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MUSICAL BANANAS!

UNFOLD TO MEET MORE BIG THINKERS ›

THE MIT MEDIA LAB VISIONARIES WHO

NICHOLAS NEGROPONTE
is back with a new column

TOD MACHOVER
is reinventing musical art

SEP KAMVAR
is democratising coding

HIROSHI ISHII
is linking bits to atoms

WIRED GOES INSIDE THE MIT MEDIA LAB

+ **TESTED**

ACTION CAMERAS

KIDS' TABLET DEVICES

SELF-HEATING FOOD *p.148*

HELPED CREATE THIS SPECIAL EDITION

JOE PARADISO
is augmenting your world

RAMESH RASKAR
is changing how we see

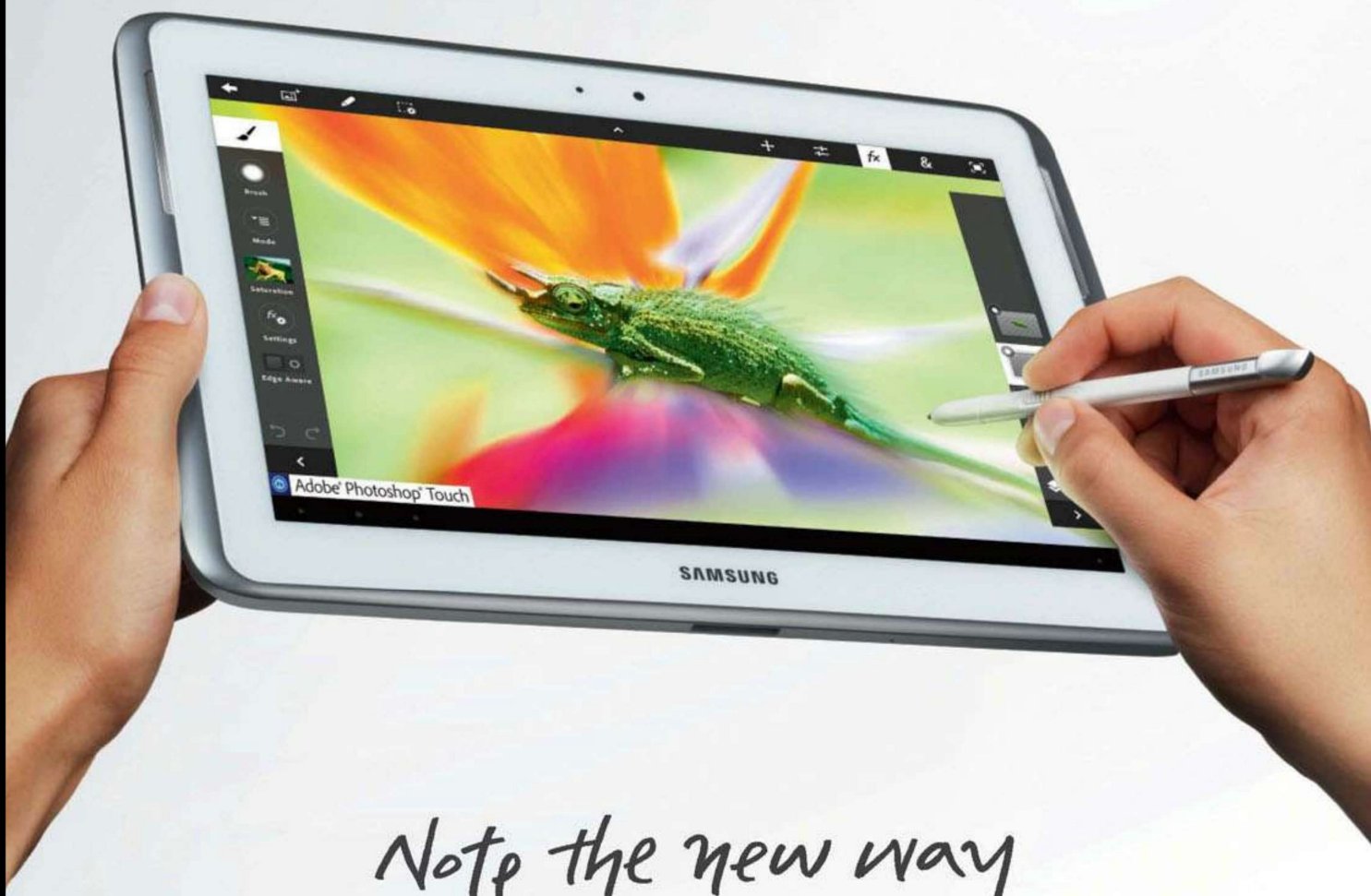
CYNTHIA BREAZEAL
is leading the robot uprising

KENT LARSON
is rethinking the city

PLUS
HOW COMPUTERS ARE LEARNING TO READ YOUR EMOTIONS *p.136*

Samsung
GALAXY Note 10.1

SAMSUNG



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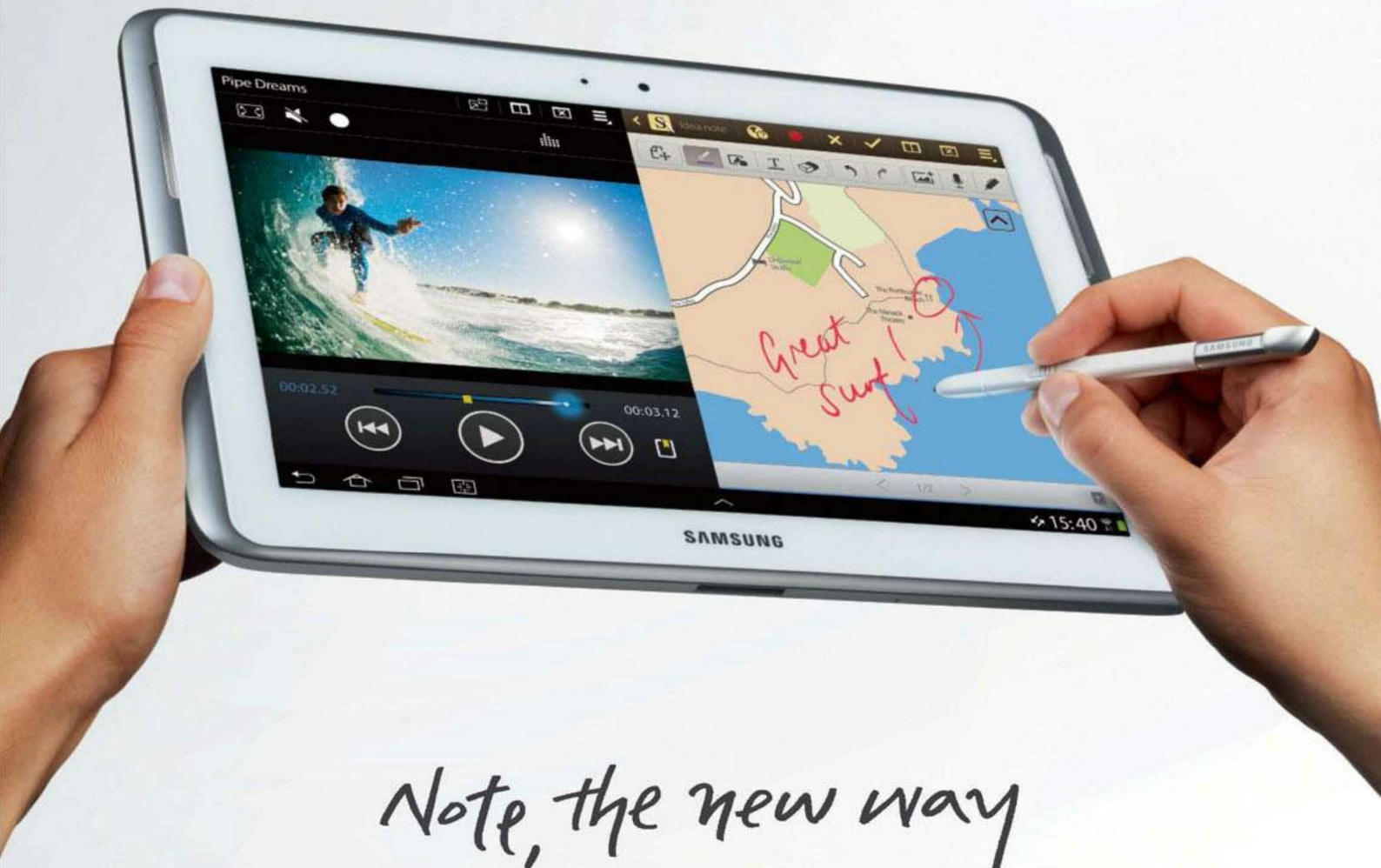

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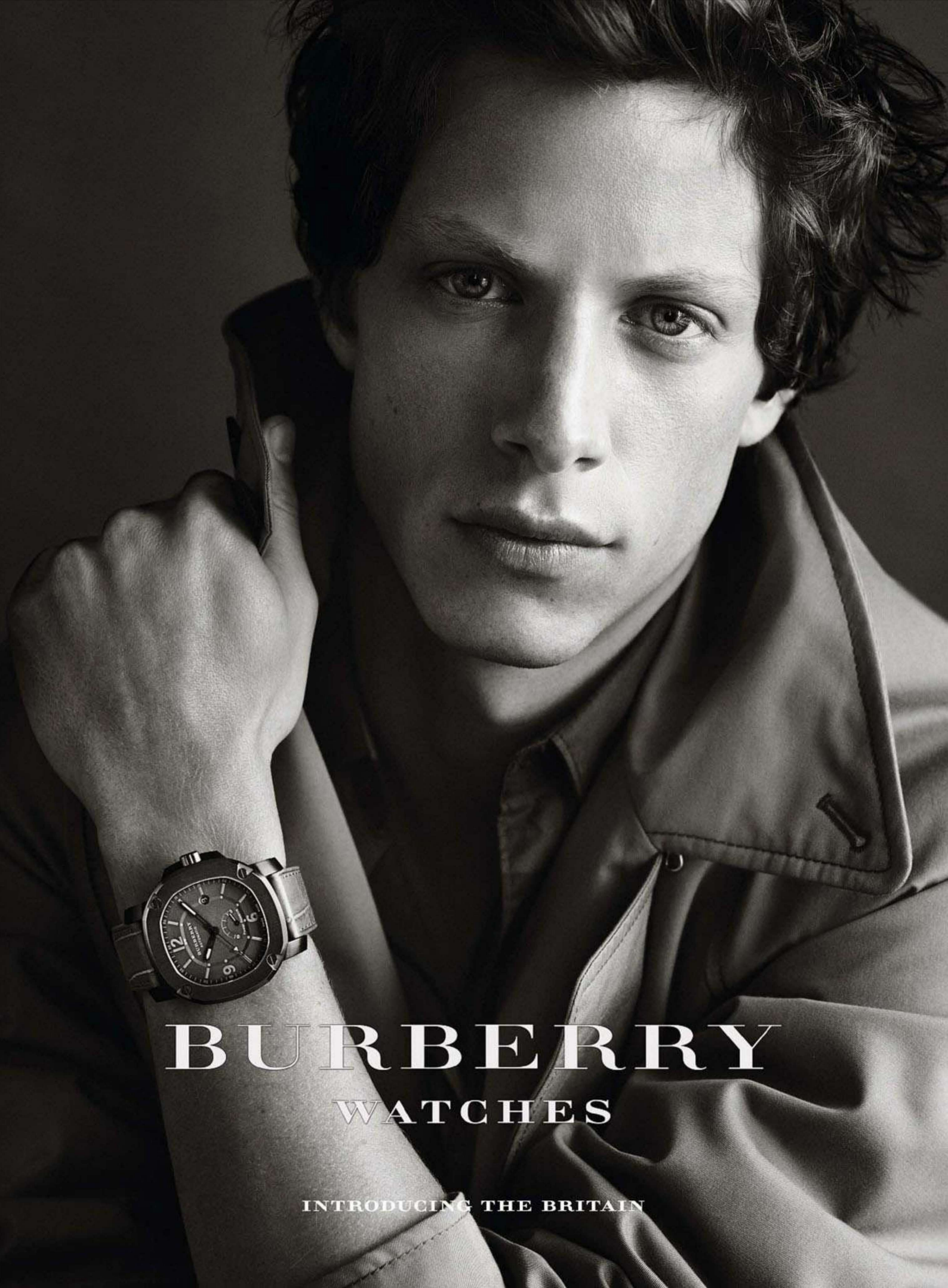
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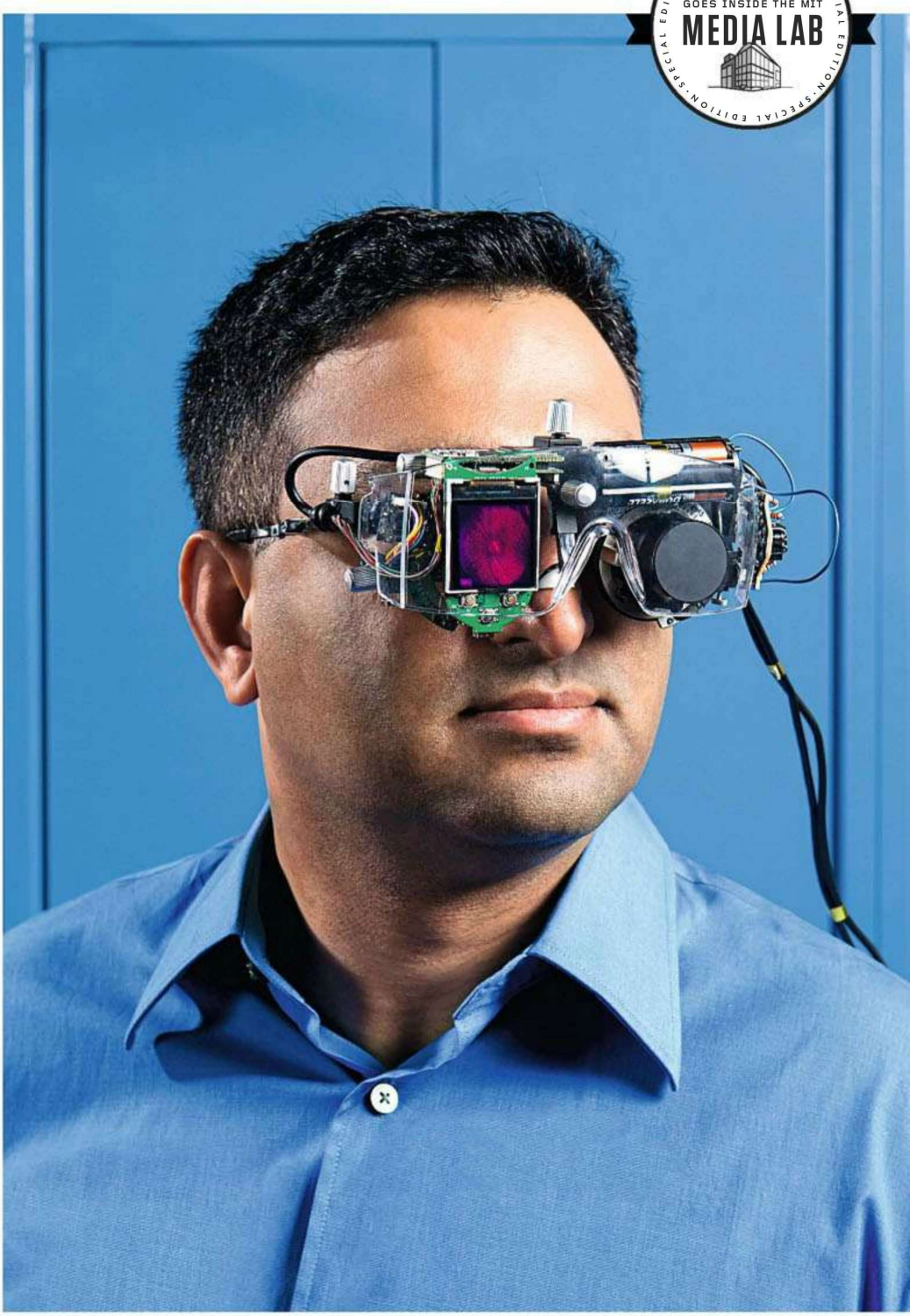
"The idea to build the Media Lab came up in 1979. It was generally considered a fool's errand"
– *Nicholas Negroponte*

FEATURES



Right: Ramesh Raskar, head of the Media Lab's Camera Culture group, with a retinal imaging machine

PHOTOGRAPHY (FRONT COVER): CHRIS CRISMAN; (THIS PAGE): BRAD SWONETZ

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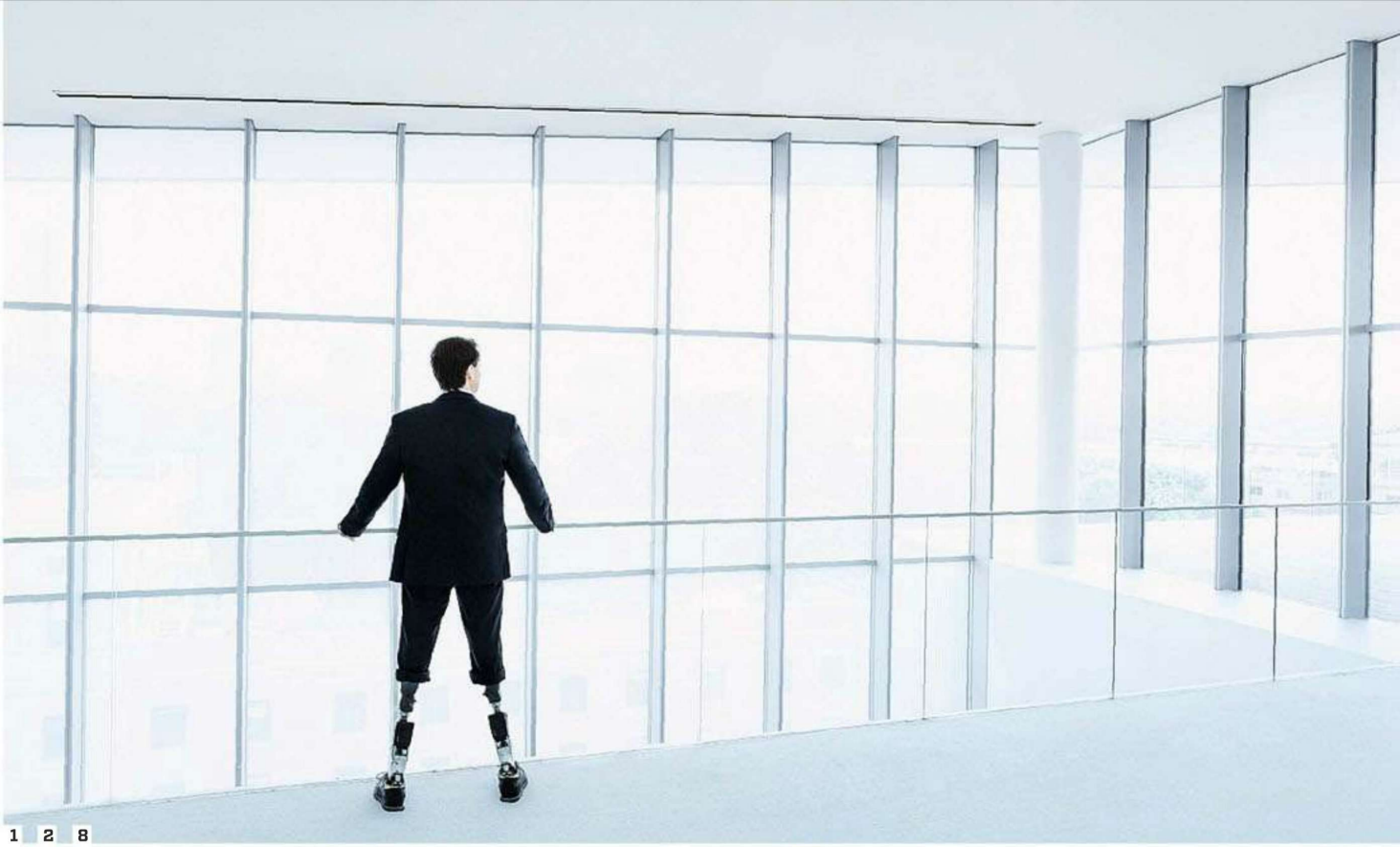

