Electronically Overhauling the *Homo Sapien*

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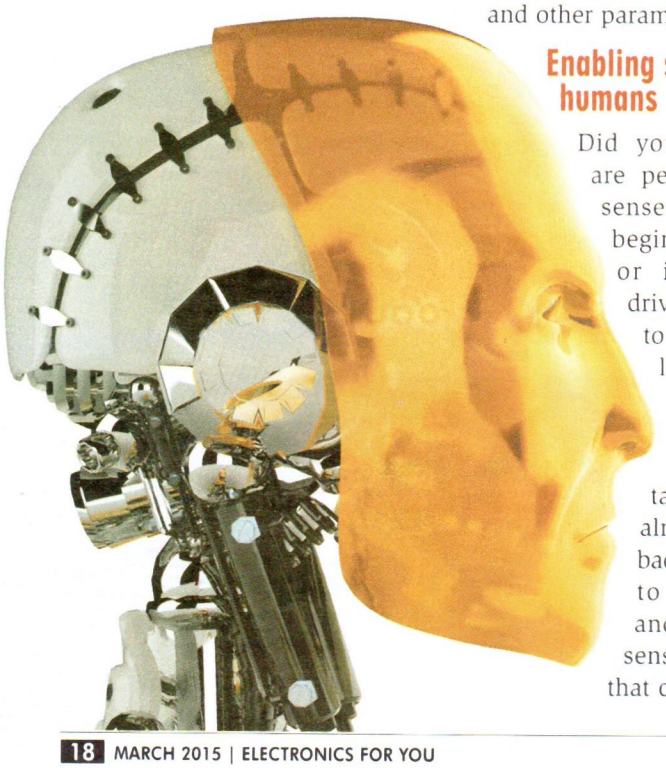
Neil Harbisson, 32, can receive phone calls directly into his head. He can perceive colours invisible to the human eye. He has an antenna that sprouts from the occipital bone in his Bluetooth-enabled skull. Neil is not a sci-fi movie character, nor from the future; he is the world's first legally-recognised cyborg.

Just like Neil, wearing and later embedding electronics is now becoming part of life for an increasing number of people. "Wearables, a nicer name for wearable computers, are not just technology strapped onto body parts. These will play a significant part in the Internet of Things (IoT), which aims to connect everyone and everything with each other," says Deepak Thomas, India sales manager at CSR.

While some people wear electronics to help them perceive their surroundings more deeply, others wear these to keep track of calories, distance walked, heart-condition and other parameters.



Enabling smarter humans

Did you know there are people who can sense their laptops beginning to stall, or if their hard drives have begun to spin-up under load? An article by Quinn Norton from Wired had talked about this almost a decade back. Fast-forward to the present, and adding new sensor technology that complements or supplements our existing five senses has already gained steam.

The Internet went wild with news coverage when people began adding rare Earth magnets implanted in their fingertips, but in 2015, you have dedicated bio-hacker communities, like biohack.me, set-up to support grinders (people who practice body modification to extend and improve human capacities). With this trend already up and running, humanity just might move at least a few steps closer to becoming entities like the cybernetic *Borg* species from the fictional world of Star Trek.

What new role does sensing play in this

After measuring calories, steps and distance, measuring heart rate is the new goal every fitness device developer aims to perfect this year. Vendors like Valencell specialise in clinically-validated biometric technology, and have come out with newer heart-rate-monitoring technology, powered by better sensors and algorithms. Their PerformTek sensor technology is licensed by the likes of Jabra, Scosche, LG and ATLAS. One important feature of their photo-detector-powered heart-rate-monitoring technology is its ability to be scalable to multiple form factors, like earbuds, armbands and wrist devices. Companies such as Belgium based imec are working on optical sensors that can give accurate pulse and blood oxygen levels, and wearable ECG sensors to monitor your heart function.

Perhaps, the most interesting of all is Xelflex technology, which enables a garment itself to become the sensor. Developed by Cambridge Consultants, the fibre-optic-thread based garment provides the user with guidance and feedback on his or her movements and can be used for a variety of purposes, like sports and fitness activities. A

The Lord of the Ring?

Rings with sensors built into them are not new, at least conceptually. There are quite a handful of start-ups that have tried to build these in one way or another.

