Adaptive Assistance: Smart Home Nursing

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Abstract. Home nursing gains in significance with the human age being prolonged. More and more people reach the state when they need some assistance in order to live independently at their own. However, home nursing is a resource demanding activity stretching medicare to its limits. In this situation, new technology can help. Reflective assistance is concerned with the construction of flexible 'smart' systems that control the eldercare environment, adapting the ambient to the needs of individuals. New technology transforms a living space to a helpful residence assistant that observes inhabitants and offers aid or calls for it in the case of need. To achieve this goal, systems must be capable of monitoring the behavior of the elderly people and of responding to dynamic changes in their performance or physical and psychological situation. This paper describes an approach to design and develop a home ambient that offers medicare, mobile monitoring, rehabilitation exercises and improved comfort of elderly inhabitants.

Keywords: Medicare, Home nursing, Physiological computing, Patient monitoring, Adaptive systems.

1 Introduction

An important characteristic of smart technology [1] is a seamless and implicit human computer interaction that uses wireless sensor/actuator devices to detect user situation and respond accordingly. In order to offer smart assistance, the system must have some means of assessing the context of interaction without explicit user intervention. This can be done by making both human's behavior and inner state a part of the processing loop, e.g. by deploying the sense-analyze-react principle performing a seamless observation, situation evaluation and active reaction. Having a generic support for such implicit and awareness-rich processing would allow deployment of smart technology in a whole range of medicare areas.

Home health care consists of "a part-time skilled nursing care, physical therapy, occupational therapy, speech-language therapy, home health aide services, medical social services, durable medical equipment (such as wheelchairs, hospital beds, oxygen, and walkers) and medical supplies, and other services" [2]. Some of these services may be performed (in its basic form) without direct human participation. Recently, a new generation of control systems has been developed [3] offering control

K.S. Nikita et al. (Eds.): MobiHealth 2011, LNICST 83, pp. 240–247, 2012.
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strategy enriched by physiological and socio-behavioral analyses. Systems are called reflective as they diagnose users' physical, social and psychological state and react accordingly in a given situation. Such systems may significantly support home nursing, performing tasks where human presence is not necessary thus leaving more time for personal contact during the visits.

2 Theory behind

This approach deploys the concept of a biocybernetic loop [4,5] allowing for a multiple physiological sensing, composite analyses and decision making. The function of the loop is to monitor changes in user state in order to initiate an appropriate adaptive response. It takes results of affective computing and combines it with higher level understanding of social and goal–oriented situations. The approach is multi-modal as it takes into account different kinds of information, processing them in multiple loops at different time scales. There are three major phases of a single loop: sense, analyze and activate. These phases are repeated endlessly, where each consecutive cycle takes into account the effects of the previous one, performing constant self-tuning and self optimization.

The first phase of the bio-cybernetic loop is monitoring of the user in a given situation. The collecting of information can be done by observing: (1) overt actions (e.g. location, looking, pointing), (2) overt expression (e.g. changes in behavior associated with psychological expression), and (3) covert expression (e.g. changes in physiology associated with psychological expression).

The analyses phase of the biocybernetic loop is a process that involves psychology, physiology and behavioral science knowhow. In order to make an effective use of such diverse data, this approach relays on affective and physiological computing results and deploys rule-based reasoning. The loop is designed according to a specific rationale, which serves a number of specific meta-goals, defined by the application needs..

The final phase of reaction is devoted to the adequate system response which is performed through a certain action of the system actuators having further influence on both the user and the controlled situation.

Based on a better understanding of both personal involvement and social and behavioural situation of the user, a reflective system [6] offers adaptive control of different types and different time scales: (1) immediate adaptation supporting safety, (2) short-term adaptation responding to a more complex states that require several steps of self-tuning, (3) long-term adaptation providing individualisation as a process that guarantees that the system has co-evolved with individual user and can target its functioning to specific individual needs.

