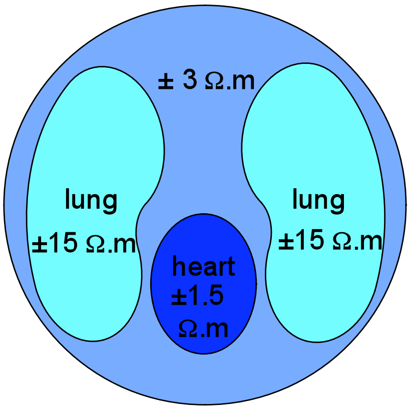
Impedance tomography as an alternative to radiation imaging techniques

by Tania and Johan Hanekom

The most popular relatively inexpensive methods to obtain medical images are X-rays, or if a three-dimensional image is required, computed tomography techniques. However, since these techniques involve radiation, safety is still a concern especially in cases where patients have to be subjected to repeated imaging procedures. Radiation exposure is cumulative implying that imaging by radiation techniques should be limited as far as possible. Electrical impedance tomography (EIT) could offer a safe, non-invasive alternative imaging technique. EIT is low-cost and the technology is also portable – a potentially invaluable diagnostic tool for rural medical applications.

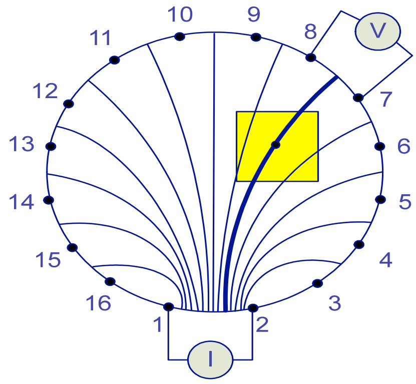
In 2006, Ms Suzanne Hugo, a student in the Bioengineering Group within the Department of Electrical, Electronic and Computer Engineering, designed and implemented a prototype EIT system. The idea of an EIT system is to form a two-dimensional image of a cross section through a human body based on impedance measurements taken on the perimeter of a part of the body. Large impedance variations within the body make it possible to reconstruct an image based on measured impedance distributions (Figure 1).



→ 1. Illustration of impedance variations in a cross section through a human body.

A back-projection reconstruction algorithm was implemented in MATLAB to obtain an image from measured impedance values. A schematic representation of the technique is shown in Figure 2. For the prototype system sixteen electrodes were mounted on the perimeter of the object to be imaged. The number of electrodes determined the resolution of the image. A pair of adjacent electrodes (e.g. electrodes 1 and 2) was selected to apply a current (I) while a separate adjacent electrode pair (e.g. electrodes 7 and 8) was used to record a differential voltage (V). Projections along equipotential lines formed by current injection through a specific electrode pair were calculated. These projections were used to find the intensity contribution to a certain image pixel given the voltage measurements obtained at a corresponding pair of electrodes.

Figure 2 shows that if current was injected via electrodes 1 and 2, the intensity contribution to the pixel indicated by the yellow block would be calculated using the projection along the bold equipotential line together with the measurement obtained between electrodes 7 and 8.



→ 2. Illustration of the back-projection method of image reconstruction. The numbered dots represent the electrodes on the perimeter of the object to be imaged.