Business Week reports that CES 2015 saw a big crowd at the display for Logbar's product called Ring. Previously seen on crowdfunding website, *Kickstarter,* where it raised US$ 880,000, these now have enough *moolah* to display at CES.

But, is the product ready yet? Their initial try was a failure with rings that were deemed not worthy of funders' fingers due to the material used (zinc) and functionality issues. Logbar says, it is ready now and will be out in March 2015, but Joshua Bernstein reported in his article from CES 2015 about spotting a disclaimer warning of potential itchiness, irritation and rashes, depending on the user's health conditions.

On the other side, there is our own *desi* team building Fin, a ring that can be used as a gesture interface. While it was successfully campaigned on crowdfunding website, *Indiegogo,* last year with approximately US$ 202,000 raised, the company has missed its target delivery date of September 2014, as the product remains under development. The team has posted an updated delivery date of May 2015 in response to queries from funders about the product's status. They have also uploaded a video of the prototype in its current stage, which is reassuring. However, it still remains to be seen how the final product will hit consumer expectations.

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small electronics pack clips on to the garment, where data can be processed and made sense of.

According to a paper published in Advanced Function Materials, researchers at Singhua University and Nanchang University in China have claimed that it is possible to use grapheme-strain sensors to monitor vital signs on a human body. This technology, once developed, could be implemented into implantable devices or on electronics skin. For instance, the strength of motion created when a person moves creates a larger strain on the sensor, which allows the signal to be recorded and monitored easily.

Using wearables as the first information tool in sports is another trend that is picking up, and about time too. Last year's FIFA World Cup Final saw one example, where a German player was injured after getting a shoulder-hit to the head. The player played for some time after the hit, before it was realised that he had a serious injury.

Blackbox Biometrics and MC10 are two companies that have been building technology for this sector. By measuring the magnitude of motion and rotational forces in the environment around the brain, these sensors can give an idea about the actual impact to the brain and the chances of potential injury.

University of Michigan is working on millimetre-scale energy-harvesting sensors, such as a wireless intra-ocular pressure sensor that is intended for glaucoma patients to measure and report the pressure in the eye. "All elements, including the sensor, solar cell, energy storage, MCU and radio, could be part of this sensor. The university has indicated that it occupies a volume of only 1.5mm^3 (0.5x1.5x2.0mm^3) and can be implanted with a minimally-invasive procedure that is routinely used for cataract surgery. Commercialisation is anticipated in two to three years," adds T. Anand, managing director, Knewron.

Smarter algorithms. Sensing data alone is just halfway to the goal when it comes to wearable devices, because the amount of noise in an everyday-use environment is pretty high. PerformTek sensor module technology, mentioned earlier in this story, has a signal-extraction method that removes noise from skin movement and footsteps, as well as the environment, to keep data clean. Additional algorithms are then run on this to accurately extract heart rate, respiration rate and other parameters. An additional proprietary algorithm leverages accelerometer data to measure running and cycling cadence, calories burned and distance travelled.

But, why did it take so long for these applications to be tapped?

"Electronics are rigid and boxy, while humans are soft and curvy."

First heard at the D11 conference in 2013, this statement is a simple way to understand the challenge put forward by wearables. You need circuits that can follow the form and elasticity of its user, yet keep functioning optimally.

MC10 and Multek are examples of companies that seem to have understood the limitation of conventional electronic board technology when considering their utility for wearable-device designs. One of MC10's patents is for what is termed as extremely stretchable electronics. The invention is built around the idea of using two isolated electronic components attached to an elastic-substrate material. An electrical interconnection is placed between components that maintain electrical characteristics, while the substrate is stretched.

An interesting MC10 design is Biostamp, a sensing sticker technology that can be placed on the skin. It stretches and flexes along with the skin, while maintaining the functionality designed into it. It can measure a variety of physiological functions, like data from the brain, muscles, heart, body temperature and movement.

Flexible printed circuit board (PCB) is a technology that has been around for some time. Multek has expertise in manufacturing flexible PCBs, and available technologies include standard flex and rigid flex, and also newer technology, like Novaflex HDI that features high-density interconnects. Novaclad is a material from Sheldahl, which is made-up of ultra-thin build-up of copper materials for flexible circuits.

