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SENSORS_OLFACTION

Plenty to Sniff At

Smaller and more sensitive electronic noses open up new applications

Your dog knows in a sniff if you have been cavorting with the despised feline next door or fingering his favorite treats. He knows because his nose is replete with more than 100,000 sensory cells that bind to chemicals wafting through the air. Humans have harnessed this fine canine sense for sniffing out bombs, drugs and fugitives, but there are many smelly jobs for which Fido won't do--including discerning if the food on the conveyor belt at the dog food plant smells exactly the same as it did yesterday. Or if a pigsty is too fetid, or treated sewage is odor-free. Human testers traditionally have pulled such pungent duties.

Electronic noses are now poised to fill these roles. The devices are collections of diverse detectors analogous to the sensing cells in a hound's nose. Each aroma pumped across the array induces a unique pattern of responses that is fed into a computer. The electronic nose "recognizes that pattern, draws it from its memory banks and says, ‘Aha, that's root beer or a rose or some other vapor that I've smelled before,'" explains chemist David R. Walt of Tufts University.

Such electronic noses are already at work in industry, detecting bad batches of food and drink as well as substandard packaging and recycled goods, to name just a few applications. But new advances in miniaturization and sensitivity promise to broaden their scope; they may eventually identify chemical spills, diagnose strep throat, hunt for truffles and even keep toast from burning.

In England in the early 1980s George H. Dodd, then at the University of Warwick, and Krishna C. Persaud, currently at the University of Manchester Institute of Science and Technology, introduced the array concept of aroma detection. Their initial research relied on metal oxide sensors, which worked properly only at about 300 degrees Celsius; these are suited "to measure the mixture of gases in, say, the carburetor of a motorcar," Persaud explains, but are potentially inappropriate to evaluate more delicate fragrances, as in coffee or perfumes.

Most electronic noses today function under gentler conditions. They exploit the fact that when vapor binds to a polymer, key attributes of the polymer, such as its conductance, change in detectable ways. One of the oldest companies on the electronic nose scene, founded in 1994, is Osmetech (formerly AromaScan), which adopted the conducting polymer technology that Persaud helped to develop. Osmetech's market is broad--its noses have been used to sniff out mold in grain and off-odor toothpaste ingredients. Now the Osmetech nose is being tested for diagnostic detection of bacteria that cause urinary tract infection and pneumonia.

Cyrano Sciences, which manufactures a handheld electronic nose, relies on a different polymer technology, one that is licensed from the California Institute of Technology. When these polymers swell on interaction with a vapor, conducting material in the polymer moves with the swelling, altering an electrical signal. Because the conducting material is added to the polymer, just about any plastic is fair game as a sensor--vastly increasing the number of suitable sensor materials for nose engineers. The Cyranose 320 retails for about $8,000 (compared with tens of thousands of dollars for typical benchtop noses performing comparable tasks) and is the size of an old walkie-talkie. The company is targeting markets in quality control for food, packaging, cosmetics and environmental monitoring.

All told, more than a dozen companies sell electronic noses--including Alpha MOS, Hewlett-Packard and Applied Sensor--and the current annual market is estimated to be in the low tens of millions of dollars. Some of the most intriguing uses so far aren't commercial, however; in 1995 a nose that Persaud helped to develop went on board the Mir Space Station. "I think this was the first electronic nose in space," he chuckles. It turned out that the nose could track subtle environmental changes in the capsule--as well as not so subtle ones, such as the occasional fire. This year the Jet Propulsion Laboratory in Pasadena, Calif., placed on a space shuttle a nose designed to detect harmful gases (happily, none were found).

Unlike a dog's nose, the electronic noses now on the market get by with a mere handful of sensors. Nathan S. Lewis of Caltech, who developed the technology licensed by Cyrano, puts it this way: "A dog has a big brain because it doesn't know what it's supposed to smell tomorrow. But if the only thing I care about is burned toast, then I'm not going to have to have a very big algorithm." The latter point is good news for the nose industry. For simple jobs, the existing technology will probably suffice. From there it's just a matter of getting it small enough and cheap enough for widespread use.

Lewis's research may offer a solution. His composite polymers are amenable to microchip fabrication. "We have chips that have several hundred different pixels on them, each one with a different polymer. They're tiny--they're a few millimeters by a few millimeters," Lewis says. When the detection electronics, processing power and a micromachine pump to deliver the vapor are all included, Lewis envisions a device that could eventually be as small as a thumbnail.

Unfortunately, polymer-based electronic noses often miss the smelliest smells: small amines and thiols responsible for fishy, skunky and rotten-egg odors, all of which interact poorly with most polymers. Lewis recently crafted composite polymers that will detect amines, but Kenneth S. Suslick of the University of Illinois has been working on a different kind of chip, based, he says, on his insight that "everything that binds to metal ions really stinks." He has developed inks based on organometallic compounds that change color when bound by vapor molecules--analogous to the iron heme in hemoglobin that gives oxygen-rich blood its scarlet hue--and can be printed on chips. "Our sensitivities are, at least for amines and most thiols, comparable to or better than the human nose," he says. This spring Suslick plans to launch a company to be called ChemSensing, Inc., to advance his "smell-see" technology into the commercial realm.

One of the biggest challenges for the future of electronic noses is detecting complex odors against an intricate backdrop. For example, Julian W. Gardner of the University of Warwick has designed a nose that can routinely distinguish among different types of bacteria in a lab culture. But getting the nose to diagnose staph versus strep infections by sniffing a patient's breath is another matter altogether. Sensitivity and resolution are crucial to pull a small signal from such a messy background.

One answer is redundancy: canines achieve sensitive and discriminating olfaction using many replicates of about 1,000 different receptor types. It's possible to squeeze many of the same sensors onto a chip. Tufts University's Walt prefers fiber optics. In a bundle less than half a millimeter thick, he makes tens of thousands of smell sensors by placing a polymer bead doped with fluorescent dye at each fiber end. The binding of vapor molecules to the polymers shifts the light emitted by the dyes, forming a color signature--a technology licensed by Illumina in San Diego. This method can detect the presence of explosives vapor in the low parts per billion--nearly doglike.

Others suggest that attempts at replicating the olfactory system may be futile. "The problem is, [an array] doesn't give you an instrument. You can't calibrate them, because the sensors are not specific," contends Edward J. Staples, managing director of Electronic Sensor Technology in Newbury Park, Calif. Staples argues that the workhorses of the analytical lab--gas chromatography and mass spectrometry--beat sensor arrays in specificity, sensitivity and quantitation. His zNose is a portable gas chromatograph/ mass spectrometer instrument that uses sound waves to detect volatile molecules. It sells for less than $20,000 and can finish an analytical run in 10 seconds. It's being used for rapid quality control in breweries and wineries, including Sutter Home. "You can set it right on a table and quantitate the chemistry around you," Staples says.

In truth, there is probably room for both the zNoses and the e-noses. There are potential markets for cheap and small devices (think toasters)--a tough row to hoe for gas chromatographs and mass specs but well suited to electronic noses of the world. And there are potential markets for precise quantitation (think process control)--an area in which electronic noses may always lag. "A fast, cheap, front-end screen is where I see electronic noses," Gardner says. "We're at the early stages of the technology. It's hard to predict which [approach] will win, but if you can do it for under $100 and make it work, then you'll be a winner."
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