

HealthPal: An Intelligent Personal Medical Assistant for Supporting the Self-Monitoring of Healthcare in the Ageing Society

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Abstract. In this paper we introduce HealthPal, an intelligent dialogue-based mobile health monitoring system, which aims at supporting the elderly people who lack IT skills into monitoring their health condition on a daily basis, in their preferred environments and without relying on the assistance of their caretakers. HealthPal is a software application that we have designed in order to assist the ageing society take care of their health related needs in an independent and autonomous manner. The most innovative feature of the HealthPal system is the dialogue-based application that it incorporates and which enables the effective interaction between the system and the user even if the latter has no technology skills at all. This paper discusses the system architecture and usage scenarios, while commenting on the expected social impact of the system on the ageing society in general.

Keywords: health monitoring application, mobile computing, dialogue system, wireless technology, PDA-based application.

1 Introduction

PDA-based medical software is revolutionizing the management and usage of patient records and special treatment needs in the health industry. Instead of jotting down notes and entering them later into a computerized system, the use of PDAs allows nurses and other staff members to instantly update the medical records and files of patients. However, existing medical software is currently targeted solely to doctors, nurses and caretakers. This paper addresses the exploitation of PDA-based medical technology from a totally different perspective, that of the ageing society.

In particular, we propose the implementation of a PDA-based medical suite that enables the elderly people monitor and control their daily health condition and health-related needs independently, in their preferred environment, while aiming to minimize the required amount of training and ICT skills required for its use. We call our system *HealthPal* because we strongly believe that it will accompany the elderly people in their daily activities, making them feel more self-confident when it comes to taking

care of themselves. HealthPal is an intelligent, powerful and adaptive health monitoring dialogue-based system, which aims at assisting the elderly people control and manage their health condition on a regular basis, without relying exclusively on their doctors or caretakers.

Taking into consideration the increasing needs of the ageing society for medical treatment, their lack of technology skills, their limited financial resources, their decreasing functional mobility, as well as their raising sense of dependency, we propose a novel proactive system, that will enable elderly people to take care of their health independently (at a negligible cost and effort). In particular, the implementation of the HealthPal medical suite aims at the following targets:

- To aid the ageing society in monitoring their health condition on an independent and daily basis. In particular, the HealthPal system will store locally the users' medical records, their medicines' specifications, diagnosed diseases, recommended therapeutically treatments, examinations, vital signs, etc. These data will be analyzed by the system in order to create a user's profile summarizing her special health needs, as well as in order to aid the doctor in monitoring the patient's health progress or deterioration. The user's health profile will be a useful referential source not only for the patient but also for his doctor, as she will be able to follow the patient's health status efficiently and to tailor a therapy to the patient's specialized needs.
- To provide a quick diagnosis of symptoms and medical reference information relevant to symptoms as they appear, as a means of helping the elderly people decide whether their doctor needs to be contacted or visited. This will be made possible through a medical database that will be incorporated in the HealthPal system and which will store: (i) a pocket medical reference book, containing basic information on symptoms, causes, treatments for a variety of diseases and (ii) a handy medical dictionary, which will define and describe (using simple terminology) medical concepts. Based on the above information, the elderly people will be at a better position to estimate their health condition and decide on how to respond to new symptoms.
- To assist the ageing society in handling emergency situations. This will be enabled via a multimodal dialogue system that will be embodied to the HealthPal medical suite and which will incorporate a phonetic emergency mechanism, a patient mimics' interpreter as well as a speech communication device. Moreover, the HealthPal application will incorporate an alert mechanism that will issue reminders about medication taking times, doses, scheduled medical exams, etc. The dialogue system as well as the alert mechanism will enable the ageing people take care of their health in an affective and effortless manner, as their communication with the system will be entirely conducted via speech. Furthermore, the issued alerts will be forwarded to the patient's therapist cell phone in the form of emergency speed-dialed calls or SMSs.
- To make the HealthPal health monitoring and proactive system a powerful next-generation medical e-assistant for the ageing society. This will be achieved by employing multimodal control technologies, speech and natural

interfaces and intelligent dialogue modules so as to make the system as easy to use as possible.

Above all, the implementation of the HealthPal system will be based on a combination of advanced-of-the-shell medical engineering, PDA, WLAN, mobile computing and natural language text and speech processing technologies which will be integrated into a common, open and intelligent medical suite. This will guarantee that the user's communication with the system is efficient, extremely convenient, prompt, and interactive and that it does not pre-requisite any technology skills on behalf of the user.

