Information Extraction System Using Indoor Location and Activity Plan

Bjørn Grønbæk, Pedro Valente, and Kasper Hallenborg

Abstract. In this paper we present an agent based system for extracting live and historic position data on multiple persons in a real environment, using a commercial off the shelves Real Time Location System (RTLS). We present a context model for representing the location data which allows composition of location data with preexisting knowledge on the environment and activities taking place at the locations. We describe our experiences using the RTLS deployed in non-laboratory environment with hundreds of participants.

1 Introduction

Since Schilit and Theimer introduced the notion of context to distributed computing in 1994 [8] location has always been among the most profound information used for adaptation in pervasive and ubiquitous computing. In decades indoor locations systems have been a challenging task in research and ranged in base technologies from infrared light, ultrasound, camera, UWB, WiFi, cameras, RFID, etc, in systems like [2, 7, 9]. In smart environments for ambient assisted living (AAL) indoor locations systems starts to play an important role in coordinating and providing intelligent services to the users, including activity recognition, task allocation, information services, monitoring, etc. However, in most of the commercial setups the systems are often limited to the last location registered, which could come from pressure sensors, passive tags (RFID) entering zones, or doors being opened. More advanced systems, such as [4], use algorithms to better estimate a user's current position based on pattern recognition or to predict a user's next location. Another problem common to such simple locations systems is identification of persons and

Bjørn Grønbæk · Pedro Valente · Kasper Hallenborg
The Maersk Mc-Kinney Moller Institute - University of Southern Denmark, Odense, Denmark
e-mail: {bjgr,prnv,hallenborg}@mmmi.sdu.dk

Y. Demazeau et al. (Eds.): Adv. on Prac. Appl. of Agents and Mult. Sys., AISC 88, pp. 33–38.
springerlink.com

activities, as described by [6]. Pressure mats or movement sensors do not distinguish efficiently between different persons, and may provide uncertain sensor data.

The choice of using a multi agent base approach it motivated by the natural mapping of having several hundreds of autonomous participants acting in the same system, each with an individual set of preferences. The reasoning and planning aspects normally considered by participants of a conference map naturally to similar components in an agent architecture.

In this paper we describe a practical experiment using an indoor location system, tracking hundreds of persons simultaneously in real time at a large conference venue with multiple rooms, hallways and floors. We will present and discuss implementation of a multi agent system , the AAL Butler system, that provides both live data access as well as historical data about participants. In addition the system provides contextual information about participants activities by combining knowledge about their location with predefined knowledge on scheduled activities taking place in rooms.

2 Architecture Overview

Figure 1 show the significant agents in the AAL Butler system. The layered organisation of agents is based on the type of services and functionality provided by each agent, following the design principles described by [3]. We do not enforce a strictly layered communication in the system, since each agent provides its own interface that matches the parts of the context model that is relevant, but use the layers to provide a logical separation of responsibilities between the agents.

The **Sensor** layer holds logical and physical sources of data. In the AAL Butler system this layer is made up by programs providing API access to two databases and the RTLS server used for the experiment. The AAL database provides information from the conference venue, most importantly the time schedules, room assignments, and participant information. Additionally this database holds information that relates the identity of the physical rooms with the location ontology's room concept. The RTLS database stores information from the RTLS server for historical use. Finally, the RTLS provides us with an API for accessing the live RTLS data.

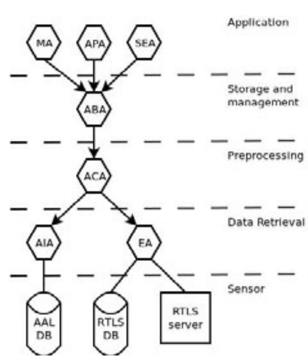

Fig. 1 Overview of the AAL Butler agent architecture. Agents are shown layered according to functionality or services they provide.

The agents in the **Data Retrieval** layer extracts data from the sensors and matches the data to the context model used in the system. They provide an ontology based access to the data sources in the sensor layer. The **Ekahau Agent (EA)** is responsible for providing access to the RTLS data. The agent provides two primary services, as well as a number of utility services. The first service is a subscription based notification service that allow other agent to receive information on new positions and events captured by the RTLS server. The second service provides access to the historical database of RTLS data. The **AAL Information Agent (AIA)** retrieves the context data in its raw form from the conference session database, matches the data with the relevant concepts of the context model, like `Participant` or `Session`. The main services provided by the AIA is getting information on the schedule of the conference, information on particular sessions and getting participant profiles.

