MARIKA: A Mobile Assistance System for Supporting Home Care

Tobias Umblia, Albert Hein[1], Ilvio Bruder and Thomas Karopka[2]

[1] University of Rostock, Institute of Computer Science, Rostock, Germany

[2] IT Science Center Rügen gGmbH, Putbus, Germany

Abstract. Documentation of care activities is a very time-consuming task of home healthcare, but necessary due to legal requirements. Automating the care documentation would relieve the nurses from writing it down by hand, resulting in more time for the patients[3]. The MARIKA project presented in this paper is addressing this problem through the development of a system which assists the home care personnel by automatically recording care activities, and integrates with other systems involved in the care process. Technical approaches for two major building blocks of such a system are described: A hybrid, sensor-based activity recognition approach, and a mediator-based data and function integration approach.

1 Introduction

The elderly currently are the fastest growing demographic group in the USA [1], a trend which is similar to other, for example European regions due to increasing life expectancy and decreasing birth rate. So the aging human is more and more getting into the focus of not only demographic research. Graceful aging is a common demand of the current and future population. Most of the people wish to stay at home as long as possible, but the home care for elderly or sick people is a serious burden for family members. One third of admissions to nursing homes are done not because of deterioration of the persons' health conditions, but because of the so-called "caregiver burnout".

An alternative to stationary treatment is the professional ambulant care at home. Especially this kind of service needs accurate documentation of care activities due to legal requirements and to allow for correct accounting with the health insurances. The usual documentation process is to this day still done manually and takes up to 40% of the working time, is error-prone and mostly inaccurate because it does not happen in situ but afterwards.

This requires solutions with which documentation tasks are accomplished "along the way", yet properly. The personnel thus is given free hand to attend to their actual role. Additional functions like reminders or giving decision guidance assist in the everyday work. These are requirements analogous among developments in the medical and affiliated sectors, like the wearable assistant for hospital ward rounds presented in

[3] The terms *patient* and *client* will be used interchangeably throughout this text.

Umblia T., Hein A., Bruder I. and Karopka T. (2009).
MARIKA: A Mobile Assistance System for Supporting Home Care.
In *Proceedings of the 1st International Workshop on Mobilizing Health Information to Support Healthcare-related Knowledge Work*, pages 69-77
DOI: 10.5220/0001815200690077

[2]. Easily operated, mobile devices and unobtrusive sensors contribute to meeting the socio-technical conditions also common to these scenarios. That is, to improve user acceptance of such systems on the one hand, as well as, on the other hand, the acceptance by the patients who understandably demand the care personnel's attention, an aspect emphasized in [2], too.

In this paper we first give a short overview of the MARIKA project in section 2, followed by a description of the problems we are addressing in section 3. In section 4.1, we present our activity recognition approach along with first test results, the data and function integration concept for the system is described in section 4.2. Concluding with section 5, we give an outlook on our further research.

2 The MARIKA Project

The demographic situation described above and the emerging challenges turn home healthcare into one of the fastest growing areas of healthcare provision. The MARIKA project (Mobile Assistance for Route Information and Electronic Health Record) aims at providing support for the home care service by automating the obligatory documentation in the care process. Particularly dedicated to accompanying the nurse's everyday work flow, different techniques are brought together in the project. Two of these are subject matter of the following sections: sensor-based activity recognition (see section 4.1) and data and function integration (see section 4.2). Other research areas involved are combined indoor and outdoor positioning, data privacy, e-learning, as well as content and knowledge management [3].

One of the key challenges is the organization and coordination of all stakeholders that take part in the care process, and the dissemination of information between them. Several projects have been developed recently aiming at providing a communication and coordination platform for home healthcare [4–6], showing that this is a field with innovation potential. In this respect, developments within the MARIKA project are also focusing on a platform that allows all participants of the care process, namely general practitioner, home help service and home care nurse to exchange information. Although cost effectiveness studies are rare, it is evident that coordination platforms have a great potential for enhancing quality of life and reducing costs in the care process.

The collaboration with a professional outpatient care service, working in rural areas and small towns mostly, allows us to test and optimize the components of the system with regard to user acceptance and reliability.