In the following sections, we present the architecture of the HealthPal system, we justify the main objectives that our proposed system addresses and we outline the benefits that we expect from the use of our system by the ageing society.

2 Related Work

Currently, PDAs are used in the medical domain for a variety of purposes. Many applications such as "ePocrates"[5] and "AMDA Clinical Guidelines"[6] provide useful reference databases to doctors, including medical references and drug databases. Services such as Best Evidence services over the Internet for Evidence Based Medicine are an increasingly popular by-product of the existence of medical reference databases. Further to these, calculator software of varying complexity is available to assist the clinical decision process or the monitoring of statistics for patients. Calculators tend to be focused for either practitioner use (MediKit)[7], or patient use (e.g. Glucose tracker, Blood Pressure tracker)[8, 9] and some of them offer combined functionality. Evidence-based calculators also exist for PDA use (InfoRetriever)[10], which provide a good tool for clinical decision support.

Telemedicine and Home care IT applications have been the focus of study for several years. Monitoring application projects (such as the telemedicine device described in [21] and developed under the AMBULANCE and EMERGENCY112 projects[22],[23], research in [17],[18] and funded EU projects such as [11]-[15]), have demonstrated the potential of IT in healthcare. Further studies have shown that homecare is important both psychologically for the patient but also for the whole healthcare service due to its cost saving potential [19],[20]. However, past projects suffer from a number of limitations. Some implementations require specialist support and well-trained operators in order to be effective, such as in the case of mobile equipment for emergency response teams or home visit nurses. Other implementations have been designed so that they are usable by the patient, however, these are limited to a home computer environment, which is restrictive of the amount of support that can be offered. Some patients are homebound or indeed restricted to their beds and as such, might benefit from a home-based healthcare support system. For the majority of potential users who are mobile, the requirement for support in their healthcare-related activities still exists while outside the home environment. For these users, a laptop computer based solution could be adopted, however laptops are heavy and also quite good targets for thieves, therefore probably not an ideal device for elderly people to carry about.

Pervasive devices such as the VIVAGO[16] pulse monitoring system which comprises of a wrist-strap unit that transmits information wirelessly, show the potential of simple pervasive applications to support the elderly population's healthcare needs. However, such devices offer a very limited and targeted piece of functionality, which on its own, is probably not of great use to the doctor or caretaker. Clearly, an integrated and combinatorial system needs to be provided that is able to collect information that the doctor can use to provide more efficient treatment.

Our proposed system aims to address the shortcomings of previous projects by providing a solution which

- a) Is easy for elderly people with little or no IT skills to use.
- b) Provides a single system to collect and convey valuable information on the progress of treatment to caretakers and medical practitioners.
- c) Can support the healthcare needs of elderly people, including drug taking, examination and doctor's appointment reminders.
- d) Does not restrict the mobility of elderly people.
- e) Provides the same level of support to the aged in and out of the home environment.

3 HealthPal Architecture

The main components that the HealthPal system integrates consist of a powerful health monitoring system, which interacts with peripheral devices (e.g. blood pressure devices, thermometers) and existing PDA software applications (e.g. blood pressure monitors), in order to keep an updated medical record of each elderly user. Medical records are stored locally in the user's PDA device as well as on the doctor's personal computer. Health monitoring components periodically record the patient's health condition and vital signs and upon tracking of abnormal indications they post a message to the system's alert mechanisms. Alert mechanisms embodied in the HealthPal medical system instantly analyze the current condition of the user and depending on the analysis' results they set the level of alert (e.g. of high, moderate or minor importance) that they issue. Issued alerts are communicated directly to the doctor's site (cell phone, personal computer, PDA, beeper, etc) through the utilization of wireless technologies, such as Bluetooth, WLAN and so forth. To ensure the doctor's prompt reaction to the emergency alerts, we associate a number of checkpoints to the emitted emergency signals, by assigning a reaction deadline timestamp to every alert. The main contribution of the health monitoring system and the alert mechanisms concern the assistance of the elderly in caretaking their daily health needs, without relying on others. Moreover, the availability of the alert mechanisms aims at increasing the aged people's confidence in living independently in their preferred environment.

