Diploma Programme
Programme du diplôme
Programa del Diploma

Computer science
Case study: computer science in medicine

For use in May 2017 and November 2017

Instructions to candidates

- Case study booklet required for higher level paper 3.

Introduction

Computer science has had a considerable impact on medical diagnosis, treatment and research. This case study explores some of these impacts. Note that in this case study, doctor and surgeon refer to medically qualified people with specific jobs. A health carer may be a doctor or surgeon, but also includes anyone involved in treating medical conditions, such as physiotherapists and nurses. Health centre refers to an establishment where medical services are available such as a hospital or clinic.

The original idea of a patient or doctor entering symptoms into a computer and receiving an accurate diagnosis in return has only been partially realized. However, *diagnosis decision support systems* (DDSS) and *clinical decision support systems* (CDSS) are being used and constantly improved.
A DDSS is intended to diagnose a condition from a given set of symptoms, and a CDSS includes the ability to suggest treatment in specific situations. Some of the most successful systems so far, have been those designed for the diagnosis and treatment of specific conditions, such as tumours.

A doctor needs experience and access to knowledge in order to make a correct diagnosis. Medical practices change over time as new discoveries are made about diseases, symptoms and treatments. This means repeated re-training for doctors as well as continual access to the latest information. Moreover, in some remote areas a trained doctor is not available to make a diagnosis. A diagnostic system incorporating an up-to-date *knowledge base* would be helpful in such situations.

Just as a doctor uses knowledge, experience and trained skills to interpret the symptoms of a patient, a diagnostic system has a knowledge base and a method of analysis known as an *inference engine* for interrogating the knowledge base and proposing a diagnosis from a given set of inputs. Current knowledge bases are continually expanding due to the increased amount of information about conditions and their causes, and also the incorporation of data in different formats from *medical imagery*. At the same time, the efficiency of the inference engine is increasing with techniques involving *fuzzy logic* and *pattern recognition*.

Health policies

Health policies are a major part of government planning and require a large part of the financial budget in most countries. Private health centres also have to balance cost with health benefits when investing in medical personnel and computer systems.

Doctor Metaxis, a medical computer consultant who works as an advisor for governments and also advises private health centres, explained some of the current computer methods being employed.

“The use of diagnostic systems was originally envisaged as being a way of saving money by using machines instead of doctors. However, the systems are expensive and still need expert interpretation. An experienced doctor can derive symptoms from the physical aspect and behaviour of a patient. Similarly, the medical history and background of the patient is often known to the doctor which is a factor to take into account when deciding on treatment. These are important pointers to certain conditions and appropriate treatments, which are currently not easily incorporated into diagnostic systems.
A comprehensive policy on *electronic health records* could change that.”

Electronic health records

Many governments are now looking to enforce compatible electronic health records (EHR) across all health services. The concept of EHRs relies on patients having up-to-date medical information and appropriate personal information stored electronically. This has been happening for some time with health centres digitally storing their own patients’ data. The plan is to extend the EHR to have only one record for each person, which can be accessed and amended in any health centre and by any authorized health carer.

The most ambitious plan is perhaps that of the European Economic Community (EEC). In 2012, a new action plan for 2012–2020 was adopted proposing a series of measures and expressing a commitment to remove the existing barriers to "a fully mature and interoperable eHealth system in Europe"*. The information in each record will include demographic data, hospital visits, past illnesses, allergies, scans, X-rays and much more. There are obvious potential advantages for the individual, for researchers and also for health care planners, but there are some implications that need to be considered as well.

Doctor Metaxis has been approached by a government representative of one of the countries involved. The representative needs advice as to how they could conform to such a new system. Doctor Metaxis explained that there are many factors to take into account.

"Apart from the different languages and health practices across the European Union, there are also hardware and software compatibilities that have to be considered. Implementing such a system is extremely expensive and complex, as has been shown in the UK; attempts in some other countries have allegedly led to clinical mistakes. The attitudes of patients and the impact on medical staff need to be considered. On the other hand, those involved in *bioinformatics*, are particularly interested in the vast amount of data that could be used for *predictive diagnosis* and the possibility of including DNA in the records could lead to advances in *genomic bioinformatics*."

Telemedicine

Doctor Metaxis went on to talk about *telemedicine*. This is expanding, particularly where access to a medical expert is difficult, and in situations when a patient is able to receive their care at home rather than in hospital. It can be used by surgeons in different areas to collaborate during a complicated operation, via communication lines.

"Another advantage of telemedicine is that a specialist can see and speak to the patient together with any health carer as well as have access to measurements such as temperature and heartbeat which can be relayed over the internet.

"I have been asked to design a computer system for a new clinic, Tall Trees, which will be opening next year in a small village with a large rural community. The clinic intends to include telemedicine in its services, in order to offer health care to all. In particular the clinic requires from me, technical details and information on the latest medical electronic advances. Starting from scratch, they want to incorporate the latest technology. I will recommend that they consider incorporating the technology relating to the *internet of health things*."

