Context-Aware System for Neurology Hospital Wards

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Abstract. In this paper we describe the context-aware Adaptive Daily Rhythm Atmosphere (ADRA) system. The ADRA system is designed to stimulate the healing process of hospital patients, neurology patients in particular. We first report on the needs and issues of neurology patients identified by an observation study in a hospital neurology ward. Based on these needs, we define several concepts to promote the healing process. Finally, the context-aware system we have designed to realize these concepts is described.

Keywords: Context-aware system, agent-based system, hospital ward, ambient healing, neurology.

1 Introduction

We explore possibilities of enhancing the patient healing process in future (single) hospital patient rooms by means of a context-related adaptation of the environment while addressing needs of both patients and staff. We focus specifically on neurology patients with the emphasis on stroke and the inpatient environments these patients find themselves in during the post event recovery process. We spent a full week in two leading hospitals to make observations on-site.

Four relevant key conclusions from workflow observations and interviews emerge. First of all, the *amount and intensity of stimuli* that a patient can handle in this environment is very dependent on his or her condition: too many stimuli could lead to aggression and restlessness. Too few stimuli could lead to boredom. Secondly, the right *balance* between a clinical environment and a personal environment needs to be achieved for all stakeholders in the neurology department. A patient room that *adapts the environment* of the patient without interfering with the activities of other stakeholders is therefore expected to be very beneficial to the patients, family and staff. Thirdly, a clear *structure* of the day is important for stroke patients to decrease the risk of disorientation and confusion, achieve a healthy sleeping pattern**,** avoid delirium, better handle rehabilitation therapy, and to consolidate their memories. Fourthly, stroke patients have a large *risk of falling and accidents*. The main reason for falling accidents is the patients' limited insight in their disease. The incidence of falling can be reduced by reducing clutter and improving lighting conditions.

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2 Literature

Many research efforts have focused on providing staff members with the right information at the right time. What constitutes 'right' information is determined based on the activity the staff member is carrying out. For example, the CISESE institute in Mexico has carried out a number of workplace studies in a public hospital, an overview of which is given by Favela et al. [5]. Based on the workplace studies, Sanchez et al. [8, 9] describe different methods for classifying activities of the hospital workers to enable context-aware communication between staff members. Bardram [1,2,3] discuss a context aware hospital bed that displays relevant information for the nurse when administering medication by e.g. displaying the medication scheme, patient record, lighting the proper medication container, when the nurse and the medication container are close to the bed. Siewe et al. [10] show how this application can be formulated using context-aware calculus. Kjeldskov et al. [7] describe a prototype to support morning procedure tasks in a hospital ward by showing patients lists and patient information based on the location of the nurse and time of day. Weal et al. [11], and Cassens et al. [4] discuss the annotation of staff activities on a patient ward to facilitate further development of context-aware systems. Our approach is unique compared to these previously proposed systems; our system focuses on providing the patient with the proper healing environment, while the focus of the previously proposed systems is on providing the staff with the proper information.

3 System Description

Based on our observations, we propose the Adaptive Daily Rhythm Atmosphere (ADRA) system, which generates a dynamic atmosphere that supports the daily rhythm of the patient. Where needed the atmosphere adapts to specific interrupts and visits, e.g. when doctor or cleaner is visiting. By using ADRA, the mentioned negative effects of the rigid environmental conditions are alleviated because the system provides a daily rhythm atmosphere in sync with, and optimized for, patient needs and the care agenda and intelligently adapts to deviations thereof.

The ADRA system starts with a series of pre-defined *day schedules* per patient. Each day schedule consists of a sequence of phases of the day with fixed start and end times, an example of which is given in Table 1.

Each phase within the day schedule is also described by at least one pair of start and end triggers. These triggers indicate the start and end events of the phase. Triggers can be used for *expected* events, such as breakfast, for which the timing is typically uncertain, but the occurrence is not. However, they can also be used for *unexpected* events such as a physical examination in the afternoon. An example of these triggers is given in Table 2.

Table 1. An example of a pre-defined day schedule

Ambiance	Start time	End time
Sleep	00:00	7:30
Wakeup	7:30	8:00
Breakfast	8:00	8:30
Morning	8:30	11:30
Lunch	11:30	12:00
Rest	12:00	14:00
Wakeup	14:00	15:00
Visitors	15:00	17:00
Dinner	17:00	18:00
Rest	18:00	24:00

Table 2. An example of start and end triggers of different phases.