3 Use Case and Problem Analysis

To identify the technical problems our project is addressing, a simplified day-to-day use case is illustrated as it will look like in the future:

A daily schedule exists for the home care service personnel (the nurses), containing information about which client will be visited and when. Clients will be given care mainly at their homes, but also at nursing homes. Usually, the nurses take off their route by car. At the client's home, the predefined care activities are performed by the nurse and documented automatically. When leaving the client, the care documentation process is completed and the associated information will be transferred to the central care documentation and planning system of the home healthcare provider. Spontaneous changes of the schedule can occur at any time, in which cases the required route information, client data etc. will be updated automatically.

There are several devices involved in this scenario: The car is equipped with a GPS-based navigation system, which dynamically adapts the route, combined with an electronic logbook, which records the duration of a tour and the distance covered. The nurse is using a mobile device, which collects and processes data en-route. One of the now omnipresent smartphones, PDAs or tablet PCs come into question, preferably dedicated to applications in the healthcare sector. Devices adhering to the *mobile clinical assistant (MCA)* reference architecture introduced by Intel recently [7] will be the target systems of our first implementations, as these already provide serviceable features like RFID scanner and digital camera. Additionally, wearable sensors will be incorporated into the system.

Hence a high degree of mobility and autonomy of the involved players and components, and a definite request for ease of use, portability and adaptability, as well as data privacy are the resultant basic conditions we are confronted with.

The organizational framework of a care documentation system is given by the statutory health insurance. All care activities are grouped into so-called *nursing care levels*, their exact duration, extent and cost are fixed and retained in a service catalog, thus building the basis for accounting. In the MARIKA assistance system for home care documentation these activities should be detected automatically. Therefore, they have to be modeled, and the recorded sensor data then has to be matched with these models adequately. In reality, there often are ambiguities between different activities sharing the same motions or gestures like carrying a glass of water or carrying a pillbox and also ambiguities between different activities using the same objects, which is e.g. using an object or simply carrying it around. These two problems are not clearly distinguishable using only a single sensing method. That is why a direct motion measurement with inertial sensors and the detection of object interactions with RFID are combined in our activity recognition approach.

Our first main objectives are to investigate whether such a combined sensor configuration is technically viable in terms of delivering reliable data without explicit compliance of the test subject, if a static classifier or a hybrid model is able to infer usable estimates on a continuous time trace and how much each sensor type actually contributes to the final classification results. The activity recognition approach is described in section 4.1.

Another main problem besides activity recognition is the integration of all subsystems into an overall architecture. The data and functions necessary for care documentation are distributed across these components and heterogeneous regarding their structure and semantics. The different types of data are sensor data streams, representing care activities, text and multimedia documents like photos or voice memos complementing the care documentation, and precise temporal and spatial logging. Altogether they allow for accurate accounting by giving answers to questions like: Who did what, when and where, and how long did it take? Furthermore, there are special functionalities requested during care service, its analysis and planning, e.g. plausibility checks in the work flow and giving decision guidance in case of ambiguities. The MARIKA system will finally be integrated with existing care documentation software (CDS), which is already in use at home care services, and aiming at a larger-scale coordination platform. The integration methods required to achieve this are described in 4.2.

4 Technical Approaches

4.1 Activity Recognition

Currently, sensor based activity recognition is widely seen as an essential technology for providing mobile assistance in *ambient assisted living (AAL)* scenarios. An ambient sensor infrastructure as in the iDorm [8] or the PlaceLab [9] is mostly unobtrusive, but (at least for now) too expensive and complex for home care settings where each apartment of every care patient would have to be equipped with environmental sensors. Wearable sensors as an alternative are already showing good results in human activity recognition, either through direct motion sampling [10, 11] or through capturing object interactions [12].

We are aiming to combine these two methods of direct motion measurement with inertial sensors and detection of object interaction with RFID for high level activity recognition. Our system uses hierarchical sensor fusion on different levels of abstraction for simultaneously integrating many channels of heterogeneous sensor data. For inferencing high level activities we use a layered hybrid discriminative and model based generative approach. This will enable us to integrate prior knowledge into the decision process in the future to reduce the amount of training while keeping the probabilistic model simple. First parts of this approach have already been evaluated on the experimental setting of a home care scenario where the hybrid approach reached accuracy rates of 96% although the RFID object sightings were not yet considered.