Furthermore, the HealthPal system aims at offering to the ageing society the means for accessing digital medical data, which currently they might be unable to explore either due to their lack of IT skills or due to the increasing costs associated with such access (these costs might include expenses for buying a personal computer, web connection fees, etc.). Medical data sources are stored in the HealthPal's local

medical database, which comes as a default module of the PDA-based HealthPal system. The user's accessibility to the medical data stored in the local database is enabled through an advanced dialogue-based data retrieval module that HealthPal incorporates.

The multimodal dialogue system, embodied in the HealthPal medical suite, is responsible for translating the user's voice requests to a formalism understood by the system and following on transform the system's responses into voice generated answers. Via the dialogue module, the elderly are able to interact with the HealthPal system in an efficient and effective manner, as it is not necessary for them to delve into the system's functional details. The most ambitious feature that the HealthPal system incorporates is an adaptive and powerful speech interface, which can be parameterized according to the aged people's differentiating healthcare needs and which forms the only entry point to the system's healthcare services and medical resources on behalf of the elderly users.

HealthPal also incorporates a series of advanced and intelligent modules, which aim not only at offering to the ageing society a complete and totally comprehensive health monitoring and proactive system but also at ensuring that this system is truly useful to the ageing people and comes to cover their real needs for healthcare services rather than being just another powerful system with a narrow usage by the ICT competent. In the following sections we describe the distinct modules that HealthPal integrates, the technologies employed for the provision of intelligent healthcare services to the elderly as well as the advanced modules that HealthPal incorporates, so as to address data privacy, data security and personalization issues.

Before delving into the technological details of the components and services offered by the HealthPal system, we briefly outline our system's architecture, as illustrated in Figure 1. Specifically, there are three different, yet complementary, types of services offered to the elderly users of the HealthPal system, namely (i) effective and effortless access to medical data sources, (ii) efficient monitoring of health condition and instant updating of the patient's medical records on both his PDA device and his doctor's server, and (iii) issuing of reminders and emergency alerts, when either the user or the doctor (or both) need to react in response to health-related requests/needs.

The implementation and provision of each of the above services is presented in the following paragraphs along with the technical requirements that will be explored, in order to enable the delivery of qualitative and intelligent services and modules via the HealthPal medical suite.

3.1 Medical Database

Immediate access to medical reference sources is vital not only for the healthcare personnel, but also for the people who are in constant need of healthcare services, as they can assist the decision making process when a medical condition needs to be treated. The proliferation of wireless technologies enable the prompt access to the plentiful online medical resources, through the use of handheld devices, like PDAs. By exploring existing technologies, we will implement a medical reference database that will be a backbone module of the PDA-based HealthPal system and will serve a

dual goal. On the one hand it will facilitate the aged people's access to medical knowledge so that they are adequately informed about the health issues they are confronting, whereas on the other it will aid the elderly in deciding how they should react upon experience of certain symptoms.

In particular, the medical database that will be a default module of the HealthPal system will comprise two distinct types of medical resources: a medical dictionary, giving simple definitions for technical medical terms, and a medical reference guide, offering small text units about the causes, the symptoms and the treatments of several diseases.

