ABSTRACT
This paper discusses the need for, and the design and development, of highly adaptable, networked, intelligent, mobile robot assistants and systems for use in patient monitoring and telemedicine. It considers the factors that were taken into account in designing these systems and provide details of the hardware and software developed by the author and how these are used, in conjunction with commercially available hardware, to build these robot assistants and systems. It discusses how intelligence, mobility and adaptability are built into these systems and how these robots can be networked and controlled over the Internet. It discusses the increasing awareness and use of telemedicine and how these assistants may be used in the practice of telemedicine and patient monitoring. It also considers how this work relates to work carried out by researchers in other parts of the world. This work is unique in that it uses only inexpensive and therefore very affordable robots and other equipment and in that these systems are designed to be highly adaptable.

KEY WORDS
Telerobotics, mobile robots, telemedicine, patient monitoring

1. Introduction

1.1. Suite of Projects

This project is part of a suite of projects aimed at identifying and making use of existing and emergent computing, robotic, communications and other related technologies to improve the quality of the lives of people, especially the aged, disabled and those needing rehabilitation or other medical, physical or emotional assistance.

1.2. This Project

This project deals with the design and development of networked, intelligent, mobile robot assistants and systems suitable for use in patient monitoring and telemedicine [1].

1.3. Affordable and Adaptable

This project is unique in that it uses only inexpensive and therefore very affordable hardware and software. It is also unique in that these robot assistants and systems are highly adaptable.

1.4. Telemedicine

In the April 1992 issue of The Journal of the American Medical association, Wasson et al. write, “…the increased contact made possible by telephone care may also improve health status and reduce mortality.” [2].

In recent times, as the many stories of surgery being successfully performed with the aid of all kinds of robotic devices [3] and the occasional stories of telesurgery [4] become common knowledge, more and more people are thinking that if surgery can be performed remotely, that it should be possible to consult a physician remotely and that in many situations, the physician will be able to diagnose and prescribe remotely.

Practices such as Teladoc are being set up to provide such telemedicine services. More details of Teladoc may be found on their website [5].

Using telemedicine, patients need not make appointments. Teladoc, for example, guarantees that a doctor will be in touch within three hours.

The elimination of travel is especially beneficial to patients with mobility problems. Everyone benefits from the avoidance of associated traffic and parking problems. A Teladoc physician can also phone in a prescription to a pharmacy close to the patient’s physical location.

The telemedicine consumer also avoids wasting time in waiting rooms and catching infections from other patients.
1.5. Patient Monitoring

Sophisticated systems are available for monitoring patients in hospitals. Such systems are developed by major manufacturers such as Philips [6] and Siemens [7].

Systems for the remote monitoring of patients during periods when patients are on the move within a hospital are also available from manufacturers such as Roke Manor Research [8]. These systems use Bluetooth technology.

UCLA Medical Center is currently piloting a system that will make digital medical records and other vital information available to doctors on their pocket computers, even when they are outside the hospital [9].

These systems, however, are usually very expensive and generally not needed for use in situations such as those that this project is trying to cater for. Some of these situations are described below.

1.6. Where Simpler Systems may do the Job

Advances in medical diagnosis, pharmaceutical products and surgery have led to people living longer. Many of these people suffer from various medical conditions and can benefit from constant monitoring, assistance and even simple companionship.

Traffic and industrial accidents, extreme sports and diseases such as stroke result in many types of temporary or permanent disabilities. These patients also need monitoring and assistance.

Many forms of therapy can be even more beneficial, if the progress of the human receiving the therapy is monitored more often and adjustments made to suit individual needs and responses [10, 11].

People who suffer from obesity or lack of exercise will also benefit from some form of monitoring, feedback and even simple reminders and encouragement. Details of such a system currently under development in MIT in Cambridge, USA can be found in [12].

1.7. Telerobotics

Telemedicine would benefit from the use of telerobotics, i.e., the use of mobile robots controlled by the telehealth provider over the Internet, especially in cases where the telehealth consumers are children, people in geriatric care or physically disabled.

Valuable references to convincing examples of real world applications of telerobotics in other areas and discussion of some recent work on an 802.11b wireless enabled autonomous mobile robot that responds to on-line requests can be found in [13].

2. Mobile Robot Assistants

2.1. A Recent Application in Health Care

There are numerous examples of robots used in medicine and surgery. A relatively recent example is the RP6, (RP, acronym for Remote Presence) developed by InTouch Health [14].

The RP6 can be navigated along the corridors of the hospital to a selected patient’s bedside. Using cameras and video screens mounted on the RP6 and in his or her office, a doctor can talk with as well as ‘examine’ the patient. The doctor can do this from even his or her home, provided he or she has the necessary hardware installed at home. The data and the control signals are sent over the Internet.

In July 2005, I had the opportunity to study the RP6 in operation at the Detroit Medical centre.

