User Interaction Design for a Home-Based Telecare System

Spyros Raptis, Pirros Tsiakoulis, Aimilios Chalamandaris, and Sotiris Karabetsos

Institute for Language and Speech Processing – "Athena" Research Center,
Artemidos 6 & Epidavrou, GR-15125, Athens, Greece
{spy,ptsiak,achalam,sotoskar}@ilsp.gr

Abstract. This paper presents the design of the user-interaction component of a home-based telecare system for congestive heart failure patients. It provides a short overview of the overall system and offers details on the different interaction types supported by the system. Interacting with the user occurs either as part of a scheduled procedure or as a consequence of identifying or predicting a potentially hazardous deterioration of the patients' health state. The overall logic of the interaction is structured around event-scenario associations, where a scenario consists of concrete actions to be performed, some of which may involve the patient. A key objective in this type of interaction that it is very simple, intuitive and short, involving common everyday objects and familiar media such as speech.

Keywords: home-based system, speech interface, text-to-speech, smart home, telecare.

1 Introduction

Within the European States the percentage of older people is growing. The population structure of all European countries is changing with a large increase in the proportion of older (65+) and very old (80+) persons. Consequently, the need for caring assistance is increasing and national health services have a responsibility to manage for this need. As the population ages it experiences more chronic health problems. Chronically ill patients account for three quarters of all healthcare expenditures.

The pattern of care is also changing. Current European policy implies transfer of resources to care in the community and informal care to facilitate supporting arrangements. The challenge for Europe will be to provide good-quality care at manageable cost to a growing number of people. Thus, support for informal caring may improve care competence, prolong or extend caring capacity and provide value with respect to care delivery [1].

The increasing cost of providing healthcare services and changing patterns of use of hospital resources (a rise in admissions but a fall in the average length of stay) are powerful forces for shifting the focus of care from the hospital to the home. Moreover,

A. Holzinger and K. Miesenberger (Eds.): USAB 2009, LNCS 5889, pp. 333–344, 2009.

there is strong evidence that most people (especially the older ones) prefer to remain at home. One of the key reasons for this is ‘independent living’. There is also substantial evidence that healthcare outcomes and quality of life improve when healthcare services are home based [2, 3].

Thus, there is a shift of interest towards enhancing patient independent living and quality of life by providing the means for safe and unobtrusive monitoring and quality care at manageable cost to a growing number of people away from hospitals.

The “Information for Health” document published by the NHS Executive in 1998 [4], recognised that "telecare technology will be used to provide reliable but unobtrusive supervision of vulnerable people who want to sustain an independent life in their own home". The development of telecare and monitoring services is also included in the published national strategic programme for IT in the NHS [5]. The recently completed Australian Coordinated Care Trials identified home telecare as having significant potential for contributing to the management of patients with acute exacerbation of chronic conditions as well as at-risk elderly people living alone at home.

In this direction, there have been numerous efforts to design and develop infrastructures that would enable and support patients with chronic diseases (see for example [6]). Home telecare technologies have been reviewed by several authors [7, 8, 9, 10]. Many of these infrastructures include a home-based component for remote monitoring with integrated medical inference and controlled decision making capabilities. State-of-the-art measurement and data acquisition is employed through communities of devices and artefacts, wireless data transfer and communications, data fusion, medical inference and decision making, and automatic planning and execution of advanced response patterns and interaction scenarios.

Work has been carried out on the user interaction design issues of wearable health monitoring devices (e.g. [11]). However, such systems are quite different in target and scope, since they are tailored towards lightweight portable solutions that are always attached to the patient and can monitor a set of crucial health parameters. They do not fuse multisensory information and they do not need to consider multimodality in the user interaction.

It should be noted that some real and potential problems in the application of telecare and smart homes have been identified [12].

2 The HEARTS System

The HEARTS project (Home-Based Everyday Activities analysis and Response Telecare System) emerged in this context. The aim of the project was to design and develop an adequate infrastructure that, based on information, communications, measurement and monitoring technologies would be able to constantly evaluate the health status of a patient at home and intervene when necessary to avoid deterioration. This involved the development of an integrated home telecare system encompassing devices from different generations available, the investigation of methods of embedding everyday artefacts and smart home technology into this system, enhance available signal processing and data analysis algorithms and finally implement a proof-of-concept system consisting of the relevant sensors, data collection devices, algorithms and networking within a typical home environment.