Newer technology designed especially for wearables is the fabric circuit board. Developed by Xiao-Ming Tao and her team from Institute of Textiles

and Clothing in Hong Kong, it is a highly-stretchable fabric formulation that can withstand multiple machine washes. The material has multiple filaments of pre-stretched elastic yarn and polyurethane-coated copper fibres. These are combined to form a thin material that can have microchips and components fixed on it, whose electrical connections are maintained even when stretched.

An interesting example of these materials being used is in a policeman's bullet-proof Kevlar vest. If the policeman is shot, then the material senses the bullet's impact and calls for back-up automatically. This allows the policeman to focus on the situation in front of him.

Another example of electronics-infused textiles started right here in India. Nihal Kashinath, founder, IoT-BLR, one of the largest IoT-focused meet-up groups in the world, says, "At IoTBLR, we prototyped a programmable shirt—a shirt on which you can load apps, such as music controller, slide-show controller, remote-camera controller, movement tracker and panic button. The project was spun-off as a separate company, ThingsEvolve, where specific use-case shirts and other apparel are being developed."

With great features comes great power consumption

The power problem is certainly not an easy one to solve, particularly in the wearable segment. "Today's technologies are allowing engineers to harvest and manage low-power (nano) from a variety of sources, including solar cells, thermoelectric cells, electromagnetic and vibration energies. These technologies are providing designers with more options to charge batteries while the device is in use," says Sachidananda Karanth, senior technical architect, Mistral Solutions.

Energy harvesting from movement, heat, light and even ambient radiation is being explored for wearables. Nihal explains how the selection of energy-harvesting method depends heavily on use-case (if it is a sleep tracker, kinetic-energy harvesting would be a poor choice) and power requirements of the device's features (if your wearable camera needs to be used for advanced image processing, energy harvesting will not be of much help).

Thin-film-battery technology is already being implemented in electronics, like Biostamp from MC10, that has partnered with Braemar Energy Ventures for its solutions. One example is Solicore, which provides flexible thin-film lithium-polymer batteries that are less than half a millimetre thick and yet hold up to 25mAh while delivering three volts. These allow design engineers to disregard bulky conventional battery designs while developing the product.

New wearable designs must support an increase in functional integration, as well as offer a reduction in overall power consumption, cost and physical footprint. "These cost-sensitive embedded designs require a move away from the traditional arms race of MIPS, bytes and megahertz, and a paradigm shift into the era of function enablement," explains Marten Smith, marketing manager, Medical Products Group, Microchip Technology Inc.

Another technology available is for those devices whose design enables these to gain from harvesting energy from the environment, like sunlight. What is required is a high-efficiency thin-film-photovoltaic technology. Organic photovoltaic seem to be one potential candidate here. One company, named Solarmer Energy, has been successfully working on organic photovoltaic technology that could be used to make power-generating fabrics. Other firms in this segment are Eight19, Heliatek and Dyesol.

Korea Advanced Institute of Science and Technology (KAIST) has a team working on developing a flexible glass fabric based thermoelectric (TE) power generator that produces electricity from the heat generated by a human body. Their journal states that they used a screen-printing technique to build the generator, which can be used to power self-sustaining devices. "With this technique, it is possible to make the device thin ($\sim$500µm), light-weight ($\sim$0.13g cm^{-2}) and flexible," light enough for wearable devices.

At CES this year, Intel's CEO, Brian Krzanich, plucked a button from his blazer and explained how that is Intel's new Quark SE SoC-powered device named Curie, their latest development module targeting the wearable market.

Deepak adds that a California based start-up, Imprint Energy, is developing flexible and rechargeable bat-

How nanotechnology could affect wearable electronics

Innovators at NASA Glenn Research Center have developed a suite of nanotechnologies that offer the potential to enhance or replace silicon based technology for high-speed, high-computing power devices that operate at low voltage and current levels. These nanotechnologies are used to make polymer nanowires, carbon nanotubes (CNTs) and other nano-ionic structures, which produce a variety of nano-scale electronic switches, which are the basic building blocks for relatively inexpensive, low-voltage and high-speed logic circuits. The nanotechnologies are more durable, with longer lasting circuits, and enable computational capabilities at specific locations.