For the tests we roughly rebuilt the floor plan of an apartment consisting of a bedroom, a bathroom, a living room and a kitchenette in our laboratory. The test runs were performed by professional care personnel (a geriatric nurse) and a student who helped out as a patient (Example still frame see Fig. 1 (left)). The test agenda and the scenario have been developed in close collaboration with a nursing service, which also provided authentic equipment for the tests. The activities were directly taken from the service accounting catalogue of the health insurances: “general service” (greeting, fetching newspaper, ...), “big morning toilet” (including washing whole body, brushing teeth), “micturition and defecation”, “administration of medications”, “bandaging”, “preparation of food” and “documentation”.

For the motion recordings we used three small sensor boards, equipped with a 3-axis accelerometer, 3-axis gyroscopes and a 2-axis magnetometer. Because of the compact size (51x41x23mm) the boards could be attached at unobtrusive positions: at the dominant wrist for recording gestures and object motion, at the chest/upper back and at the hip. RFID is a popular technology for contactless identification of objects. A basic system consists of a reader module with an antenna and several active or passive tags in the form of small boxes, stickers or even implants. Especially, passive RFID stickers are a cheap, battery free solution for reliable object detection. RFID practically does not return any false positive object sightings. Because currently no wearable RFID modules

Fig. 1. Still frame taken from a surveillance fisheye camera. The test person is equipped with sensors at the hip and upper back and dominant wrist (left). RFID Wrist Antenna and Inertial Sensor Board (right).

are available commercially, we used a multi function reader with a custom-made wrist antenna (see Fig. 1 (right)). Depending on object geometry and material it has a reading range between 10 and 30cm. All data streams were wirelessly transmitted to a laptop computer where they were immediately formatted and synchronized.

Based only on the motion sensor data we compared different supervised and unsupervised learning methods in conjunction with an automatically synthesized Hidden Markov Model for evaluating the general feasibility of our hybrid approach with very promising results with recognition accuracies up to 96% (Table 1). For a detailed description of the approach we have to refer to [13]. As the presented classification results are based on very few experimental training data, they have to be treated carefully in respect of generalization. Future experiments will have to follow under real world conditions to allow a reliable evaluation of a comprehensive set of care activities and multiple test subjects. This is expected to provide more realistic results allowing an outlook on everyday use.

Table 1. Comparison of several supervised and unsupervised discriminative approaches: The table shows the specific recognition accuracies in % for both test runs. (The first test run has 451, second has 471 single observations.)

	1st test run	2nd test run
Decision Tree	86.9	86.6
Support Vector Machine	85.8	85.6
Naive Bayes	77.2	70.9
k-Means ($k = 35$)	**98.2**	**96.0**

4.2 Data and Function Integration

The recorded motion and RFID sensor data are the basis for the activity recognition component. In the intended overall architecture it will be combined with several other technical components to form a mobile assistance system for care documentation. A proper integration strategy is pursued in order to utilize data and services associated with these components. This comprises sensor data streams, spatial and temporal data, context and knowledge information, history and logging data, as well as multimedia documents and healthcare records. Furthermore, components may offer special functions and services towards applications.

These data and function sources can be characterized as being highly heterogeneous regarding their structure and semantics, autonomous, distributed and subject to frequent changes, therewith describing a common integration problem [14]. Its solution is expected to run automatically, that is, without the need for user interaction after it has been implemented, allow for adaptations, and to stay both flexible and consistent across evolution stages.

This is also demanded from the applications' point of view, where the integration approach mainly aims at building an extension to existing care documentation software (CDS), and moreover, merging the MARIKA subsystems into a communication and coordination platform for home healthcare.

To achieve this, we choose a mediator based integration approach, utilizing logical views of the data, which is widely accepted as an applicable solution for such integration problems [15–17]. Here we follow the Local-as-View concept at first: The source schemata are defined as views of a global schema. Data in the global schema is not materialized, but made available dynamically on request. Its the mediator's responsibility to translate queries from applications and to respond accordingly by means of those view definitions. Resulting from this concept, the mediator will perform different tasks, depending on the perspective, as depicted in Table 2.