The project focused on congestive heart failure (CHF) patients. Its scope well exceeding the simple monitoring and plain comparison of measurements to predefined values that could lead to alarms. It also covered the identification of time-varying patterns of important health variables and the prediction of their evolution. The sensitivity and specificity of the system's operation provide the basis for measuring the quality of the performed medical inference and decision-making.

The infrastructure of the HEARTS system comprised of:

- a local *data collection mechanism*, fusing information from multiple diverse sensors, both body-attached and fixed at specific locations at the home environment. These sensors provide not only measurements of important patient health parameters but also information on activities of daily living (ADL)
- a local *data processing system*, that performs some preliminary checking on the obtained data, takes any emergent actions necessary, and forwards the data to the remote server for further processing
- a *remote server* that, based on the collected information, performs preventive medical inference and medical decision making, also taking into consideration the patient's past medical data
- a *local response mechanism* for conveying system feedback to the patient and initiating interaction scenarios when appropriate
- a *remote response mechanism* involving a health service provider to take appropriate measures when deemed necessary.

Minimal daily life disturbance and unobtrusive supervision were very important factors. This relates both to the arrangements required for setting up the system to the patient's home and to the patient participating in the process. Necessary devices and sensors needed to be as transparent to the user as possible and should avoid affecting their mobility. This implies movable wireless low consumption devices (with the exception of the ones that need cannot be to be large or devices that are attached to fixed objects).

The patient's active participation should not be required in the system routine use. However, for tasks where this is inevitable (e.g. during measurements that cannot be done automatically or, periodically, when sensor need to be calibrated) the interaction with the system should be very simple, intuitive and short.

When potentially negative trends are identified in the monitored health variables, the system issues effective pre-alarms or alarms, involving the automatic creation and execution of in-situ responses (such as audible and/or visible feedback through appropriately adapted familiar common devices) and external responses (engaging health service providers and other formal and informal health structures). Interaction scenarios with the user are integrated into the system's operation either as part of a medical data acquisition schedule or as an automatically created system response. These involve a set of (intelligent) communication devices such as visible feedback devices (e.g. a TV set for displaying a message or alert), and audible feedback devices (e.g. a text-to-speech system for voice messages).

3 System Responses

The medical inference and decision making process of the system provide estimates on the patient's health condition, identifying potentially dangerous patterns in the monitored variables based on the patient's personal profile.

To the event of such a potentially dangerous situation being identified, the overall system has to provide appropriate responses the range of which should differ according to the nature of and level of the predicted declination.

Two major response paths can be identified:

- *In situ responses*, i.e. actions taken at the patient's site
- *External responses*, i.e. actions involving the intervention of external health service providers

3.1 In Situ Responses

In situ responses refer to the actions taken at the patient's site, i.e. locally at home. When a declination pattern has been identified, system responses could range from a quite simple to more complex interaction schemes. Such responses ranged from:

- An audible feedback conveyed through to the patients informing them of a potentially dangerous situation
- A voice message being conveyed to the patient providing simple instructions, e.g. informing them that they should take a rest, try to relax, take a medication, etc.
- A voice message prompting the patient to call their attendant physician for further instructions
- A visible feedback conveyed through common house media, such as the television, etc.

Common house communication media provide the main interaction channels used during an in situ response. These devices will need to be appropriately adapted and enhanced with wireless LAN support to serve for these purposes. They offer audio and image.

Audio (sounds and voice) may be conveyed through the patient's stereo or television set. Text-to-speech technology will be employed to synthesise audible messages and prompts. This provides an important advantage over pre-recorded messages since it enables easy customisation, personalisation and maintenance of the message content and alleviates the need for producing recordings of the all required material. Moreover, voice parameters such as rate and pitch can be configured according to each patient's personal preferences.

An important issue that needs to be addressed when designing such interaction schemes, is the location of the patient. Information on which room the patient is currently in is important for the system to route feedback to the appropriate devices, so that the message can reach and be perceived by the patient. Body-attached devices or motion capturing devices can serve for this purpose.

The medication schedule component is an additional function provided by the system. Each patient's medical profile will contain information on the patient's medication program. An in situ response may be produced automatically by the system at appropriate times to remind the patient to take the necessary medication.

3.2 External Responses

When a potentially problematic situation is identified for a patient by the medical inference and decision making module, the system may also trigger alerts directed to the health service provider (in parallel to the in situ responses that may be scheduled) depending on the severity of the situation.

The health service provider will need to respond by taking the necessary actions and intervening, when appropriate, to assist the patient and prevent deterioration.