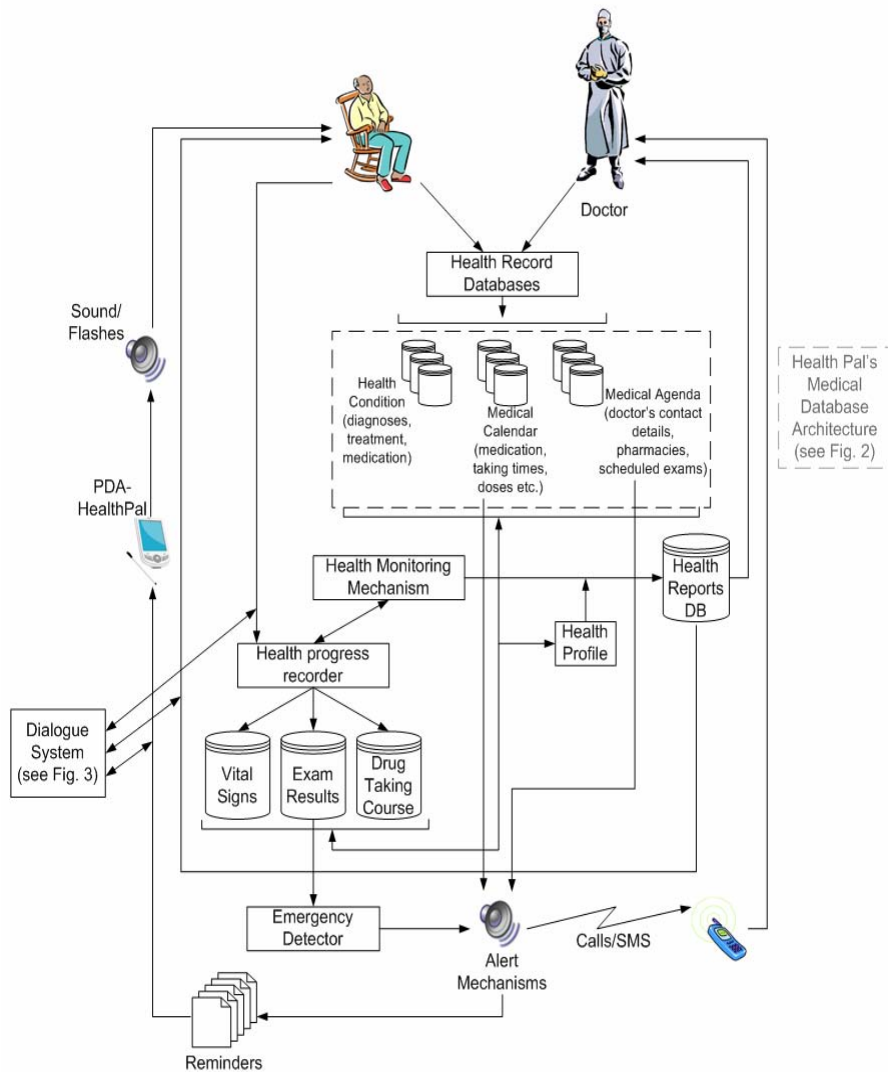


Fig. 1. HealthPal general architecture.

The medical resources field of the database will be populated according to the users' specific medical profile. In particular, upon creation of a new user profile in the HealthPal system, this profile will be analyzed in order to conclude on the diseases that the user is suffering from. For profiles' analysis existing medical ontologies will be consulted. Based on the analysis output (i.e. the suffered diseases) the database indexing modules will collect from a large pool of medical data harvested from the Web (such as the PubMed Online Medical database, the MEDLine database, etc.) those documents that relate to the user's profile. Those documents will be linguistically processed in order to extract short summaries descriptive of the disease causes, symptoms and therapy. The generated summaries will be used to fill the PDA's local medical database. The availability of those medical summaries will serve towards either informing the aged persons about the medical conditions they are interested it, or assisting them in making a decision as to whether their doctor needs to be reached. The medical database will be also a useful resource of information for the elderly peoples' caretakers and therapists. Figure 2 outlines the general architecture of the RDBMS medical database stored in the HealthPal PDA-based system, which will be implemented following a multi-tier architecture.

