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EDUCATIONAL NOTE

Opportunities for the transfer of astronomical technology to medicine*

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Abstract

There are many examples of technology transfer from astronomy to medicine, for example algorithms for reconstructing X-ray CT images were first developed for processing radio astronomy images. In more recent times, X-ray detectors developed for the Hubble Space Telescope have been used in a fine-needle breast biopsy system. Software originally developed to mosaic planetary images has been incorporated into a system for detecting breast cancer. Australia has expertise in the development of instrumentation for producing radio images from an array of radio telescopes and in multi-object fibre systems for capturing the spectra of hundreds of stellar objects simultaneously. Two possible applications of these Australian technologies are suggested that may merit further exploration. A meeting between interested parties is suggested to discuss future directions and funding.

Key words

Introduction

This paper discusses previous examples of technology transfer from astronomy to medicine and discusses the potential for active technology transfer from astronomy to medicine in Australia. A major advantage of technology transfer is a reduction in the cost and development time of a new technology. The new technology may result in an improvement of an existing technique or could be a new way of doing something not previously possible. This paper is not an exhaustive historical review of technology transfer from astronomy to medicine but makes the point that it has and is happening elsewhere in the world and could happen here in Australia.

There are many examples of technology transfer from space to medicine. In this context space technology is considered to include astronomical technology. For example, NASA has a commercial technology program and publishes a book and website called *Spinoff* (http://www.nasa.gov/vision/earth/technologies/spinoffs_index.html) which details technology transfers which have taken place over the previous year. *Spinoff* has been published each year since 1976 and has been online since 1996. A NASA website also showcases many examples of technology examples, for example scratch resistant sunglasses, intelligent highway control system, anti-shock garment, telemedicine, programmable heart pacemakers, etc. The European Space Agency also has a technology transfer program for transferring technologies from space to a variety of fields including medicine (http://www.esa.int).

Examples of technology transfer from astronomy to medicine

In 1973 the X-ray Computed Tomography (CT) scanner was developed by Hounsfield[1] at the Thorn EMI Central Research Laboratories, London, UK, and the first clinical use was described by Ambrose[2]. The CT reconstruction algorithm was first used in radio astronomy and described by Bracewell and Riddle[3]. The algorithm is now also used in the reconstruction of Magnetic Resonance (MR) images.

The X-ray CT scanner was the first digital medical imaging modality. The advent of digital images opened up the use of digital image processing algorithms first developed for space applications. The 1960s's saw the first space probes sent beyond the orbit of the earth. The first electronic processing of an 'extraterrestrial' image took place on the Lunar Orbiter series of spacecraft (1966-7) (http://nssdc.gsfc.nasa.gov/planetary/lunar/lunarorb.html). Photographs taken on board the spacecraft were processed and optically scanned before being telemetered to Earth. The first images required cleaning which spurred the development of algorithms to process electronic images. By the time digital medical imaging arrived, algorithms originally developed for space science were available to process medical images.

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The European Space Agency (ESA) is developing X-ray sensors for future space missions in cooperation with European industry that will have an application to medicine[4]. Scientists at the Max Planck Institute for Extraterrestrial Physics in Germany have developed an algorithm known as the Scaling Index Method (SIM) for extracting weak signals embedded in noise in X-ray images taken with the ROSAT satellite (http://wave.xray.mpe.mpg.de/rosat). The SIM algorithm has been incorporated into a system for early detection of skin cancer in highly magnified visible-light images of the skin – the Melanoma Recognition Documentation and Quality Assurance System (MELDOQ) (http://www.imse.med.tu-muenchen.de/mi/derma/English/ index.html).

In the 1990s work was carried out in the US to actively transfer space technology to medicine. For example, in 1992, a partnership was formed between the National Cancer Institute (NCI) and NASA to consider technologies that could improve the detection and treatment of breast cancer[5]. An expression of interest was circulated to over 300 aerospace, defence and other Federal research laboratories. Forty promising technologies were identified and 15 of these were discussed at a workshop in May 1993.

