Sensing advantages in application

Tom Shelley reports on the potential for capacitative sensing technology and how it can be used to bring real benefit to users

Capacitative sensing can now be used to scan objects in three dimensions, for example allowing medical scans to be produced without the need for X-rays or massive NMR magnets.

The first applications being studied are the assessment of decay in teeth and the onset of breast cancer. But the base technology is already well established and the approach can be used to detect defects in carbon fibre composites and to locate and monitor people in various places, even when they are behind walls.

Sensatech Research in Brighton has been solving customer problems using bespoke capacitative sensing technologies since 1993. But advances in computing and electronics mean that much more can now be done than the company's staple businesses of detecting industrial products, objects round car bumpers, machine guarding and intruders in buildings.

Particularly impressive are array sensors for detecting tooth decay as an alternative to X-rays.

The base method depends on a two dimensional array of pads, two or more of which are energised at any one time, but which are out of phase with each other. The electrical relationship with other pads is measured either in terms of current flow – electrical impedance – or in terms of voltage – electrical capacitance.

The measurement vectors are steered in space, without moving the array of pads, in a manner analogous to that used in a phased array radar. This produces what managing director and company founder Tom Bach describes as a 'CT [computed tomography] type scan of what is in a volumetric space'.

Voltages are typically tens of volts, while capacitances are tens of femtofarads (10^{-15}) with a resolution of attofarads (10^{-18}). These quantities are related to what Bach says are, 'just hundreds of electrons'. A very sophisticated algorithm is then used to deduce the volume scan.

The goal is to show up very small changes in water content, normally extremely hard to detect using X-rays. This work is being undertaken in collaboration with the University of Brussels. Bach says: "The X-ray contrast ratio in decaying teeth is very difficult to detect but, theoretically, measuring capacitance is much better."

This is because it can detect the loss of calcium from tooth enamel, so giving an indication of 'pre-decay', as opposed to decay that has already happened.

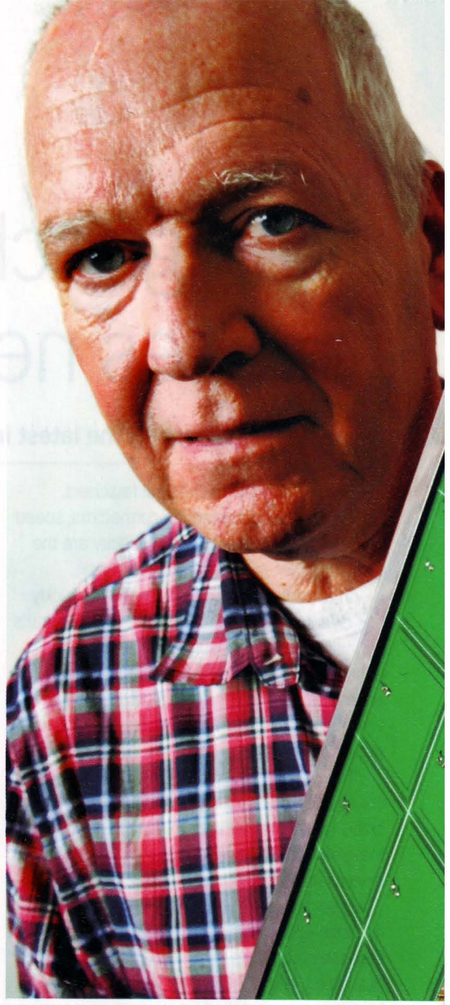
Arrays with 12 or 16 electrodes mounted on a miniature PCB are positioned over the top of a tooth, while eight small electrodes go on each side. Because of the tiny amounts of charge involved, a practicable system would need the electronics to be mounted immediately adjacent to the electrodes. To address this, the team is looking at polysilicon on glass technology.

Meanwhile, the team is developing its own application specific integrated circuits (ASIC) for their various sensing systems. Once the algorithms have been fixed, making ASICs that would directly sense what is going on in teeth would not present challenges that had not been tackled before.