Internet of health things (IoHT)

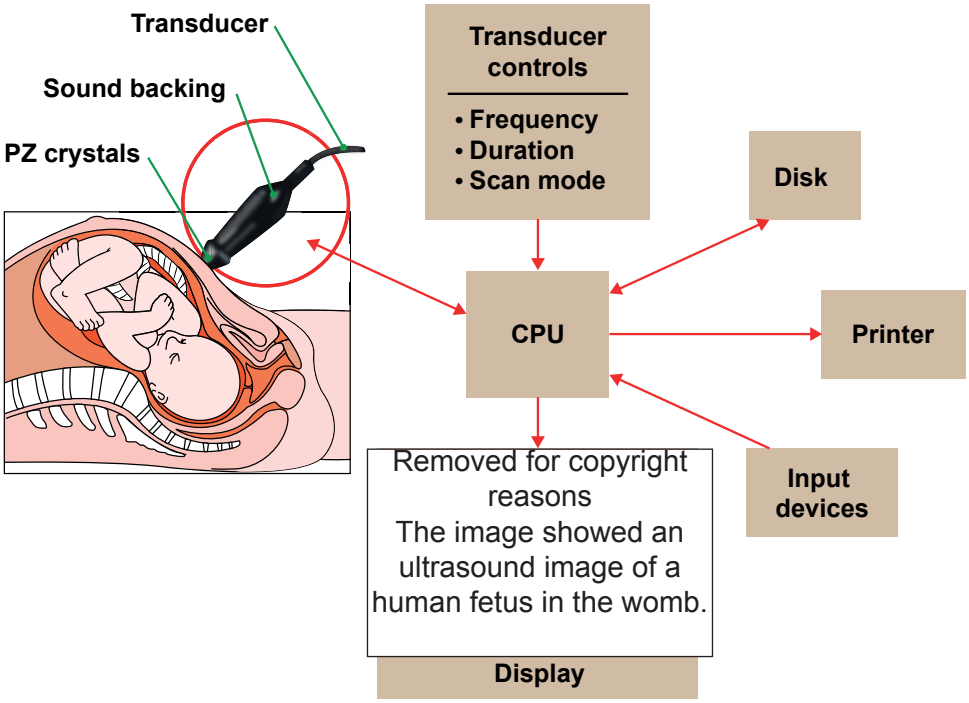
An addition to telemedicine is the rapid development of the internet of health things, which can be incorporated into telemedicine. It can also be used by people wishing to monitor their own health, thanks to the use of wearables and the incorporation of *near field communication* (NFC) and *radio-frequency identification* (RFID) into many mobile devices. This allows medical data to be relayed continually to a health centre. Doctor Metaxis mentioned that many people now access the internet for a possible diagnosis of symptoms, and to help interpret results, such as blood tests. This trend is expanding, with the increased amount of information on health available through the internet.

Doctor Metaxis also offers advice to health departments that have a fixed budget from the government to spend on medical services in hospitals.

"Of course, the hospitals want to employ the latest techniques to give the best possible service. Medical imagery can help in meeting their needs."

Medical imagery

Medical imagery is an important part of diagnosis and treatment. *Magnetic resonance imaging* (MRI), *computed tomography scan* (CT scan) and *ultrasound* are three available systems. Ultrasound is non-invasive, is widely available and less expensive when compared to the other two; hence it is used extensively when there is a choice of methods. The image below shows the different parts of the system from the *transducer* to the *sonogram* shown on the display.



The transducer emits high frequency sound waves at the points chosen. The way in which these are reflected back is processed to build up an image of the area scanned in the form of a sonogram. The 2D images of the sonogram can be used to make a 3D image. There is no doubt that the advances in the quality and analysis of medical imagery are giving excellent results, but they can be computationally intensive and expensive and need trained personnel for interpretation. One recent and useful development is the extension of ultrasound 3D imaging to *augmented reality* imaging.

Research into the use of augmented reality imaging, points towards revolutionary changes in medical practice for diagnosis and for surgery; it provides simulations for medical students, it increases accuracy in the operating room and it offers valuable assistance in telemedicine. This together with *robotic controlled surgery* has the potential to make the operating theatre a safer place. A radio controlled robotic instrument can be guided by a surgeon to the exact position where an intervention is needed, thanks to the quality of the 3D image. The surgeon can also be working from a distance.

Doctor Metaxis summarized the issues considered by governments and private clinics looking to update their systems.

“Research is funded by companies hoping to make money with results, and also by governments wanting to improve health for their population. Exciting developments in technology could improve the standard of health globally. The latest advance in robotic controlled surgery can mean savings in hospital costs and can be monitored by expert surgeons from a distance. The computer analysis of medical images has the potential to give early diagnoses which in turn could save lives and health costs. However there is an initial expenditure in machines and electronic communication which has to be considered as well as the difference this makes to training medical staff.”

Challenges faced

Doctor Metaxis and his clients must focus on the following challenges:
- the feasibility and consequences of developing a coherent EHR system;
- the effect of technological developments on health carers;
- development and implication of bioinformatics for predictive diagnosis;
- combining electronic and human resources in order to get health services to those in remote or underdeveloped areas.

Additional terminology to the guide

Augmented reality
Bioinformatics
Clinical decision support system (CDSS)
Computed tomography scan (CT scan)
Diagnosis decision support system (DDSS)
Electronic health record (EHR)
Fuzzy logic
Genomic bioinformatics
Inference engine
Internet of health things (IoHT)
Knowledge base
Medical imagery
Magnetic resonance imaging (MRI)
Near field communication (NFC)
Pattern recognition
Predictive diagnosis
Radio-frequency identification (RFID)
Robotic controlled surgery
Sonogram
Telemedicine
Telesurgery
Transducer
Ultrasound

Some companies, products, or individuals named in this case study are fictitious and any similarities with actual entities are purely coincidental.

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* European Commission, *eHealth Action Plan 2012–2020*, http://ec.europa.eu/health/ehealth/docs/com_2012_736_en.pdf (2012)