3 Implementation

Developing reflective software involves tasks like real-time sensor/actuator control, user and scenario profile analyses, affective computing, self-organization and adaptation. To accomplish these requirements, a service- and component-oriented

[6,7] middleware architecture, based on reflective ontology [8], has been designed that promises a dynamic and re-active behavior featuring different biocybernetic loops. According to the reflective ontology, the reflective software is grouped into three layers: (1) Tangible layer - a low-level layer that controls sensor and actuator devices; (2) Reflective layer - with more complex services and components that evaluate user states; (3) Application layer - a high level layer that defines application scenario and system goals; by combining low and high level services and components from other layers, application layer runs and controls the whole system.

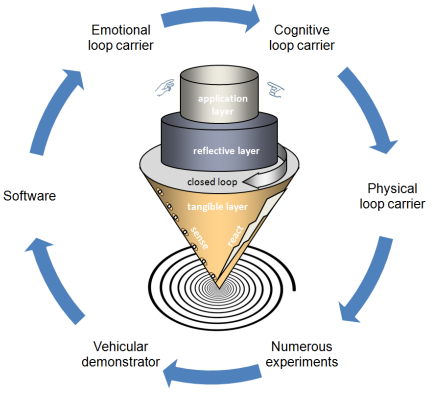


Fig. 1. Reflective architecture with the closed loop

Figure 1 metaphorically illustrates the reflective layered architecture as a spin top, exercising different temporal loops at tangible, reflective and application level. A control loop (initialized with users' profile and scenario settings) starts by sampling the psycho-physiological and other measurements, continues with their analyses and finishes by adaptive system reaction. In a next iteration the system influence (caused by the reaction) can also be sensed and further tuned. The overall design goal is to have a generic modular structure that follows the patterns of immediate, short and long term adaptation and is capable of dynamic configuration and efficient functioning.

4 Application

Reflective technology has been successfully tested in the automotive domain [9] implementing the concept of a "vehicle as a co-driver". Based on a comprehensive driver's psycho-physiological analyses and driving situation evaluation, the reflective vehicle features active support in driving by warning in case of high mental effort or dangerous driving situations, by adapting car entertainment according to driver's mood and by re-shaping the seat according to drivers comfort. However, being genuinely generic and re-usable, reflective framework can be deployed in a range of different application domains.

4.1 Reflective Home Care

A reflective home care for elderly people is currently under development [10]. The goal is to construct a flexible 'smart' ambient to control the home for elderly people offering both medical and rehabilitation services at one side and improving the quality of living at another. The system should transform a home into friendly and supportive home nurse. The functionalities offered include:

- Medical (physiological) monitoring;
- Rehabilitation support
- Seating/laying comfort;
- Monitoring of inhabitant movement;
- Monitoring of home appliances;
- Control of TV and media-rich entertainment;
- Communication with mobile devices.

Enriched with reflective assistance, a smart home plays an active role in everyday life supporting medical diagnoses and check-ups, rehabilitation and or physical exercises, watching health condition as well as emotional and mental state of the inhabitants.

Reflective support for each of the above mentioned functionalities is achieved by embedding numerous sensor and actuator devices into home settings and by deploying reflective control to these devices.

- Medical support consists of heart rate and blood pressure measurements – as regular daily check up, with warnings displayed on TV - and remote mobile monitoring by medical staff.
- Rehabilitation support controls exercise devices (e.g. home cycle or walking track) according to the instruction displayed on television. Physiological monitoring (e.g. heart rate, blood pressure) is done simultaneously guiding the exercise according to the body response.
- Comfort control is done via seating and laying sensors, checking the body pressure at critical points and modifying (if necessary) the shape of the armchair/matrices via air pumps [11].
- Movements control is done via cameras placed at each room and is used only for critical hot line warnings (in case of sudden fall).
- Home appliances are connected to automatic switch-on/off device allowing remote/mobile monitoring and control.
- Entertainment control consists of a mood player [6] designed to control entertainment center according to emotional response.
- Communication control connects to mobile devices allowing for urgent calls and remote monitoring.