These actions may range from a telephone call to the subject from a specialist to provide some instructions, to an emergency signal and an ambulance departing to transfer the patient to the hospital.

Of course, the technological and administrative issues related to this framework, including the health service provider signalling and response mechanisms, need to be explicitly defined.

4 Interaction Scenarios

There are certain tasks where the patient's active participation is inevitable, e.g. during measurements that cannot be taken automatically (e.g. systolic, diastolic and mean blood pressure, blood oxygen saturation etc.) or, on a periodic basis, when the sensor will need to be calibrated. In these cases, the interaction with the system should be very simple, intuitive and short.

Scheduled interactions scenarios can be used for different purposes. A regular interaction can be useful for asking simple questions to the patients aiming to evaluate additional aspects of their health (such as their mood, their psychological state etc) and to detect signs or symptoms that are still not evident in the other monitored parameters but which could have predictive value for early identifying an upcoming degradation.

An additional reason for invoking interaction scenarios is the widely recognized significance of patients being aware of their health status, the feeling of active participation in its improvement and the appreciation of the results of the therapy followed.

The aim is to design a module for forming and executing appropriate scenarios. The interaction can be much more immediate and effective if it involves familiar objects and familiar modalities such as speech.

Some of the scenarios that have been foreseen are summarized in Table 1 below:

Table 1. Some examples of possible scenarios involving the user

Scenario	Type[1]
S1. Scheduled daily test. This is actually a variant of the 6-minutes-walk test, that patients carry out daily, usually at morning hours. This test can be used to identify indications that could endanger the patient's health. The test can lead to some preliminary conclusions on how the patient's health evolves.	S
S2. Examining patient's speech. In this scenario the patient's speech is recorded and certain parameters of the signal are analyzed aiming to identify significant deviations from his/her regular speaking patterns. A deviation could, conditionally, be considered as an indication of an impending deterioration.	S
S3. Cardiogram. A cardiogram is an important tool for drawing initial conclusions on the evolution of a patient's health. This scenario is carried out 4 times a day.	S
S4. Basic consultation. Often, it is possible that a patient feels atony, fatigue or dysphoria. The purpose of this scenario is to support to the patient in such cases by providing basic advice and guidance. The scenario is based on a set of questions and answers between the system and the patient through which the system collects information regarding the symptoms and offers suggestions for dealing with the situation such as, for example, taking a rest, taking a medicinal product or contacting the attendant physician or a family member.	U
S5. Medication reminder. Based on stored information regarding the medication schedule of the patient, the system automatically engages into interaction scenarios to ensure that the patients follow their program.	S
S6. Manual alarm. An emergency device, such as an alarm button, can be used to automatically fire an alert for immediate contact with the appropriate recipients, such as the security personnel or a family member, or to raise a (pre-)alarm.	U
S7. Monitored parameter off the limits. Except from the constant and periodic sampling of the patient's monitored health parameters and posting them to the remote server, the local system is also responsible for performing a first check of their values. This check roughly consists of comparing against the personalized limits that have been defined for each patient. A significant deviation from the reference values will activate this scenario.	U

5 The Scenario Execution Module

5.1 Structure and operation

The operation of the interaction scenario execution module is based on *events*. Different situations raise different events. For example, if a monitored parameter of patient is found to be outside its acceptable range, then an event is triggered. The execution module associates every possible event to an *interaction scenario*. As soon as the event is triggered, the module invokes the corresponding scenario step-by-step.

Structuring the execution module on the basis of event-scenario associations, provides an open solution offering flexibility and adjustability to diverse requirements and different needs. New scenarios can be designed and dynamically linked to different events.

Fig. 1 below illustrates the link between measurements, events and scenarios.

[1] Scenario type. Can be "S": Scheduled, or "U": Unscheduled.

