A LONG TERM DIAGNOSTICS SYSTEM BASED ON INTELLIGENT SMART SENSOR TECHNOLOGIES

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Abstract. Developed countries have been facing the problems of demographic change. Due to decreasing birth rates and the simultaneously improved quality of medical care that results in a rising lifetime expectancy, the imbalance between people who need care and professional caring personnel is dramatically deteriorating.
Thus, systems assisting care-dependent people in their daily life at home are urgently needed. This subject is associated with Ambient Assisted Living (AAL). The presented project focuses on patients suffering from dementia.

Keywords: AAL, ADL, Behaviour Analysis, Smart Sensors

1 Introduction

In the course of the demographic change AAL technologies can help to compensate the lack of caring staff by supporting demented people to stay as long as possible in their own home. Thus, high costs for care can be reduced and elderly can remain independent instead of moving to a nursing home. In this way the quality of life can be improved for people suffering from dementia.

2 State of the Art

There are many approaches for building up a smart home. Clement et al. [1] utilized smart meters, which measure the current consumption of electrical devices in the flat. With this information behaviour profiles are constructed by training semi Markov models and conclusions about the activities of the person can be drawn.

Steen et al. [2] equipped a flat with motion detectors, laser range scanners and contacts at doors and windows. They recorded the events detected by these sensors over time and evaluated the data with regard to mobility, sleeping habits, personal hygiene etc. Nevertheless, personal interviews were needed to obtain an overall view.

Scanaill et al. [3] employed body-worn sensors. However, it is a fundamental demand to AAL systems that they apply contactless sensors, because demented people tend to forget to wear these sensors or they intentionally put them off as they do not like to wear them. Moreover, the sensor technology shall be unobtrusively integrated in any home without changing the infrastructure of the flat.

The project at hand applies so-called Smart Sensors that are able to manage these requirements.

3 Objectives

The first objective is an investigation, whether current Smart Sensor technologies can contribute to a more convenient life for dementia patients.

After that, in order to optimize the process of care, a marketable, long-term diagnostic system shall be designed that can monitor if patients carry out Activities of Daily Living (ADLs). ADLs are activities related to categories, like mobility, nourishment and social contacts. Therefore these activities have a high medical relevance, because long-term analyses of the ADLs give information about the medical state of the patient.

Statistical data evaluation also enables a later interpretation by physicians. A vital emphasis lies on the privacy concerns and acceptance issues of the patients. In order to meet ethical requirements the Smart Sensors are limited to only deploy meta data instead of raw video information.

4 Methods

An interdisciplinary team of scientists, engineers and medical experts from Klinikum Chemnitz gGmbH and Heim gGmbH has examined the international list of ADLs and evaluated them according to their relevance for the creation of a long-term diagnostic system.

In Table 1 these ADLs are listed. The left colum shows the general ADL term, which is separated

into more detailed, elementary activities that, according to the medical experts, are relevant for a system supporting demented people. Furthermore those activities have been analysed for their feasibility with respect to the implementation using novel Smart Sensor technologies and state-of-the-art visual behaviour analysis algorithms. Table 1 shows that the analysis of most of the ADLs that are marked as highly relevant is realizable.

5 Results

The outcome is a novel system design that can master the complex needs of the project goals. The overall functionality bases on a Smart Sensor Network that can cope with a complex living environment. Smart Sensors comprise stereo vision techniques in order to enhance RGB video data with 3-D information of the vicinity of the sensor. A central fusion engine merges the information streams of the sensors and is controlled by the System Management Application. This application focusses on the interaction of the customer (e. g. the demented person) and the qualified personnel with the system. The high level design is outlined in Figure 1.

5.1 Smart Sensor

The Smart Sensors are the central devices enabling a powerful but also privacy-sensitive servicing. In case of stereo vision-based sensing it provides depth and RGB video information for performing algorithms of low level vision and low level semantic vision, which we consider as *Low-Level Behaviour Analysis*. Algorithms for low level vision comprise methods for *Scene Modelling* (e. g. stochastic pixel models), *Motion Detection* (e. g. frame differencing, background subtraction and optical flow) as well as *Change Detection* (e. g. background subtraction, feature modelling and template matching). Founded on this data the semantics of the scene can be considered by employing *Object Detection*, *People Recognition*, *Tracking* and *Low Level Activity Recognition* (e. g. motion models). A comprehensive overview of the design of embedded vision systems can be found in [4]. For instance, we analyse the sleeping habits of a person. Therefore, we determine the location of the person by employing human recognition and tracking methods. The pose of the person is furthermore estimated by pose estimation approaches. All generated meta data is tagged with a time stamp and written into a central database (Behaviour Analysis Database).