2.2. Multi-purpose systems

All the robot assistants and systems I am working on are designed to be adaptable so that they can be used in a wide range of situations. These are also designed to be part of a general suite of robot assistants and systems that will easily be able to make use of newer and more capable robots and technologies as these become available. The concept and thinking are similar to the concepts and thinking behind open standards [15], open source software [16] and open courseware [17].

2.3. Specific Focus of this Project

While maintaining this broader aim, the systems under discussion in this paper are designed specifically to suit applications in telemedicine and patient monitoring.

3. Design Considerations

3.1. Most Desired Features

Apart from the adaptability discussed in some earlier paragraphs, it was decided that the robots are to be mobile, intelligent and controllable over the Internet, Local Area Network (LAN), Metropolitan Area Network (MAN), Virtual private Network (VPN) or other network.

3.2. Mobility

It was decided not to use fixed robots as these would not be able to follow the patient around a house or other venue. Having decided to use a mobile robot, a choice had to be made between robots on wheels or tracks and those on legs. Robots with legs were chosen as these will
eventually have the capacity to move up and down stairs as well as open doors.

The final question was, “How many legs?” This was decided based on the prediction that many future robots will have two legs and two arms like us, humans. These will have better balance and capabilities than the current models as their designers start using gyroscopic technologies such as those used in mobility devices such as the Segway [18] and the Segway Mobility Platform [19] and fuzzy control algorithms like the ones developed in Germany and Mexico [20].

As homes, hospitals and other buildings as well as the tools and other equipment, including those used for diagnostic purposes are designed for use by people, it was thought best to use humanoid robot assistants.

3.3. Intelligence

It was decided to build the intelligence initially into software that runs on a notebook computer controlling the robot assistants. When the software is mature enough and has been tested thoroughly, the intelligence will be uploaded to the robots, making any necessary hardware modifications and freeing the robots of their umbilical cords to the notebook computer. This is similar to the current practice of companies such as InTouch Health [14], who do not sell their robots or software but lease these and keep updating these.

3.4. Controlling the Robots over the Internet

Some of the inexpensive commercial robots that will hit the markets soon are likely to have Bluetooth or other wireless technologies. However, the models that are being used at present use only infra-red, although modifications are possible to use other technologies.

Two options were considered. The first was to keep using a notebook computer to receive data and control signals over the Internet or other network, and then communicate these over the infra-red to the robots.

The other was to make some hardware modifications to the robots.

It was decided to use the first option and modify the software and hardware when Bluetooth-equipped humanoid robots become available in the near-future.

4. Final Design

The final generic design consists of backbone software, running on a notebook computer, receiving data and control signals from a number of sources, (including the robot assistants, the remote sensing equipment they carry, the cameras, the telehealth provider, the patient and the physical environment), controlling the robot assistants and providing useful data and alerts to the patient and/or the telehealth provider. The communication with the telehealth provider is over the Internet or other network.

More than one computer, robot, camera and network connection and the ordinary telephone may be used when needed in specific applications.

In applications such as an aged-care facility, the backbone software will be scaled and installed on a server controlling a number of roving robots and monitoring a number of people.

5. Work Completed

5.1. Hardware

Basic details of the earlier versions of the robots and the hardware developed by the author were given in an earlier paper [21].

The hardware has been modified to take control of the newer, larger robots with more capabilities and to be able to control more than one robot and more than one model.

5.2. Software

The backbone software was developed in C++ so it can be easily ported to both major operating system platforms, Linux and Windows.

In conjunction with the backbone software, open source software, shareware and commercial software are also used. Details of one of the successful configuration being trialled for use in telemedicine are given in the next section.

5.3. One Successful Configuration

A mobile humanoid robot equipped with a video camera was set up in the ‘patients’ room to be controlled by the signals (currently infra-red) it received from the purpose-built infra-red transmitter tethered to a notebook computer.

The notebook computer ran the backbone software under Linux. It was also connected to the Internet and set up as a SSH (Secure Shell) server.

A ‘telehealth provider’ used another computer from his ‘clinic’ at a different physical location. This second computer ran Windows, Mozilla FireFox and a SSH client and was also connected to the Internet.

Using SSH and the Internet, the ‘telehealth provider’ logged on to the first notebook computer located in the ‘patients’ room.
The ‘telehealth provider’ controlled the robot and used it to ‘examine’ the ‘patient’, by typing simple commands such as “forward” and “camera left”.

The camera attached to the robot made the ‘visuals’ available to the ‘telehealth provider’, over the Internet using a third notebook computer located in the ‘patient’s room and a separate Internet connection.

The audio was carried over the ordinary telephone with speakerphones being used on both ends.

The telehealth provider needed only minimal training to be able to control the robot, as the commands were typed out in plain language such as, “forward” and “lower camera”.