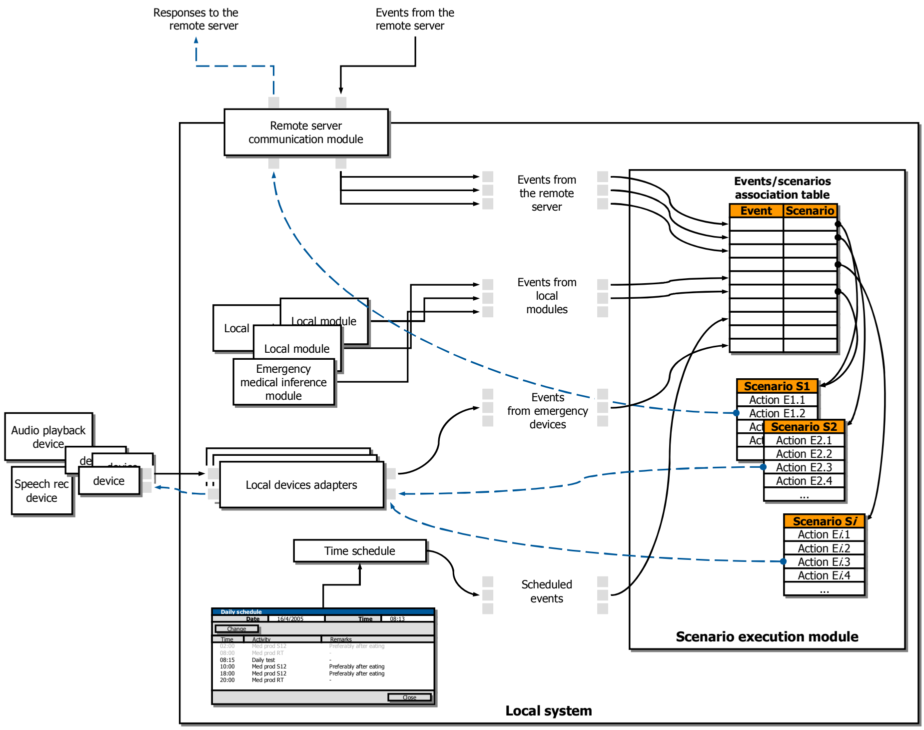

Fig. 1. Measurements, events and scenarios

The basic event categories are shown in the following table.

Table 2. Basic event types

Event Type	Description
Time-scheduled events	Such events are triggered, for example, from the medication scheduler of the system at the times when the patient needs to take a medication. A regular daily test is another example of a time-scheduled event.
Events from local modules	These are events that are triggered from the modules of the local system as, for example, the medical inference module, when significant deviations are observed in the monitored parameters.
Events from the remote server	Such events are triggered from the remote server. This could happen (a) automatically, e.g. in case a problematic situation is identified by the remote medical inference module, or (b) manually, e.g. by the security personnel in response to a pre-alarm.
Events from emergency devices	These events are triggered from specific types of emergency devices, such as emergency buttons, alarms or devices attached to the patient that are able to detect a fall.

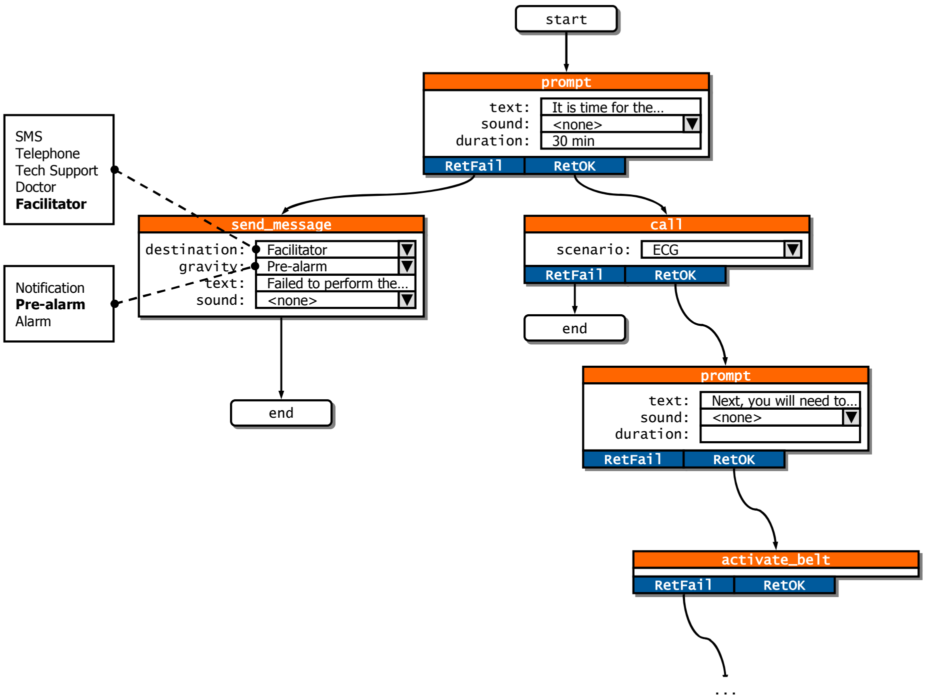

Fig. 2. Part of an interaction scenario for the 6-minutes-walk test

The execution module associates each event to a scenario. Each scenario is composed of a set of *actions* that are executed sequentially, each of which can involve other modules, devices or the patient himself.