5.2 Fusion Engine

The *Fusion Engine* combines the meta data with further information like the sensor position. Context information, like the floor plan of the living

Activity Group	Elementary Activities	Assessment of Relevance by Medical Staff	Assessment of Feasibility
Feeding	Open fridge	low	moderate
	Using devices (microwave, waterboiler)	high	complex
	Eating & Drinking	high	complex
	Preparing meals	medium	complex
	Staying at the kitchen for long time	low	moderate
	Interacting with delivery service	medium	complex
Toileting	Sitting on the toilet	high	moderate
	Dropping pants	medium	moderate
	Wet clothes	medium	complex
	Washing hands	low	complex
	Using towel	low	complex
Bathing/Grooming	Sitting in bath tube	high	moderate
	Showering	medium	moderate
	Brushing teeth	medium	complex
	Washing face, hands, ...	medium	complex
	Combing, drying hair, ...	medium	complex
Proper dressing	Putting on trousers, socks, shirt, ...	high	complex
	Undress	high	complex
	Open wardrobe	low	moderate
	Leaving house with improper dress	high	complex
Movement: Walking and Transferring	Standing up	high	moderate
	Sitting down	high	moderate
	Sitting	high	moderate
	Standing	high	moderate
	Lie down	high	moderate
	Lying	high	moderate
	Walking	high	moderate
	Climbing	high	complex
	Change of gait	medium	complex
	Movement of extremities	high	moderate
	Not moving during a longer time	high	moderate
	Going out	high	moderate
Communication	Using telephone	medium	complex
	Visitors	high	moderate
	Going out	high	moderate
	Reading books and newspapers	medium	complex
	Using PC	medium	complex
	Radio, television	medium	complex
	Screaming	high	complex
	Writing	medium	complex
Managing medications	Taking medication	high	complex
	Apply ointments, other treatments	high	complex
	injections	high	complex
Housework and basic home maintenance	Washing clothes	medium	complex
	Cleaning the flat	medium	complex
	Using vacuum cleaner	medium	complex
	Washing up	medium	complex
	Making bed	medium	complex
	Tidy up	medium	complex
Recreation	Sleeping (place, position, how long, with interruption)	high	moderate
	Sitting	high	moderate

Table 1. List of ADLs with the assessed relevance for a long-term diagnostic system and the feasibility with respect to smart sensor technologies and visual behaviour analysis algorithms.

environment, enables a *High-Level Behaviour Analysis* by employing reasoning methods. Turaga et al. [5] describe methods like Dynamic Belief networks, probabilistic Petri Nets and stochastic Grammars. They also introduce ontologies, that provide compact high-level definitions of behaviour.

In order to recognise whether the person is sleeping, for instance, we combine low level information (e. g. position, pose) with context knowledge (e. g. position of the sleeping accommodation, current time). The acquired data is also written into the Behaviour Analysis Database.

5.3 System Management Application

A *System Management Application* interfaces the system for configuration. Furthermore it operates as *Human Machine Interface* (HMI) as well as a data interchange system for medical staff and patients.

In order to generate final information of medical relevance the application interoperates with the Behaviour Analysis Database and queries the average sleeping time during a certain period, for example. This functionality is fully customizable by the caring stuff. Special events can be defined and are released immediately when occurring, e. g. when the average duration of sleep decreases dramatically or an prospective dehydration is detected.

5.4 Messaging Chain

In the situations described above, the system displays messages to the patient on a screen. The purpose of these messages is to motivate the patient and to give advice for further proceedings (e. g. "Please, drink something.").

In case of severe occurrences, e. g. the patient is not drinking at all, relatives or the caring staff is informed using a messaging chain, for example via a short call. The system is also customizable with respect to other applications related to medical issues, like fall detection.

6 Conclusion

It is possible to project the requirements for a medical assistance and diagnostic system onto modern Smart Sensor network-based surveillance systems. Future investigations will show whether it can substantially increase the quality of life for people that suffer such severe mental disease.

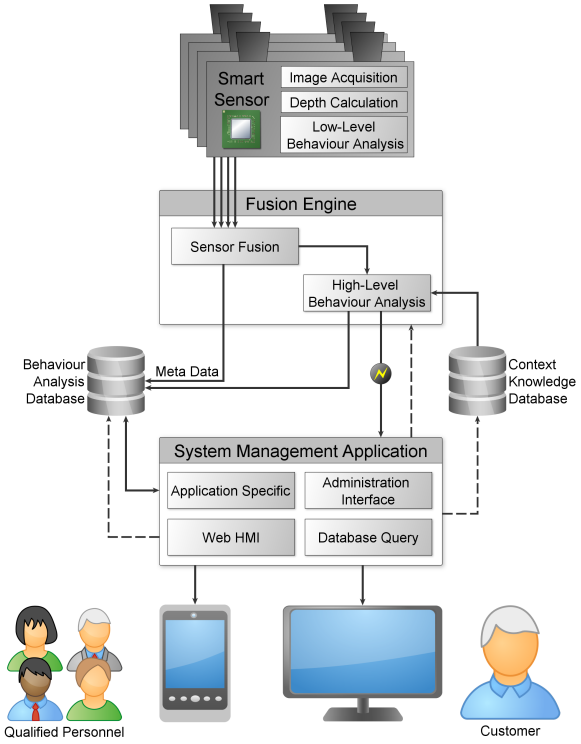

Fig. 1. Long Term Diagnostics System Design.

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