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Wireless Multimedia Technologies for Assisted Living

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Abstract

Health care systems are struggling to meet the needs of the increasing elderly population, resulting in a significant increase in the demand for aging services. Recent technological developments are expected to assist caregivers in providing both effective and economical care in the home and in long-term care facilities. This paper describes our ongoing efforts toward improving the quality of life of elderly and homebound patients. Our work is currently focused on the development of the *Assisted Living Monitoring and Analysis System* (ALMAS) project, an intelligent, multimodal tracking and observation solution for Assisted Living Facilities (ALFs). It extends concepts and ideas from our previous work (CodeBlue: a wireless, web-enabled, health monitoring system) by incorporating RFID technology and employing video analysis algorithms for patient tracking and monitoring. ALMAS employs wireless transceivers in the patients' rooms and hallways, to monitor their current location, and periodically collects their vital signs by communicating with their personal wearable devices. Any unusual behavior exhibited by the patient triggers an event, enabling the capture of relevant video footage, which is transmitted wirelessly to a health-care professional's PDA. Based on the information received, an appropriate course of action is taken.

Keywords

Assisted Living Technologies, Wireless Communications, Pervasive Computing, Elderly Care, Video Processing and Analysis.

1. Introduction

The population of individuals 65 and older is growing significantly worldwide and is expected to increase by 76% between 2010 and 2030. The elderly are often faced with impaired physical and mental functions. Such impairments can prevent them from being able to perform daily tasks. As the resources for aging services are growing scarce, there is a widely recognized health care crisis in the United States in the field of elderly care.

The use of technology to track patient movement and monitor patient's vital statistics reduces the need for constant supervision by caregivers. This reduces the health-care costs and increases the quality of life of the patient while decreasing the burden on the caregiver. It is expected that technological support built into future generations of homes should help older adults with Activities of Daily Living (ADL) such as bathing, toileting, and eating, Instrumental Activities of Daily Living (IADLs) such as managing a medication regimen, maintaining the household, and preparing nutritious meals, and Enhanced Activities of Daily Living (EADLs) such as engaging in lifelong learning, community volunteering, and social communication (Mynatt and Rogers, 2002).

There are opportunities for scientists and engineers to improve the quality of care for the indigent and the elderly using new technologies that are inexpensively available on the consumer market. Resources such as wireless networks, RFID technology, sensors, robotic devices, and video surveillance cameras have potential in this market. A successful solution will be one that combines some of these technologies in an integrated, easy-to-use, environment that also addresses some of the well-known concerns behind the implementation of these systems, namely: privacy, acceptance, and ease of use.

This paper is structured as follows: Section 2 provides an overview of recent related work in the field of aging-related technologies. Section 3 describes some of our past work in wireless multimedia. Section 4 introduces ALMAS and describes its main components. Finally, Section 5 contains our conclusions.

2. Related Work

There has been a significant amount of activity in the area of aging-related technical research over the past few years. The Center for Aging Services Technologies (CAST) was recently established by the American Association of Homes and Services for the Aging. Its goal is to bring researchers from universities and companies, facility administrators, and government representatives together (Center for Aging Services Technologies, 2004). The main focus of CAST is to identify technologies that will help provide potential solutions to the aging services challenges faced by the global community.

Leading universities and companies are exploring the problem from different angles. Some research groups have built entire facilities, densely equipped with a variety of types of sensors, cameras, panels, etc. and observation rooms from where they can monitor the activities of the elderly and their interaction with the smart environment. Examples include the *PlaceLab* at MIT (PlaceLab, 2004), the *Smart Medical Home* Research Laboratory at the University of Rochester (Smart Medical Home, 2004), the *Medical Automation Research Center* (MARC) at the University of Virginia Health System (MARC, 2004), and the Aware Home Research Initiative (AHRI) at Georgia Institute of Technology (Mynatt, 2000).

Other groups are focusing on more specific aspects of the use of technologies to improve living conditions, such as Microsoft's *EasyLiving* Project (EasyLiving, 2004), which focuses on the use of sophisticated video tracking technologies to determine who and where an individual is; the *Assisted Cognition* Project at the University of Washington (Assisted Cognition Project, 2004), which employs state-of-the-art AI techniques to enhance the quality of life of people suffering from Alzheimer's disease and similar cognitive disorders; and Intel's *Proactive Health Research* (Intel research – Proactive Health, 2004), which explores ways in which ubiquitous computing can support the daily health and wellness needs of people in their homes and everyday lives.