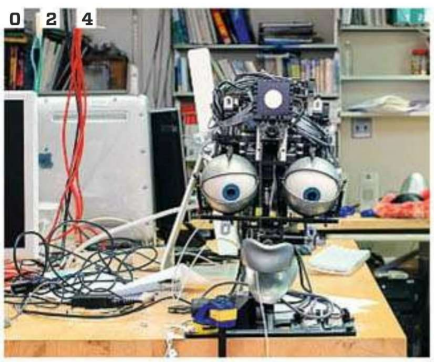

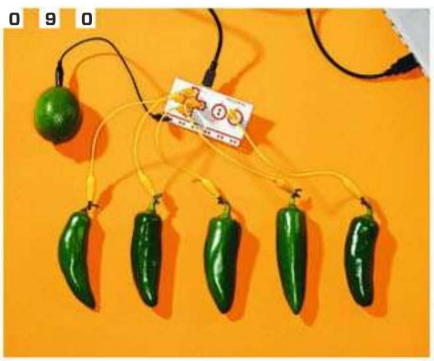

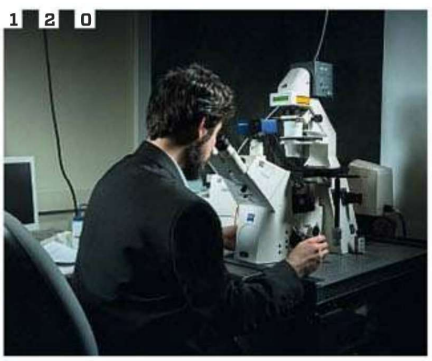

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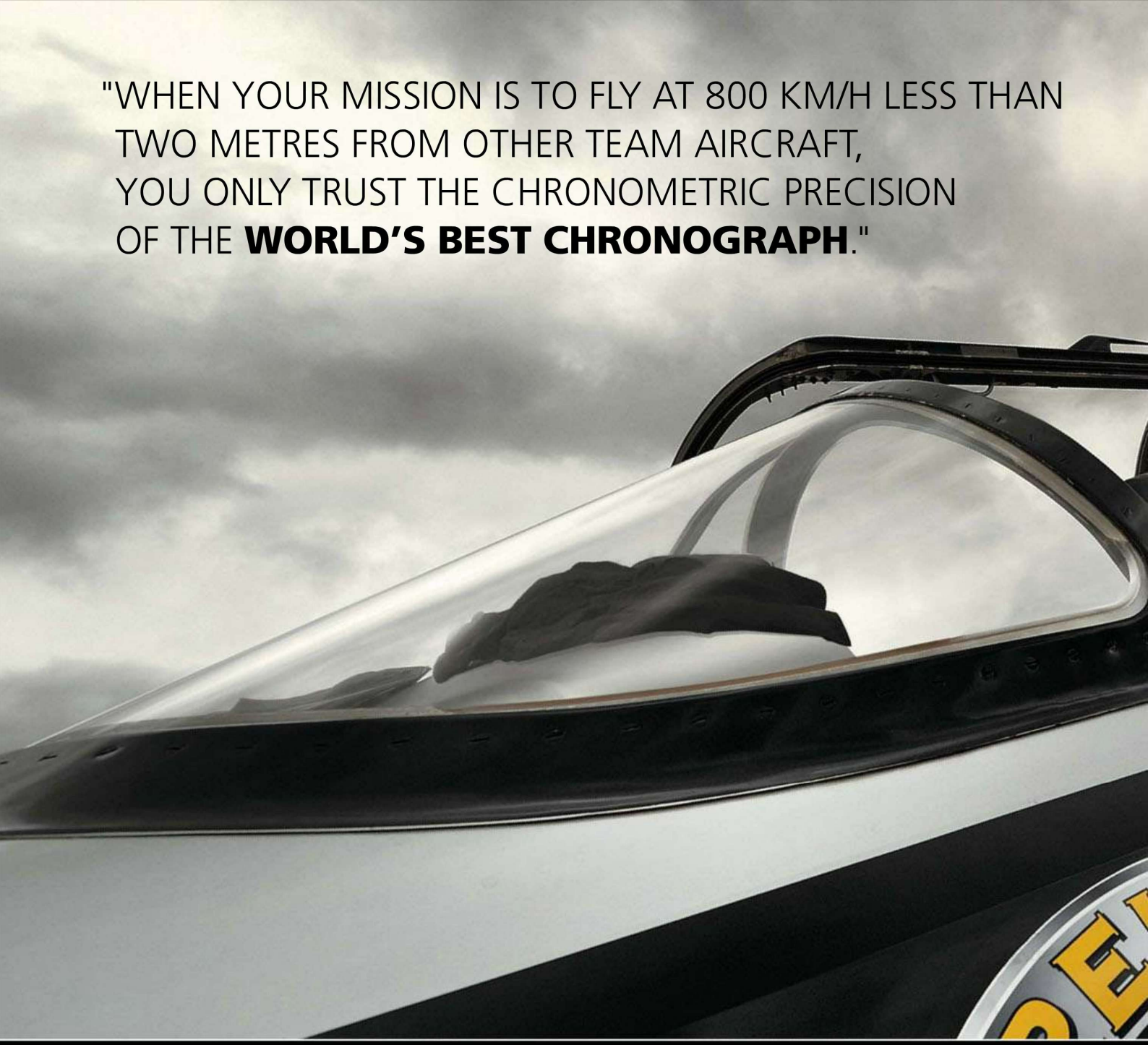

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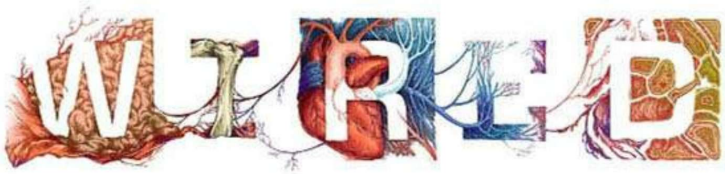

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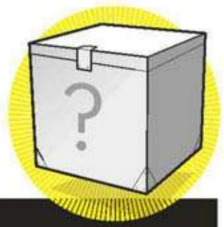
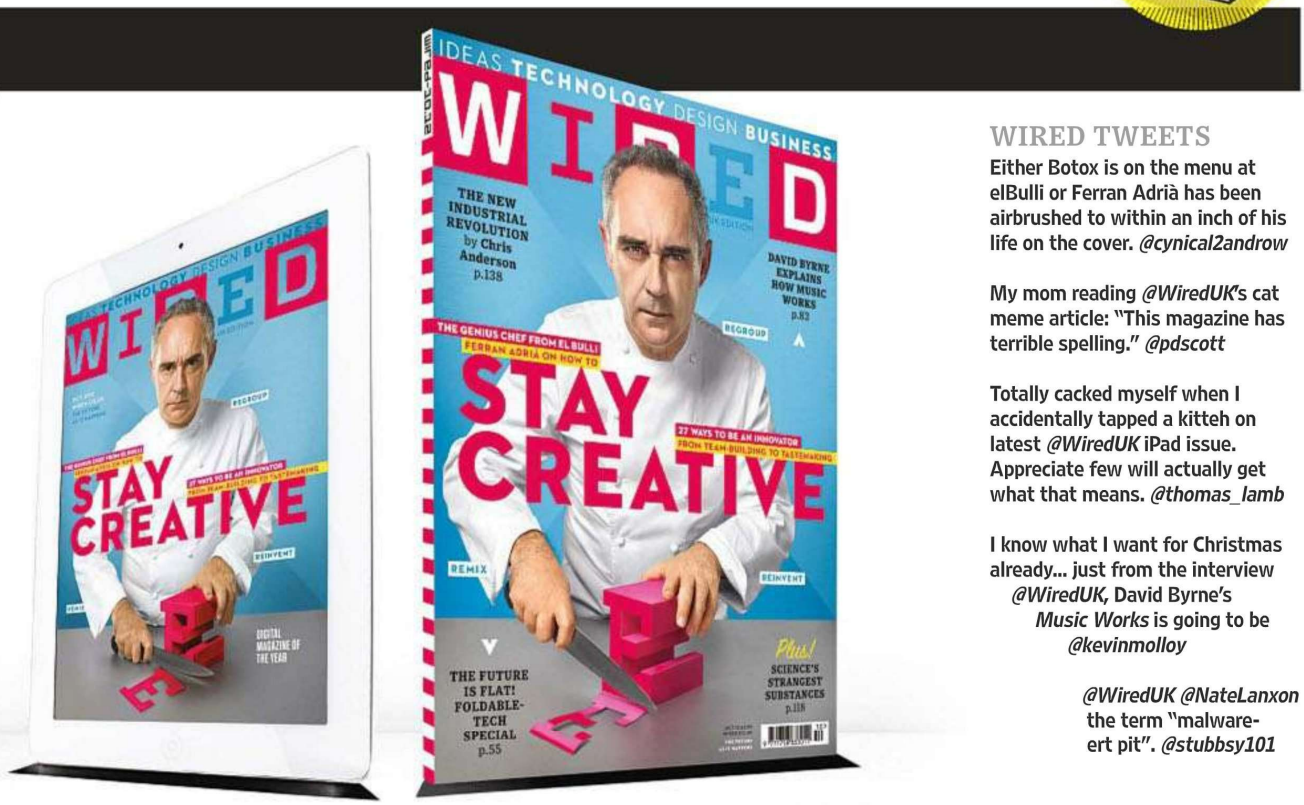
RANTS

WHAT'S IN THE BOX?

A mystery 1.5m³ box arrived at WIRED HQ, so we asked our Twitter and Facebook followers what it contained. Top answers: Prince; weasels; the cloud; Schrödinger's cat; Julian Assange. Answer below.





WIRED TWEETS

Either Botox is on the menu at elBulli or Ferran Adrià has been airbrushed to within an inch of his life on the cover. *@cynical2androw*

My mom reading *@WiredUK*'s cat meme article: "This magazine has terrible spelling." *@pdscott*

Totally cacked myself when I accidentally tapped a kitteh on latest *@WiredUK* iPad issue. Appreciate few will actually get what that means. *@thomas_lamb*

I know what I want for Christmas already... just from the interview *@WiredUK*, David Byrne's *Music Works* is going to be *@kevinmolloy*

@WiredUK @NateLanxon* the term "malware-ert pit". *@stubbsy101

10.12 Stay creative: Ferran Adrià closed the world's most lauded restaurant to open a foundation for innovation. We met the chef to find out about working smarter – and published 501 pictures of elBulli dishes alongside the interview. Did it inspire you? Or did it just make you feel peckish? Let us know: rants@wired.co.uk

GIVE GREECE A LIFT

Deploy Uber in Athens, please (Neat street meter beater, 09.12). Its not the ranks we want to avoid, but the rude drivers. Find a solution and we are your slaves. ***marios p, via wired.co.uk***

NOT HYPNOTIC

Alex Garland, *Dredd*'s writer and producer (Hypnotic filming, 10.12), says that the super-saturated slo-motion tableaus "separate you from the violence. You don't notice that you're watching a kid's cheek being shot over the screen." He is then quoted as saying, "You watch it and you become hypnotised by someone being shot by a machine gun." I do not think cinema should shy away from showing violence, but let's at least show its true nature and dreadful consequences, instead of suggesting that violence is a thing of beauty to be admired and imitated. *Mark Vernon, via email*

A SHAKY ECONOMY

As a technology user, I'm offended by Rachel Botsman's article (Welcome to the new reputation economy, 09.12). The concept of a "global reputation" is driven by a need to mine more information from me, and broker it behind the scenes (an attempt to appeal to my vanity, so I'm willing to let companies like Facebook mine and share my information). Is eBay feedback really an accurate predictor of anything, outside of eBay? Nope. "Playing nice" is a condition of service with them, and the rules by which I get what I need there. It's not a predictor of how I behave elsewhere, nor are eBay's terms universally applicable. Just because I make my car payment on time does not mean that I don't rob banks or steal your retirement savings to do it. *Not a sucker, via wired.co.uk*

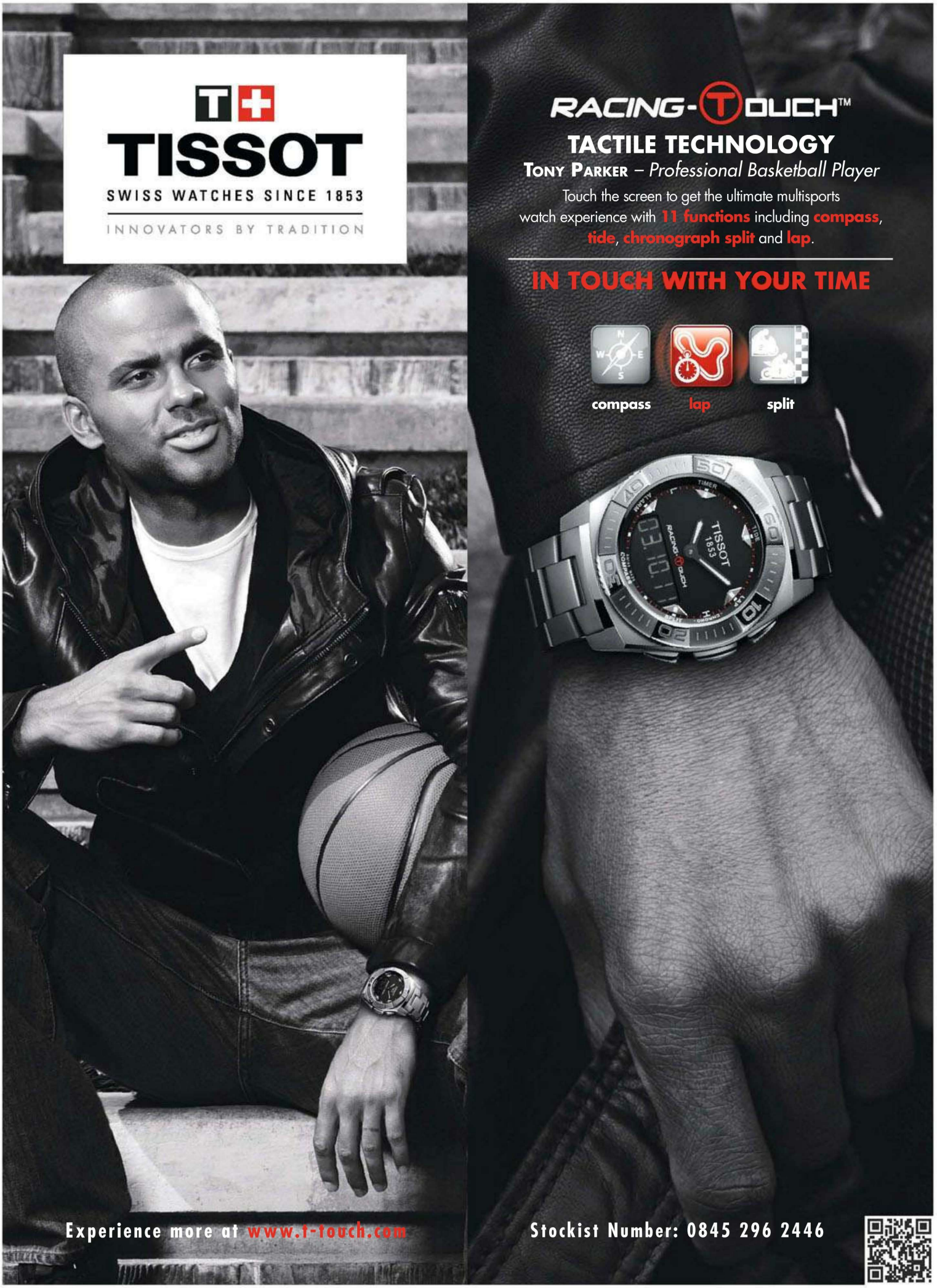
LEAGUE'S AHEAD

Great article (League of extraordinary women, 09.12)! The Levo League provides the resources Generation Y needs to learn to succeed professionally, personally, and socially. As [cofounder] Caroline Ghosn explained, there are behaviours we need to unlearn, and The Levo League provides the tools necessary to develop the level of confidence that is crucial to succeed. ***Elana, via wired.co.uk***

UNDO

Ovelin's founders are Christoph Thür and Mikko Kaipainen (Europe's 100 hottest startups).

IT'S A SUPERPLEXUS VORTEX. SEE NEXT MONTH'S WIRED FOR THE BIG REVEAL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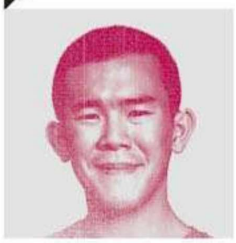


Ed Yong

Yong travelled to Massachusetts to examine the work of Ed Boyden – MIT's pioneering optogeneticist, who says he wants to solve the brain. "Boyden is very passionate," says Jong. "He speaks at rocket speed – a joy to interview, but a nightmare to transcribe. He and his lab have a totally different feel to regular science outfits."

Steve Peck

WIRED's picture editor (no relation to our Test contributor, BTW) has been ensuring our images are truly inspiring since issue one. So, have we ever asked the impossible? "I have had a request for a picture of James Bond's invisible car," he says. "No one's beaten that yet. But if I get asked to do a zero-G shoot, I'll try to arrange a quick trip to the ISS."

Alex "Sandy" Pentland

Pentland, director of MIT's Human Dynamics Lab, discusses the Big Data revolution. "Big Data is radical transparency," he explains. "You are what you do, not what you just *say* you do." But is there a downside? "There is a danger that we will not understand systems based on Big Data. Human intuition and computational social science must keep up."

Andy Barter

Barter took on a tiny challenge for WIRED – photographing a mouse. "Mice move very quickly, but they also get tired out," says Barter. "We had three, which their handler rotated." So, which does he prefer: humans or rodents? "Humans – they don't try to escape at every opportunity, and they don't constantly urinate on your backgrounds..."

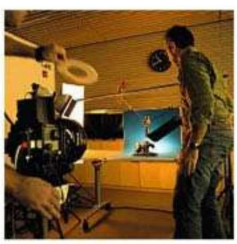
Emily Peck

We sent Peck into the wilderness to test self-heating food packs – no campfire required. "It does seems like the death of basic camping survival skills," she says. "But we can't go around with spears, looking for edible things to kill, either. This food isn't fancy, but it is a clever way to travel light – I wouldn't mind a self-heating pizza with olives and rocket on it."