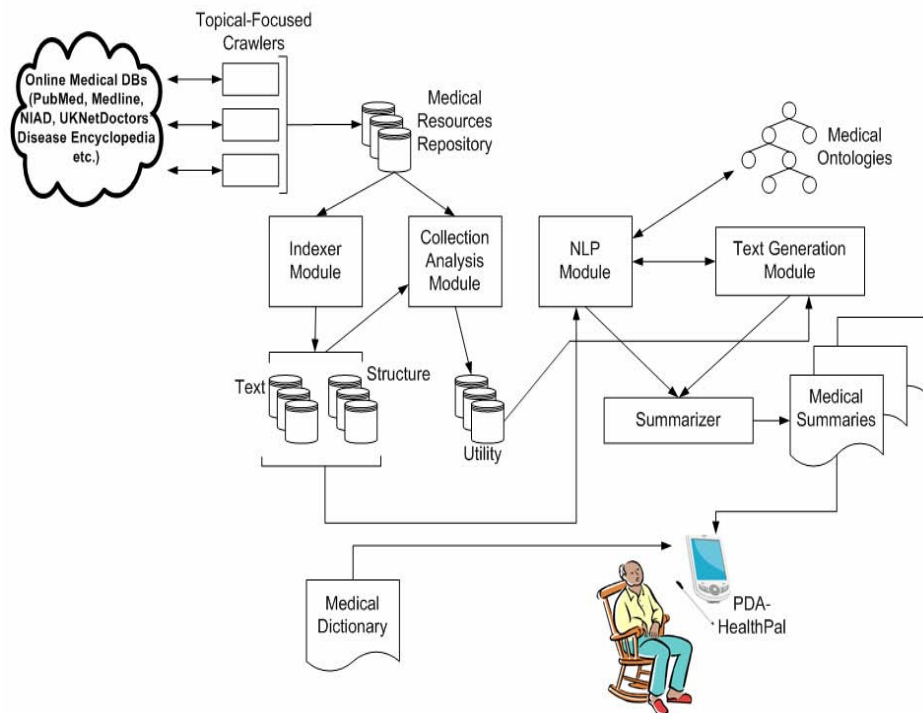


Fig. 2. HealthPal's medical database architecture.

4 HealthPal Multimodal Dialogue System

The HealthPal project will develop a user-friendly, mixed initiative multimodal dialogue system, which will facilitate the interaction with the users. It will provide functionality which will contribute for comfortable interaction with persons who have visual, vocalization, or hearing impairments. The general architecture of the dialogue system is presented in Figure 3.

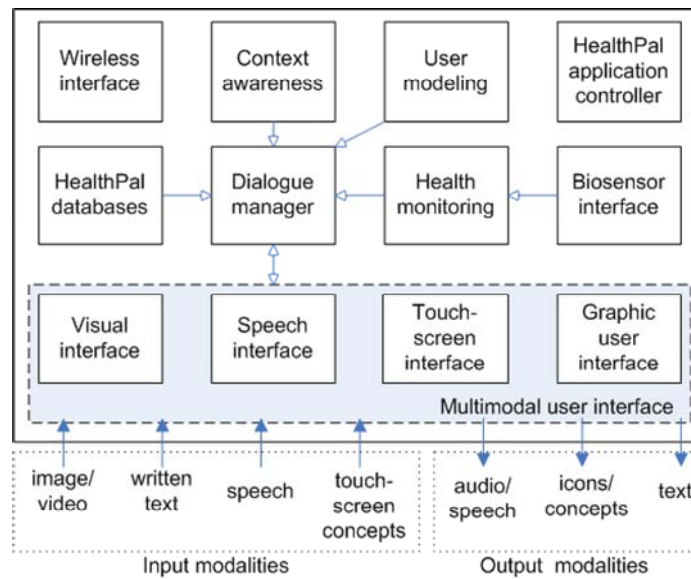


Fig. 3. Relations between the dialogue manager and the rest of the HealthPal system.

In order to facilitate the human-machine interaction, HealthPal will be capable of dealing with various modalities (image/video, written text, audio/speech, touch/GUI-based concepts, etc). In order to accommodate these different modalities, the dialogue manager will operate on level of concepts, which are modality and language independent abstractions. The conversion of the user input to concept and the system feedback from concept to output will be performed by the multimodal user interface. The user modeling and context detection components will also operate on level of concepts. They will provide supplementary information, which will be used in the system response generation and the dialogue flow steering process. In addition, the dialogue flow will be affected by concepts generated by the health monitoring and emergency alert components.

Besides the touch-screen/GUI interface, which is a standard for handheld mobile devices, speech interface will provide alternative means of interaction. This functionality will make it easier for elderly people, who are not technically inclined, and which often suffer from impairments, to communicate with the HealthPal device. The basic components of the speech interface are: speech enhancement, automatic speech recognition, speech understanding (speech-to-concept), dialogue manager,

natural language generation (concept-to-speech), text-to-speech. In addition, speaker recognition and emotion recognition components are options, which enhance the human-machine interaction.

The HealthPal project will build upon the existing speech technology, which will be ported to the HealthPal hardware. However, the limited resources of PDAs will certainly set many constraints. The main research efforts will be towards adapting the existing technology for the specific needs of the HealthPal users, accounting for the limitations of the specific hardware platform.

4.1 User System Interaction

HealthPal aims to facilitate a closer patient – doctor relation with the use of state-of-the-art technologies. The use of audio and visual signals and the speech engine, create a new human oriented environment for people that are not adept at using technology. HealthPal enables medical staff to acquire a better overview of their patient’s altering condition in order to promptly cater for their needs and to anticipate emergencies.