With the above described functionality, reflective home performs many of the routine functions of a home nurse. It does daily medical check-up, assists in active exercise and rehabilitation, cares for inhabitant physical, emotional and mental state, reminds and/or overtakes the control over switching on/off the home appliances and supports mobile communication with emergency center, friends and relatives. In summary it

overtakes numerous medical, psychological, physical and social functions, complementing the work of a home nurse.

4.2 Reflective Support

The reflective framework [6] with its already existing support for ambulatory psychophysiological measurement and diagnosis offers a ready to use solution for a number of problems that appear in the domain of remote measurements and analyses of user states. This makes the reflective framework a straightforward means for the use within the home care scenarios.

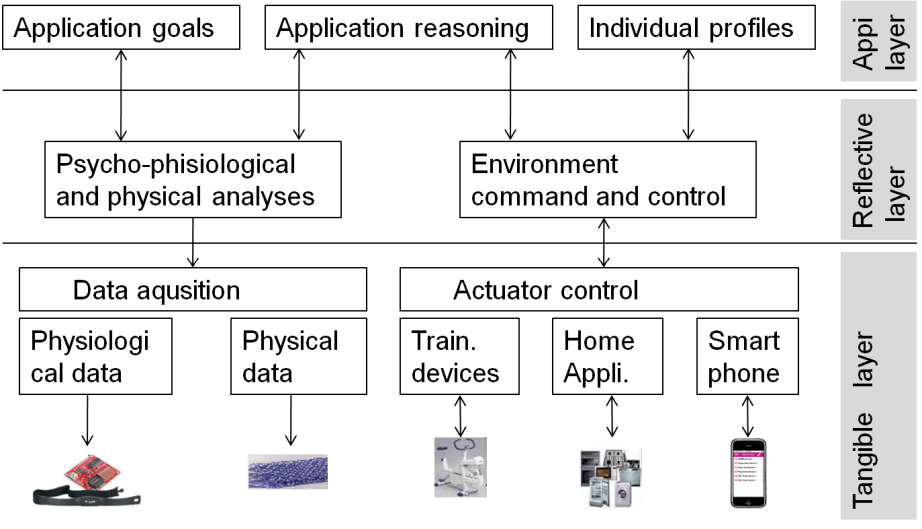


Fig. 2. Home care reflective layers

Figure 2 shows the organization and structure of the home care reflect deployment. The tangible layer provides interface to the required devices. The sensors are: the camera (for location tracking and posture detection) and physiological measurement devices. The devices containing both sensors (report the device state) and actuators are: home exercise tools, kitchen appliances, heating, air-condition, lighting, television (used for visual assistance and entertainment) and the communication module. Tangible interface for the devices from Table 1 already exists and the interface for the devices from Table 2 is currently under development.

Reflective layer fuses the sensor measurements and performs diagnoses of the user condition (e.g. by physiological measurement during exercises). At this level, high-level commands are given to the system control component, which are further decomposed to the concrete actuator devices. The core logic for the event driven behavior and supportive reaction of a biocybernetic loop is given in the reflective taxonomies [8] for the concrete situation. For example, safety actions in case of exceptional values obtained from the sensors are triggered automatically as they are built into the system through inter-relationship among ontology entities and short term

biocybernetic loop response (in case that camera through posture recognition detects "an accident" – emergency will be alarmed). The reflective layer also deploys a rule-based reasoning to perform diagnosis and to trigger further system actions.

The application layer maintains a personal database and uses the same rule based engine to make decision how the system should function, according to the predefined system goals. Different factors are used in making the control strategy. For example, if the blood pressure shows "high" value during a routine check-up, an alarm will be raised contacting the medical center. However, if the same value is obtained during the exercise, a warning will be raised instructing to stop with the training and to repeat blood pressure check after 10 minutes. Such a strategy is combined with personalized charactreristics as "critical margin" may differ from person to person. In a similar fashion all other system strategies are implemented as rules and are used to control other system components (remote medicare, remote/mobile kitchen control, etc).