Table 2. Tasks of the mediator based integration, from the sources' perspective in contrast to the applications' perspective.

Sources' Perspective	Applications' Perspective
Define local source schemata as views (within wrappers)	Define unique, global schema
Provide data containers (tables) and function hooks	Provide data and functions
Permit write access	Permit read access

Deciding advantages of approaching an LaV model are that sources can be kept distributed and autonomous, that changes of their schemata as well as adding or removal of sources can be controlled better, thus allowing for easier maintenance and evolution of the overall system. The global schema, representing the interface towards applications, remains constant and does not need to be changed frequently. This meets the requirements of the targeted users, namely healthcare instead of IT professionals, to spare them the necessary adaptation and update procedures. A complicated query translation process is seen as the main drawback of the LaV concept, since it leads to poor performance in case of frequent, complex queries. For now, these are not part of the MARIKA use cases and can be disregarded. Evaluating the combination of concepts of Local-as-View and Global-as-View to solve this problem, as proposed in literature [18, 19], is part of our future work.

A mediator based integration always implies the implementation of wrappers. They wrap the information sources by imposing the local schemata on them, in the form of views of the global schema. For our scenario different wrappers have to be defined for the data and functions associated with the components listed above. Thereof, wrapping sensor data streams is one of the demanding tasks in the integration process. To address it, database system extensions for stream data processing are evaluated, which utilize caching of data and allow for dropping irrelevant data based on filter mechanisms. This is part of our idea to optimize the performance of the integrated system in the long term: Data and processes which are not inherent in the final care documentation will, architecturally, be kept at a low level, that is inside of the wrapper. That applies particularly to motion sensor data streams or GPS tracking data. On the other hand, information and functions essential for the care documentation will be modeled at a higher level, that is within the mediator, to ensure proper responsiveness of the applications above it. That applies to more complex tasks like, for example, analyzing the convalescence after an injury by comparing photos taken during the home care. Implementation of the mediator and wrappers will focus on object-relational database techniques, which have been standardized with SQL:1999 and further extended with SQL:2003 [20, 21]. They facilitate integration of the several subsystems by supporting user-defined data types and methods in the data model. Furthermore, the *foreign table* concept defined in the SQL/MED part of the standard allows for integrating sources residing at distributed places and regardless of their SQL capabilities (*SQL-aware* and *non-SQL-aware foreign servers*), [22]. Using these standardized techniques is supposed to be future-proof, since external information systems could be integrated with less effort and tools adhering to the standards would be available for modeling and implementation.

5 Conclusions and Future Work

Activity recognition and data and function integration are two important research areas within the MARIKA project towards automatic healthcare documentation. A combination of sensor data, knowledge and context information, as well as spatial and temporal data is needed to differentiate between activities in the nurse's work flow. First tests are described in this paper and first results show the feasibility of the approaches.

Regarding the activity recognition, our next steps will be, in close collaboration with a home care service, to collect a much larger and more realistic out-of-lab dataset recorded during the day-to-day work and integrating the RFID sensor data into the recognition module. There are still open problems in integrating more data in the decision making process and more analysis is needed for increasing the recognition quality.

Implementation of the mobile assistance system will primarily focus on devices conforming to Intel's MCA specification. Case studies involving the home care service personnel will be tackled to prove whether the features are suitable for our scenario and whether performance of the overall system is sufficient for daily use.

These studies will also serve as basis for evaluation of the SQL-based, object-relational integration approach, to clarify whether the Local-as-View concept is viable or has to be extended with regard to the intended coordination and communication platform. An evolution strategy for the integrated system will be developed in parallel, to ensure its usability and maintainability in the future.

Acknowledgements

MARIKA [3] is funded by the state of Mecklenburg-Vorpommern, Germany, within the scope of the "Landesforschungsschwerpunkt Mobile Assistenzsysteme" main research initiative.