Continuous reachability and interaction with on-line medical data repositories or medical staff is achieved with the help of an enhanced communication platform based on mobile Internet technology. This will deliver the facilities for ubiquitous and reliable connectivity as well as security for data and telecommunications.

The data flow of the HealthPal monitoring system is illustrated in Figure 4. User-System interaction is triggered via speech enquiries, gestures or emergency notifications. In any such event, the system reacts by issuing a report, displaying a message or invoking an alert mechanism. The latter may initiate an alarm or contact medical staff. In any case, the system returns content to the patient that can be displayed or played back with respect to patient’s profile.

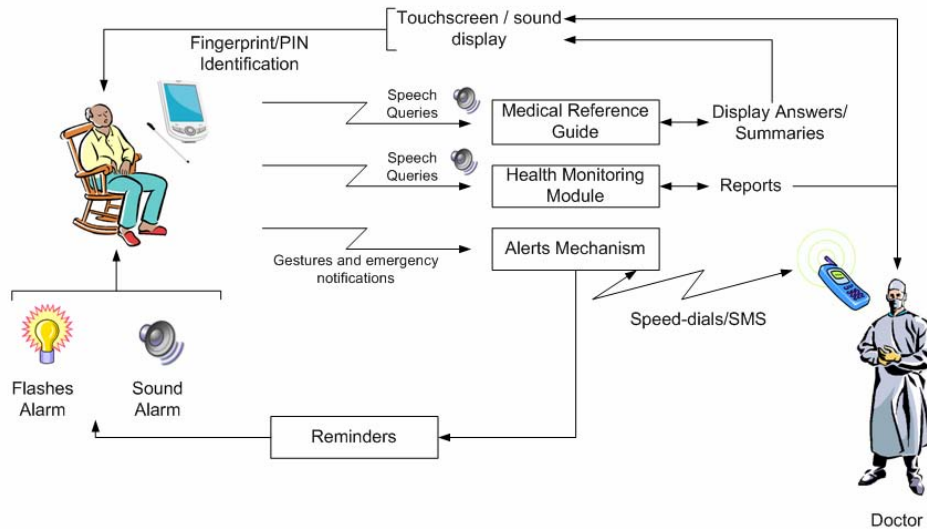


Fig. 4. Dataflow Diagram.

5 Data Security Mechanisms

For securing the data stored in the HealthPal medical suite, the following steps will be taken:

- We will deploy strong authentication and authorization controls. These technologies including secure ID tokens, digital certificates, fingerprint and voice identification, will ensure that only authorized users gain access to the system. Appropriate authentication and access controls protect against not only unauthorized access, but also minimize the risk of system being infected by malicious software.
- We will employ available cryptographic technologies, which will seamlessly integrate encryption into the medical data that is being transmitted across the user's and the doctor's devices.
- We will use digital signatures and secure date-time stamps. Specifically, we will use fingerprints to verify that data whether in transit or in a database has not been modified by unauthorized parties. We will also assign secure date-time stamps to the HealthPal's medical records upon creation and/or modification.

6 Societal Impact of the HealthPal System

The HealthPal system aims to create new standards for elderly people medical monitoring. The basic principle that this system follows is the enabling of elderly people to remain at home at an optimum level of health and independence rather than institutionalizing them. Also the system is regarded as a technological gateway to health care systems due to its human oriented software creation that enables people with no-knowledge on Information Technology to have access on it. As an enabling tool to elderly people to monitor their own health (in an automatic way) HealthPal gives once again access to a series of freedoms and peace of mind that were lost through time. We expect that once elderly people take advantage of this "health" enabling technology, they will return to their social habits with a higher self esteem.

On a wider level, the importance and value of providing an effective support to this sensitive group can be illustrated by examining the findings of the Blackwell, *et al.* (1992) [24] study which compared the costs of caring for the elderly in institutions and in the community. It was clear from this study that there were a number of ways in which expensive hospitals and institutional resources were being used by elderly people who could be cared for at home if adequate technological support was available.

A proactive rather than a reactive approach on national policy making could help to economize in some areas, thus releasing funds for other services. For example, it may well be in some cases that regular health monitoring for the older person together with relaxation therapies - e.g. reflexology - will take the place of medication. The result will be to reduce the demand on the existing health service while enable quality of service.

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