In cooperation with the other modules of the local systems, the execution module supports a specific set of possible actions that can be combined to create appropriate responses for any event. Thus, a scenario is basically an action script.

Fig. 2 shows part of an interaction scenario with the respective actions that comprise it. This scenario corresponds to the daily 6-minutes-walk test.

For each action there is a set of associated:

- *arguments*, that specify the different parameters of the action
- *results*, that capture the possible outcomes of the executing the action (success/failure)

Thus, an interaction scenario is actually a script or a “program” written in the language of the system, and every “instruction” corresponds to one of the available commands.

5.2 The Operational Environment

The execution module operates in the background, receiving events from the local system (and, through that, from the remote server too) and executing the corresponding interaction scenarios.

The module interacts with:

1. the *end-user* (the patient) in the course of executing an interaction scenario, for example to remind the patient of a task or to offer information
2. specialized personnel that is responsible for designing and/or configuring the interaction scenarios so that they meet the patient's particular requirements and needs.

Interacting with the End-user. During the execution of certain actions from an interaction scenario, it is necessary to update or to engage the patient. For such interactions, the execution module employs simple patterns involving the equipment of the local system (monitor, speakers, keyboard, mouse etc).

For example, an action that would need to carry a notification message to the patient would display the following window:

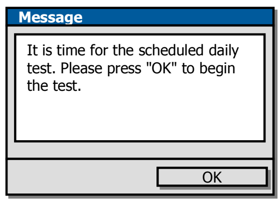

Fig. 3. A message box with an audible notification

This message is also read out loud through synthetic speech and, optionally, accompanied by an audio prompt. If the scenario is required to make sure that the patient gets the message, the synthetic speech (and the audio prompt) would be repeated for a specified number of times or until the patient dismisses the message box by hitting any key on the keyboard. This interaction step, as described above, corresponds to an action of the execution module, the `prompt` action.

The execution module integrates text-to-speech technology for producing the audio messages and prompts. Synthetic speech presents several advantages over prerecorded messages, since it allows easy adaptation and personalization, and can offer the ability to change the content of the message without the need to manually produce all the new recordings for the necessary prompts. Furthermore, its parameters such as the speech rate and pitch can be adapted to preferences of each patient.

The user has access to the full set of scheduled interaction scenarios, including the ones that relate to the medication schedule. This information is made available through the simple view shown in Fig. 4.

In this figure, the various activities (corresponding to interaction scenarios) are displayed ordered by time. Gray letter font is used to differentiate past activities that have already been performed. In the specific situation displayed in the figure, the current time is 08:13; all activities scheduled for earlier times have already been performed. The next scheduled activity is the daily morning test. The majority of the activities shown in the figure relate to the medication schedule.

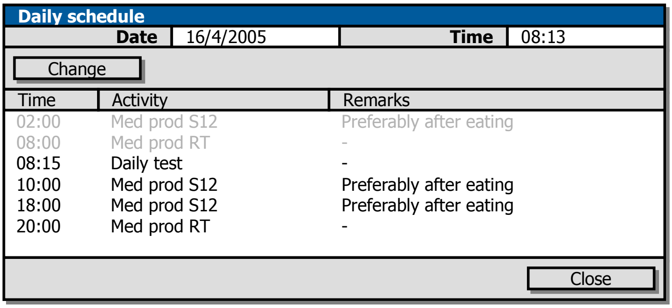

Fig. 4. The list of daily schedule activities

Event-scenario Association Environment. This purpose of this environment is to link possible events to appropriate interaction scenarios and is only addressed to specialized personnel.

The basic interface of the environment is shown in Fig. 5 below. In this view, the user can activate or deactivate event-scenario associations and to define new ones.