These circuits can be used to make sensing systems, wireless and embedded communications, large-area flexible electronic displays, active matrix light emitting diode (LED) displays, along with antennae and radiofrequency identification (RFID) devices, such as smart keys and smart cards. These could also find applications in electronic-circuitry-protection elements.

—James Colby, manager, business and technology development semiconductor business unit at Littelfuse

Bend, stretch, flex and back. These are words you usually hear in those early morning fitness programmes on TV, but these now apply to circuits too

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teries that can be printed cheaply. Yes, printed! In the meantime, smaller batteries mean shorter battery life, which will need advancements in wireless power and charging, over and above what wireless power alliances, like Qi and A4WP, are supporting today.

"A lot of research is being done to solve the battery-power issue. Imprint Energy has come up with an ultra-thin and flexible battery that can power your wearable gadget, by making it less bulky and more designer friendly. They have used Zinc battery technology, called ZincPoly, which is stable and safer than conventional lithium based batteries. Screen printing is the technology used by them to create custom-shaped batteries for wearables," says Arvind Sanjeev, founder of DIYHacking.com and creator of the indigenous Google Glass clone.

He adds that transparent wearables is something that is gaining a lot of attention. Imagine wearing a transparent band/watch, wouldn't it be cool? The major hindrance towards making this a reality was batteries, which had to be transparent too. However, SLAC National Accelerator Laboratory has come out with a solution to this as well, by making transparent batteries using a transparent, slightly-rubbery compound known as poly-di-methyl-siloxane (PDMS).

T. Anand also explained about an alternative battery technology that sounds interesting. "A new alternative in the form of solid-state batteries is coming up. These batteries would be fabricated over silicon dye and would undergo almost the same process as that of chip manufacturing. These batteries are expected to have very-high-density energy stored, just like a chip would contain millions of transistors."

Materials technology is now more significant than ever

When the game is about building products that are in constant contact with human skin, choice of material gains a new level of significance.

While selecting materials might seem purely cosmetic to some, there are examples where a wrong selection has resulted in a rash of recalls (notice the pun). Fitbit Force was one such product that had to be recalled due to complaints of irritation by customers. The cause was presumed to be either the nickel in the stainless-steel part of the device or adhesives used in the strap. This was so serious that it resulted in the initiation of an investigation by Consumer Product Safety Commission of the UK. Another example is the use of zinc in Ring gesture device by Logbar, which caused signal interference.

"Over US$ 100 billion will be spent on materials for wearable electronics in the coming decade," reports Dr Peter Harrop and Dr Guillaume Chansin in their research report, Wearable Technology Materials 2015-2025.

While sports products like my Jawbone UP24 came with hypo-allergic medical-grade TPU rubber, premium products like Apple's iWatch are claimed to come with stainless steel, silver aluminium or 18-karat yellow and rose gold. Nike's FuelBand came built with a mix of thermoplastic elastomers, polypropylene, magnesium and stainless steel. Fitbit band was also marketed as having a flexible, durable elastomer material without latex. Fitbit's clasp is made of surgical-grade stainless steel and contains traces of nickel.

Looking at the material space, it looks like luxury brands have their own game to play here. For instance, Mont Blanc (yes, the old upmarket pen company) has launched an e-strap for their line of luxury watches. Made from leather with a carbon-fibre texture, it holds an organic LED display in a carbon-coated steel housing.

In an example of taking it all the way, Austrian luxury brand Swarovski has teamed-up with Misfit to create a giant crystal, embedded with an activity tracker that can be matched with whatever pieces of jewellery you have from Swarovski. This could be a dangerous combination for your purse if you have a nerdy girlfriend, but it is still impressive from a purely technical standpoint.

Will society accept wearing and implanting electronics

When computers were first introduced, there was uproar on the jobs it would displace, the automatons that would substitute humans at work and the emotion-less digitisation of life. Today, we have computers on our desks and laps, in our cars, homes and pockets. Wearables and implantables will probably have the same destiny. Dr Nagesh tells us that, under Obama Care, America is planning to use implantables for greater social benefit.

It seems apt to use the most-used dialogue of the cybernetic *Borg* here, and quote: "Resistance is futile." ●