Making WIRED

Inside the Media Lab

We sent a squadron of photographers to the MIT Media Lab in Cambridge, Massachusetts, to capture the essence of what makes this place so exciting. The answer, of course, isn't just the incredible inventions, from neuron-manipulating robots to musical bananas, but also the people behind these ideas. Here are just a few of our photographers who put faces to the lab's big ideas.



David Arky

Arky photographed MIT projects ranging from an intelligent milling tool (*above*), to prosthetic limbs, to a levitating steel ball that doubles as an interface. "I felt pretty heady when I saw the ZeroN ball floating in the air," he says. "It was a science-lover's dream."

Chris Crisman

Crisman (*shown above, helping Cynthia Breazeal find her pose*) shot our cover portraits, among other stories. So who made the biggest impact on him? "Neri Oxman," he says. "She's an atypical scientist, an impressive free thinker and a truly ground-breaking artist."

Spencer Lowell

Lowell specialises in images with a scientific bent, so obviously he's long been a friend of WIRED. He's shown above with Pattie Maes, creator of the EyeRing, but his other photographs for our MIT special include the MindRider helmet and Nexi robot family.

Brad Swonetz

Swonetz crossed the US, from San Diego to Massachusetts, to shoot at MIT. "One of my favourite moments was shooting Tod Machover (*above*), and seeing him play his hypercello," he says. "And it's such a beautiful building – I want to go to school there."

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Few cars cut as impressive a figure as the new Continental GT V8. The sharp exterior lines, the dynamic 4.0 litre V8 engine, the eight-speed gearbox, 500 miles on a single tank. Naturally, with a car that boasts such impressive numbers it's only fitting it now comes with a remarkable monthly repayment too. It all adds up to a driving experience that both stirs the soul and calms the spirit. One guaranteed to give you goosebumps beyond measure. For more information and to book a test drive visit www.uk.bentleycontinentalv8.com/finance or call 0845 689 1624†.

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Fuel economy for the Continental GT V8 in mpg (l/100km): Urban 18.4 (15.4); Extra Urban 36.7 (7.7); Combined 26.9 (10.6). CO_2 Emissions (g/km): 246.

Bentley Solutions representative example for Bentley Financial Services based on 5,000 miles per annum# for Bentley Continental GT V8 with additional cost option Mulliner Driving Specification.

24 monthly payments of..... £888.00	Customer deposit or part exchange.. £43,555.86	Amount of credit..... £80,334.14
Duration..... 25 months	Acceptance fee (payable within first payment). £169.00	Total amount payable..... £144,201.86
On the road cash price..... £133,890.00	Optional final payment..... £69,255.00	Rate of interest..... 6.7% Fixed
Deposit contribution..... £10,000.00	Option to purchase fee*..... £79.00	Representative APR..... 6.8% APR

Bentley Financial Services Terms and Conditions: All prices include VAT at the current rate. #72p per mile excess mileage charges apply. Retail sales only. *Payable with optional final payment. Further charges may be payable if vehicle is returned. Indemnities may be required. Subject to status. Available to over 18s in the UK. Bentley Financial Services, Freepost VWFS. Available for cars ordered and delivered before 31st December 2012. All offers are subject to vehicle availability from participating Bentley dealers and may be varied or withdrawn at any time. Other finance offers are available but cannot be used in conjunction with this offer. †Calls will be recorded for training purposes.

 Model shown: Bentley Continental GT V8, 13.5 model year mrrp £125,000. Price correct at time of going to press and includes VAT at 20%. Price excludes road fund licence, registration and delivery charges.


The
REAL DEAL
Toyota GT86
GT86
5 year
TOYOTA
WARRANTY
Official Fuel Consumption Figures in mpg (l/100km): GT86 range, Combined 36.2 (7.8) - 39.8 (7.1), Extra Urban 44.1 (6.4) - 49.6 (5.7),
Urban 27.2 (10.4) - 29.4 (9.6). CO_2 Emissions 164g/km - 181g/km. 5 year/100,000 mile manufacturer warranty subject to terms and conditions.


TOYOTA
ALWAYS A
BETTER WAY
Scan to watch film
toyota.co.uk/GT86

VICTORINOX

COMPANION FOR LIFE

VIS (CROATIA), 2009

THE TREASURE

As a fisherman diver on the Croatian island of Vis, I regularly pulled special things out of the sea: not only sea urchins, crabs and squid, but also personal items. Once I saw something sparkling down below on the sea bed. I dove deeper and there it was … a Victorinox Swiss Army Watch. Engraved on the back were the words "Félicitations Docteur F. Millet" and it was still running! I decided to reunite Mr. Millet with his watch as he had most likely spent his holidays here. Through the Internet, I traced the watch back to its owner, Dr. François Millet, a French diving enthusiast who had been on holiday in Vis two months before. I shipped the watch back to Dr. Millet, who was delighted to have his precious watch returned to him after two months lost at sea.

Drago Radic, July 2009

Victorinox products are a companion for life. What experiences have you had with Victorinox products? Share your story at victorinox.com

FROM THE EDITOR

WIRED GOES INSIDE THE MIT MEDIA LAB

Welcome to this special edition of WIRED, devoted entirely to sharing with you the extraordinary innovations coming out of the MIT Media Lab in Boston. Why the Media Lab? Because of all the corporate research labs, innovation hubs and university campuses we visit, this one most consistently and reliably predicts how technology will affect our lives in the future – mainly because its experts are inventing that future.

So this month, we have worked with the lab to pack every section of WIRED – apart from a few regulars such as Test – with products, people and stories from the lab. There are in-depth features on Ed Boyden's work on "solving" the brain, Ros Picard's project to train computers to recognise human emotion, and Hugh Herr's journey towards creating advanced prosthetic limbs. You can read about Neri Oxman's beautiful architectural creations and Ramesh Raskar's transformative photographic inventions; about Tod Machover's reimagination of musical performance and Sep Kamvar's attempt to democratise the learning of computer code. Every Ideas Bank column, every Start, Play and How To story, taps into the talent found in a corner of Cambridge, Massachusetts.

PHOTOGRAPHY: CHRIS CRISMAN

WIRED and MIT Media Lab have a long shared history. The lab's first director and cofounder, Nicholas Negroponte, was the first investor in US WIRED more than 20 years ago, and for five years wrote a celebrated back-page column in the magazine. It's been a break of 14 years, but we've commissioned Negroponte to write a new column – and, for those of you who are relative newbies to WIRED, we've reprinted his very first column from 1993.

It's been an ambitious project: six of our editors based themselves at the Media Lab to tell these stories, alongside the world-class photographers and writers we sent there. Thanks to Joi Ito, Ellen Hoffman, and all at the lab who gave us access and inspiration – and to the wider team there, today and in the past, for giving us such powerful stories to tell.

THIS MONTH IN OUR TABLET EDITIONS

Download the tablet edition to hear our MIT cover stars introduce themselves and reveal what's exciting them.

Interact with some musical bananas, courtesy of MIT's MaKey MaKey, and play a unique fruit-based tune.

Watch a video about neurons and optogenetics, where neural networks can be manipulated with bursts of light.

David Rowan, Editor

- D&AD Award: Covers 2012
- DMA Editor of the Year 2011
- DMA Magazine of the Year 2011
- DMA Technology Magazine of the Year 2011
- BSME Art Director of the Year, Consumer 2011
- D&AD Award: Entire Magazine 2011
- D&AD Award: Cover 2010
- Maggies Technology Cover 2010
- PPA Designer of the Year, Consumer 2010
- BSME Launch of the Year 2009

START

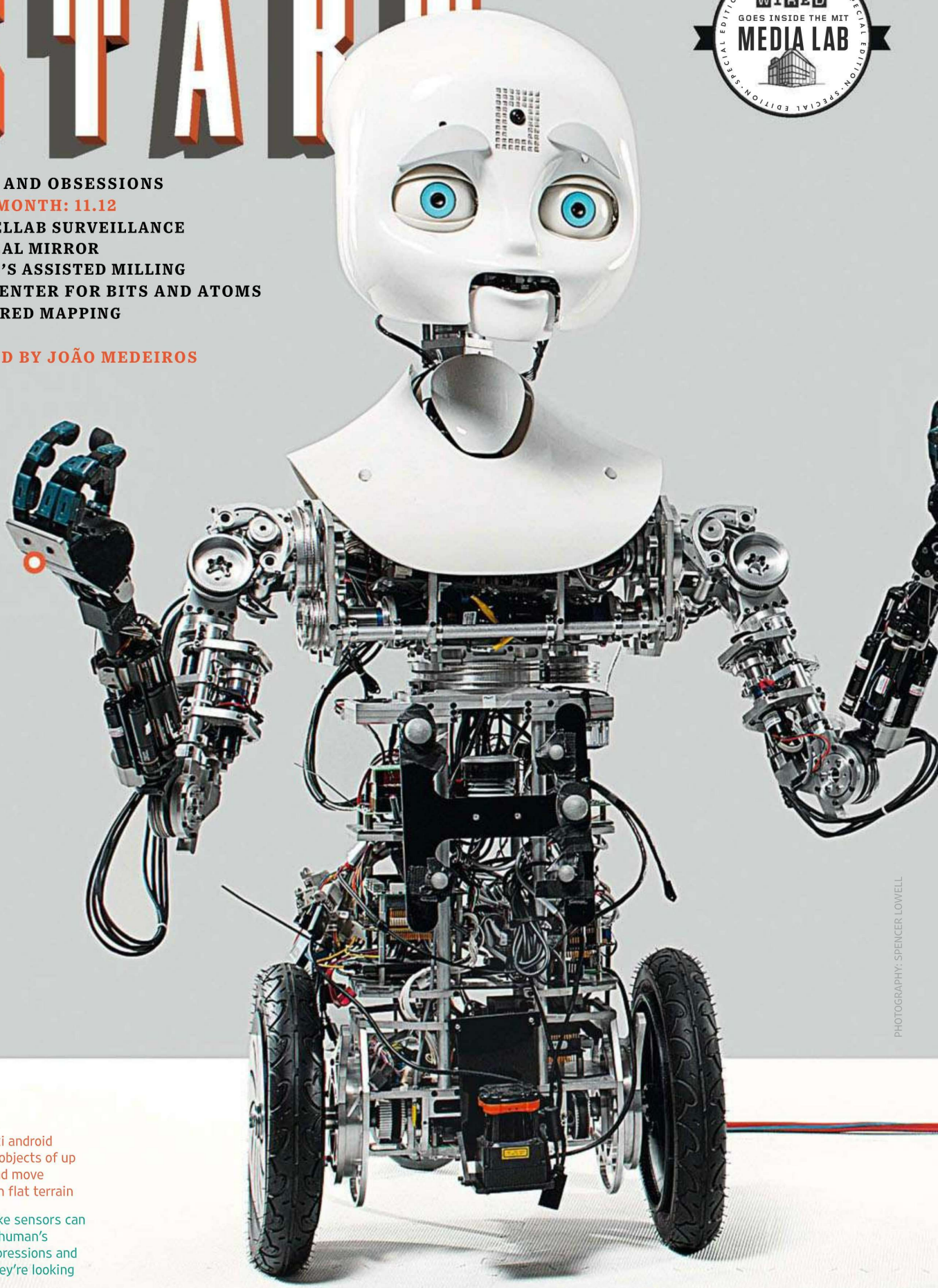
WIRED GOES INSIDE THE MIT MEDIA LAB

NEWS AND OBSESSIONS

THIS MONTH: 11.12

- DOPPELLAB SURVEILLANCE
- MEDICAL MIRROR
- FREED'S ASSISTED MILLING
- THE CENTER FOR BITS AND ATOMS
- INFRARED MAPPING

EDITED BY JOÃO MEDEIROS



PHOTOGRAPHY: SPENCER LOWELL

Each Nexi android can hold objects of up to 5kg and move around on flat terrain

Kinect-like sensors can detect a human's facial expressions and where they're looking

Hug a robot

MIT Media Lab's androids are adding empathy to their armoury

Cynthia Breazeal has big dreams for androids. The director of the MIT Media Lab's Personal Robots group and her colleagues are overseeing research that will transform robots from machines that can do predefined tasks, into beings that can understand what we are thinking – and anticipate what we want them to do.

The team manages an ever-increasing family of robots, with about 30 active in the lab or out on field tests. Some of the most intriguing are a humanoid group called Nexis (*left*), each one about the size of a three-year-old child. "We programmed a Nexi to nod while saying 'yes'," says Breazeal, 44. "That subtle sign reduces human stress levels. We need these non-verbal signs to feel comfortable with robots."

Breazeal now wants the Nexis to understand our minds. "I see a way opening up to technology that is matched to our humanity," she says. "That makes it useful, it delights us, it makes us feel empowered – it's not just task, task, task, which is what we have now." **David Baker**
robotic.media.mit.edu


THE WIRELESS HiFi SYSTEM. ALL THE MUSIC ON EARTH, IN EVERY ROOM, WIRELESSLY.
SONOS

Traffic lights for the mind

Arlene Ducao has invented a device to help you cycle safely – a brain-reading helmet

If only cyclists and motorists could read each other's minds. Arlene Ducao agrees – so she has built a wearable mind-reading device. Ducao (*below*) is a computer programmer and digital animator at the Media Lab's Information Ecology group (see p44), and is shown wearing MindRider – a modded bicycle helmet with an EEG sensor, which displays the wearer's stress levels. "It indicates your mental state by flashing a visual vocabulary of traffic lights," says Ducao. "Green is low stress, red is high stress – and blinking lights indicate panic."

Ducao had previously designed helmets with manually operated lighting, but realised a hand-free solution was preferable. The MindRider uses a NeuroSky MindSet (see WIRED 07.11), picking up ten types of brainwaves that signal emotions such as concentration, fear and anxiety. An Arduino microcontroller translates these signals into a series of light values, causing a strip of embedded LED lights to change colour according to input. The next step, says Ducao, is expanding the range of mental states detected, and perhaps even mood. "Road rage" should make an impressive light show. **MV** *media.mit.edu/research/groups/information-ecology*

Under the lid of MIT's sensor helmet

The prototype uses two EEG sensors. The next version will have more

S T A R T

PHOTOGRAPHY: SPENCER LOWELL

SAMSUNG WIRELESS AUDIO DOCK WITH VALVE AMPLIFIER

Compatible with

Samsung WIRELESS AUDIO DOCK

Samsung GALAXY

Made for iPod iPhone iPad

Compatible with Android handsets with Bluetooth, including Samsung Galaxy range. Wireless Music App available free of charge from Google Play Store may be required. Android is a trademark of Google Inc. Compatible with iPhone, iPod and iPad. "Made for iPod", "Made for iPhone", "Made for iPad", means accessory has been designed to connect with such Apple devices and has been certified to meet Apple standards. Apple is not responsible for operation or compliance with regulatory standards. Use of this accessory may affect wireless performance. iPad, iPhone, iPod classic, iPod nano, iPod shuffle and iPod touch are trademarks of Apple Inc., registered in the U.S and other countries.

SAMSUNG

INTERNET LIES ARE ABOUT TO GET BUSTED

The internet is peppered with factually incorrect news stories. To help sort through it, Dan Schultz, a masters student at the Media Lab's Information Ecology Group, has built Truth Goggles. The web software runs on your browser like a bookmark, scanning internet content and highlighting fact-based sentences. These lines are sourced from PolitiFact, a fact-checking database that evaluates public statements by US Congress members, the White House, lobbyists and political interest groups.

"The user has the option to explore the highlighted information," says Schultz, 25. "They can click on it to be redirected to the PolitiFact website, which provides a true or false verdict on the claim." The database currently holds about 5,500 statements fact-checked by journalists at *The Tampa Bay Times*, so Truth Goggles isn't any good at spotting dubious sentences beyond that. To scale it up, it will need to be synced with other fact-checking databases such as factcheck.org, the *Washington Post* fact column and snopes.com.

"We want to get people to open up to other points of view," Shultz's project supervisor Henry Holtzman says. "Get them to engage in critical thinking and weigh evidence objectively, not parrot what they read." The truth is out there. **MV**
truthgoggl.es/demo.html

PHOTOGRAPHY: DAVID ARKY. ILLUSTRATION: ROBIN BOYDEN

FreeD is a tool for wannabe Rodins who don't have time to learn the craft. "I was fascinated by sculpting, but couldn't spend ten hours a day for five years to develop the skill," says Amit Zoran, a computer engineer at the Media Lab's Responsive Environments group. "So I thought of borrowing this ability from a computer."

Zoran, 36, developed the FreeD: a handheld tool that allows you to sculpt freely from a foam block, while software prevents you from making mistakes. Trackers on the tool's head are connected to a CAD model to monitor your handiwork. If the tracker pushes past a geofenced boundary, the tool pulls itself back; if you keep pushing, it turns itself off. Zoran's goal is to bring the artist's hand back into digital fabrication, allowing for a freedom of artistic expression – backed with the precision of CAD. "The element I'd like to preserve is the quality of authenticity," he says. **Jeremy Kingsley** *resenv.media.mit.edu*

A stabiliser for first-time sculptors

Want to mill pretty things but didn't go to art college? Prepare to be FreeD

Drive it, fold it, park it

A hinged electric car could reboot transport

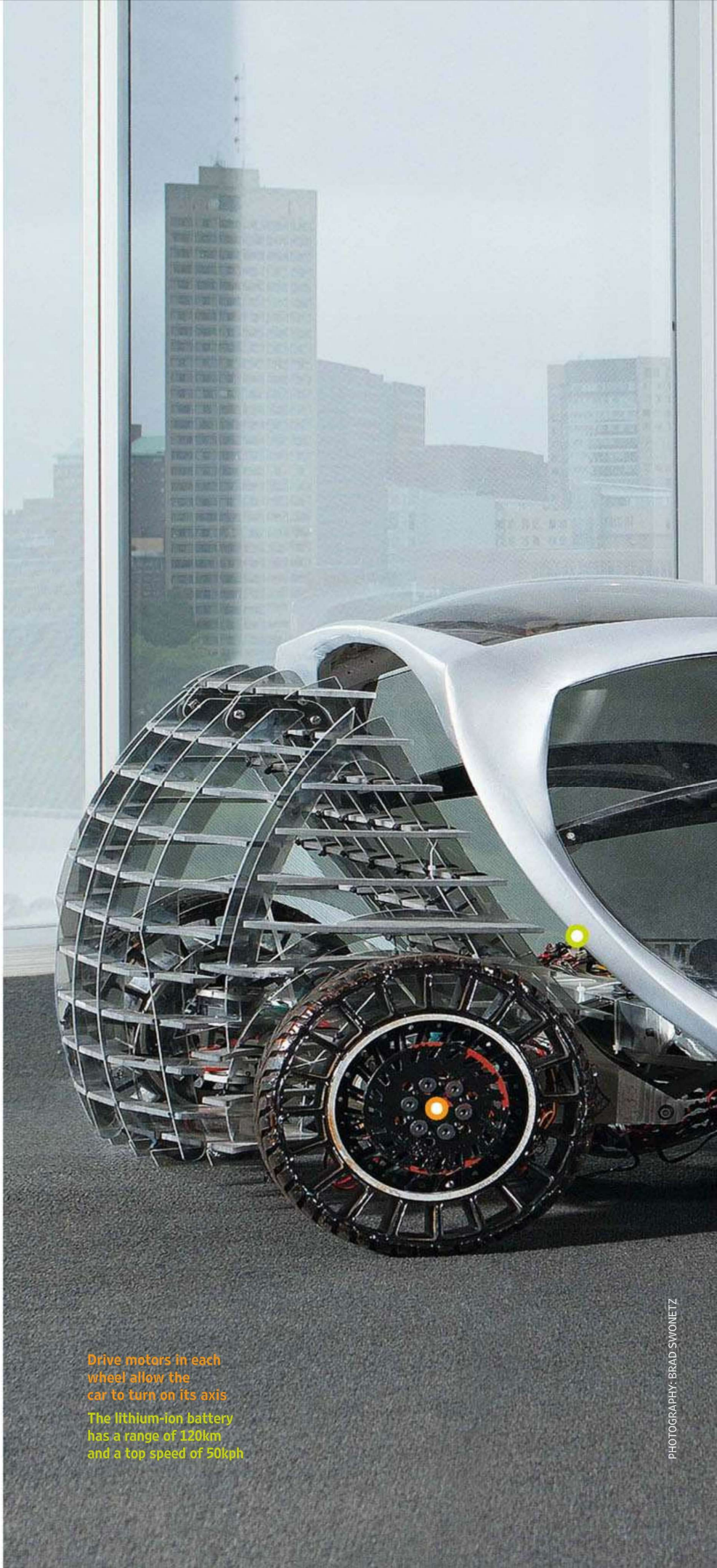
Right now", says Kent Larson, "we need to get rid of private, polluting vehicles." It's a bold idea, but 54-year-old Larson is director of MIT Media Lab Changing Places group, and its CityCar project may have a solution.