References

1. Roush, R.E.: Smart home technology for aging in place longer and better. Technical report, Roy M. and Phyllis Gough Huffington Center on Aging (2004)
2. Adamer, K., Bannach, D., Klug, T., Lukowicz, P., Sbodio, M., Tresman, M., Zinnen, A., Ziegert, T. In: Developing a Wearable Assistant for Hospital Ward Rounds: An Experience Report. (2008) 289–307
3. Landesforschungsschwerpunkt: http://marika.lfs-ma.de/ (2008)
4. Bricon-Souf, N., Anceaux, F., Bennani, N., Dufresne, E., Watbled, L.: A distributed coordination platform for home care: analysis, framework and prototype. International Journal of Medical Informatics 74 (2005) 809–25 PMID: 16024285.
5. Karopka, T., Bruder, I., van den Berg, N., Hoffmann, W.: Ict architecture for a community medicine nurse project. In: Proceedings of the First International Conference on Health Informatics. Volume 2. (2008) 26–30
6. Hägglund, M., Scandurra, I., Moström, D., Koch, S.: Integration architecture of a mobile virtual health record for shared home care. Studies in Health Technology and Informatics 116 (2005) 340–345 PMID: 16160282.
7. Intel: Products and solutions for health and healthcare, mobile clinical assistant (mca). http://www.intel.com/healthcare/ps/mca/ (2008)
8. Rivera-illingworth, F., Callaghan, V., Hagras, H.: Detection Of Normal and Novel Behaviours In Ubiquitous Domestic Environments. The Computer Journal (2007) bxm078
9. Hightower, J., LaMarca, A., Smith, I.E.: Practical lessons from place lab. IEEE Pervasive Computing 5 (2006) 32–39
10. Bao, L., Intille, S.S.: Activity recognition from user-annotated acceleration data. In Ferscha, A., Mattern, F., eds.: Pervasive. Volume 3001 of Lecture Notes in Computer Science., Springer (2004) 1–17
11. Lester, J., Choudhury, T., Kern, N., Borriello, G., Hannaford, B.: A hybrid discriminative/generative approach for modeling human activities. In Kaelbling, L.P., Saffiotti, A., eds.: IJCAI, Professional Book Center (2005) 766–772
12. Patterson, D.J., Fox, D., Kautz, H., Philipose, M.: Fine-grained activity recognition by aggregating abstract object usage. iswc 0 (2005) 44–51
13. Hein, A., Kirste, T.: Towards recognizing abstract activities: An unsupervised approach. In: Proceedings of the 2nd Workshop on Behaviour Monitoring and Interpretation, BMI'08, Kaiserlautern, Germany, September 23, 2008, Kaiserlautern (2008)
14. Sheth, A.P.: Changing focus on interoperability in information systems: From system, syntax, structure to semantics. In: Interoperating Geographic Information Systems, Springer US (1999) 5–29
15. Halevy, A.Y.: Answering queries using views: A survey. The VLDB Journal 10 (2001) 270–294
16. Lenzerini, M.: Data integration: a theoretical perspective. In: Proceedings of the twenty-first ACM SIGMOD-SIGACT-SIGART symposium on Principles of database systems, Madison, Wisconsin, ACM (2002) 233–246
17. Busse, S.: Modellkorrespondenzen für die kontinuierliche Entwicklung mediatorbasierter Informationssysteme. Logos-Verl., Berlin (2002)

18. Xu, L., Embley, D.W.: Combining the best of global-as-view and local-as-view for data integration. In: ISTA. (2004) 123—136
19. Boyd, M., Kittivoravitkul, S., Lazanitis, C., McBrien, P., Rizopoulos, N.: Automed: A bav data integration system for heterogeneous data sources. In: Proceedings of the 16th International Conference on Advanced Information Systems Engineering, CAiSE 2004. (2004) 82–97
20. ISO/IEC: Iso/iec 9075-9:2008 - information technology – database languages – sql – part 9: Management of external data (sql/med). http://www.iso.org/ (2001)
21. Türker, C.: SQL 1999 und SQL 2003: Objektrelationales SQL, SQLJ und SQL/XML. 1 edn. Dpunkt Verlag (2003)
22. Lindner, W.: Konzepte für ein offenes, objektrelationales Multimedia-Datenbanksystem. 1. aufl. edn. Diplomica, Hamburg (2002)