A prototype home robot with an ambient facial interface to improve drug compliance

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Summary

We have developed a prototype home robot to improve drug compliance. The robot is a small mobile device, capable of autonomous behaviour, as well as remotely controlled operation via a wireless datalink. The robot is capable of face detection and also has a display screen to provide facial feedback to help motivate patients and thus increase their level of compliance. An RFID reader can identify tags attached to different objects, such as bottles, for fluid intake monitoring. A tablet dispenser allows drug compliance monitoring. Despite some limitations, experience with the prototype suggests that simple and low-cost robots may soon become feasible for care of people living alone or in isolation.

Introduction

Caring for people in their home offers many advantages to patients, providers of home-based services and insurers. Telehealth is one of many techniques that may assist in this aim, via ambient assisted living.[1] The term ambient assisted living (AAL) includes assistance in carrying out daily activities, health and activity monitoring, enhancing safety and security, and gaining access to social, medical and emergency systems. All these functions are provided in the patient's home. This reduces the need for caregivers, personal nursing services or transfer to nursing homes.

We have previously developed a lifestyle and health management system for AAL using mobile technology.[2–4] Our system can be instructed to carry out certain tasks in the patient's home. We have also developed a home robot that carries medicine, checks compliance of food and fluid goals, and expresses emotions using its digital face. We believe that such robots will be important in future home health care. Home robots may be able to carry out tasks such as helping the elderly to get out of bed or moving them around after surgery. The facial interface is important in allowing the robot to mimic facial expressions.

Compliance monitoring

An important factor in the success of medicine is how closely the doctor's instructions are followed by the patient, i.e. the level of compliance. Adherence to a drug regimen, for example, means taking the correct medications at the prescribed dosage and on time. During the treatment of chronic diseases, the compliance of patients is often below 50%, i.e. more than half of patients do not take their medications correctly. Recent research shows that patient compliance can only reach satisfactory levels if the patients receive guidance, support and instructions.[5] Clearly poor compliance may result in the weakening or loss of the therapeutic effect, cause the condition of the patient to worsen, and may even lead to death in some cases. Epilepsy, asthma, diabetes, congestive heart failure and depression are common diseases, which require continuous and disciplined care. It is possible to live with these diseases, perhaps almost symptom free, if they are treated properly. However, incorrect or insufficient treatment can lead to serious complications, and a loss of quality of life or even life itself. Various studies show that the compliance of patients who have these diseases is almost always less than 50%, and sometimes as low as 20%.[5] Furthermore, nearly 70% of people simply do nothing when faced with the necessity of some sort of change in their lifestyle to help improve their health.[6]

Continuous home-based monitoring and motivation of patients who take medication using telehealth technologies and intelligent systems would greatly improve the quality of patient care and at the same time have beneficial economic effects as well. For this purpose we have developed a prototype robot with facial feedback to help motivate patients and thus increase their level of compliance.

Home robot

Home robots offer a new way to communicate and interact with patients while they remain in their own homes. For

Accepted 6 July 2008
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DOI: 10.1258/jtt.2008.007016

example, ConnectR is a virtual visiting robot.[7] The robot can perform face recognition to help locate people in rooms, and has an RFID interface to identify pill bottles and to monitor food intake. It also has a facial display to provide feedback to patients, for example about compliance.

We have built a similar robot (Figures 1 and 2). It uses an ultra mobile PC (UMPC) with a built-in camera and touch screen. The UMPC is mounted on the robot and used for finding faces in the room for the purpose of approaching people; when there is no-one in sight, the UMPC is used for autonomous navigation. Attached to the device is an RFID reader mounted as a service tray for keeping medicine bottles on; this is used for intake monitoring. A facial interface is used to provide an easy-to-understand display for the elderly, so that they know if they are complying with all requirements. The basic system elements are:

(1) a moving and programmable robotic platform capable of autonomous behaviour, as well as remotely controlled operation;
(2) a UMPC to provide face detection, communication, sensory processing and emotional display algorithms;
(3) a miniature programmable display and buttons for visual interface purposes;
(4) an RFID reader and tags attached to different objects, like bottles, for fluid intake monitoring;
(5) a tablet dispenser for drug compliance monitoring.