Table 1. List of devices with existing reflective controllers

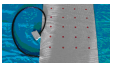
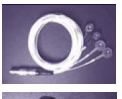
Device	*Picture*	*Description*	*Model Id.*	*Data*
Force Sensors Cushion		16x16 Force sensors matrix	pressure mat system Pliance X (Novel)	CoP position vs time
Camera		web cameras	Hercules Classic1,3 MgpixVGA	Facial exp.; posture
HR sensor		2 channel ECG sensor cable	Article: NX-EXG2-2A	ECG raw signal
Respiration sensor		RSP sensor (respiration)	Article: NX-RSP-1°	RSP raw signal
Bio-sensors		Multi-channel datalogger (10-chan.)	Nexus10	Bio-sensors raw-data
Skin Conductance		GSR sensor (incl. fingerclips)	Article: NX-GSR-1A	SC raw signal
Skin Temp sensor		Temperature sensor (skin)	Article: NX-TMP-1°	SkinTemp raw signal
Smart phone		Remote monitoring and control		Internal objects

Table 2. List of new devices needed for home medicare

Device	*Picture*	*Description*	*Model Id.*	*Data*
Training devices		Speed meter,	-	Speed effort
Home appliances		Fridge, cocking devices, air condition	-	Switch On/Off
Entertainment		TV set	-	Multi media
Bubble mattress		Anti Decubitus mattress		Pressure points

The modules for interfacing and high-level diagnoses for the devices from the table 1 could be used without any change. The corresponding software for the devices shown in table 2 is presently under development.

5 Conclusion

The paper presents the use of the reflective approach, a novel technology featuring seamless man-machine interaction in solving problems in domain of health care (home nursing), ambient assisted living and eldercare. A new application domain responds to the challenge of modern societies "growing older" with increasing need to support elderly population in independent living. A number of scenarios are described that are designed to support senior citizens in medicare, comfort living, socializing and home services. The reflective assistant effectively supplements a number of duties that home nurse traditionally performs.

The major reason for developing reflective computing has been to enrich smart systems with genuinely supportive behavior in terms of doing what the users need in a seamless and personalized way. The advantage of this approach is in introduction of an adaptive component-oriented technology that offers a generic solution for a wide application spectrum, from entertainment, via ambient assisted living and medicare up to embedded real-time systems. Reflective computing uses psycho-physiological measurements to determine emotional, cognitive and physical user states that are further used to tune the system reaction. The framework features multiple levels of adaptation and pervasive behavior.

Most of the functions described in this paper have been already developed for another application domain[6,9] and could be re-used directly. Other functionalities (e.g. home

exercise control and home appliances control are under development). Looking at the nursing home checklist [2], it may be concluded that reflective support – as a home nurse assistant - fulfills important requirements, a nurse must satisfy: medical competence, pleasant behavior, a good sense for temperature, atmosphere and well being at home, remaining at the same time silent and respectful towards residents, sensitive to emotional, physical and mental state of the people, 24 hours available and ready to communicate with friends, relatives and medical experts. Covering such a spectrum of activities, the system eases the home nurse work and leaves the nurse more time for human contact – the function that technical system can never substitute.

The future work is seen in further extension of the use of reflective technology in medicare domain. This primarily requires refinement and enrichment of the reflective ontology in providing support at all levels of reflective programming: namely interfacing new devices, diagnosing new situations and enlarging its knowledge base. Mobile monitoring is also under development including access to most of information collected by the system via mobile phones, thus binding smart technology with human control and intervention. Improvements in the domain of information protection are also on the research agenda as the system deals with highly sensitive personal information that should not be available for any other but humanitarian use.

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