The Hiriko is a lightweight, foldable two-passenger electric car for short journeys. The team is working with suppliers in Spain ("hiriko" is Basque for "urban"), where the car is entering trials and is likely to form a kind of shared-use, cycle hire-style city fleet. Safer than bikes and with room for shopping, the Hiriko also frees up space because it can be folded when parked – allowing three cars to fit in a single parking space.

"There are no large mechanical elements," explains Larson. Independent drive motors, steering motors, braking and suspension are integrated into each wheel. Dubbed "robot wheels", they enable software-only drive-by-wire control and agile turns (the car can spin on the spot).

"The focus is less on the particular vehicle, and more on what sorts of new mobility scenarios it enables," says Praveen Subramani (*pictured right with a small-scale Hiriko prototype*), graduate student and researcher at the Changing Places lab. "Things like being able to pick up the vehicle best suited for your trip, whether that's a car, an electric scooter, or even a vehicle which we have not yet designed." Now, if they could just reinvent traffic wardens...

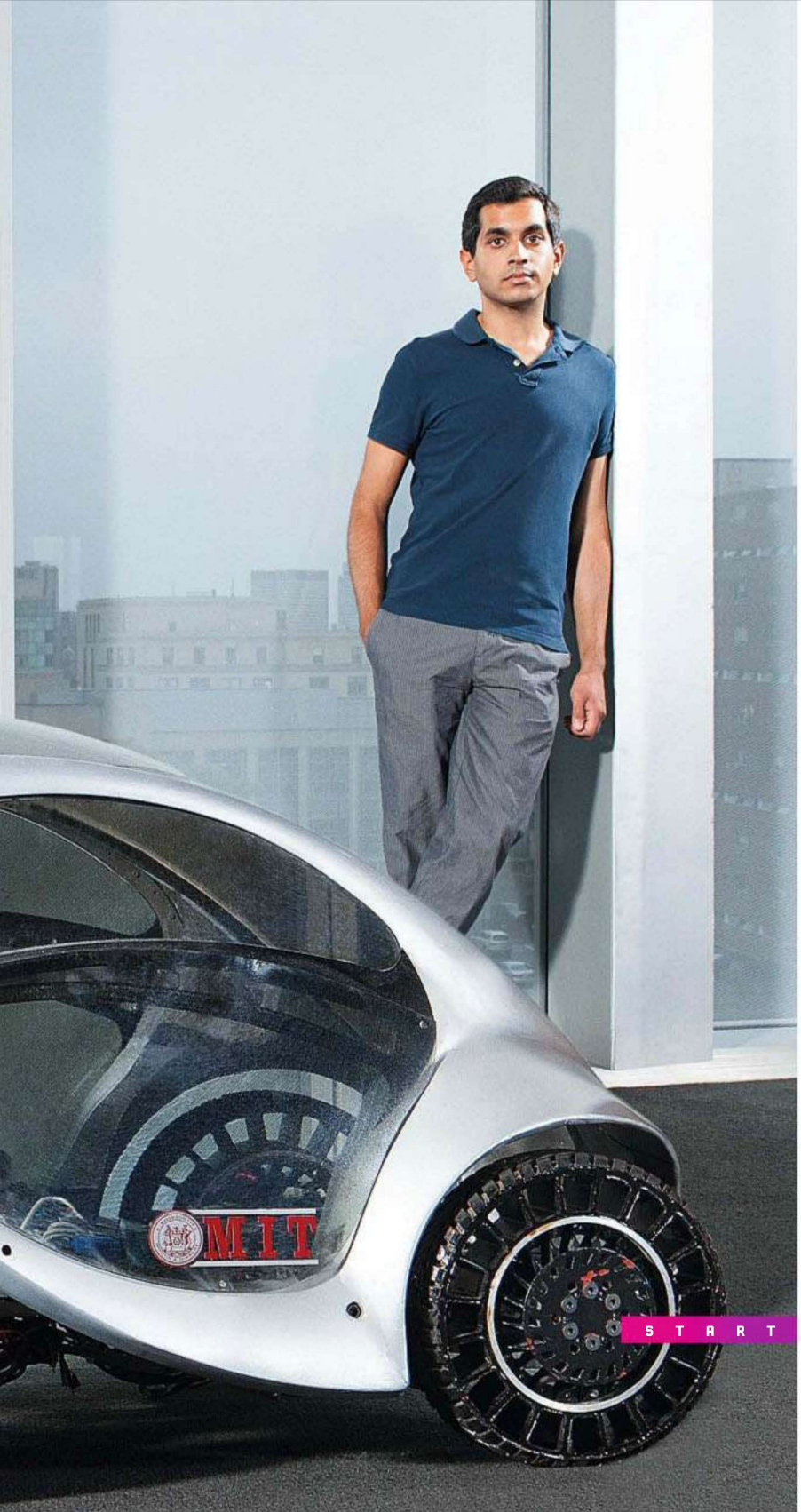
Jeremy Kingsley *cp.media.mit.edu*



Drive motors in each wheel allow the car to turn on its axis

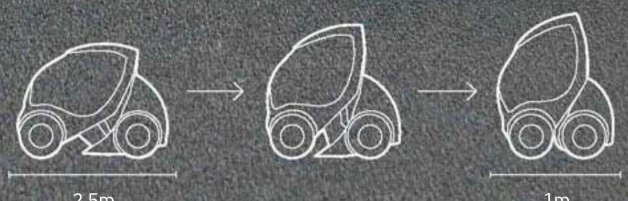
The lithium-ion battery has a range of 120km and a top speed of 50kph

PHOTOGRAPHY: BRAD SWONETZ



Now fold your car...

The Hiriko's hinged chassis permits the rear to retract and the chassis to tilt upwards to 1.5m, giving the driver extra visibility during parking



THE BIG QUESTION

"What new technology will be significant in ten years' time?"

FRANK MOSS
DIRECTOR, MIT NEW MEDIA MEDICINE GROUP

"We will see 'anti-social networks', support groups where self-diagnosed 'digital addicts' will meet each week for a few hours, without any devices. They will share experiences, express real emotions and seek out ways to return control, privacy and sanity to their lives."

RANA EL KALIOUBY
COFOUNDER AND CTO, AFFECTIVA

"Today's technology augments our cognitive abilities, but is largely oblivious to how we feel. In ten years, emotion-enabled technology will be everywhere – computers, phones and clothes. It will manage our calendars to minimise stress and recommend content based on our likes."

MICHAEL BOVE
HEAD, OBJECT-BASED MEDIA GROUP, MIT MEDIA LAB

"I think we will see a vastly broader definition of telepresence. Systems will not just create ultra-high-definition links between meeting rooms, but will apply semantic understanding of scenes and tasks. New interface affordances will reconfigure collaborative environments."

CATHERINE HAVASI
RESEARCH SCIENTIST, MIT DIGITAL INTUITION LAB

"3D printing is already making custom medical devices, replacement parts, art and buildings. It is still an alternative culture, but it won't take long for it to become cheap and mainstream, and for current problems to be solved. It will allow anyone to be a cutting-edge inventor."

GLORIANNA DAVENPORT
VISITING SCIENTIST, MIT MEDIA LAB

"I envision new methods for exploring planetary ecosystems. Inexpensive, sensor-rich networks will record natural events. Data streams will be transformed into a highly patterned history of place via advanced mobile devices, inviting us to become interpreters in a living observatory."

ANDREW LIPPMAN
ASSOCIATE DIRECTOR, MIT MEDIA LAB

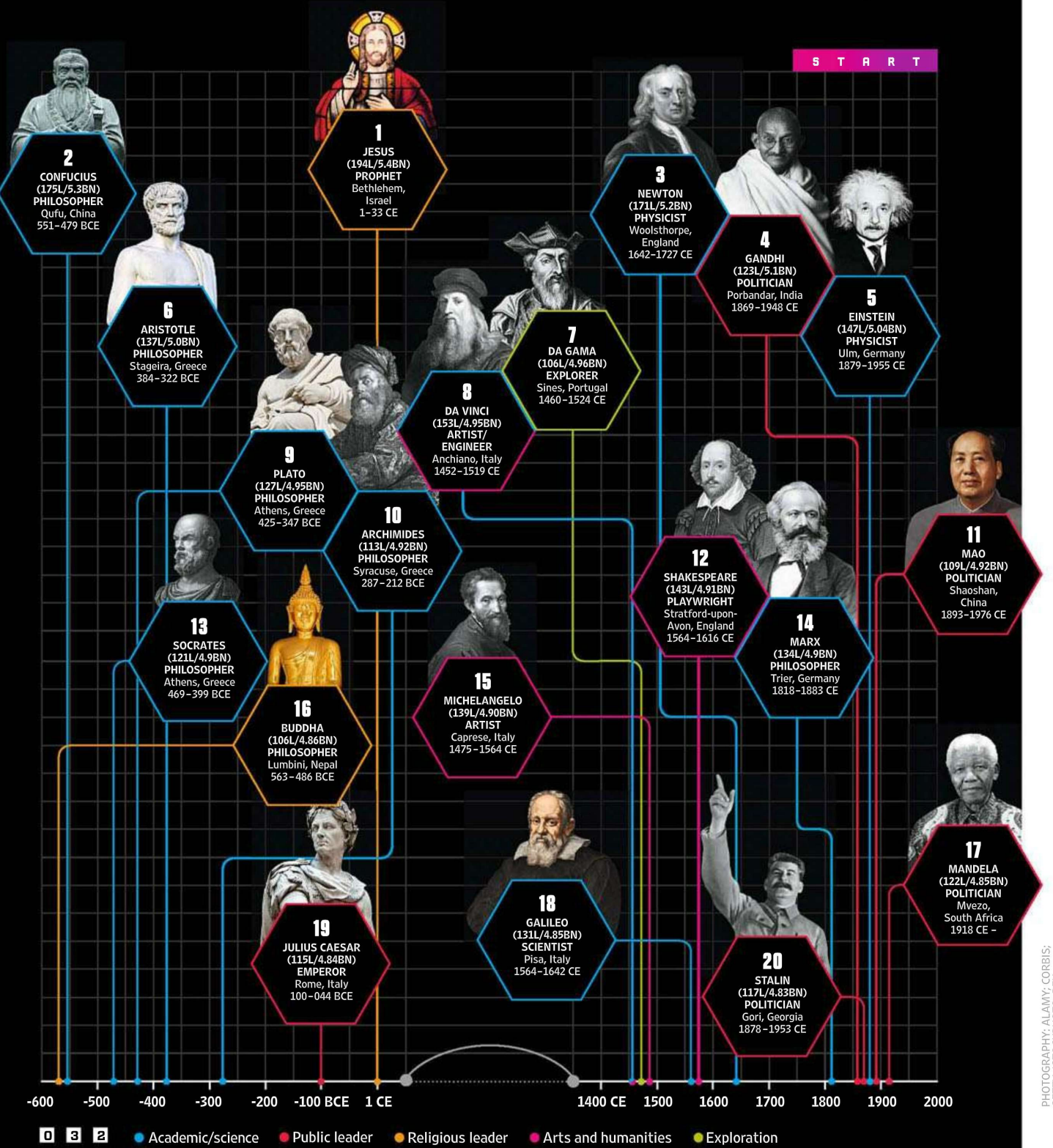
"We will be building systems that in some sense know what they are doing and know us – cars that can drive themselves, cities that reflect human needs and respond in human ways and designs that encourage people to engage in real understanding of the underlying principles." **MV**

Wikipedia's top 20: religion pips science

History's most influential people, ranked by Wikipedia reach. Feel free to edit...

This infographic reveals the world's most influential people, born before 1950, using data from all language editions of Wikipedia. "It shows you how the world perceives your own national culture," says César Hidalgo, head of the Media Lab's Macro Connections group, who researched the data. "It's a socio-cultural mirror." Rankings are based on parameters such as the number of language editions in which that person has a page, and the number of people known to speak those languages (L/BN). "We use historical characters as proxies for culture," says Hidalgo. "It's easier to track knowledge about Shakespeare than about each of the characters he created in his writing." Using this quantitative approach, Hidalgo is now testing hypotheses such as whether cultural development is structured or random. "Can you have a Steve Jobs in a country that has not generated enough science or technology?" he wonders. "Ultimately we want to know how culture assembles itself." **JM**

INFO PORN



PHOTOGRAPHY: ALAMY; CORBIS; GETTY; ISTOCKPHOTO; REX

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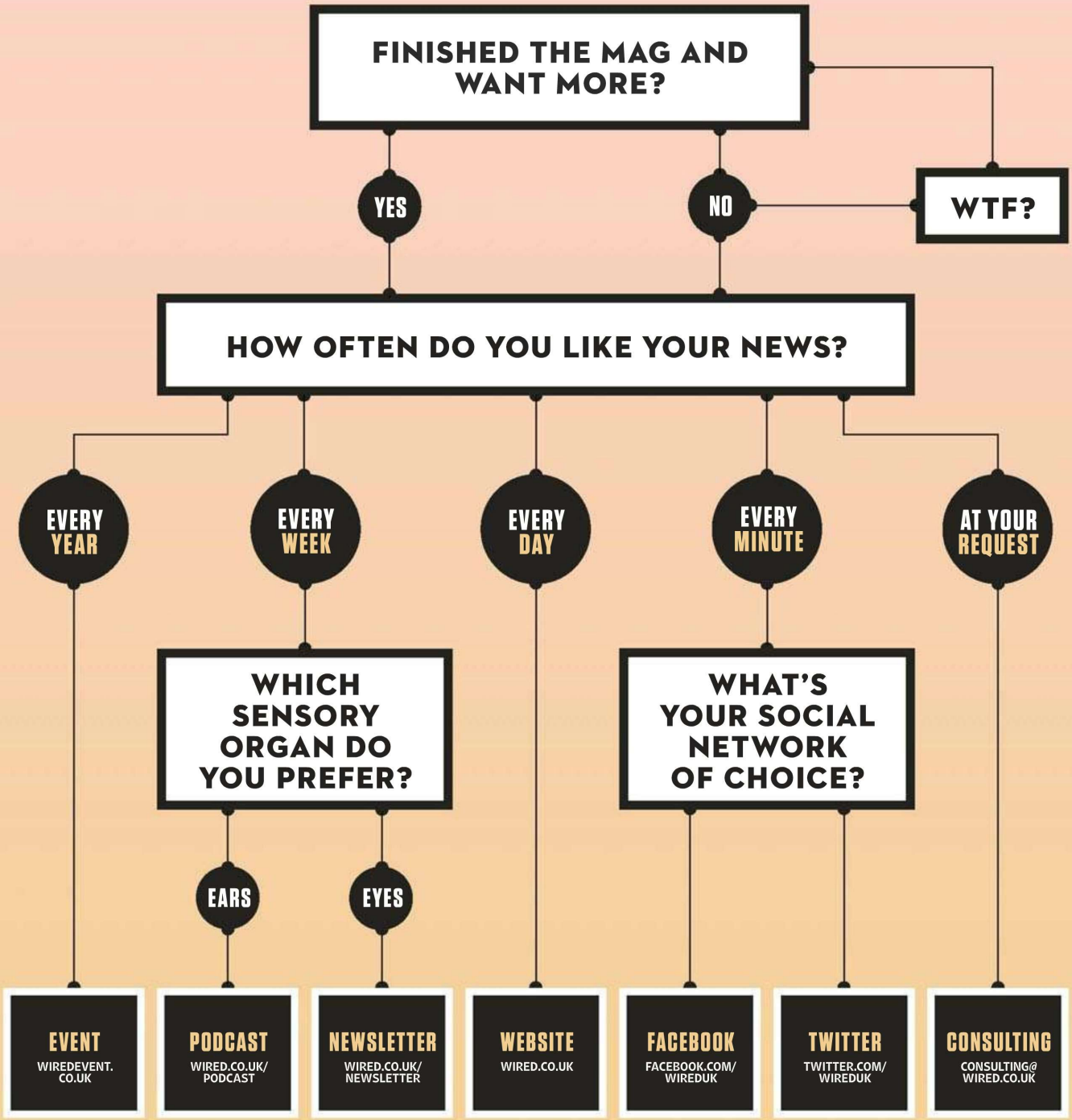
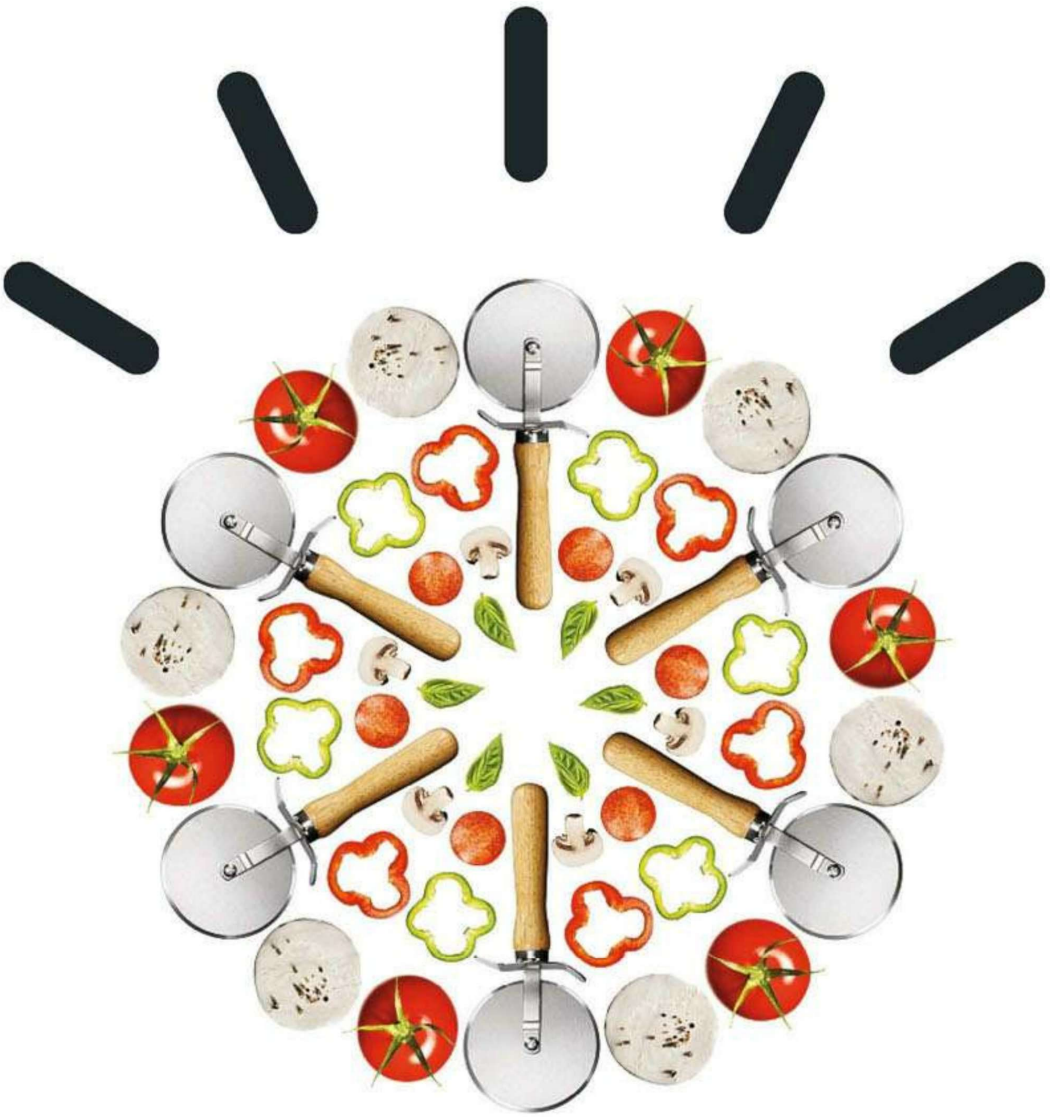


Do you think you should be writing for wired.co.uk, or are you doing something online that we should know about?
Email *nate.lanxon@condenast.co.uk* with a link – we'd love to hear from you



How a midsize restaurant group is earning a bigger piece of the pie.