A number of cooperative projects arose from this workshop and were funded by a joint NCI-NASA Program Announcement. Subsequently, the Research Triangle Institute (RTI) assisted the Health and Human Services Office on Women's Health (OWH) to identify additional technologies that might improve the image-guided detection, diagnosis and treatment of breast cancer. This collaboration led to a further workshop in May 1997 in which about 50 technologies with the potential to advance breast imaging were assessed. A comprehensive list of successful technology transfer projects under these categories is described by Winfield[5].

Much of the focus of the work in the US has been to develop better ways of detecting breast cancer. For example, back-thinned CCD detectors originally developed for the Space Telescope Imaging Spectrometer (STIS) (http://www.stsci.edu/instruments/stis/) have been incorporated into a stereotactic fine-needle biopsy system. The requirements for a breast imaging system are the same as for most optical astronomical detectors, i.e. high resolution, wide dynamic range, and low light sensitivity. The new system enables a fine-needle biopsy to be performed rather than a conventional 'thick' needle biopsy. The improved sensitivity of the imaging system enables the position of the needle with respect to the lump to be seen.

Since a fine-needle is used this is a non-surgical procedure (effectively it is an injection with a very long needle). The cost of fine-needle biopsy in the US is about US$800 compared to over US$2,500 for surgical biopsy. According to Winfield, radiologists using the fine-needle biopsy system predict it will reduce annual national health care costs by approximately US$1 billion. Apart from the monetary savings to the health system, the fine-needle biopsy system is less painful, quicker, and does not result in scarring. (A video clip that briefly mentions this system is available at the NASA Spinoff URL cited earlier).

A problem with conventional mammography is that only 25% of breast biopsy samples turn out to be malignant. Therefore an imaging system better able to differentiate between malignant and benign lumps will have an advantage over current systems. An American company, ThermoTrex (http://www.mdatechnology.net/ techsearch.asp?articleid=349#sec6) has developed a film-less mammography system using a caesium iodide crystal to convert X-rays to visible light. Twelve overlapping images acquired using a CCD camera are assembled into a mosaic using software originally developed by NASA to mosaic astronomical images. Tests of the system have shown that microcalcifications, often an indication of malignancy, are detected with greater efficiency compared to conventional mammography. Also the digital system is able to produce higher resolution images of younger, denser, breasts than is possible using X-ray film.

Are there opportunities for Australia?

Australia has particular strengths in radio astronomy and optical astronomy multi-object fibre spectroscopy[1]. If technology transfer from astronomy to medicine is to be explored further it would make sense to start looking at these two areas. For example, the Anglo Australian Observatory (http://www.aao.gov.au/) has developed a robotic fibre spectrograph (AAOmega) that enables the spectra of about 400 objects to be acquired simultaneously (http://www.aao.gov.au/AAO/2df/aaomega/aaomega.html).

It is possible that this technology could find an application in Light-Scattering Spectroscopy (LSS) - a relatively new technique used to determine the properties of epithelial cells[6]. Studies show that 85% of all cancers arise on epithelial surfaces, i.e. in the oral cavity, oesophagus, stomach, colon, skin etc. The early stages of cancer are very difficult to detect; it is only when the cancer has grown that it can be detected using, for example, an endoscope. LSS holds out the promise of being able to detect pre-cancerous and cancerous cells very early on by analysing singly and multiply-scattered light. If cancers are caught early there is a good chance of a complete cure.