3. Previous Work in Wireless Multimedia

ALMAS is an extension of our previous research in the areas of wireless medical monitoring and content-based motion detection in video sequences to an assisted living scenario. In this Section we provide a brief description of two relevant past projects: a wireless, intelligent, health-monitoring system (CodeBlue) and a video surveillance system with automatic motion detection capabilities (VSS).

3.1 CodeBlue

Most individuals who require constant physiological monitoring are compelled to make frequent trips to a hospital or clinic and stay there for extended periods of time in order to have their health monitored. CodeBlue presents an alternative to this scenario. It is a wireless, web-enabled, health monitoring system that allows patients to retain their mobility and independence by allowing wireless transmission of a patient's vital signs to a base station for analysis.

CodeBlue uses a Bluetooth wireless protocol to enable communication between the patient's wearable unit and a base station. Bluetooth's power consumption, range, and data rate capabilities have proven to be particularly suitable for this type of application, where the patient is moving inside their home wearing a portable, battery-powered device which sends data samples every few seconds.

CodeBlue consists of three functional components (Figure 1): a wearable unit (WU), a base station (BS), and a web server (WS). The wearable unit collects the patient's physiological parameters and transmits this data wirelessly to a base station where it is analyzed and stored. Based upon the data analysis, the base station determines if the patient's physiological data warrants medical attention or critical care. If so, the base station automatically contacts the patient's nurse and/or paramedics. The web server component allows medical professionals to remotely access the patient's physiological data over the Internet, and provide feedback to the patient by phone or text-messaging.

The WU is a small, portable device that consists of a Bluetooth transceiver, a microcontroller (MCU), RF-based vital sign monitors, and associated circuitry. It collects the patient's vital signs such as heart rate, blood pressure, and body temperature, and warns the patient of any serious health conditions.

A health-care professional (HCP) is responsible for setting up and customizing CodeBlue for a specific patient. Using the BS, the HCP can also specify a range of normal and critical values for the vital signs so that the system can alert the HCP when an abnormality is detected in the physiological state of the patient as well as monitor the history of previously collected readings. The WS allows the HCP to remotely view the patient's physiological data over the course of up to 24 hours, and submit text instructions to the patient.

3.2 VSS (Video Surveillance System)

Video surveillance systems with built-in motion detection capabilities have many applications, from enterprise security to smart homes and assisted living. Regardless of the final intended application, any such system requires one or more cameras and associated video capture hardware in addition to intelligent software, able to detect and take action upon a motion-triggered event. The exact nature of the triggering event and the type and amount of motion that is considered relevant may vary from one application to the next, as well as the action that results from such detection.

VSS uses two X-10 security video cameras, a video multiplexer, a PC with video capture capability, and a wireless PDA with video playback capabilities. The multiplexer alternates between the two cameras, each of which monitors a separate room, where it is assumed that there should be no movement. VSS software implements automatic thresholding algorithms for motion detection. Once a significant amount of motion is perceived in either room, the system generates a trigger event to capture one minute of video in compressed MPEG format, which is wirelessly transmitted to a PDA.