On a smarter planet, midsize businesses need analytics to better serve their customers, operate more efficiently and encourage growth. Papa Gino's Inc., the Boston-based pizza and sandwich chain with about 150 corporate employees, was sitting on a gold mine of untapped sales, marketing and operational data. However, they needed a better way to leverage all this powerful data to make better decisions for their company. Working with IBM® and Business Partner QueBIT, they deployed a business analytics solution based on IBM Cognos® software that quickly transformed their data into actionable business insights. Analytics helped them discover that reward members visit their restaurants 35% more frequently and spend 50% more on online transactions. With new insights into the impact of their loyalty program, they can develop offers based on purchase patterns to increase the size of orders and purchase frequency. To see how IBM and our Business Partners can help your midsize business work smarter, visit **ibm.com**/engines/uk/pizza. Let's build a smarter planet.

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IBM

A room for making anything

At MIT's Center for Bits and Atoms, you'll find machines that use electron beams, supersonic water-jets and 1,500cm-per-minute cutters, all in the name of making stuff

PHOTOGRAPHY: SPENCER LOWELL

What is the best way to create objects from bits? That's a key question at the Media Lab's Center for Bits and Atoms (CBA), where researchers explore new ways to turn digital information (bits) into physical objects (atoms) and vice-versa.

"One of the core themes is the idea of digitising fabrication," says Neil Gershenfeld, the CBA's director. "That's not only computers controlling tools; it's also about putting programs into materials themselves." To that end, Gershenfeld and his colleagues have programmed self-assembling strings of robotic modules and are now using biological proteins to create self-assembling nanostructures.

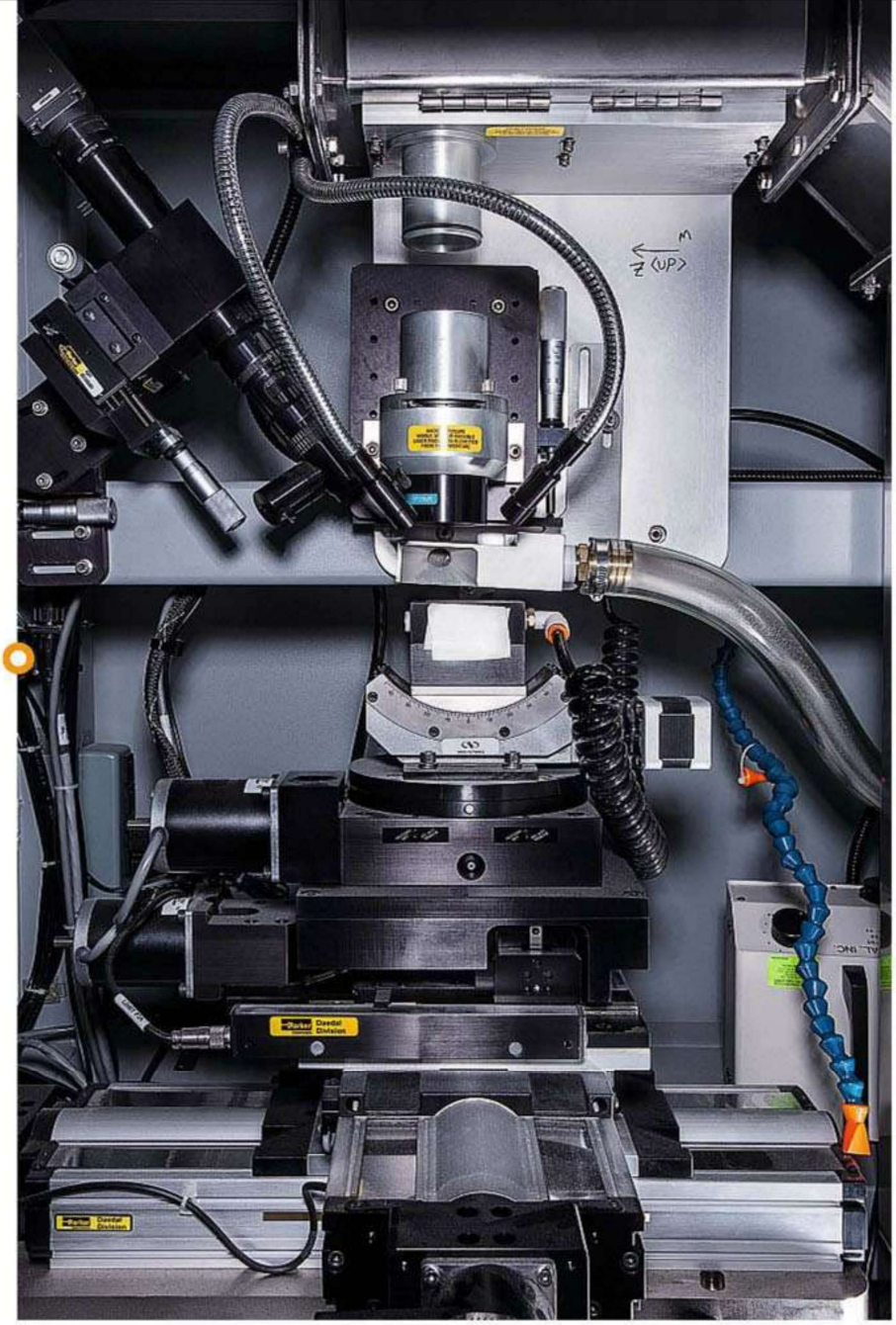
The CBA is home to an impressive collection of machines. In fact, it's the ultimate workshop, and it's freely available to researchers and students. "The freedom of access means they get used in a very different way from conventional settings," says Gershenfeld. "People get to play around more, which encourages speculative work." Your lab open day starts here. **Daniel Cossins** *cba.mit.edu*

TOOL KIT

Three-axis router

SHOPBOT PRSALPHA 120-60

This computer numerical control (CNC) router cuts, drills and carves wood, plastics and aluminium at speeds of up to 1,500cm per minute. The motor moves the cutter around a tabletop, and up and down, allowing for 3D movements to create all sorts of shapes. It's yours for £13,000.



TOOL KIT

DIY micromachiner

RESONETICS RAPIDX250-L

Laser micromachining helps designers to prototype complex micro-scale components. Design something in CAD and the X250 will cut, drill, strip or etch it in the material of your choice with a precision down to one micron.

Supersonic cutter

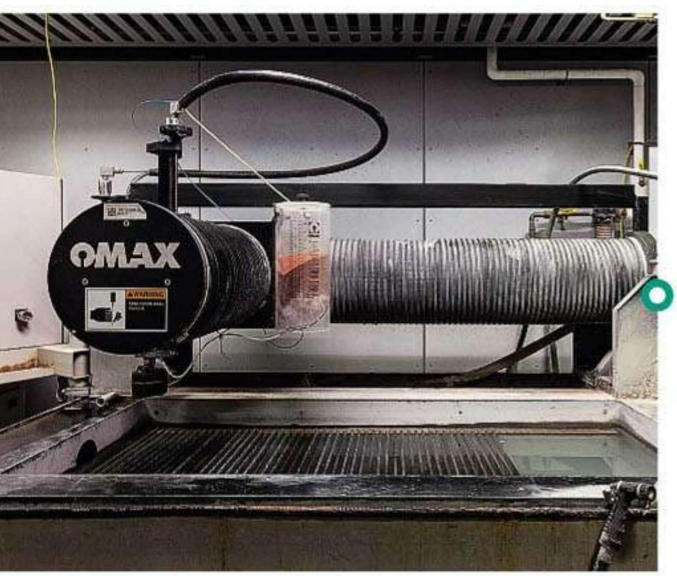
OMAX 2652 JETMACHINING CENTER

This uses a supersonic jet of water and garnet, an abrasive silicate material, to cut and carve complex shapes from nearly any material. Unlike other methods, it doesn't create heat-generated or mechanical stresses, leaving a smooth finish.

360-degree miller

BRIDGEPORT SERIES 1 TRAK AGE 2

The Bridgeport is popular with professionals and hobbyists alike. Its turret-mounted head can rotate 360° and tip 90° so the spindle can cut and drill from all angles. Some models are manual but the one here is controlled by software.



START

PHOTOGRAPHY: SPENCER LOWELL

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47 Monthly Payments (duration 48 months)	**£290.00**	Total Amount of Credit	**£17,205.00**	Total Amount Payable	**£19,733.91**
On The Road Price (cash price)	**£17,495.00**	Final Payment (inc. Option to Purchase Fee)	**£5,813.91**	Interest Rate per Annum	**4.38%**
Customer Deposit	**£290.00**	Option to Purchase Fee	**£65.00**	Representative APR	**4.90%**

Fuel consumption for the Civic 1.8 i-VTEC Ti Manual in mpg (l/100km):
Urban Cycle 38.7 (7.3), Extra Urban 57.6 (4.9), Combined 48.7 (5.8). CO_2 emissions 137g/km.

Model shown: Civic 1.8 i-VTEC Ti Manual in Alabaster Silver at £17,495. **Terms and Conditions:** New retail Civic Ti registrations from 19 September 2012 to 31 December 2012. Subject to model and colour availability. Offers applicable at participating dealers and are at the promoter's absolute discretion. **Honda Aspirations (PCP):** Example shown based on annual mileage of 10,000. Excess mileage charge: 5p per mile. You do not have to pay the Final Payment if you return the car at the end of the agreement and you have paid all other amounts due, the vehicle is in good condition and has been serviced in accordance with the Honda service book and the maximum annual mileage of 10,000 has not been exceeded. Indemnities may be required in certain circumstances. Finance is only available to persons aged 18 or over, subject to status. All figures are correct at time of publication but may be subject to change. Credit provided by Honda Finance Europe Plc. 470 London Road, Slough, Berkshire SL3 8QY.

Desktop 3D printer
ROLAND MODELA MDX-20

This desktop machine can create models from computer-drawn designs and capture 3D scans. It works with existing CAD programs, so novices can create using familiar tools. If you replace the spindle with a Roland Active Piezo Sensor you can scan objects to create 3D renderings.

Micro scanner
FEI/PHILLIPS XL30

Fire a beam of electrons at a design sample in the XL30 and they interact with atoms on its surface. This reaction generates X-ray, electron and photon signals that display topography, chemical composition and other information as 3D images magnified up to 200,000 times.

TOOL KIT

START

'NAME THAT TUNE' FINDS ITS VOCATION

Neuroscientist Adam Boulanger claims that music isn't just a pleasant distraction – it can help diagnose early onset of Alzheimer's disease. Boulanger, who recently graduated from the Media Lab's Opera of the Future group, proved his theory by examining people's brain-activity while they composed their own tunes, and then again as they played a memory game.

First, 18 patients aged between their mid-50s and early 70s made music on a program called Hyperscore, developed by Tod Machover (*see p78*) and Mary Farbood, in Boulanger's Media Lab group. "You create compositions by painting with coloured lines, which represent melodies," says Boulanger. Next, Boulanger's desktop app *CogNotes* kicked in – "As your melodies evolve, *CogNotes* takes your material, chops it up and turns it into a memory game," says Boulanger. The ten-level quiz tests associative memory, which Alzheimer's cripples early on. His study shows that people with Alzheimer's never get beyond level three; healthy patients perform, on average, two levels better.

In June, Boulanger, 30, moved to California and launched a startup, Hear for Yourself, which scales up the *CogNotes* concept for use in video games. He wants people to manage and assess their own healthcare as part of their everyday lives. "I know now that anywhere there is music, we can measure cognition," he says. MV ***cognotes.net***

PHOTOGRAPHY: SPENCER LOWELL. ILLUSTRATION: PARKO POLO

One lens for every moment

Focal length: 270mm ▶
Exposure:
F/6.3, 1/640 sec
ISO 250

15x ZOOM

◀ Focal length: 18mm
Exposure:
F/4.0, 1/2000 sec
ISO 250

VC Vibration Compensation
PZD
Di II

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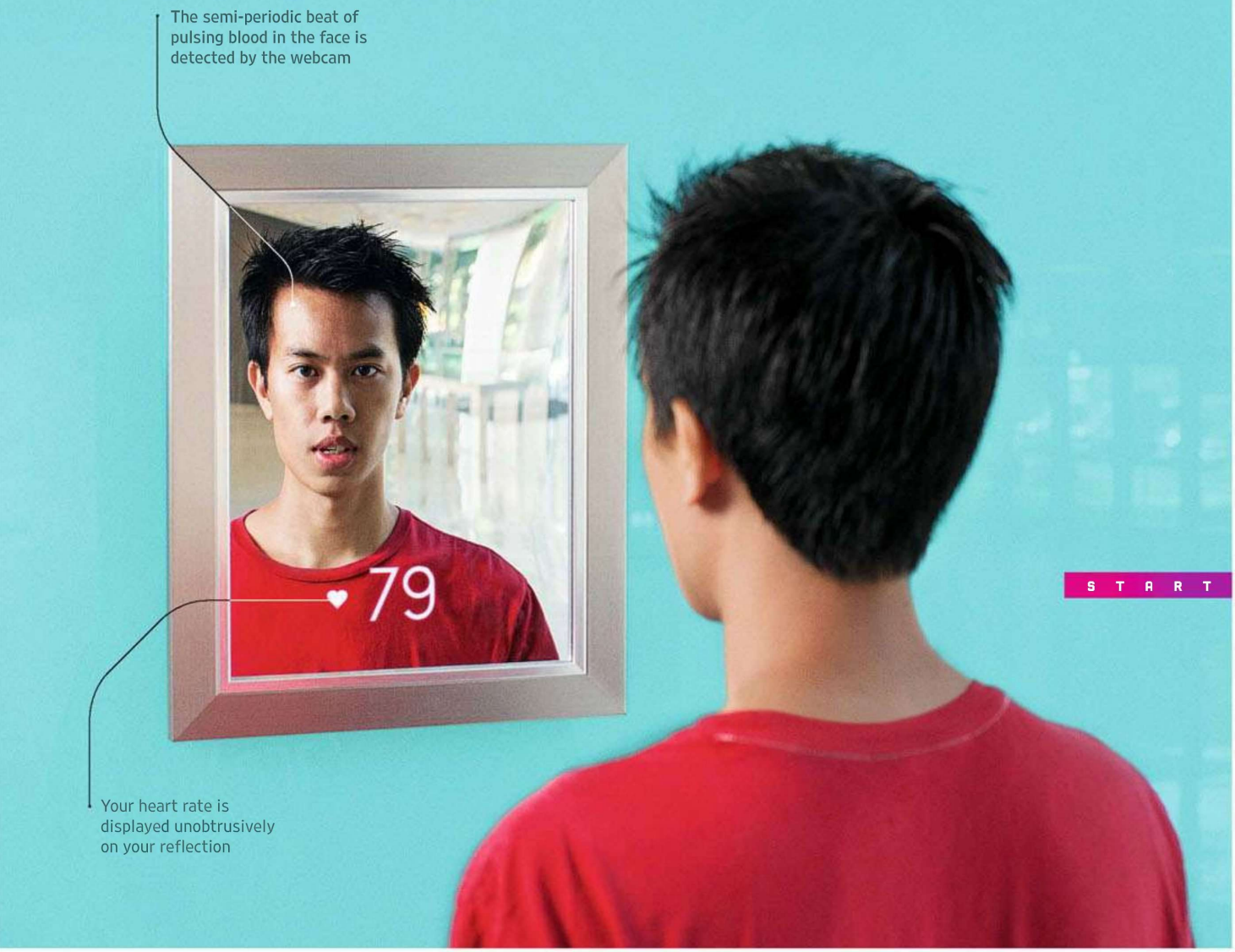
Medic on the wall

Ming-Zher Poh's mirror displays your pulse – by monitoring skin-tone changes

Ming-Zher Poh (*below*) wants to hold a looking-glass up to your wellbeing. His invention, a two-way mirror with a built-in webcam, can read your pulse from your image. "It's an augmented-reality mirror that overlays information about your body," explains Poh, 29, an electrical engineer in the Affective Computing Group at the MIT Media Lab. The mirror is a reflective LCD monitor with a standard webcam. "Blood absorbs light," says Poh. "Every time your heart beats, the blood in your face increases and less light is reflected to the camera." The change in brightness is so tiny that Poh adapted a signal-processing algorithm originally designed to pick out single voices from a room full of conversation.

