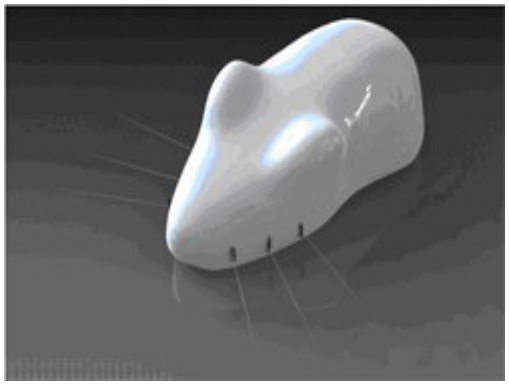
Feature Stories - A whisker-inspired approach to tactile sensing

Inspired by the twitching whiskers of common rats and Etruscan shrews, EU-funded researchers have developed rodent-like robots and an innovative tactile sensor system that could be used to help find people in burning buildings, make vacuum cleaners more efficient and eventually improve keyhole surgery.

DIGITAL ECONOMY



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Sensor systems that replicate the sense of touch have been the focus of increasing research in recent years, largely for robotics applications. But the focus has normally been on developing sensors that in some way or another replicate the way humans touch and sense the world: with our skin and particularly our fingertips.

'The main reason people explored fingertip-like sensors is because we have fingertips, but any kind of tactile sensor has to interact with objects and surfaces - and fingertips have a big problem with wear and tear,' explains Tony Prescott, a professor of Cognitive Neuroscience at the University of Sheffield in the United Kingdom.

Nature, however, has devised a much more robust, and often much more sensitive, kind of tactile sensing device: whiskers.

'If you look at the natural world, almost all mammals except humans have whiskers - it's actually us that have lost them. Whiskers are a natural way to sense things with touch,' Prof. Prescott says.

And, it turns out, just like their biological counterparts, artificial whiskers offer some big advantages over other approaches to tactile sensing as Prof. Prescott and a team

of researchers from seven countries have proved in the Biotact (1) project. Supported by EUR 5.4 million in research funding from the European Commission, the researchers studied rats and mice, tiny Etruscan shrews and other mammals and attempted to replicate the way they use their whiskers, or 'vibrissae', to sense their environment, detect objects and follow prey.

Their work has led to the development of an active vibrissal tactile sensor array and a series of rat-like robots that can move around by touch alone. The technology could potentially be used commercially for applications as diverse as search and rescue, consumer appliances, product testing or medicine.

'To begin with we had to understand how mammals use their whiskers. Around one third of the project was therefore dedicated to behavioural neuroscience, including filming rats and shrews using high-speed cameras to see how they use their whiskers whilst monitoring patterns of neural activity,' Prof. Prescott, the Biotact project coordinator, explains.

The team then worked out how to replicate natural vibrissal sensing in an artificial system. Their system works by measuring the vibration at the base of the shaft of a whisker caused by it coming into contact with an object or surface. Miniature motors enable individual whiskers or arrays of hundreds of whiskers to be moved and brushed against objects in much the same way that rodents move their whiskers back-and-forth at high speed. Software and powerful processing algorithms analyse the feedback from the whiskers to determine, for example, whether a surface is rough or smooth, if there is a corner or wall, how far away an object is or even if an object is moving.

For rodents, most of which have poor eyesight, active control of the whiskers allows the animal to accurately position the tip of the whiskers as well as control how the whisker moves in order to gain as much information as possible about an object or surface. In this way, they can rely on touch alone to explore and even hunt for food.

Robust robotic rodents for search and rescue

Applied to robotic devices, this same kind of active sensing approach greatly improves the accuracy and effectiveness of the sensors, enabling a robot to delicately feel its way around, rather than clumsily bumping into objects. In addition, while finger-like robotic probes can easily be damaged because the sensing components are directly exposed to the environment, with the Biotact technology the delicate electronic components are at the base of the whisker and do not come into direct contact with objects or surfaces. And artificial whiskers, just like their natural counterparts, continue to function even if they are broken or damaged, and they can be cheaply and easily replaced.

Several generations of sensors and robots developed by the Biotact team prove just how effective the approach can be. Shrewbot, the latest incarnation, looks a little like its namesake and can navigate its way around by touch alone.

'Shrewbot can even follow a moving object simply by using its whiskers. It has no visual sensors or any other type of sensing device,' Prof. Prescott says. 'Because the Biotact artificial whisker is modular, it can be used for a lot of different robots and devices, we've used it with a range of educational robots including the Lego Mindstorms robot, we have also produced a miniaturised version that uses a new kind of polymer-based actuator to move the whiskers.'

'We wanted to ensure that these sensors can be used as universally as possible, so you could go into a store and buy one much like you can buy a webcam today and mount it on any robot or any device,' Prof. Prescott adds. 'At the moment, the price of the technology is still relatively high, but we envisage that coming down over time and we've talked to some manufacturers - there's definitely interest in this.'

Indeed, the range of applications for the technology is extensive. A Shrewbot-like robot could be used, for example, to help fire-fighters find people in burning buildings or other environments, where smoke, dust or darkness impede visual sensing. An aquatic version, which members of the Biotact team are looking to develop in a planned follow up project, could be used to inspect murky underwater environments.

'Instead of rats and shrews, it would be more like seals and walruses which also use their whiskers underwater,' the project coordinator says. 'Companies involved in nuclear decommissioning have expressed interest in this as they need devices that can inspect nuclear waste ponds, there are also potential applications in the oil-industry and in underwater archaeology.'

In medicine, vibrissal sensors could eventually, after further research, provide highly sensitive tactile feedback to doctors performing keyhole surgery, detecting different kinds of tissues or bone for example. In manufacturing, the sensing technology could be used to test product quality or sort products by analysing the texture of materials. And in vacuum cleaners, the system could automatically detect different surfaces and switch settings to ensure the most effective cleaning, depending on whether a floor is tiled or carpeted.

In a slightly different application of the sensing and actuator technology developed in Biotact, the University of Sheffield is currently working with South Yorkshire Fire and Rescue to develop a helmet for fire fighters that combines ultrasound sensors for navigation in smoke-filled environments with actuators to provide tactile feedback to the wearer.

Biotact received research funding under the European Union's Seventh Framework

Programme (FP7) as part of the Future and Emerging Technologies (FET) sub-programme. The results from Biotact illustrate how this type of long-term, foundational research can lead to research in other areas and use the techniques to solve problems elsewhere.

(1) 'Biomimetic technology for vibrissal active touch'

Useful links:

- 'Biomimetic technology for vibrissal active touch' website
- Biotact factsheet on CORDIS

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PROJECT

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