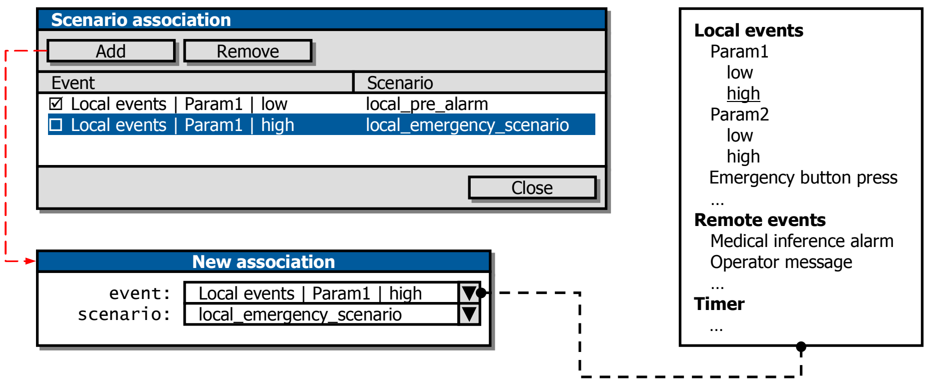

Fig. 5. The event-scenario association environment

Scenario Creation Environment. The execution module offers a basic simplified graphical environment for creating interaction scenarios (scripts), and is addressed to specialized personnel. The approach follows that of a typical simplified programming language.

Starting from an initial state, the user can add commands (selecting from a list of available commands) and configure their arguments. Furthermore, the user can define the execution flow by linking commend results to appropriate following commands.

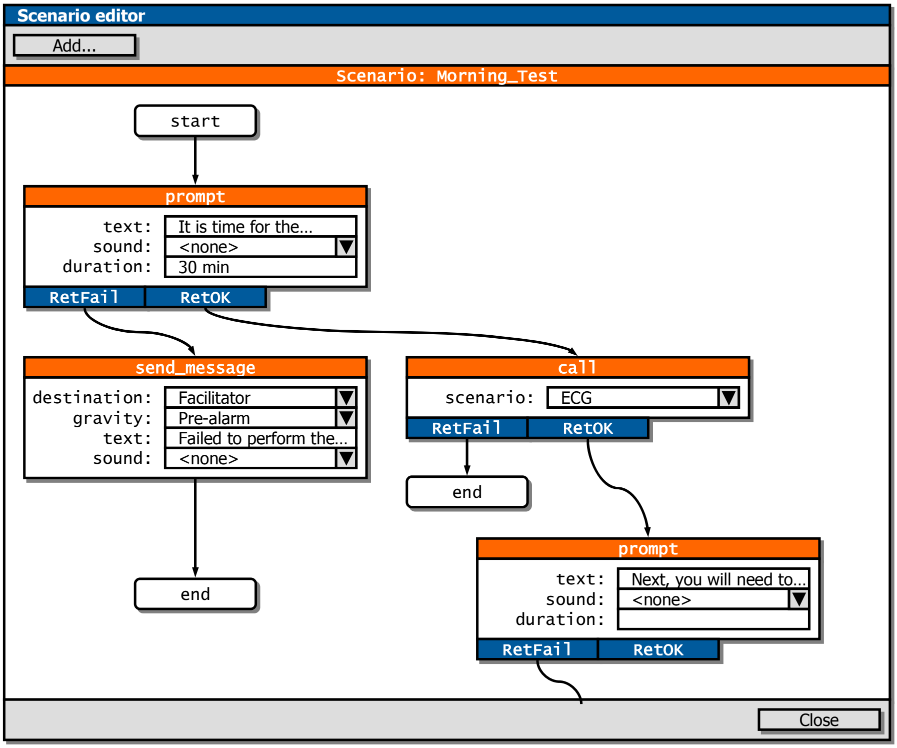

Fig. 6. The scenario editor

6 Conclusions

An overview of the mechanism and the underlying concepts of human-computer interaction for the case of a home-based telecare system has been presented.

The system's operation is designed to be mostly transparent to the patient. However, in certain cases when a potentially hazardous situation is predicted the system intervenes and interacts with the user. The interaction is triggered by events of interest which, in turn, activate interaction scenarios that involve home devices and the user himself. The interaction can be made much more direct, effective and intuitive when it involves common everyday objects such as the TV set, and familiar media such as speech and image. However, depending on the information to be conveyed to the patient, the patient's location within the limits of the house, and other factors, appropriate interaction patterns need to planned and executed. Structuring the execution module on the basis of event-scenario associations, provides an open solution offering flexibility and adjustability to diverse requirements and different needs. New scenarios can be designed and dynamically linked to different events.

Acknowledgements

The work presented in this paper has been co-financed by the Greek General Secretariat for Research and Technology, Ministry of Development in the context of the "Competitiveness" Operational Program under the Third Framework Programme.

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