In January, Poh cofounded Cardiio, which launched as an iPhone and iPad app in August. "It turns your phone into a stethoscope. There's an image of a virtual heart that beats according to your heartbeat," says Poh. "We want to build tools to help you experiment with, learn about and manage your own health." **MV** *cardiio.com*



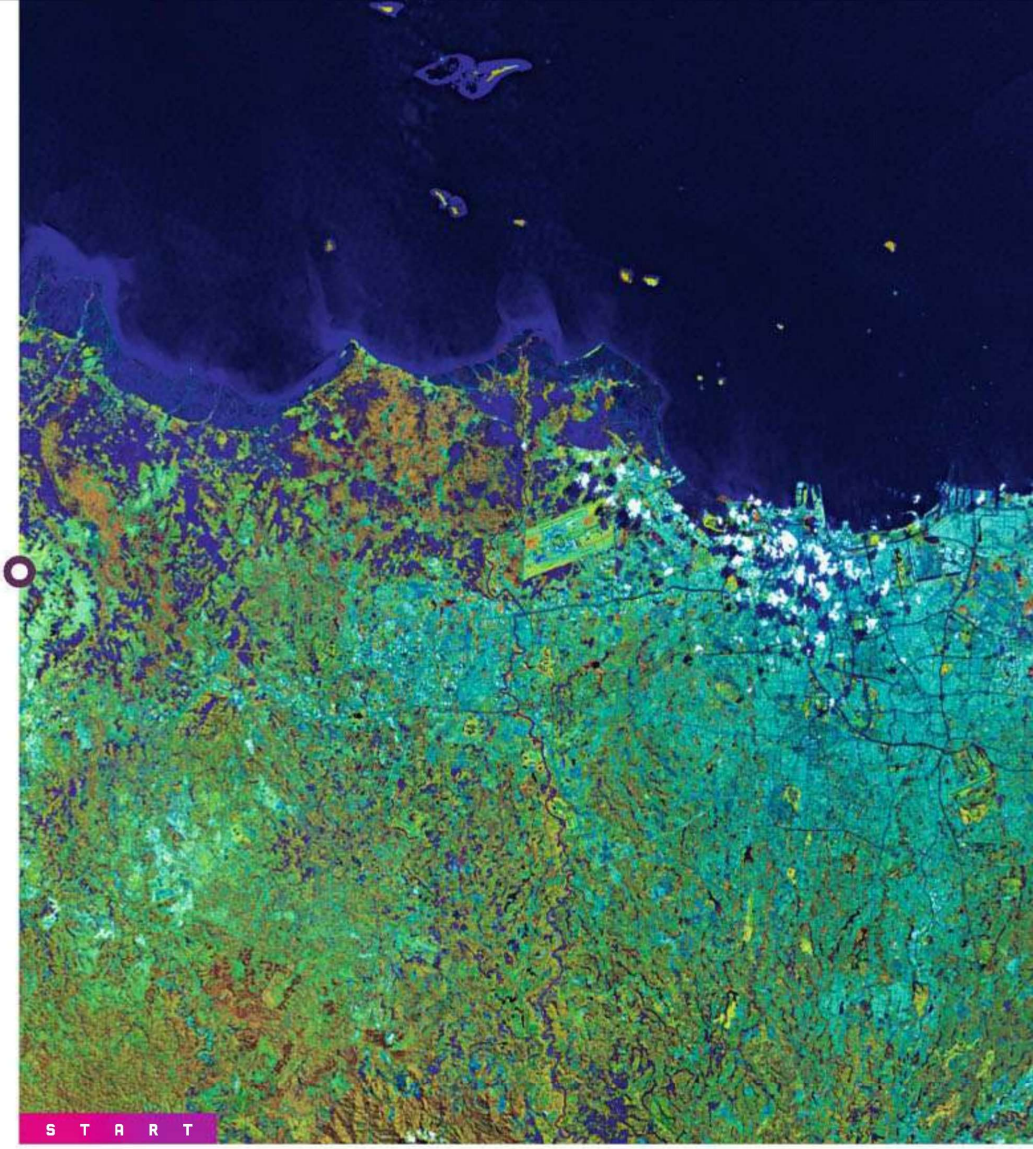
PHOTOGRAPHY: SPENCER LOWELL. ILLUSTRATION: BEN MOUNSEY

QR TO VR: THE SMARTCODE REBOOTED

QR codes are on their way out, according to Andrew Lippman, director of the Viral Spaces research group at the Media Lab. To replace them, Lippman and his graduate student Grace Woo have invented video response (VR) codes, designed for digital displays, which transmit data through light. VR patterns are imperceptible to humans, but are picked up instantly by smartphone cameras, and allow all kinds of data to be pulled from any video display. To show off their new codes, Lippman's lab set up a public display called Newsflash: a wall of nine iPads showing the front pages of different newspapers with VR codes hidden in them. When you snap the photo, your phone can pull off specific articles, images and links from the display for future use. "We could have done this ten years ago, but no one was walking around with high-quality sensing devices then," says Lippman, 63. "Now you can use the sensor you've already got to capture personalised data from the world around you. They are a component of the future." Say "cheese", adverts. **MV** *pixels.media.mit.edu/newsflash*

Satellite maps – but better

A Media Lab team is using infrared light to reinterpret landscapes



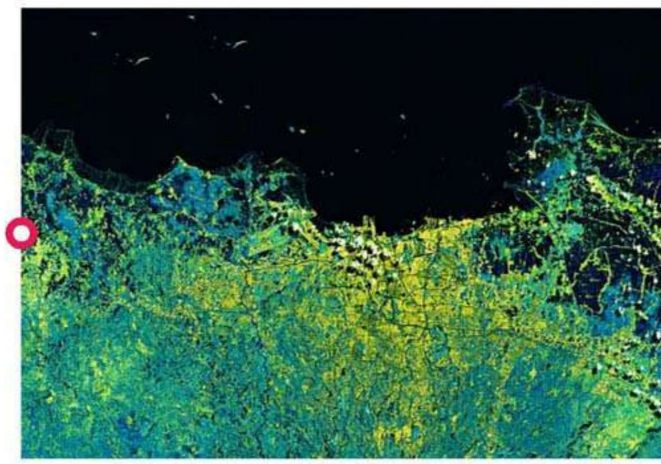
Arlene Ducao wants you to see with infrared eyes. Her project, OpenIR, interprets infrared data collected by Earth-observing satellites such as Landsat 7, Modis and Ikonos to make it useful to the rest of us.

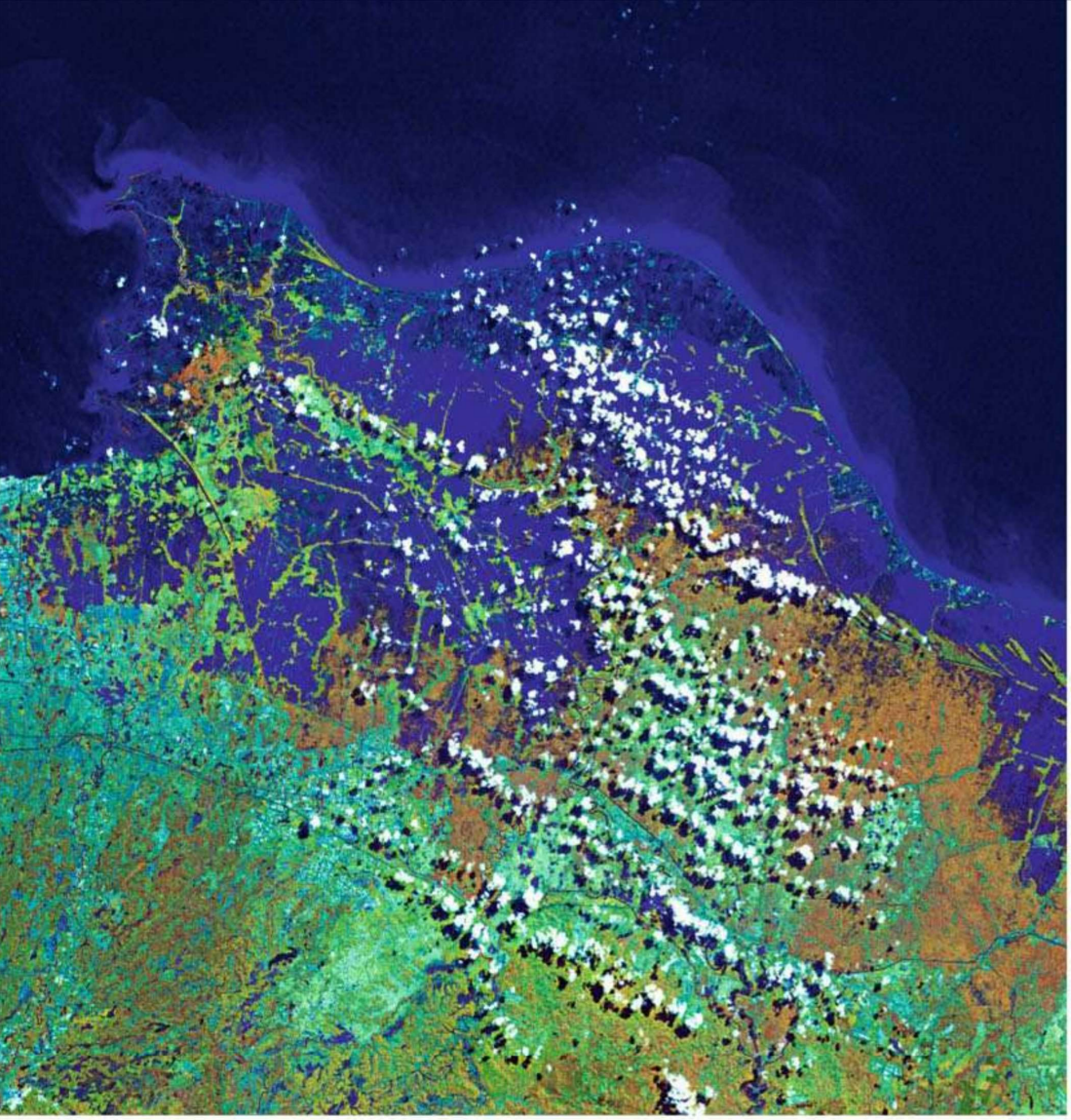
"Infrared imagery reveals aspects of the environment you can't normally see," says Ducao, a computer programmer and digital animator at the Information Ecology group in the Media Lab (see p39). "You can see water clearly – areas of flooding and irrigation." Ducao, 32, has combined publicly available data and a standard map to reveal rich environmental details that are otherwise invisible. "The data is available but it's difficult to visualise, so it remains in the hands of climate scientists and urban planners," Ducao says. Her team has built software that processes the data into coloured images and integrates it with mapping tools such as the Ushahidi platform (WIRED 07.10).

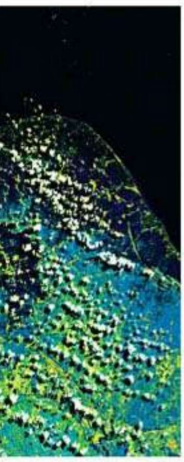
In September 2011, OpenIR launched in Indonesia, a country prone to tsunami and earthquakes. The United Nations Global Pulse Lab is using OpenIR technology to pinpoint dangerously low-lying areas; it will then simulate environmental crises and chart an emergency-management plan. OpenIR could have plenty of other applications. "A farmer, for example, may have a mobile phone but not a mapping app," says Ducao. "We could give him a bulletin on whether his fields need watering today." The world looks different in a new light. **Madhumita Venkataramanan** *openir.media.mit.edu/main*

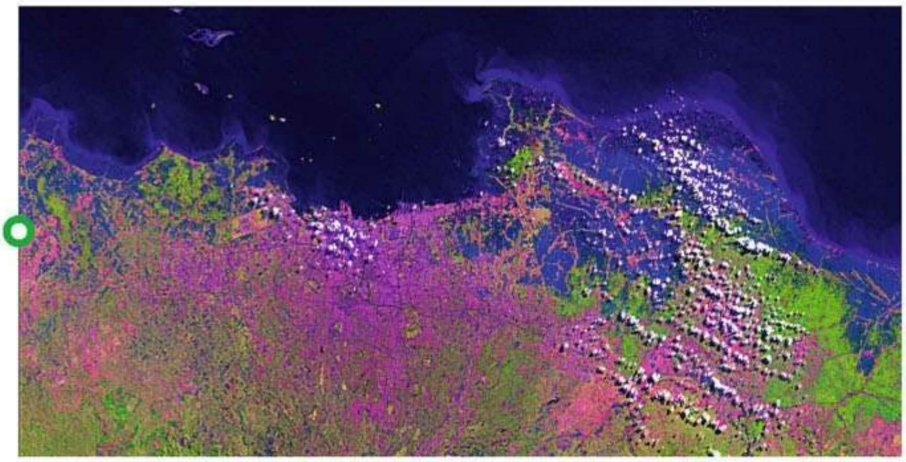
OpenIR decodes infrared data for Jakarta, Indonesia

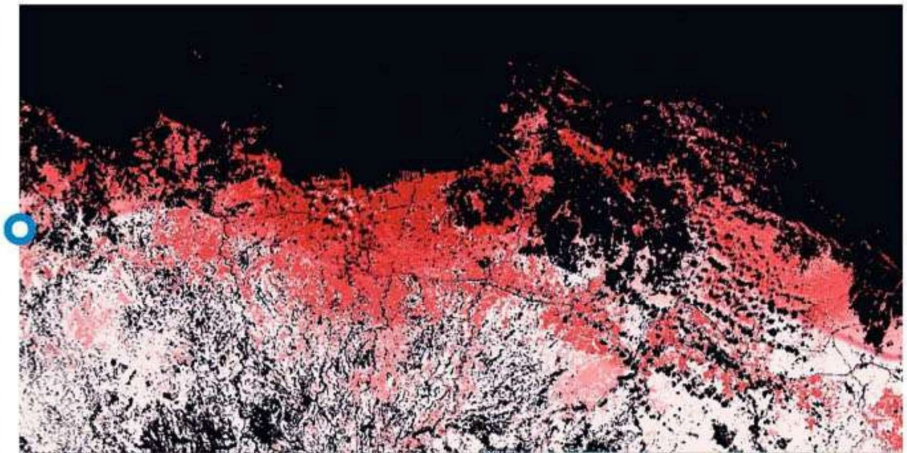
This combination of infrared bands reveals variations in soil type across the region. This image, of saturated paddy-fields, reveals high levels of moisture. The pink patches reveal urban landscapes or other types of impervious surface. Areas of vegetation are shown as red zones in this selection of infrared bands. A prototype flood-risk map: low-lying parts are in red, paler parts show high-level forest.











EARLY ADOPTERS

What's exciting...
JENNY BROUTIN
PhD student, Changing Places Lab, MIT

"My vote would be for the work of Jennifer Lewis's group at the University of Illinois at Urbana-Champaign, specifically **soft/flexible printing of 3D materials** using origami-like techniques, and the invention of a conductive ink. The ideas are brilliant and they are prototyped and proven."

What's exciting...
DAVID LAKATOS
Visiting researcher, Tangible Media Lab, MIT

"**The Self-Assembly Line** project by Skylar Tibbits and Arthur Olsen is a beautiful manifestation of self-constructing materials, resembling a virus capsid. If we can embed computation at small scales, we can control texture and colour as well as properties such as shape and size."

What's exciting...
GRACE WOO
PhD student, Viral Communications Group, MIT

"**Printable computing** is extraordinary and is only just taking shape. Rice University recently showed a way to spray-paint battery components such as electrodes on to metal, glass or plastic bases, making a rechargeable lithium-ion battery out of an ordinary surface."

Front-seat driver

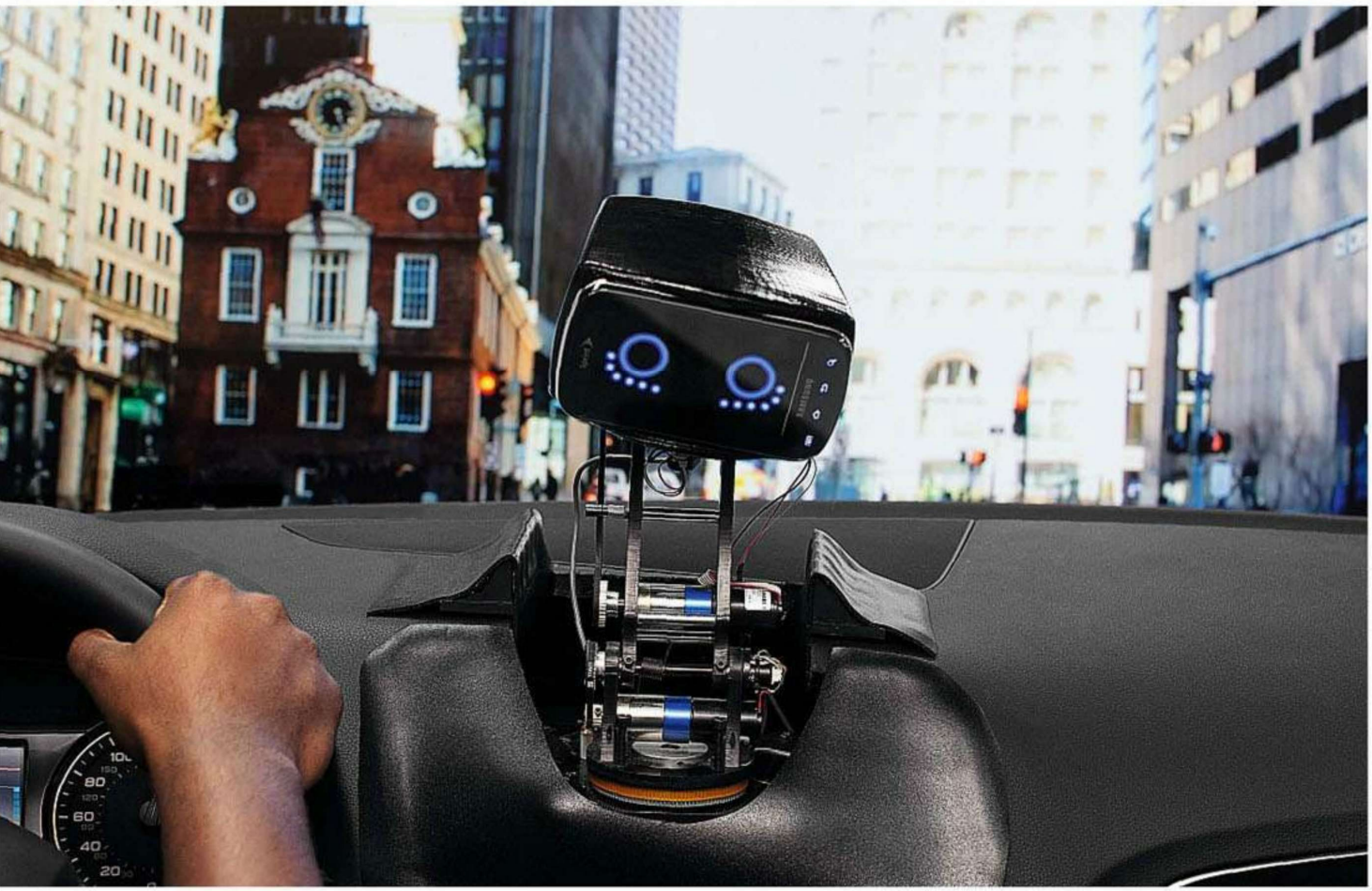
Stressed? Lonely? Running late? Meet MIT's friendly car-bot, who just wants to help

AIDA is an intelligent dashboard companion that not only reads the road, but should soon read your mood too. "People tend to have this inherent bond with their cars," says Kenton Williams of the Personal Robots Group, who is lead researcher on the project. "If you can leverage that to create a stronger bond, then we think you can make the driving experience more enjoyable."

AIDA (the Affective Intelligent Driving Agent) is an MIT collaboration with the Personal Robots Group, the SENSEable City Lab (WIRED 04.11) and the Volkswagen Group of America's Electronics Research Group. It can learn the driver's habits and needs by combining behavioural data with real-time feeds from onboard systems and the web. At first, in 2009, AIDA was a standalone unit. Since then, smartphones have become such repositories of data on their owners that it's being recreated as an Android app.