Other medical applications being studied include an array of sensors worn around the chest, which would respond to the presence of water in the lungs – indicating a circulation problem and the likelihood of a heart attack.

Bach summarised the potential benefits of medical volumetric scanning as being low cost, lightweight and not requiring the use of ionising radiation. The approach also does away with the need for enormous and expensive superconducting magnets used in NMR machines.

The downside, however, is that image resolution is not as good, at least not at present.



Non contact but very accuracte readings make capacitive sensing suitable for a host of medical and environmental applications. It could also be used to detect people, explosives and internal defects and delaminations within carbon fibre composites

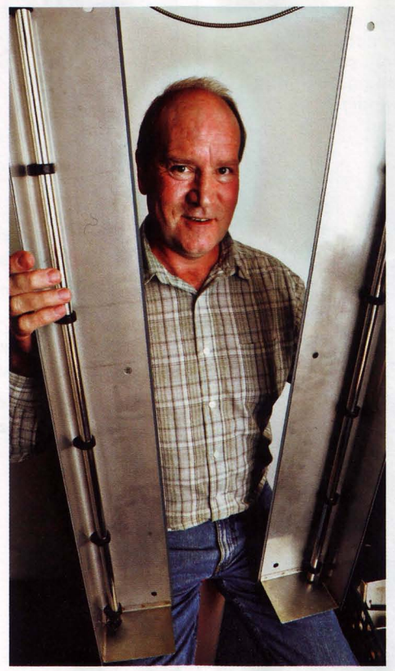
Photographs: Charlie Milligan

Array capacitative scanners also have a lot of applications that are not medical. Some of these are commercially sensitive, but one intriguing application is as a fish scanner for the US Forest Service. It wanted a method of counting and identifying fish swimming up streams, but which did not interfere with the habitat. A capacitative sensing system that works in water is unusual but Sensatech claims the system would also work in sea water.

Related techniques could also be applied to short distance anti collision underwater sensing, working in a similar fashion as obstacle detection systems used on many car bumpers.

Sensatech can also use the technology to detect internal damage within a carbon fibre composite. Capacitance sensing would act as an alternative to ultrasonic scans, which can sometimes miss delaminations if the surfaces are still in close proximity. Sensatech say s its sensing technology will detect delaminations because the two surfaces become capacitance plates.

Other potential applications for capacitance sensing include running detections and scans at different frequencies in order to detect what an object is made of.



Here, the variation of permittivity with frequency identifies a material and this approach has been proposed for the detection and identification of explosives.

This is currently achieved by 'chemical sniffing detectors', but the advantage of capacitance is that sensing can be done from a distance.

Meanwhile, a pair of copper PCB plates with an etched track may be able to detect the beating of a human heart at distances of up to 3m. The idea of this scheme is to either detect people behind walls, to count the number of people using public transport or retail outlets, or to detect intruders.

Bach says the human body is basically a dipole and a heartbeat is quite easy to pick up. He added that Japanese automotive developers are interested in such techniques to monitor the physical state and exact position of people in cars.

Alternatively, the technology could be strapped to the chest to monitor a hospital patient's heart without the need for electrodes.

"We could probably work to a range of 30m with capacitative sensing, although the most we have so far done is 9m," says Bach. "But we don't know yet the maximum range we could get."

As well as advanced applications, Sensatech continue to devlop other more mundane products, such as devices for accurately measuring loads and forces in nuclear radiation environments, and for detecting whether somebody has inadvertently stepped within the danger zone under an aircraft loading scissor lift.

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Design Pointers

- An array of pads can be used to map three dimensional volumes in space using capacitance
- The technology is being developed to detect breast cancer, tooth decay, and fish in streams
- The company has already developed technologies to detect delamination in carbon fibre composites, and the presence of human activiety, even from up to 3m distance away or behind a wall. This allows the detection, location and monitoring of humans in a non intrusive manner