Cancer cells tend to have larger nuclei than normal cells with a greater variation in size and shape (pleomorphism), resulting in greater light absorption and therefore a darker appearance (hyperchromasia). Cancer cells also scatter and absorb light differently from normal cells which affects the spectrum of the scattered light. Therefore LSS could detect abnormal cells even when invisible in the field of view of an endoscope. Since LSS is a wide field technique, entire epithelial surfaces can be checked for cancerous cells. Normally a tissue sample would be required to verify the

[1]*Other types of astronomical research are conducted – for example gravity wave detection (University of WA) and high-energy astrophysics (University of Adelaide) and of course, it is possible that these fields are using technologies that could be used in medicine.*

presence or absence of cancer cells.

The expertise of the AAO could be used to research and develop a fibre optic spectrometer capable of analysing the light from an endoscope for the early detection of cancer. A number of fibres could be arranged in a grid to sample endoscopic images. The AAO is currently developing other methods of positioning fibres in place, for example by using spines that can be pointed in different directions in space (http://www.aao.gov.au/local/www/echidna/).

The Australia Telescope National Facility (ATNF), a division of CSIRO, (http://www.atnf.csiro.au/) operates an array of six 22m dishes called the Australia Telescope Compact Array located at the Paul Wild Observatory, about 23 km west of Narrabri, NSW, Australia http://www.narrabri.atnf.csiro.au/ . The signals from the six dishes (five of which can be moved along a 3 km 'railway' track) are processed using hardware system known as a correlator. The correlator works on the principle that random noise tends to be uncorrelated and the science signal correlated, therefore signals processed by the correlator have a higher signal to noise ratio. As the Earth rotates, the array of radio dishes also rotates forming a synthetic aperture. Very accurate timing information is also available that enables a radio image of the sky to be formed (after a lot of signal processing).

This technique could possibly be used for amplifying weak biogenic signals deep inside the body. One such example might be acoustic signals. For example, a defect in the wall of a blood vessel might generate turbulent sound energy. This sound would be very difficult to detect by placing a microphone on the skin as sound from the region of interest will be mixed with numerous other sounds from within the body. A possible way to record the sound from a certain location deep within the body would be to have a number of microphones placed on the skin forming a phased array. Adjustment of the phase lags would enable focussing on a region of interest. Correlation of the signals from pairs of microphones could then be used to increase the signal-to-noise ratio, similar to the technique used in radio astronomy.

Research could also be done on applying correlator technology to the measurement of small electrical or magnetic signals within the body – however a major challenge here is the fact that the noise is highly correlated as the body acts as an antenna to pick up electric fields in the environment. At QUT we have begun a research project to explore technology transfer in general looking at the possible medical applications of radio astronomy correlator software as a specific example. The outcome of this study will be published in due course.

Where to from here?

Unlike the USA and Europe, Australia does not yet have an overarching space organisation such as NASA and ESA. However, in 2007, an organisation called Astronomy Australia Ltd (AAL) (http://www.astronomyaustralia.org.au/) came into being to oversee the management of $45 million allocated to Australian astronomy as part of the recent NCRIS funding round and to manage other astronomy projects. Although a different organisation from NASA or ESA and of course nowhere near the scale, this is the first time that an organisation of this type has brought together all branches of Australian astronomy under an umbrella organisation.

AAL would be ideally suited to initiate and manage research projects looking at the issue of technology transfer from astronomy to medicine as the organisation encompasses the observatories where the technologies reside and the universities containing many of the users and developers of the technologies.

Medical physicists and biomedical engineers are the best group to be involved with such a project as they are able to bridge the gap between astronomy and medicine. Another possible group to involve are clinicians with a background in physical science. Medical physicists and biomedical engineers are able to 'speak the language' of both physical science and medicine – or at least can do it better than any other group. Another possibility might be to have two students working on a project in tandem – one with a physical science background and the other with a medical background. One possibility might be to develop ARC Linkage grants in which AAL is the industrial partner to a university group. AAL might also be a good organisation to handle intellectual property issues. A first step should be a meeting between interested parties to explore the options. In view of the fact that technology transfer has successfully taken place in other parts of the world, can we confidently assert it can never happen in Australia? Surely it is worth at least discussing the options and possibilities.

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