S T A R T

So how can AIDA help? It can text to warn your host that you're running late – based on your calendar, contacts and the traffic conditions ahead – before you've even thought of it. AIDA could even advise on your driving – if you're not in a bad mood. Future versions will use mood-detection technology; its expressive digital blue eyes will chime with your mood, fostering a bond. "A lot of existing technologies don't take into account the social aspect of driving," says Williams, 27. "Having a happy driver leads to better and safer drivers." Sadly, there are no plans to add a *Knight Rider* turbo boost. **Jeremy Kingsley** *robotic.media.mit.edu*



PHOTOGRAPHY: SPENCER LOWELL.

SMART ROOMS KNOW WHAT YOU LIKE

Indoor spaces are getting smart; now they are embedded with sensors that monitor humidity, temperature and light. "The challenge is connecting to this nervous system," says Joe Paradiso, director of the Responsive Environments Group at the MIT Media Lab. His solution: WristQue, a plastic wristband that gives you remote control over your surroundings (*shown right, on its charging dock*). The low-power, 16-bit device has buttons to control temperature and electronics, and a slider to adjust lighting. The building stores weekly usage patterns for each room; when people enter, it adjusts heat and light based on the previous week's data. When they leave, windows are closed and air conditioning is turned off, which cut energy use by a quarter during a three-week test.

WristQue can also identify who's in the space and automate their preferred conditions. What if some like it hot and others like it cold? Easy: "We give you a happy medium," says Paradiso. **Sam Scott** *media.mit.edu/research*

No ordinary Night Sky

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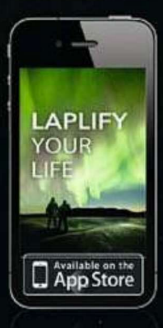

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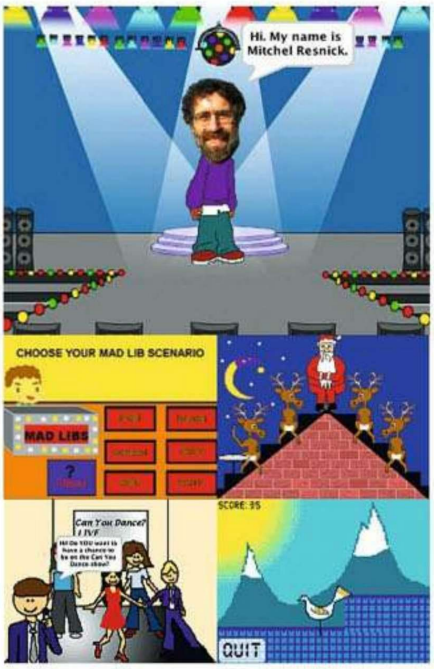


TECH EDUCATION IS CHILD'S PLAY

"Instead of children bored out of their minds being taught how to use Word and Excel by bored teachers, we could have 11-year-olds able to write simple 2D computer animations using an MIT tool called Scratch," said UK education secretary Michael Gove earlier this year. A programming language for kids released in 2007 (version 2.0 comes out this autumn), Scratch allows children to create interactive stories, games, animations and simulations and share their creations online. "We take the ideas of the Media Lab and see how we can bring them into the lives of children," says Mitchel Resnick, head of the Lifelong Kindergarten group that made Scratch.

At the time of writing, more than 2.6 million creations are being shared online. "Kids like their virtual construction kits where, for instance, they'll do their own LEGO building kits on screen or reconstructions of classic videogames," says Resnick, 56 (*pictured above with a selection of children's Scratch creations*). "There's a variety of places that are trying to add Scratch to the curriculum."

Resnick's life hasn't always been this playful: he graduated in physics and covered Silicon Valley for *Businessweek* in the early 80s. A partnership with Seymour Papert, one of the lab's founding fathers, changed his career. "Seymour was one of the first to see that computers could help kids express themselves and design and create things," says Resnick. "That was an inspiration."

In 1985, when Resnick and Papert made a prototype connecting LEGO to a computer, the toy giant got in touch. Later, Resnick managed to squeeze the computation inside the LEGO brick, which let children program and build interactive robots – and became the basis for LEGO's Mindstorms kit, released in 1998. "I proudly hold the title of LEGO professor," says Resnick. "Its bricks are designed to help people learn through design and creation. We try to extend that spirit to the digital world." **JM** *scratch.mit.edu*

Inventing a new field in vision

Ramesh Raskar and his Camera Culture team are creating ways of seeing the world differently

An ergonomic adjusting frame enables self-testing without a trained operator

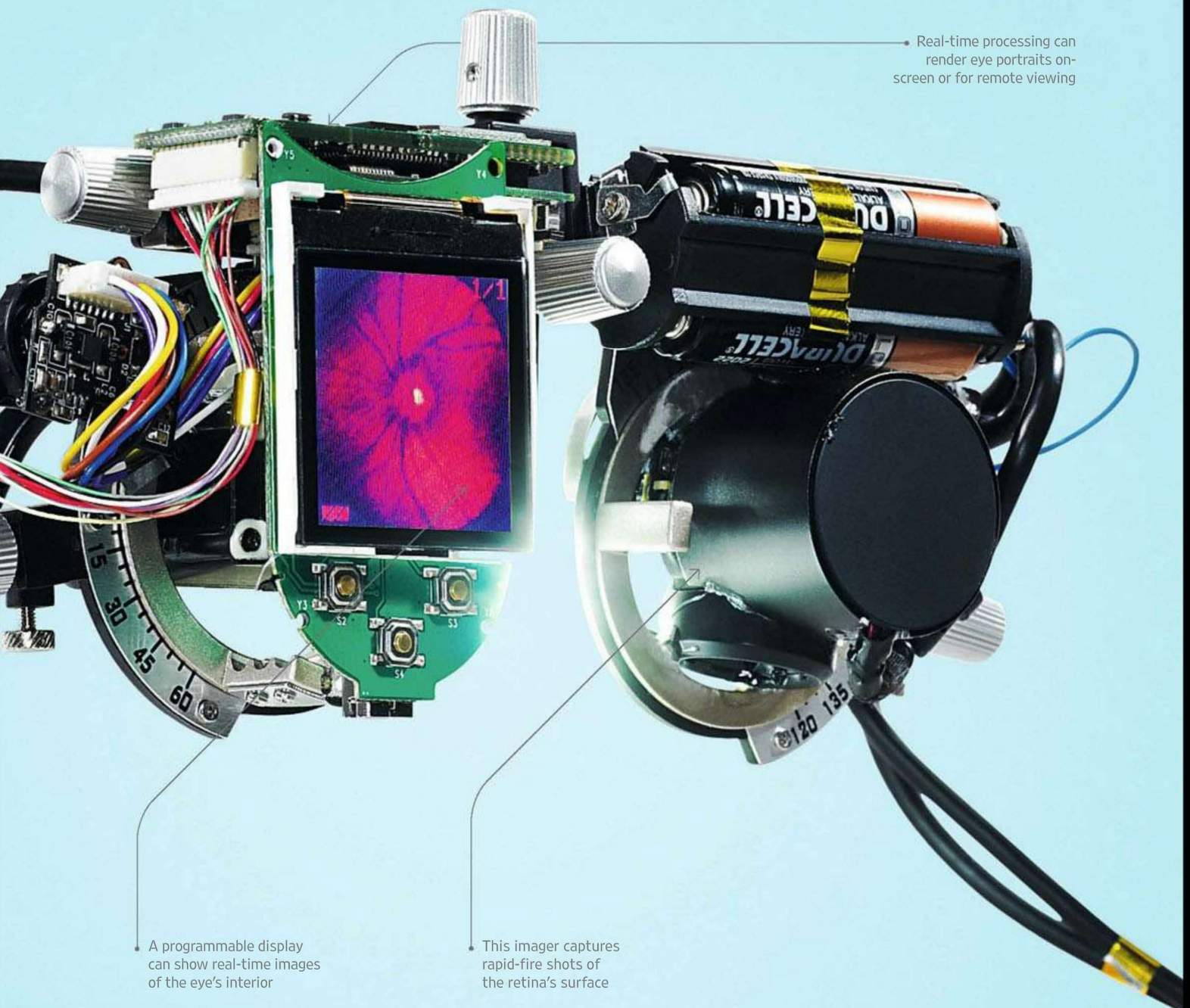
Ramesh Raskar: "It's great to invent *things*, but I wanted to invent a new field. That's why I came to MIT."

Ramesh Raskar wants to make the invisible visible. "My work often starts with a goal that to others appears impossible," says Raskar, who heads the Camera Culture group at the Media Lab. "Then it becomes merely improbable; then, finally, inevitable." One of his "impossible" ideas is Looking Around Corners, in which users can sense objects not in their line of sight with a device that uses short laser pulses and a fast detector. "Growing up, I was always interested in vision," the 42-year-old says. "I used to have this strange feeling that what I would see in front of me wouldn't be there any more when I turned around."

Born in Maharashtra, India, Raskar showed potential from an early age – he finished top out of 500,000 students in his university entry exams. In 2000 he joined Mitsubishi Electric Research Labs in Cambridge, Massachusetts, where he developed a multiflash camera. "I had about 40 patents, I was getting calls every week but was getting too comfortable," says Raskar. So he moved to MIT and started a new field: computational light transport. "It's about how light goes from one place to another," he says. "We create a movement of photons, study the image and use computers to invert the process and learn about the original scene."

S T A R T

Raskar and his team are developing projects such as retinal imaging glasses (*below*), glass-free 3D displays (see p51) and Netra, a low-cost medical device that you can attach to smartphones to get spectacle prescriptions and cataract tests. "I believe that the fun is at the intersection of design, computation and optics," he says. "We can build devices that cost a billion dollars and are used by one person, and devices that cost one dollar and can help a billion people." **JM** *Ramesh Raskar will be speaking at* WIRED2012 *on October 25-26 in London (wiredevent.co.uk)*



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YOUR URBAN LIVING SPACE, MICROFARMED

Architect Jennifer Broutin wants to turn busy urbanites into farmers in their spare time. "Imagine if people in your neighbourhood grew food in small quantities," she says. "We could change the way good, fresh food is produced and distributed in cities." So Broutin, a graduate student at MIT's Changing Places lab, built a little patch of synthetic land – a 30cm² module that can be installed in even the smallest home.

Each module, called a SeedPod, is made of a reflective plastic fitted with discs of neoprene, a black rubber into which seeds are planted. "You don't need any soil or water, because we provide water and nutrients in the form of a misted spray," says Broutin, 30.

Green, leafy plants and root vegetables such as potatoes grow particularly well this way, according to Broutin. "It's much quicker too – you can get five to ten more crop cycles per year," she says. The SeedPods come with sensors that monitor water, light and nutrient levels. "This data feeds back to the spraying system, which adjusts itself accordingly," she explains. "Over a period of time, your system would learn the best way to grow specific plants." **MV**

jenniferbroutin.com/projects/seedpod

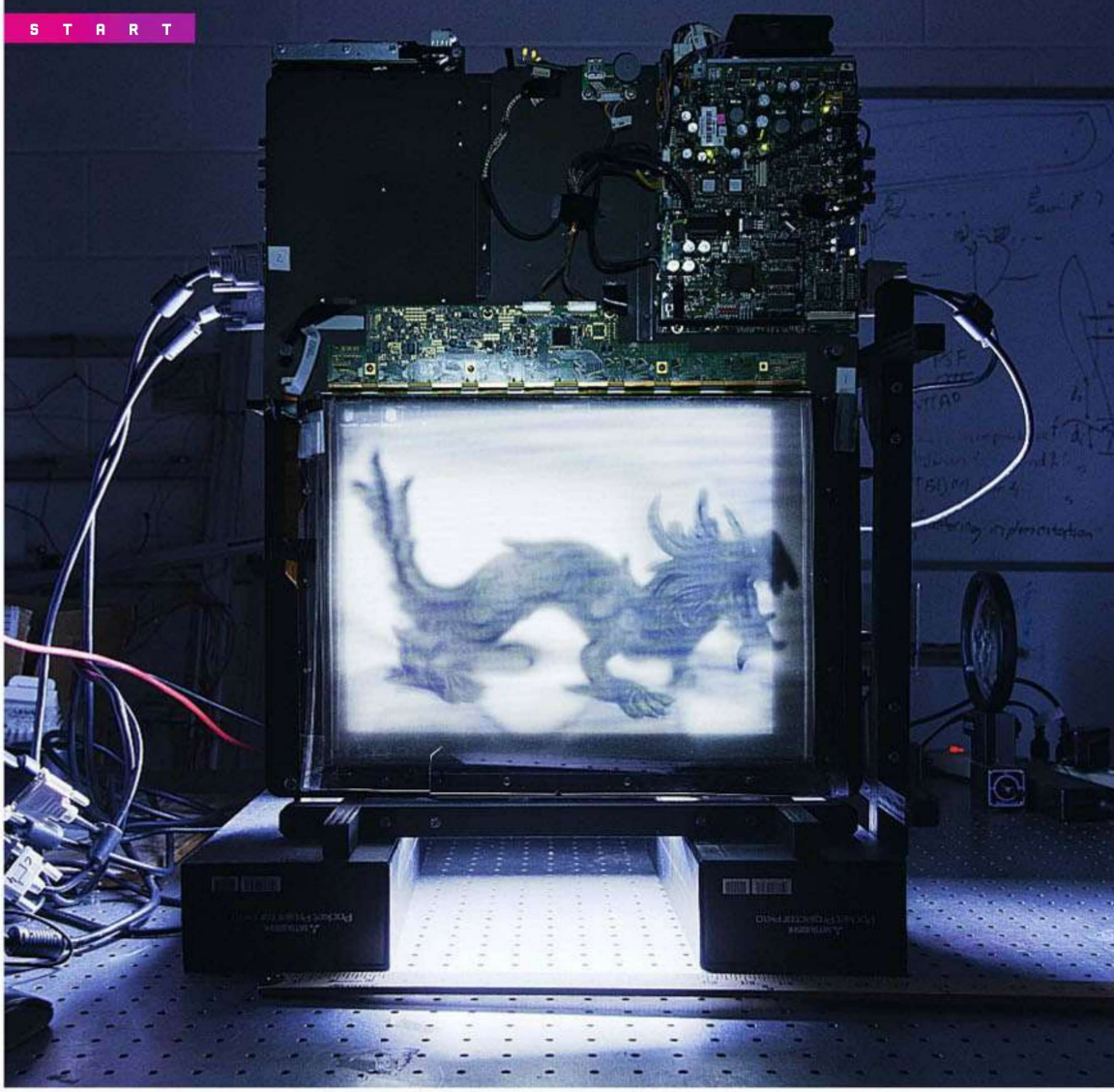
This revolution will be televised

MIT's Camera Culture group is working on a goggle-free 3D TV experience for us sofa surfers

Holographic TV may remain a distant prospect, but the Media Lab's Camera Culture group is developing the next best thing: screens capable of producing glasses-free 3D images that can be seen from various angles. "We want something that's commercially viable in the near-term," says Douglas Lanman, one of the team behind two prototypes. "So we're using something that's commonly available: multi-layered LCD panels."

To expand the viewing angle, the group combined three layers of LCD panels, each one capable of creating pixel-by-pixel light-filtering patterns. These can refresh 120 times per second, thanks to a specially tailored algorithm, allowing for sophisticated manipulation of the backlight to display a series of different images. Since the human eye cannot perceive flickering at such a high rate, the viewer sees a coherent, high-resolution 3D image. And because the system is programmed to project pairs of offset images in various directions, the viewer sees 3D images from multiple perspectives within a 20° viewing angle. A second prototype uses two LCD panels with a sheet of lenses between them to refract light left and right. With this version, the viewing angle is expanded to 50°, with little resolution loss.

Lanman is cagey about when these prototypes will come to market: "Our job is to demonstrate capability," he says. "But I'd say the two-layer version has the best chance of reaching the consumer." Hopefully those 3D goggles will soon be forever consigned to the back of the sofa. **Daniel Cossins**



LCD panels are combined with linear polarisers to create a 3D effect (*below*)

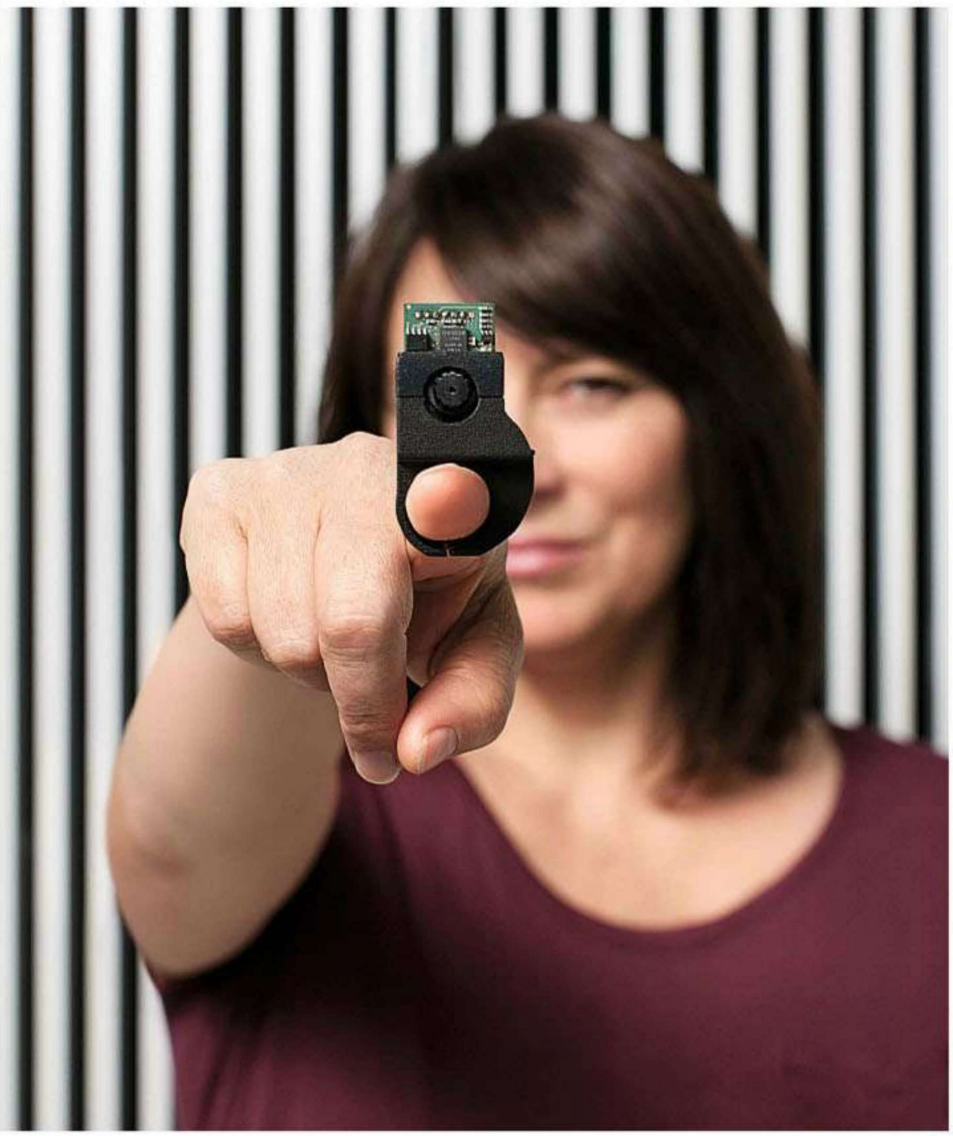
PHOTOGRAPHY: SPENCER LOWELL. ILLUSTRATION: DALE EDWIN MURRAY

Look, point and get the lowdown

Pattie Maes hopes to mix the digital and physical worlds in a data cascade

Pattie Maes wants to blend the physical world and the digital world. "I want our natural senses to be augmented with information about the stuff and the people around you," says Maes, 51. "If I bump into someone at a conference, I would like to be given information about our previous interactions, our email correspondence and all the other information available online about that person."

