using anonymous sensors designed to track one person living in an apartment (Rahal, Mabilleau, and Pigot 2007). We extended Domino towards a multiagent system to enable it to cope with many people at the same time. In our solution a localization agent is responsible to monitor one person in the apartment. Each agent manages its own particle set that is updated with event triggered by anonymous sensors (*Figure 1*). A potential incoherence is detected when an event doesn't correspond to a plausible reality. For instance the event is considered to have occurred too far from the previous event within a too short timeframe. As the known occupant could not be the cause of this event, a new localization agent appears, localizing a new human actor on the barycenter of this last event. Indeed the multiagent localization system infers the presence of a person from the chain of sensors events triggered by the movements and activities of this person in the smart environment. The process of agent creation is comparable to an induction system fed by on sensor-based events.

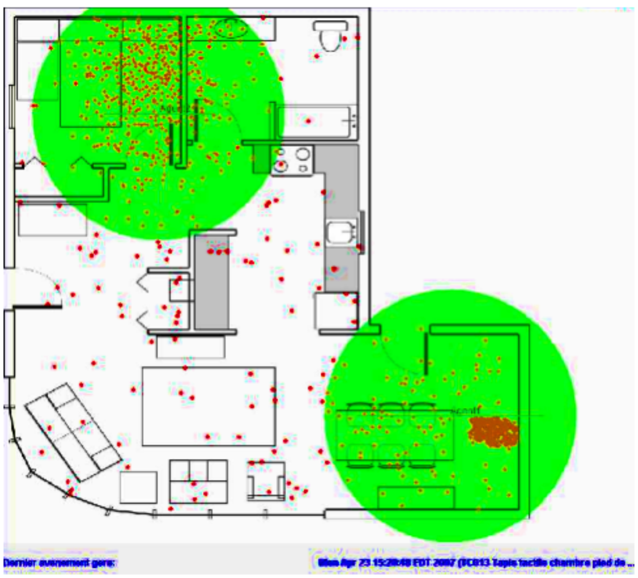

Figure 1 *Two localization agents: particles and possible localization area of their user.*

Collaboration and Decision

When more than one agent are operating and monitoring the environment, each event is communicated to each and every localization agent. If they all react to the event without considering the probable cause for it, the match between virtual agents and monitored people is disrupted. Indeed when an event occurs in the environment, the problem to resolve is to determine which person caused this event. Therefore the localization agents must negotiate to reach a common agreement about which one is the best induced fit for the disturbance caused by the event and who will treat the event.

Here the concept of incoherence is used to propose an operational solution to this problem, without requiring external identification. Using the principle of circle of context, each person can interact in a defined area that can be delimited by their walking speed, their current activity and goal, or by a mix between their speed (distance from the last event considering the time elapsed) and the sensors that must have been triggered before going further (considering the living space and moving constraints). The latter option is the one we implemented. The coveted event is then attributed to the closest agent.

To implement this decision model, each agent was endowed with this algorithm and a communication protocol to ensure that just one agent will ultimately take into account the event. This may result in the closest agent accepting the event and moving the location of its user, or in splitting the agent to create a new agent onto the incoherent event barycenter. The communication protocol also implies a strong connection between every localization agents in order not to skip the negotiation of an event. Such a miss would widen the gap between virtual monitoring and real movements of a user in the smart home.

Identification vs Anonymous Sensors

To provide for an accurate identification of a person present in a smart space, a solution frequently used is to equip the subject with wearable technology, for instance using RFID (Philipose 2003) or Ultra Wide Band (Jourdan 2005). Even if we cannot consider their uses in health smart homes, those technologies can be useful during the localization system's learning. We put the constraint that no equipment has to be worn by the occupant in order to avoid or diminish a feeling of being constantly tracked and the issues tied to visits of external people, and to have a system that would still be reliable if a user has forgotten to wear the tag. That is why we favor an approach based on anonymous sensors.

However for the experimentation described later, user were identified statically on their entry in the flat, and the system is thereafter considered as always right. We hope that this hypothesis of perfect identification by the system is a temporary one, and we expect it should disappear with the adjunction of the profile and activity management coupled with the duplicating of localization agents when having doubts on user identity.

Environment Agents

Besides localization agents, environment agents manage devices and user interfaces (Figure 2). These agents are created dynamically from a description of each device (capabilities, computational power, available settings and input/output interfaces, etc.). Examples of environment agents are intelligent speakers (with control on the sound level, type of voice and knowledge on its effective area), ambient microphones, LCD screens, coffee machine, position LED on a cupboard, etc. Those agents can communicate with other agents to synchronize and avoid collisions, interferences, or redundancies of message to users.