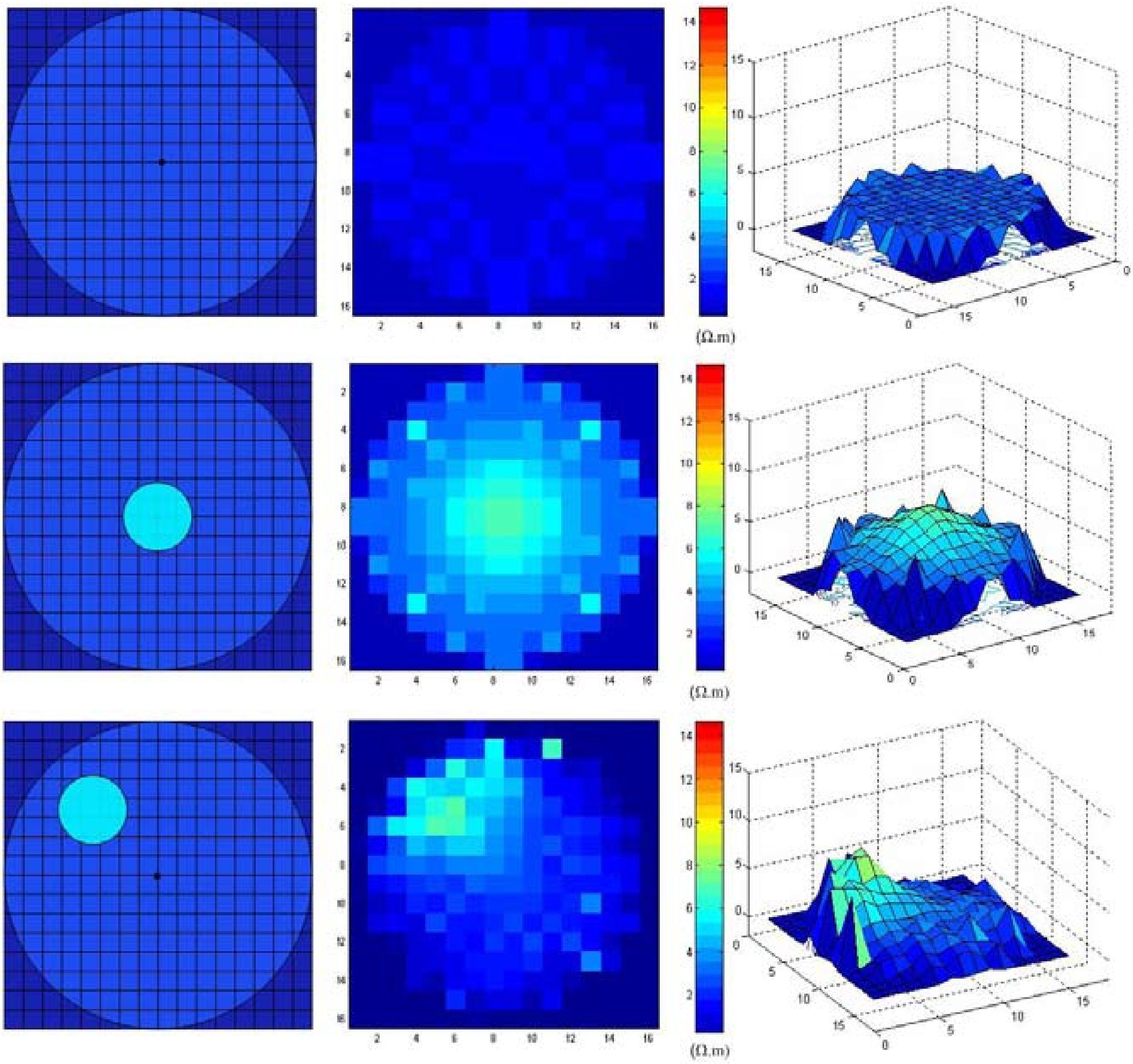
Hardware for the system was designed and implemented from first principles. It included an electrode selection module which was implemented using logic circuitry.

A test set-up to model a cross section through a human body was necessary for in vitro evaluation of the prototype system. A tub filled with saline solution was used to model a tissue volume. Through electrodes mounted inside the test set-up, a current could be applied and voltage measurements obtained in order to obtain an impedance distribution. Figure 3 shows the constructed test set-up with 16 horizontally aligned electrodes mounted to the internal perimeter.

→ 3. Test set-up for the EIT system.

The results of the prototype EIT system are shown in Figure 4. In each case, the leftmost image illustrates the actual test set-up divided into 256 pixels. The resulting reconstructed images of the EIT system are displayed in two-dimensional format and in the form of a contour plot, with a colour bar indicating the intensity of the resistivity distributions in Ω.m.

Although the resolution of the reconstructed image produced by any EIT system is limited, the system provides a cost-effective, portable and safe medical imaging technique that has possible applications in rural hospitals and clinics.



→ 4. Results of the EIT system for three different test set-up scenarios. Top: no object placed in the test set-up (saline solution only). Middle: a plastic cylindrical object placed in the centre of the test set-up. Bottom: a plastic cylindrical object placed in the upper left quadrant of the test set-up.

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