The **AAL Context Agent (ACA)** in the **Preprocessing** layer provide contextual information by aggregating multiple data sources into a single context source. This is done by collecting the data from the context atoms in the data retrieval layer and providing a higher level of context. The agent's responsibilities include providing a service for agents to retrieve information on the location of a participant in the form of a room. This is done by extracting relevant information about the participants id, querying the EA for the area of that participant, and then matching the area to a room by querying the AIA. The agent is also capable of providing a information on a given participants session history, by comparing the participants location history with location of sessions. The method used for providing this service is described further in section 3.1.

The **AAL Butler Agent (ABA)** in the **Storage and Management** provides a logical interface to applications build on top of the system by exposing the functionality of the AAL Butler infrastructure for the purposes of doing information extraction and providing context information on participants at the conference.

The **Application** layer is meant for agents that are end-users, either in terms of software agents or human agents. Application specific context management is also handled in this layer. The **AAL Participant Agent (APA)** agent serves two roles in the system. First, in future implementations, it is intended to serve as an interface between users of the system and the system's agents. This includes routing information to the users most convenient interface, Ekahau tag, PC or mobile device, and capturing user input for the system. Additionally, it currently implements a simple user model by storing a participants user preferences along with the history of the participant to enable the agent to perform simple recommendations to the user. The **MapperAgent (MA)** agent provides an user interface for examining live and historic position data. The **SessionEvaluationAgent (SEA)** agent provides an user interface for accessing the session history of a participant. It instructs the ABA agent to perform the relevant data processing, and present the context information for the user in a human readable way.

3 Context Modelling

The AAL Butler system expresses its content using an ontology based model, which according to [3] fulfil a few basic requirements that we wished to achieve for the context model: Simplicity, extensibility and expressiveness. By embracing these properties we seek to ensure that we can extract and extend elements of the presented ontology to future projects.

The domain specific AAL Butler ontology supports the task of providing both live and historical information on participants, and also supports reporting on a given person's current or past activity. The location specific part of the ontology supports the representation of indoor environments in a simple form. The focus is on representing locations in the form of either coordinates, rooms or special points-of-interests (POI). The primary concepts in the ontology needed for the system are described in figure 2, which shows the taxonomy of the relevant elements of the ontology used in the AAL Butler system. These concepts provides enough expressiveness to implement the AAL Butler system when combined with a number of predicates to describe the status of the system.

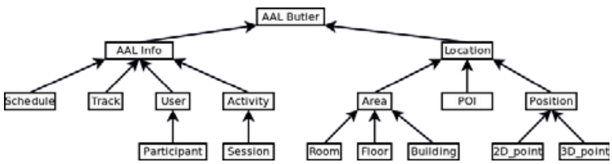

Fig. 2 The AAL Butler Ontology

3.1 Determining Session Participation

To detect which session a participant has spent time in, the gathered positions are clustered into groups. While *k*-means clustering analysis is simple to use, we don't know the number of locations a participant will visit in a given time interval, and therefor can not know the number of clusters to use, which is a requirement when using *k*-means. Instead the AAL Butler system utilizes the DBSCAN algorithm [5], in an approach similar to [1]. The DBSCAN algorithm create clusters based on the density of the spatial data, and does not require knowledge about the number of clusters to find. To handle the time dimension of the gathered position we analyze the data not as the complete set for a participant during the whole conference, but instead for one session time slot at a time. This effectively eliminates the need for considering the time-line of the positions, since we can then assume that every position in a given location will be connected to a particular session currently going on in that room, if the cluster is found to be in that room. After the clustering has been performed, the most significant of the clusters are found. The location of the cluster is then matched against all sessions that takes place in the time slot being investigated, and if any session has a room that matches the location, the participant is considered to have been at the session. For simplicity we do not consider the duration of the stay at the session, or the possibility of attending more than one session in a time slot.