Phase	Start trigger	End trigger
Wakeup	Time>7:00 & Time<7:30 & sleepState = awake	Caterer enters department OR caterer enters room OR Time=8:00
Meal	Caterer enters department OR caterer enters room	DurationMeal = 0:45
Sleep	(Lights off & Time>20:00) OR (sleepState = asleep & Time>20:00)	Time = 7:30
Nurse Call	Call button pressed	Nurse call completed button pressed

Each trigger schema is stored in a database and retrieved by the ADRA system based on the date and patient identifier. The status of all defined phases and their triggers are continuously monitored in the system. Next to the triggers the system reacts to the entering and leaving of the staff into the patient room. Based on an identifier of the current phase, the corresponding atmosphere for that phase is retrieved and used by an ambience system to start the predefined corresponding e.g. lighting and audio settings.

We envision that the ADRA system runs for multiple patient rooms (n > 100) at the same time. Scalability and maintainability are therefore the most important non-functional requirements. We therefore created a distributed system architecture, in which each room is an independent system that can be maintained separately without interrupting the ADRA systems in other patient rooms. The only resource that all patient rooms share is a centralized database server that contains the patient information and ambience settings. All processing resides in controllers within the separate room that are connected to one or more sensors and that communicate over a TCP/IP network. Concurrency only occurs in the database calls to the centralized database. However, these calls happen at low resolution making the ADRA system very scalable.

For each room the system consists of a separate room controller, bedside controller, and ambience controller. The bedside controller communicates its observed bed state to the corresponding room controller over TCP/IP, which utilizes this information together with the room state to determine the current phase of the day for the patient. Based on this phase, the room controller retrieves and communicates the corresponding ambience settings to the ambience controller over TCP/IP that generates the correct lighting, audio, and video settings. The system architecture is illustrated in Figure 1.

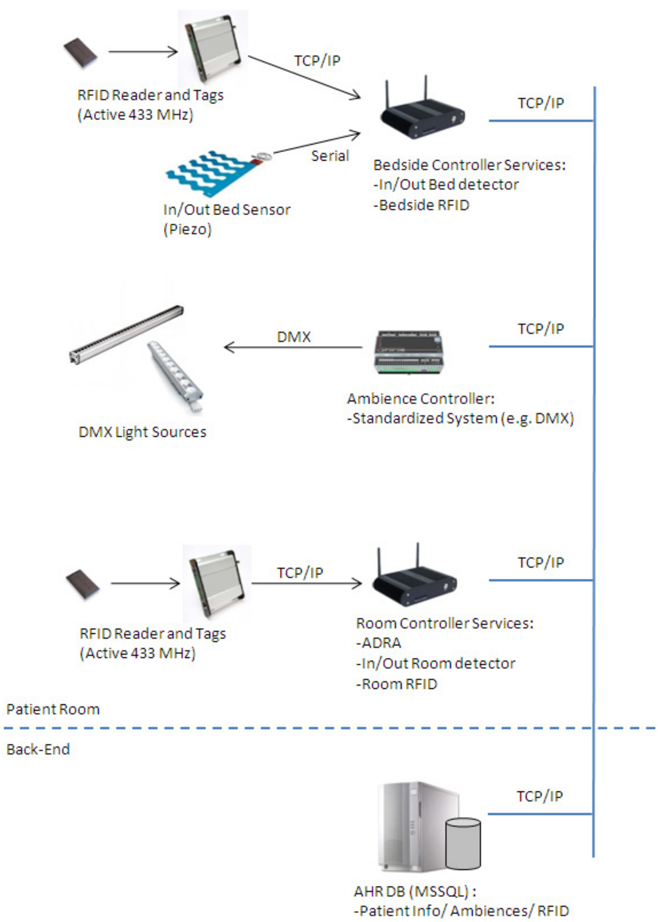

Fig. 1. System architecture

The development and execution of the different services within the different controllers and the communication between the services is based on the agent paradigm to execute peer-to-peer applications that can seamless work and interoperate in a network environment. The ADRA system makes use of standard runtime services that enable the execution, search, and discovery of agents and the communication between them. These standard agent services that run on different machines automatically connect with each other, resulting in one distributed agent support layer. Each agent is identified by a unique name and provides a set of services that it registers within this agent support layer. Agents communicate by exchanging asynchronous messages. The properties of an agent-based system make this technology very suitable to realize a distributed ADRA system for multiple rooms. The services within the controllers are represented by agents that communicate with other agents in order to provide the intended functionality. The agent architecture is illustrated in Figure 2.