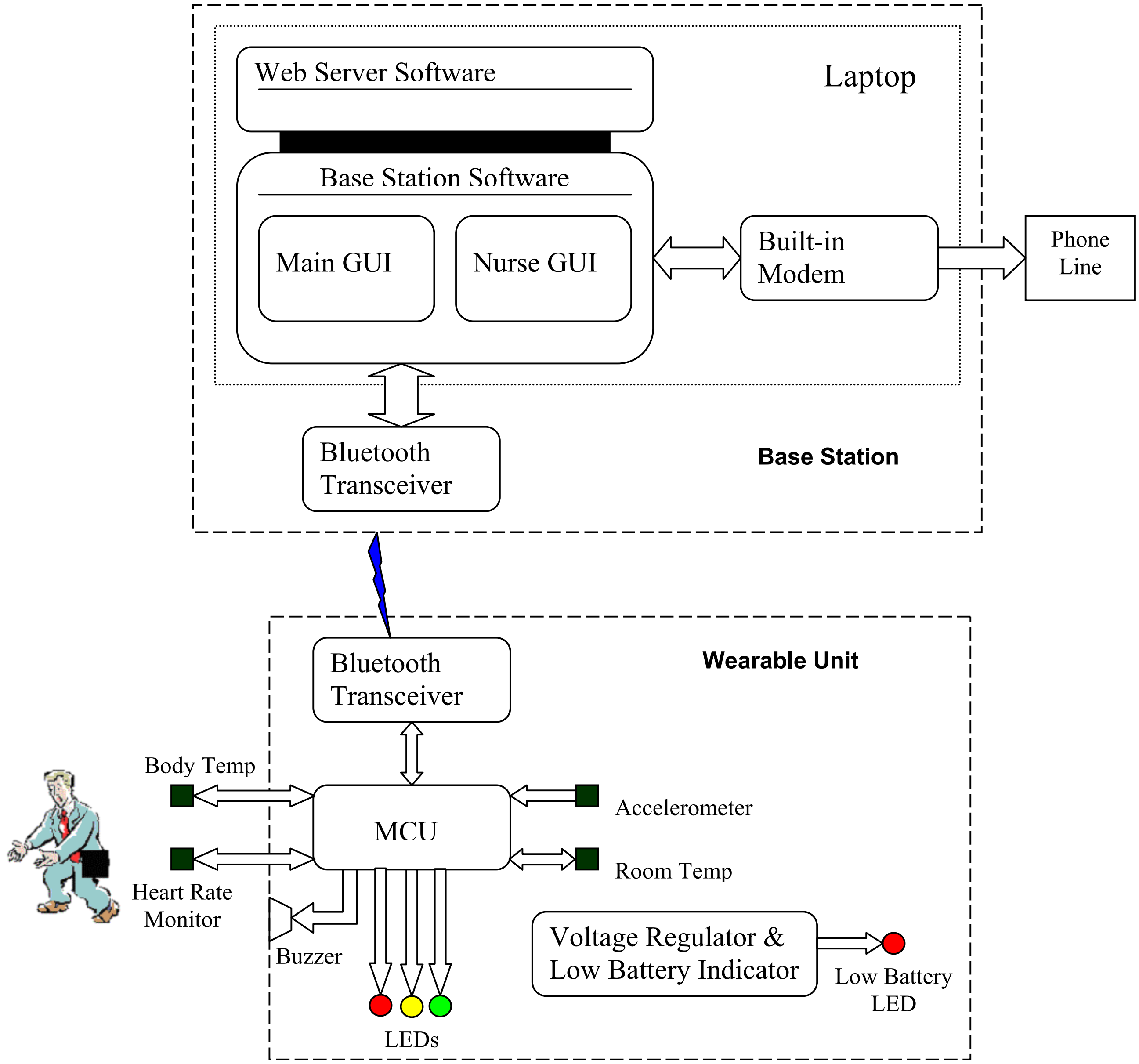

Figure 1: CodeBlue: conceptual diagram.

4. ALMAS

Our vision for the ALMAS project is to integrate location tracking technology with sophisticated video analysis and wireless multimedia technologies to create an environment that provides safe and effective health care for the elderly.

A prototype of the ALMAS system has been designed and developed at the Multimedia Lab in the Department of Computer Science and Engineering at FAU. It consists of the following physical components (Figure 2):

- a CodeBlue wireless wearable unit and a RFID tag attached to the patient, which store and transmit the patient's vital signs and location, respectively;
- wireless transceivers located throughout the facility, which communicate with the RFID tags and wearable units worn by the patients to track and locate them;

- video cameras throughout the facility, which constantly monitor the patients' activities and record them when a problem is detected by the tracking system;
- a PC with video capture capability, to which all the hardware (cameras, multiplexer, transceivers) are connected and on which all the software runs;
- a PDA capable of receiving alerts, video clips, and vital signs of the patient; the PDA is carried by a nurse or other health-care professional.

In addition to the CodeBlue vital signs monitoring capabilities, ALMAS employs wireless transceivers located in the patients' room and/or the hallway, which constantly monitor the location of the patient by communicating with the RFID tags attached to the CodeBlue WU. In the current patient tracking scheme, a patient's location is determined by the relative strength of the RF signals received by the RFID transceivers: the transceiver with strongest response is the one closest to the patient's current location.

ALMAS video analysis software uses a modified version of the algorithms originally developed for VSS, such that the video cameras continuously record the activities of the patient and automatically detect if there is a situation that warrants attention by the health-care professional. Examples of such situations include: patients that are perceived to be leaving the room or hallway towards an unauthorized area (a major problem particularly for ALFs with dementia patients) or patients that are found in unusual conditions (e.g., lying on the floor) for an extended period of time.