Intake monitoring

RFID tags are attached to a tablet dispenser[8] with its own compliance reminder capabilities and also to the bottom of milk bottles, food items or any other object to be recognized. Drug intake (i.e. level of compliance) is monitored by checking whether the user removed the tablet dispenser from the tray and returned it there subsequently. Similarly, drinking bottles and food items may be scanned when taken out of the refrigerator, allowing the system to keep track of hydration levels and dietary intake, based on the product information stored in a database.

Whenever an RFID tag is scanned by the reader, its identifier is looked up in a table, and the associated information is acted on. For example, the RFID tag placed on a water bottle could be associated with the information that the patient's water consumption should be increased by 2 dl, i.e. the assumption is made that picking up the water bottle is followed by drinking a glass of water.

Figure 1 The home robot uses face recognition, an ambient facial interface and an intelligent pill dispenser combined with RFID technology

Figure 2 The ambient facial interface provides immediate visual feedback and an easy-to-understand display of compliance levels

Fluid changes can be positive or negative. For example, IDs placed on alcoholic beverages should be associated with negative water level changes, since consumption of alcohol leads to dehydration. In addition to external events such as scanning an RFID tag, internal clock alarms also modify monitored levels. Specifically, all amounts are decreased regularly at a predefined rate, modelling the natural loss of water and calories, and the decay of the effect of drugs taken. For example, considering the general advice that everyone should drink about 2 litres of water every day, equates to a decay rate of 80 ml per hour. The accuracy of the decay rate could be improved by using estimates of the physical activity of the patient, measured with wearable sensors.

Facial interface

The ambient facial interface is designed to provide visual feedback on compliance levels in a manner that can be readily understood. It uses a realistic animated face to display facial expressions. These digital faces are controlled by the compliance data derived from the monitoring system. The facial expressions are arranged in a sequence, thus forming a scale from 'good' to 'bad' with 0 referring to a sad expression, 5 being neutral and 10 as a positive smile. The faces express up to 60 different facial expressions using a parametric model of human emotions.[2] Our ability to discern facial signals is very sensitive and people can read the slightest changes in facial expressions very easily, irrespective of age, cognitive state or capabilities even with visual impairments.

Compliance

In addition to passively monitoring compliance and consumption, the prototype system can also take action when the monitored levels indicate the need for it. For example, when the controller detects that it is time to take the next dose of medication, it starts up the robot and navigates it through the apartment. When it detects a human face on the image captured by the built-in camera, it approaches the person in sight. It then plays a short video clip reminding the patient to take their drugs.

The robot is equipped with sensors for detecting obstacles. These sensors include bump sensors on the front, wheel drop sensors to detect stairs, and an infrared sensor which can be activated by an external source to confine the robot within a limited region. The two-way Bluetooth communication between the robot and the controlling UMPC on top of it carries the status of the signals in one direction and the commands to control the robot in the other. Part of the navigational algorithm, such as the triggers reacting to dangerous situations (i.e. wheel drop implies stairs) is also run on the robot itself, which reduces the reaction time.

Telelink and central database

The WiFi capability of the UMPC allows the system to connect to a central database through the Internet (the robot has Bluetooth to connect with the UMPC which in turn uses Wifi for the Internet and remote control). The central database could be located in the health-care facility responsible for the treatment of the patient, or in a more central location. The purpose of this connection is to transmit the current health status of the patient, so that medical staff can review the data and decide whether intervention is necessary. This might take the form of a telephone call or a personal visit, depending on what seems necessary to improve medication compliance. To avoid transmitting confidential data, our system does not record any video images. It uses the video stream internally for navigation and any monitoring data are transmitted in an encrypted form to the server.

Experience with the prototype

The prototype system we have implemented demonstrates how a home robot may be used in the field of AAL. It may provide a simple yet efficient way of keeping track of food and liquid consumption, as well as medicine intake. The ambient facial interface provides clear and easy to understand feedback on the monitored values. The telelink allows medical staff to follow events remotely and contact the patient when necessary.

The navigational performance of the system is somewhat limited and requires further work. First, room exploration is performed by a random walk. Second, finding faces has its limitations since the algorithm is sensitive to changes in lighting conditions. Third, the camera view is also limited, i.e. the robot is not able to see what is behind its back. Finally, consumption monitoring is not entirely accurate: the results probably have an uncertainty of 10% or so, although this may be an acceptable result for fluid intake. For pill dispensers this value is more precise because the intake is more accurately quantized. Despite these limitations, simple and low-cost robots may soon become feasible for care of people living alone or in isolation.

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