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Challenges in the Design of Sensors for Telemedicine

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Sensors for portable telemedicine are a fast-growing market. They are changing the way in which health service providers interact with patients. Hardware devices, alongside software and communication systems, are enabling the rapid change in quality of the monitoring patients outside hospitals. This constant flow of data may be used to check a variety of medical conditions, including compliance with a physician's instructions. However, new technology is posing new challenges.

The problems encountered in the design and implementation of sensors for telemedicine systems are, in general, common to all health related devices and software. This article is based on our 'out of the hospital' monitoring system under development at Kuziemski.pl. It covers many, but by no means, all the challenges we have encountered. Most importantly, our lessons can be extrapolated to other systems for telemedicine.

Sensor Accuracy

Sensor accuracy is not a problem in typical medical solutions. However, given the requirements of miniaturisation and the need to contain costs for mass market devices, the choice is tough. The use of advanced software algorithms is one way to ensure the right interpretation of gathered data, as it is common to use different kinds of sensors to monitor one function.

Data Interpretation

Correct interpretation of gathered data is critical, given the differences between individual patients and the lack of an 'ideal' readout from sensors. First, data integrity has to be checked. This is followed by appropriate algorithm checks for anomalies and results are obtained via an expert system. The latter are rarely easy to implement, not least due to human factors and the need to cover, combine and program different fields of expertise.

Software and Hardware Errors

Software and hardware errors are major threats to an entire IT system and telemedicine is no exception. Extensive testing on all phases is required, along with solid design and prototyping. Communication between sensors, processors and memory has to be carefully planned. Algorithms have to be checked and proven, with interference and risks of malfunction eliminated. The system has to run 24/7 without any memory leaks, unexpected loops or other behaviour which makes it unreliable.

Communications

Fast, secure, reliable and safe communications are crucial. Ideal sensor units in a telemedicine system must be compact, without wiring. Due to a the need for ease in wearing, the processing and long range communication unit is usually separate from the sensor unit. Communication between units should, if it is possible, be wireless with minimum power (and so minimum range). Securing uninterrupted, safe communication is difficult due to proximity to a patient's body, power supply limitations and possible interference.

Communication between the processing unit and a healthcare provider is usually obtained with Internet using a GSM modem; the key challenge here is encryption and security. Newer choices such as a smart phone are more versatile and easier to implement, but are complex devices and not designed to fulfil medical reliability standards.

Power Source and Power Consumption

Power supply impacts directly on ease of use, especially for a portable telemedicine device. The charging intervals should be long (from 24 hours to a few days) and should be performed without a need to stop the devices. Technology is advancing. Current LiPo cells reach almost 200 W/kg and more futuristic LiS (lithium – sulphur) are rated at 350 W/kg.

Minimising power consumption via sophisticated algorithms to harness hibernation capabilities, energy efficient sensors and radio links can do wonders for run times. The unit should also be watertight, to be worn, for example, in a shower.

Miniaturisation

For 'out of the hospital' monitoring on a 24/7 basis, the weight and size of the sensor unit is essential. Miniaturisation is a very important factor here: the unit has to be compact, as light as possible, and preferably elastic. This makes the design of the electronics of the sensor unit an especially tough challenge.

There is a contradiction between battery capacity and miniaturization, and the trade off has to be weighted carefully.

Materials, Health Regulations

Materials in contact with a patient's skin have to be carefully chosen, according to health regulations. Minimally, this means dermatological safety and inflammability, as well as comfort.

The product has to comply with national and international regulations for medical devices and the risk management process must cover its life span from production to disposal.

Some kind of ruggedised design would be preferable to assure long life of this component and increase safety of the user.

User Interface

A high quality user interface is essential to assure good communication with the patient. It has to be clear, easy to read and understand (especially for older people). The screen resolution should be high and its size should be sufficient to ensure good readability of the messages to the user in all lighting conditions.

Being intuitively-friendly to users not familiar with modern computer interfaces is also important, as a majority of potential users of such systems today would consist of the elderly, who are a relatively computer-illiterate demographic group. The design of the system has to therefore be clear, concise and logical, and tested carefully with the full range of target groups.

Security

To ensure the safety of the information gathered by a portable telemedicine system, access rights and encryption algorithms have to be implemented. During the planning phase, all information users must be named and a stringent data protection policy developed.

The data and communication have to be protected from tampering – which could have serious (even fatal) repercussions. This is an especially important point given that the number of medical data hijackings is growing by the day.

Communication has to be secured from all potential errors. Commands have to be answered with confirmation, double and triple checked. The design of the electronics, software, and above all, algorithms, have to be closely monitored.

Reliability

The reliability of such systems must be extremely high. For instance, malfunctioning of an insulin pump due to incorrect sensor data or a misinterpreted command from tele-operation could result in coma or even death. Reliability is closely correlated to the security issues discussed above.

Training

Extensive training of personnel is required to ensure that operating procedures are followed rigorously, while unexpected events are handled professionally. A swift response to alarms is of specific importance. The medical data and events/incidents chain has to be logged correctly, so that they can be swiftly recalled during an emergency. Human factors are always a risk in telemedicine systems, and well-designed operational procedures are essential, both for data privacy and the proper functioning of the system.

The training program should also include awareness of combating common techniques used by hackers and data thieves. Users of the system

should be queried routinely – even if they suspect any misbehaving software or hardware or if they encounter any signs of intrusion into the system. As always, a skillful network and system administrator is a must.

Testing

The testing of system components should be performed during all stages of design. External experts must be consulted during the design phase to proactively prevent or detect impending errors. A test program should be developed and test procedures designed and implemented. Even if a system is working well, it must be closely and routinely monitored through the test program.

Costs

One of the main challenges in telemedicine, especially sensor systems, is to achieve low cost per patient year. The design of sensors has to take in to account the final cost needed to manufacture the device, how long it will operate, and the cost of the communication device (especially if it entails an expensive Smart phone).

The eventual goal is to achieve a low-enough price point, so that sensor systems can be included in typical health insurance schemes.

The Future

To sum up, the future of telemedicine is bright. The pace of development in the field of sensor systems is rapid, and is in turn expected to lead to the application of mini-robots. The main challenge at present is to ensure that sensors continue to perform better and more effectively, and do so with safety and reliability.

More than anything, this will drive market uptake and bring down unit costs which will in turn, further boost sales in a virtuous cycle.

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