4 Experiment

The system implementation was evaluated in a practical experiment, collecting location data and extracting predefined knowledge, in the context of the Intellicare[1] research project at the AAL Forum 2010 conference on Ambient Assisted Living. The conference venue included three plenary rooms, ten session rooms, a lunch and break area, some additional areas, and all the connecting corridors etc. between those rooms. The conference was placed in a single building with two floors and the dimensions of the conference area was more than 7000 m^2. The RTLS system employed [2] is based on Wi-Fi technology and provides 2D real-time position, with one meter precision and accuracy errors of three meters. The system use tags as it's tracking asset, with the tags providing a two line screen and three buttons, making the system capable of two-way communication.

In terms of performance we tracked 268 of the 736 participants simultaneously, resulting in 2.6 million position records, with each user represented as an agent in the system, and observed satisfactory performance on both the RTLS server and the AAL Butler system. Each agent was able to keep track of the location of it's related RTLS tag, observe the participant's session history and perform a simple prediction on the next session of the participant. Table 1 shows a comparison of the session participation found by the AAL Butler system for a particular participant and the actual session history of that participant. We have data on six slots, out of which the AAL Butler system correctly found four, missed one session completely and found one session incorrectly, e.g. found a different session than the participant actually attended. After investigation we have determined these inaccuracies to be the result of low RTLS coverage and bad calibration, rather than a problem with the AAL Butler systems clustering technique. We therefore consider the AAL Butler system to have determined the participants session history in satisfactory way.

Table 1 Comparison of a participant's session history with results from the AAL Butler system. For each time slot the name of the session found by the system and the name indicated by the participant is shown. Only time slots for which we have information is show.

time slot	16.30-18.00	09.00-10.30	10.30-11.00	12.00-13.00	13.00-14.30	12.30-15.00
known history	R1	F2	Break	F3	Lunch	Closing
AAL Butler	R1	F2	Break	C6	-	Closing

5 Conclusion

The work presented in this paper is a initial attempt at creating a system for providing contextual information on persons, or agents, based on their current and previous location data by aggregating that information with predefined knowledge on

[1] http://www.intellicare.dk
[2] http://www.ekahau.com

time schedules and locations of activities. The current implementation was focused on a specific use case, described in the experiment section of this paper, and on providing functionalities for that use case. We have described an approach to do mapping between the information presented as predefined knowledge and the location data of a person using an ontology based context model. We have designed an agent-based system that consists of a number of cooperating agents, that can utilise the context model to provide data access to the location of a person as well as context information on that person's activities. In our future work will utilise the MAS approach of the AAL Butler system by implementing an user agent with a Belief-Desire-Intention model, which will allow us to focus on prediction and recommendation functionality. We are currently working with partners on adapting the system for use in elder care environments.

Acknowledgements. The presented work has been conducted under the IntelliCare project, which is supported by The Ministry of Science, Technology and Innovation in Denmark.

References

1. Adams, B., Phung, D., Venkatesh, S.: Extraction of Social Context and Application to Personal Multimedia Exploration. ACM Press, New York (2006)
2. Addlesee, M., Curwen, R., Hodges, S., Hodges, S., Newman, J., Newman, J., Hopper, A., Steggles, P., Steggles, P., Ward, A., Ward, A.: Implementing a sentient computing system. IEEE Computer 34(8), 50–56 (2001)
3. Baldauf, M., Dustdar, S., Rosenberg, F.: A survey on context-aware systems. International Journal of Ad Hoc and Ubiquitous Computing 2(4), 263 (2007)
4. Das, S.K., Cook, D.J., Bhattacharya, A., Heierman, E.O., Lin, T.Y.: The role of prediction algorithms in the MavHome smart home architecture. IEEE Wireless Communications 9(6), 77–84 (2002)
5. Ester, M., Kriegel, H.-P., Sander, J., Xu, X.: A density-based algorithm for discovering clusters in large spatial databases with noise. In: Published in Proceedings of 2nd International Conference on Knowledge Discovery and Data Mining, vol. 96, pp. 226–231. AAAI Press, Menlo Park (1996)
6. Hong, X., Nugent, C., Mulvenna, M., McClean, S., Scotney, B., Devlin, S.: Evidential fusion of sensor data for activity recognition in smart homes. Pervasive and Mobile Computing 5(3), 236–252 (2009)
7. Andy Hopper, R.W., Falcao, V., Gibbons, J.: The active badge location system. ACM Transactions on Information Systems 10(1), 91–102 (1992)
8. Schilit, B., Theimer, M.: Disseminating active map information to mobile hosts. IEEE Network 8(5), 22–32 (1994)
9. http://www.ubisense.net (2010)