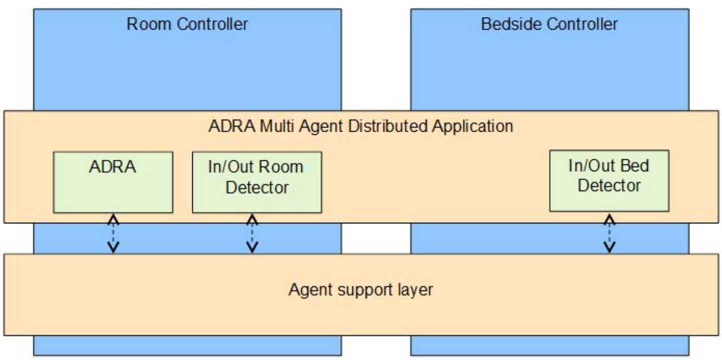

Fig. 2. Agent architecture

To be able to evaluate this concept and its performance, we are developing a prototype ADRA system integrated in a concept patient room. The system contains the commercially available Emfit monitor device (D-1070-2G) and the under-mattress bed sensor (L-4060SL) to detect if the patient is in or out of bed, and the Wavetrend system with active tags to detect that a person is entering a room or a department and what that person's role is.

The actuators of the ADRA system consist of several lighting devices. All light sources are connected to the main ambience controller, which is a DMX controller supporting static, dynamic and interactive scenes. Scene creation is done by programming timelines for the different lighting devices. These timeline specify the DMX values of the lighting devices over a predefined time period.

Figure 3 to Figure 6 illustrate how a patient room can be adapted over the day to the patient's needs and the clinical activities taking place in the patient room. These environments differ per patient and depend on for example the stage in the recovery process, and planned or unplanned treatment sessions. Furthermore, the timing of the different phases can differ per patient, based on the planned and unplanned actions of patient and staff.

When it is time for the patient to wake up, lights are slowly turned on, giving the patient sufficient time to wake up in a relaxed manner, and avoiding too much stimuli at once. A nature video is visible on the center panel, with calming nature sounds. A clock is displayed on the left panel at all times to provide the required structure. Figure 3 shows the patient room at the end of the wake up phase. During clinical care, see Figure 4, bright white light is used to create a clinical environment, and the nature view in the center panel is removed to prevent distraction during the clinical care.

Fig. 3. Wake up

Fig. 4. Clinical care

During the resting hour after lunch, the curtains are closed half, lights are dimmed, and a nature video with calming sounds is displayed as illustrated in Figure 5. This stimulates relaxation, yet maintains the connection with the outside world by not fully closing the curtains. To stimulate the feeling of being connected to the outside world, the right panel shows photos and/or drawings of family and friends. When going to sleep, the lighting becomes more reddish as illustrated in Figure 6, because blue light keeps us awake and alert, while the absence of it makes us sleepy, as shown by Gooley et al. [6].

Fig. 5. Rest

Fig. 6. Going to sleep

4 Conclusion

There are needs in hospital contexts which may be addressed by intelligent, context-aware systems in order to realize an optimal healing environment for patients. We have shown that neurology patients need a personalized environment to optimally stimulate their recovery process. Patients have limited abilities to cope with stimuli, are in need of clear structure, and are at risk of falling and other accidents. Their capabilities, needs and risks differ per individual, per time of day, and depend on their stage in the recovery process. Therefore the environment needs to be continuously adapted to each individuals needs at every moment in the recovery process. While doing so, the right balance between the clinical environment needed by the staff, and a personal environment for the patient and his visitors, is needed as well. To realize these objectives, we propose the ADRA system. The distributed nature of the ADRA system is versatile, and is particularly suited for easily extending the number of rooms, patients, sensors, and actuators in the system. Although our solutions have been tailored to neurology patients, many of the identified issues generalize to other diseases. Hence, the proposed ADRA system can be applied, possibly after some modifications, to other patient groups. As next steps, we will evaluate the system in a concept patient room lab setting and in an actual hospital environment.

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