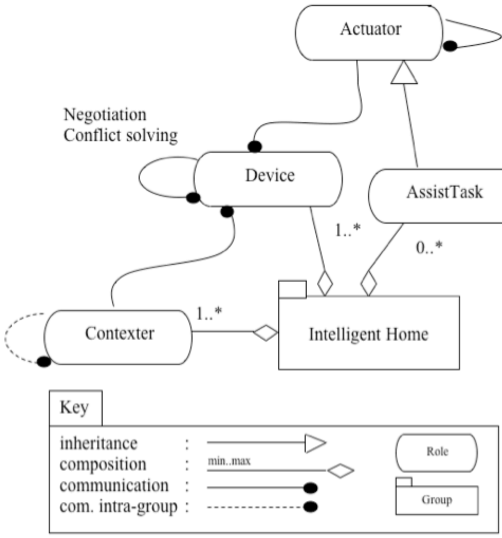

Figure 2 *Environment agents' organization.*

Personal Agents

For each person in the smart home, there is an associated personal agent (Figure 3). This personal agent is in fact composed of many subagents. Personal agents manage three main categories of personal information: profile, activities, and preferences. A person's profile indicates the level and the kind of assistance the system should provide. This profile is broadcasted to every environment agent in the near spatial context of the person. A person's activities describe especially the activities of daily living and the tasks to complete. Such information help to determine the context in which the person evolves, and is used to provide consequent assistance as needed. Finally a person preferences focus on the personalization of the environment: light level, sound level, voice for vocal messages, etc.

Modelling and Assigning Agents Behaviors

Agent behaviors are modelled using MOISE methodology (Boissier et al. 2013). First a structural specification defines the agent roles and missions (goals) (Figure 4). Then the goals of the multiagent system are decomposed hierarchically till low-level goals can be easily dispatched among individual agents (Figure 5). In particular, leaves are then translated into activation schemas. An activation schema will be triggered when all its input data are available and adequate and when all preceding goals have been satisfied (Figure 5). During next step the interactions between the roles of the agents are specified. A deontic specification associates missions to agent roles and defines constraints on the agents while performing the missions, e.g. mandatory, permission required… Finally the implementation is specified: agent software implementation, communications, resource allocation, and deployment.

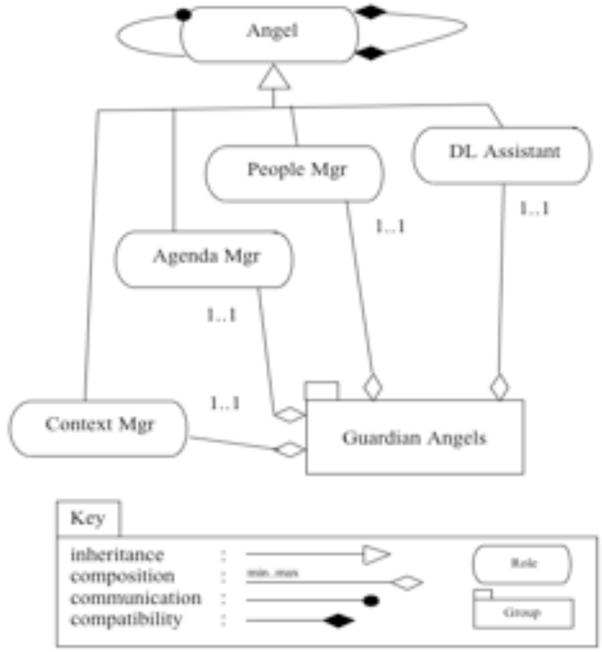

Figure 3 Specification of the structure of one's agent personal organization.

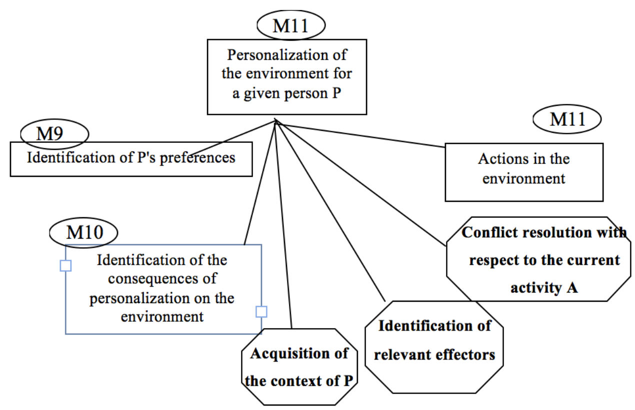

Figure 4 Functional specification of the personalization process for a person P performing activity A. Hexagons are used to define activation schemas.