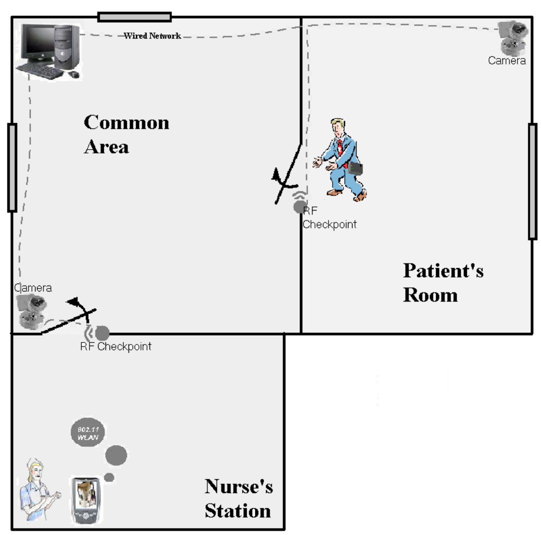

Figure 2: ALMAS: conceptual diagram and current physical layout.

Patient monitoring is handled by modifying VSS motion detection algorithm to understand what type and amount of motion is acceptable (and considered normal) and which areas of the screen should be closely monitored as potential indicators of the patient leaving an authorized area (room) and moving to an unauthorized area (common area). In our current implementation, we assume that one camera constantly monitors the patient's room, focusing on detecting motion in portions of the screen that may suggest that the patient is moving towards the common area. If such motion is detected and the patient is perceived to have crossed the line between the room and the common area, the second camera begins to monitor patient's activity and generates signals to alert the HCP. The alerts and associated video clips are wirelessly transmitted to the HCP's PDA. The HCP responds to the event by monitoring the video clip and taking appropriate action.

Determining a patient's position is the subject of ongoing improvements to ALMAS's video analysis software, to include the capability of inferring the patient's type of activity. The video analysis software tracks relevant objects for a number of consecutive frames, in order to classify the object's movement as either rigid or non-rigid. Once a moving object is identified as a non-rigid object such as a human patient, further analysis is performed to determine if the patient is standing, sitting, or laying down and consequently, determine the status of the patient.

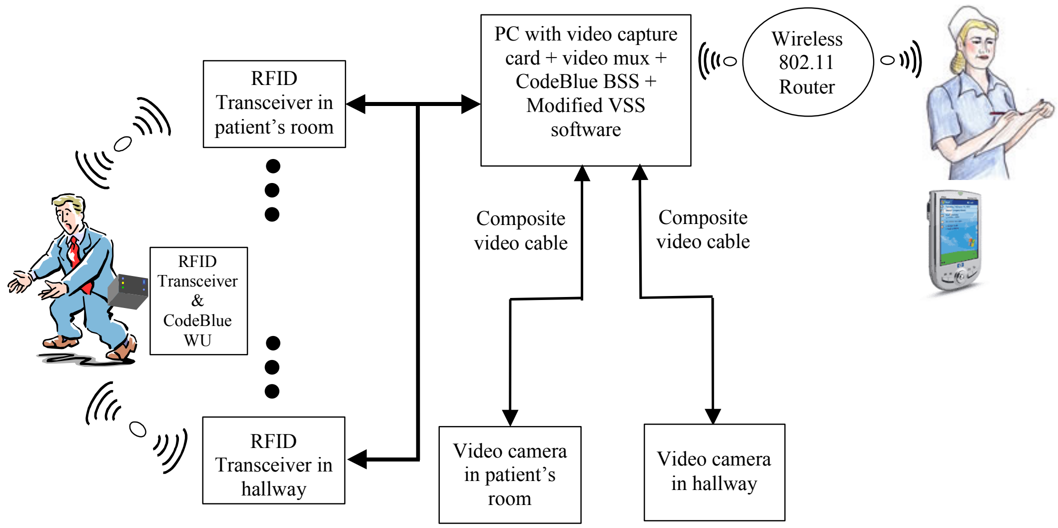

Figure 3: Functional block diagram for the current prototype of the ALMAS project.

5. Conclusions

Better quality of life in an aging society is an increasing problem and viable solutions must be presented as medical technology continually extends the human lifespan. By combining video and RF technologies into a ubiquitous care environment, a patient gains more freedom and a healthcare provider works more effectively towards the safety of those in their care. The concepts developed in the ALMAS prototype brings many inexpensive, commercially available technologies together into a cost, time and life saving system that the medical community and concerned family members can all benefit from. An authorized individual has the ability to monitor the location and physiological status as well as visually inspect any given patient within their health care environment. The ability to take that health care environment into patients' homes provides the freedom and independence that a patient may need to decrease the recovery time and regain a sense of pride.

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