6. Results

The experiment described above and other related experiments and trials were so successful that work is continuing on this project and the other projects in the suite of projects.

The rest of this paper deals with some possible real world applications for these robots and systems in telemedicine and patient monitoring, why the legal impediments to such use may soon be sorted, related work by others, future work planned and the development of an international collaboration with doctors in the USA trying out these systems to examine patients in New Zealand.

7. Real World Applications

7.1. Customising to meet Specific Requirements

The systems developed in this project can relatively easily be customized to each particular application depending on the specific requirements of that application. The following section considers two specific applications.

7.2. Telemedicine Applications

The system can be given the ability to recognize that one of the persons (or the only person) sharing the house with the robot assistant(s) has a vital sign that is a cause for concern and suggests that the patient contact a doctor. The patient may then instruct the system to make contact with a telemedicine provider.

The telemedicine provider at the other end of the Internet may get the robot assistant to perform some of the tasks a doctor may perform at a clinic and collect the sort of data a doctor may collect during a face-to-face consultation. These data may be data such as the heart rhythm or ‘visuals’.

The telemedicine provider can also take complete control of the robot assistant(s) over the Internet or other network and get these to walk around to another side of the patient’s bed or wheelchair.

The possibilities are numerous. The more sophisticated the robots, the more customized equipment that they are provided with and the more intelligence that can be built into our highly adaptable backbone software, the more these systems can help.

7.3. Patient Monitoring Applications

It is not hard to imagine all kinds of possibilities in monitoring people’s health and helping them with access to telemedicine as discussed above but also in monitoring patients in so many varied situations.

Near-future versions of these robots can be programmed to be constant monitoring companions for individual patients, following them wherever they go – personal robots.

They will also be suitable to be deployed as roving robot monitors that can be programmed, networked and controlled, as swarms or teams of robots within limited spaces such as hospitals and special care facilities for the elderly, monitoring all the occupants’ health.

8. Legal Issues

The legal issues that could prevent such systems being used in the real world will most likely be sorted soon as people and lawmakers see that the benefits outweigh the risks and are provided with evidence of reliability.

In New Zealand, a student who is very ill with a severe cold or flu on the day of an examination will need to produce a medical certificate, if he or she wants to do a special examination at a later date.

Patients such as these and patients with mobility problems and those on busy schedules will surely be willing to press for changes in the legislation and to sign indemnities so that they can use systems such as these, in order to be able to access better quality telemedicine.

9. Related Work

Researchers at MIT are working on a project where they are using Sony’s AIBO to monitor a person’s food intake and exercise and other related parameters and respond in a number of ways [12].

Several companies such as Intel, GE, Matsushita, Honeywell and Motorola are working on projects and
products that will enable the elderly to live independently, by providing them with assistance and monitoring. [22].

Universities and hospitals are collaborating on a large number of projects involving robot-assisted therapies and rehabilitation [10 & 11].

10. Future Work

Numerous models of humanoid robots will soon be mass-produced making them affordable and suited to these type of projects. Every new generation of these robots will have more capabilities and better reliability. The adaptable backbone software and control software will take advantage of these models of advanced humanoid robots as these become available.

As these new models come with Bluetooth or other wireless capabilities, this system will also take advantage of these.

Haptic devices [23] will be added to these systems giving the telehealth provider the ability to ‘touch’ and examine patients remotely.

Cognitive behaviour therapy (CBT) is a very useful tool in modern times in preventing and treating various forms of mental diseases [24, 25, 26 and 27]. The delivery of CBT over the Internet is also gaining popularity [28 and 29]. The robot assistants and systems discussed in this paper can also be applied here.

Loneliness is identified as a stressor that can “trigger an illness in a person susceptible to mental illness” [30]. These robot assistants can not only provide monitoring but also companionship in the form of intelligent conversations and even music dependent on the mood. The automated music composition software developed by the author will be used in this context [31].

11. Conclusion

Mobile, humanoid robots with ever-increasing capabilities are being designed and mass-produced. As mass production increases the affordability of these robots, I am designing systems making use of these robots and related sensor, computing and communications technologies for use in a wide range of real world applications that will help improve our lives.

The system described here was designed for the use of these robots in telemedicine and patient monitoring.

These systems can also be adapted for use in other areas, especially for applications in mental health and cognitive behavior therapy.

The legal impediments to the use of robots in such situations will be sorted out soon as the benefits outweigh the risks and systems become more reliable and secure.

Depending on the availability of resources and based on ideas similar to those behind open systems, open software and open courseware, I plan to let interested researchers take control over the Internet and study the latest systems with a view to encouraging the building of more such systems.

As more such systems are developed and deployed, all of us, especially the elderly and the disabled will, hopefully, benefit greatly.

An exciting recent development is that negotiations are under way to trial one of these configurations for use by doctors on a different continent - pediatricians in the USA examining patients in New Zealand.

References