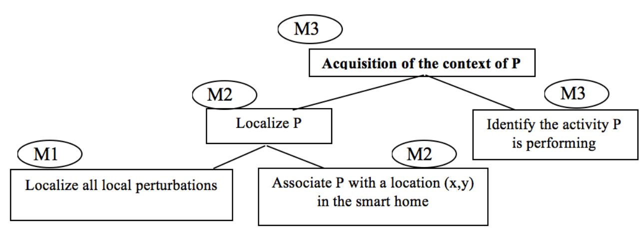

Figure 5 The activation schema associated to the goal "Acquisition of the context of P".

Conflicts Resolution and Priorities Management

When considering that only one person is in the smart home, the personalization of the environment only depends on that person localization. But if many are there simultaneously, adjustments need to be made to adapt the system to all the persons and conflicts may emerge. Two persons in the same room would imply two sets of preferences required from the environment. In this case, we can define statically some obvious priorities, for instance, the occupant personal agent being always dominant on a visitor's one. However some cases need a more in-depth consideration tough, like the need to limit the sound level after 11pm may go against the user command to pump up the stereo volume (law respect against personal choices and responsibilities). Two activities at the same time in the same smart space (kitchen for example) can also lead to a conflict between two assistance modules needing the same environment agent. A careful management needs to ordinate the input and output without jumbling the signals to avoid confusion. At last, two output interactions from the system need to be sorted in order to prioritize the most urgent.

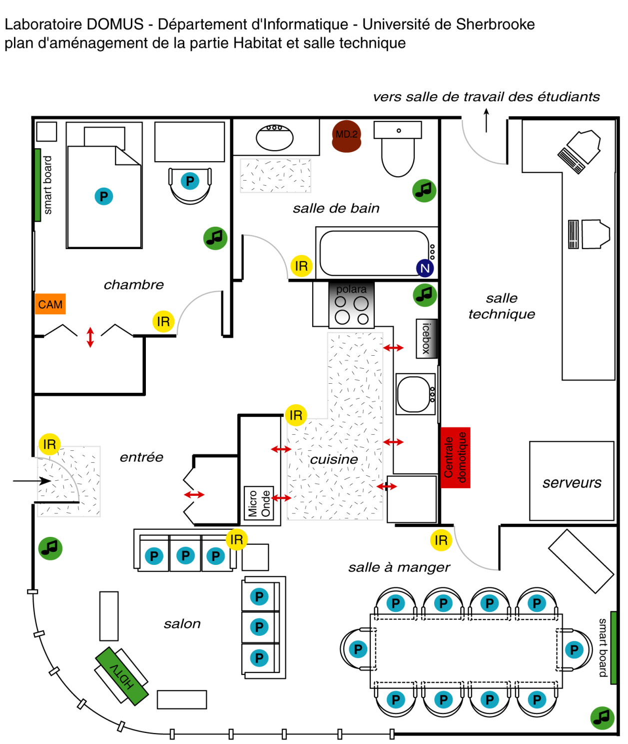

Figure 6 Experimentation: Domus apartment and IR anonymous sensors.

Implementation and Validation

Five scenarios were designed to validate how such a multilayer multiagent system can cope with personalization and assistance in a smart home where many people evolve at the same time. These scenarios are fragments of the daily life of a single person in interaction with other people in her apartment. They address the morning routine, a medical visit intertwined with the unexpected arrival of a caregiver, the visit of a friend, and the visit of a professional caregiver. They were used to evaluate localization accuracy, personalization and assistance, and conflicts management. The multi-agent system was implement in JADE and built upon (Boissier, Hubner, and Sichman 2007). It was tested against the scenarios in the Domus smart apartment (Figure 6).

Conclusion

This paper has brought a multi-agent oriented vision for the localization of many people evolving at the same time in a smart home, for the personalization of the smart home with respect to all people present, for the definition and application of local general rules, and for transparent assistance adapted to a multiple person context. This approach was aimed to get close to the real conditions of daily living activities for a person needing external care, or living with another in a smart home.

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