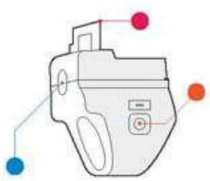
The projects that Maes (*pictured*) develops at her Fluid Interfaces group are a reflection of her vision. Take EyeRing, a wearable ring with a micro camera that allows the user to point to an object and hear information about it. Or Sixth Sense, a prototype comprising a pocket projector, a mirror and a camera, that enables the user to project a visual interface on any surface and augment hand gestures, to take photos or check email. "It allows you to interact with digital information superimposed on to physical objects," says Belgian-born Maes.



The Fluid Interfaces group is a continuation of the work that Maes started when she was invited by artificial-intelligence pioneers Marvin Minsky and Rodney Brooks to join the Media Lab and start the Software Agents group in 1989. "Then the computer was seen as a tool, much like a hammer," says Maes. "But I always advocated that the computer should take a more active role in assisting us continuously." In the 90s, Maes was one of the first to develop collaborative filtering. One of her spinoffs was Firefly, a startup that offered personalised recommendation systems to clients such as Barnes & Noble and Yahoo!, and was sold to Microsoft for $40 million (£25 million) in 1998.

"We were a bit green," says Maes. "We did well but the company was not focused. My work now is not short term. We try to launch totally new ideas in terms of user interface just as proof of concepts, just to see where it takes us." **JM** *fluid.media.mit.edu*

PHOTOGRAPHY: SPENCER LOWELL. ILLUSTRATION: ROBERT BALL



The secrets of the EyeRing

Microprocessor
Camera
Trigger

YOUR LIFE AS AN APP

You take your smartphone everywhere, so it knows a lot about you: where you are, who you're with, what you're listening to, even whether you're standing or sitting. To make the most of this, Media Lab alumni Nadav Aharony, Cody Sumter and Alan Gardner have developed Funf, an open-source Android platform that simplifies data collection and lets developers create apps that tap into this huge cache.

"Instead of building end-user apps, we'd rather enable a whole ecosystem and empower developers to be innovative," says Aharony, 34, who left Google to cofound Behavio, the Bay Area-based company behind Funf, in June 2012. "We also want to help researchers and non-profits." To this end, the One Laptop Per Child project is using Funf to collect data on how children in Africa interact with tablet devices. There is even an option for non-programmers, Funf in a Box, which allows you to select from pre-set options and send the resulting app directly to your Dropbox account. "We want people to tap into all this smartness," says Aharony. **Dan Cossins** *funf.org*

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The ES9000 has the capability to change forever the way TVs are viewed. RRP £7,999.99. For more details, visit *samsung.com/uk*

TECH GALLERY

VIDEO	AUDIO	SMART
Screen size 75	**3D sound** Yes	**Camera built-in** Yes
Resolution 1,920 x 1,080	**Dolby** Dolby Digital Plus / Dolby Pulse	**Face recognition** Yes
Wide Colour Enhancer Wide Colour Enhancer plus	**SRS** DNSe	**Motion control** Yes
Ultra clear panel Yes	**dts 2.0+ Digital out** Yes	**Voice control (embedded)** Yes
Digital noise filter Yes	**Sound output (RMS)** 15W x 2	**Smart Evolution** Yes
Clear motion rate 800Hz CMR	**Speaker type** Down firing + full range	**Camera app** Yes
Micro dimming MDU + Precision Black	**Auto volume leveller** Yes	**Samsung TV apps supported** Yes

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FEATURES

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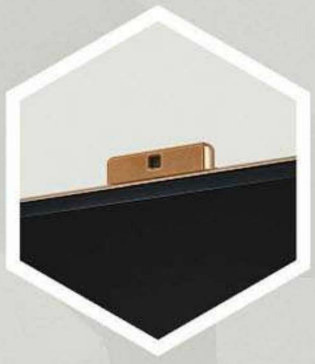


DISCREET HD CAMERA
The built-in camera is neatly hidden within the top of the bezel, making it invisible when not being used for video conferencing, user recognition or gesture control.

BEST IN CLASS
Samsung is the UK's number-one TV brand and has won five-star and best-in-class reviews in *T3*, *Stuff*, *Home Cinema Choice*, *What Hi-Fi*, *Sound & Vision*, *Which?*, and WIRED.

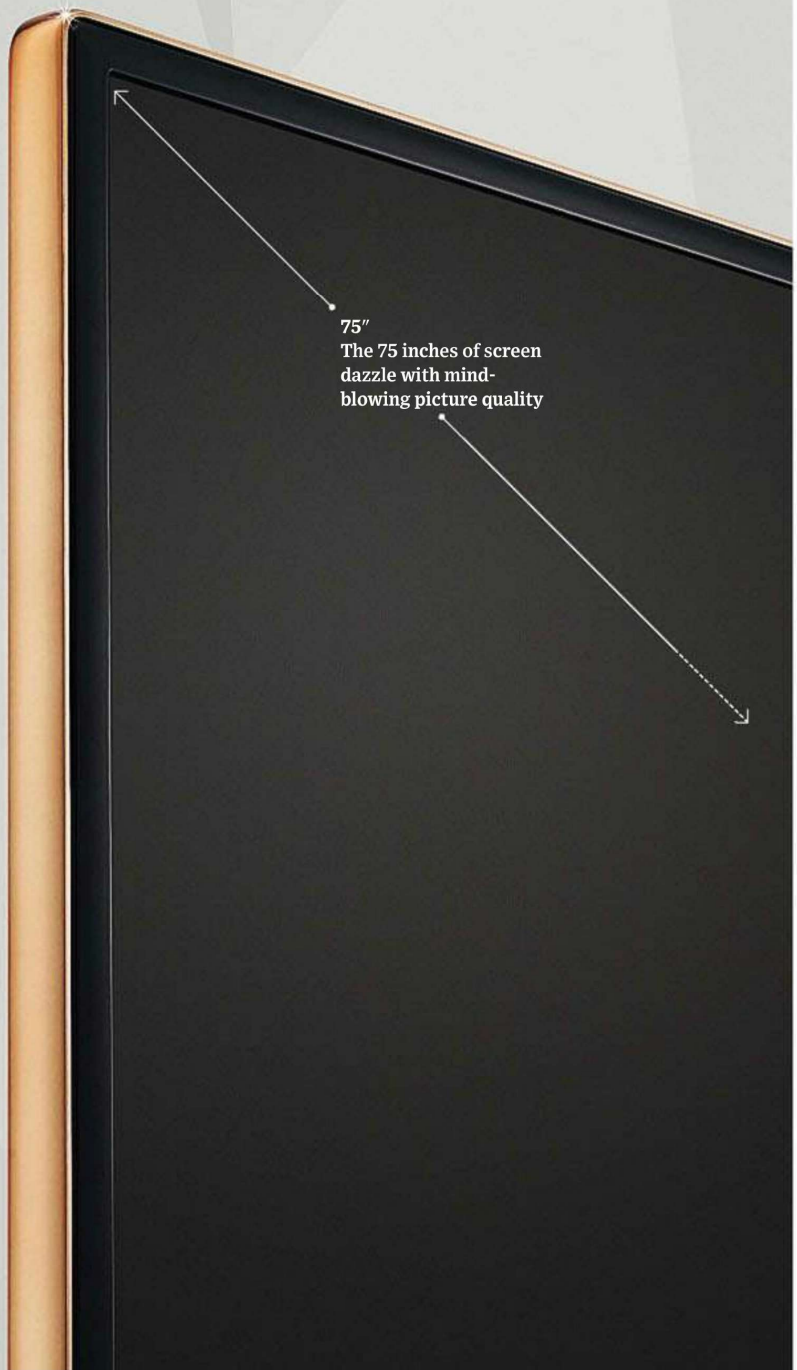
Samsung will be headline partner at WIRED2012 where guests will be invited to experience the unique qualities of the ES9000 first hand.

Its higher contrast ratios and deeper blacks make TV viewing a cinematic experience and reflect an uncompromising stand on picture quality. The sumptuous rose-gold finish and super-slim ONE DESIGN 7.9mm seamless bezel mean it remains unparalleled in style.

Samsung's largest ever LED television* will take pride of place in a stunning exhibition of cutting-edge products, showcasing the very best in advanced technology and design.

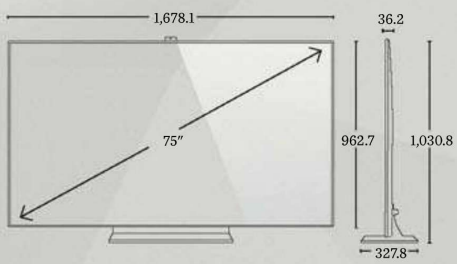
WIRED2012 delegates will also be invited to Samsung's opening night drinks, while Samsung's future-gazing breakfast will give a glimpse of how technology will shape our lives. A special talk will also be hosted at the Samsung exhibition where we invite you to join in and experience the future.

Find out more at wired.co.uk

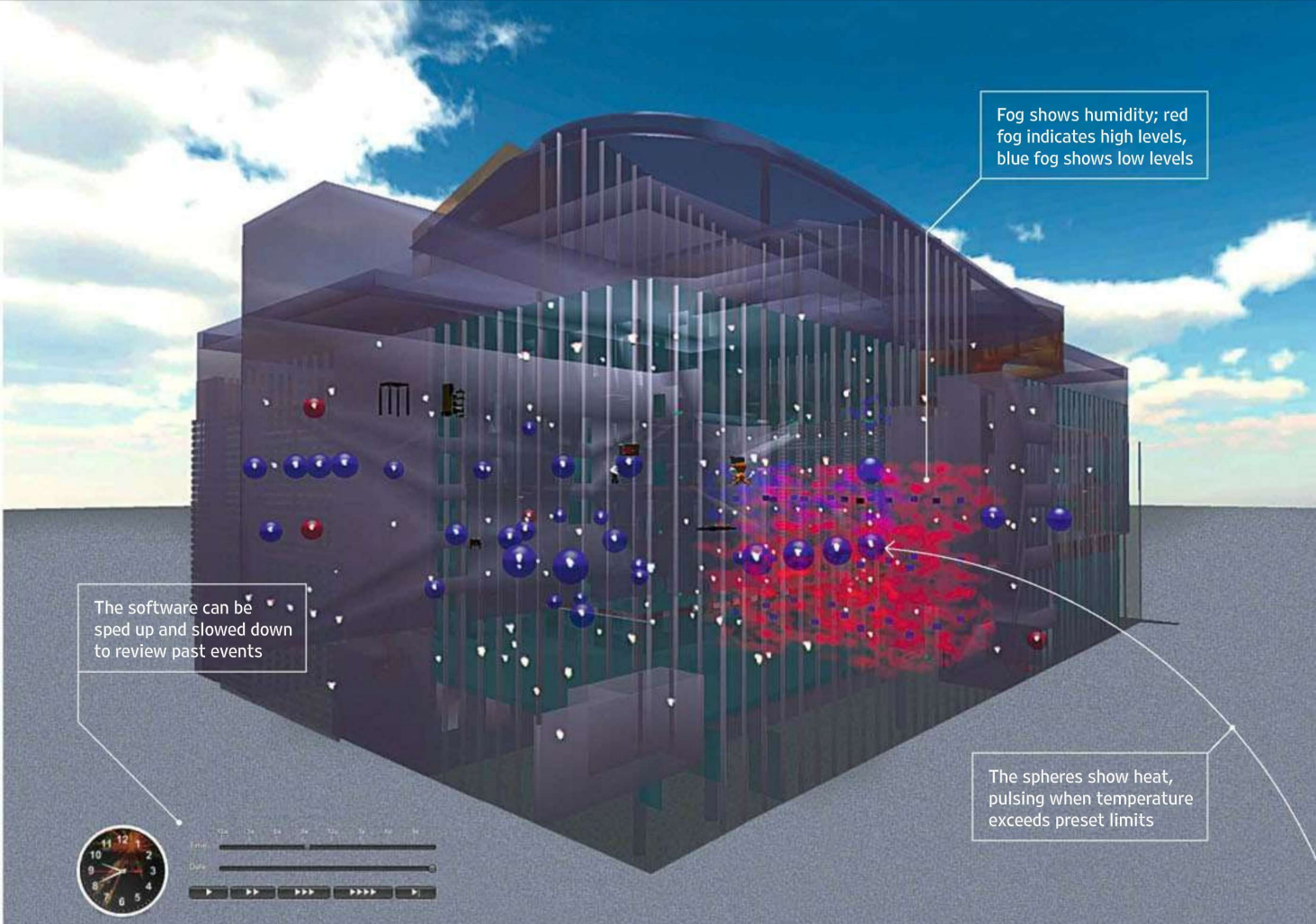


MEASUREMENTS

SAMSUNG ES9000 VITAL STATISTICS (MM)



*Featuring Samsung's back-lit technology



Surveillance, Second Life-style

Snooping just got fun with *DoppelLab*, which lets you remotely monitor how hot a room is – and what people are tweeting

***DoppelLab* is an app that** lets security guards, caretakers and busybodies monitor people, temperature and humidity in a sensor-equipped building. Developed by Joe Paradiso, director of the Media Lab's Responsive Environments group, *DoppelLab* draws inspiration from *Second Life*. It brings on to a screen an interactive 3D image of a building that changes in real time. Click on a flame icon and you can check the temperature of a room. A foggy overlay shows humidity. A third icon tells you the state of the lighting.

But it's in tracking humans that *DoppelLab* shows its real strength. Zoom in on a corridor and tiny snakes of coloured spheres show the density of people in it and their direction. Microphones in the wall pick up conversations (distorted so as not to pry). The system can even display what they are tweeting.

DoppelLab is currently confined to MIT (the images here show the Media Lab building). But Paradiso and his team are about to take it outdoors to a Media Lab alumnus's cranberry bog, where they will focus on its audio capabilities. "We'll be able to turn the ecological data of trees and plants into sound – a symphony of nature."

Will this do away with live human interaction? "Probably not yet," the 56-year-old says. "But we're already living in a virtual world, with people walking around with their heads in their phones. This is more fluid and intimate." **David Baker** *doppellab.media.mit.edu*

The all-seeing home

Deb Roy built tools to track his young son's movement and speech – and now retailers want to use them

In 2005, Deb Roy, director of the Cognitive Machines group at MIT's Media Lab, installed 11 cameras and 14 microphones in his Boston home to study how his newborn son learned language (p97 and WIRED 03.12). The result was more than 240,000 hours of multitrack audio and video that proved incredibly hard to decode. "The cameras had fish-eye lenses,"

says Roy, 44. “When someone walked in a straight line, their image would walk out of one warped image into another. It was extremely difficult to make sense of.”

The solution, which came to Roy’s team “after struggling for years”, was to use software to unwarp the images back into linear space. The pixels were then overlaid on to a 3D virtual model of Roy’s house, making the data look real again. A “camera”, whose output resembles the point-of-view in a first-person shooter game, lets the viewer fly from room to room and gives the software its name: HouseFly.

Thousands of hours of video and audio footage showing caregiver and child activity are recorded and scrutinised by Deb Roy and his team

S T A R T

Now the data is yielding results. “We found a surprising degree to which all three primary caregivers in the household continuously adjusted the complexity of our utterances in the presence of [my] son ⟶»

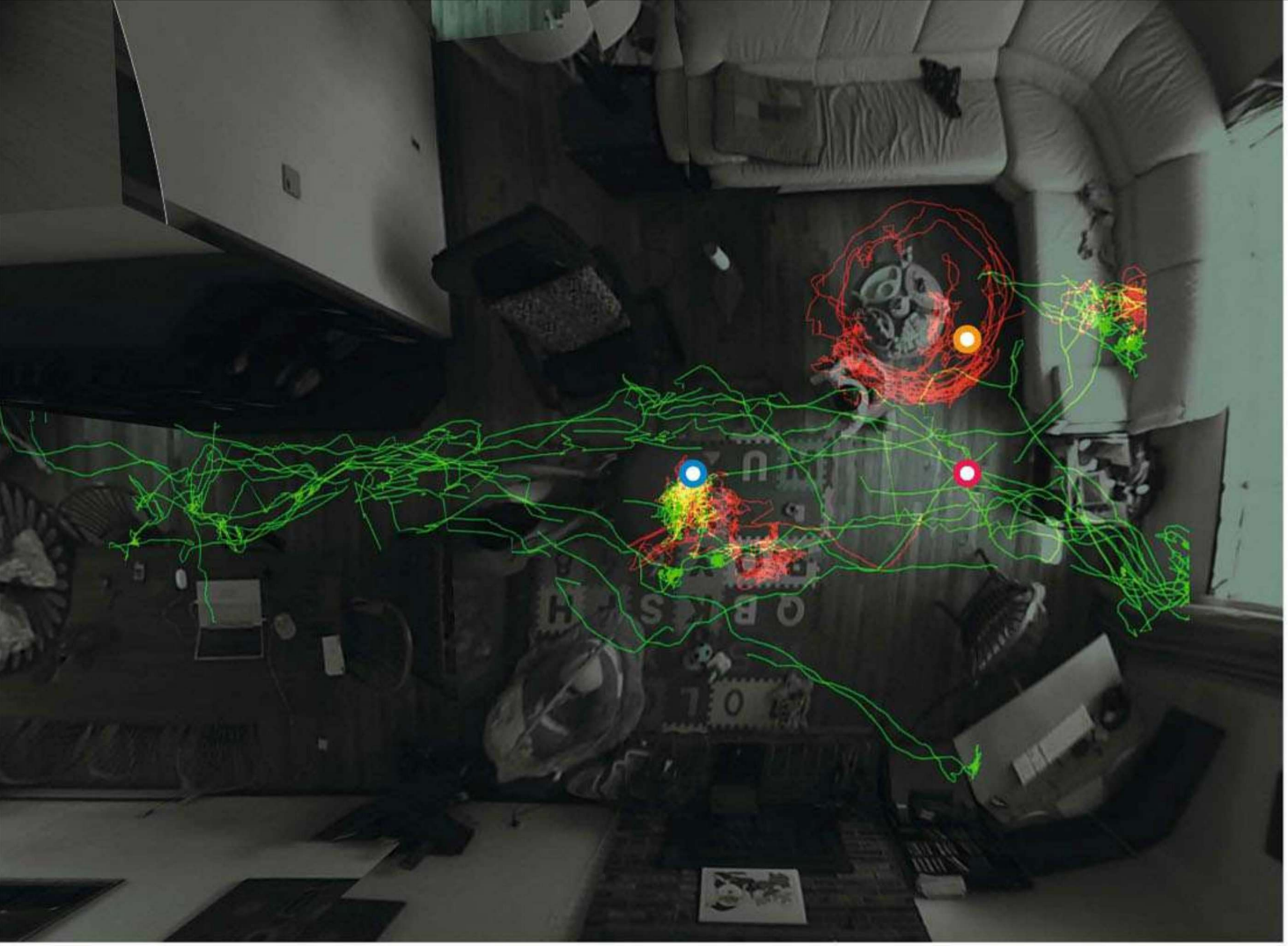
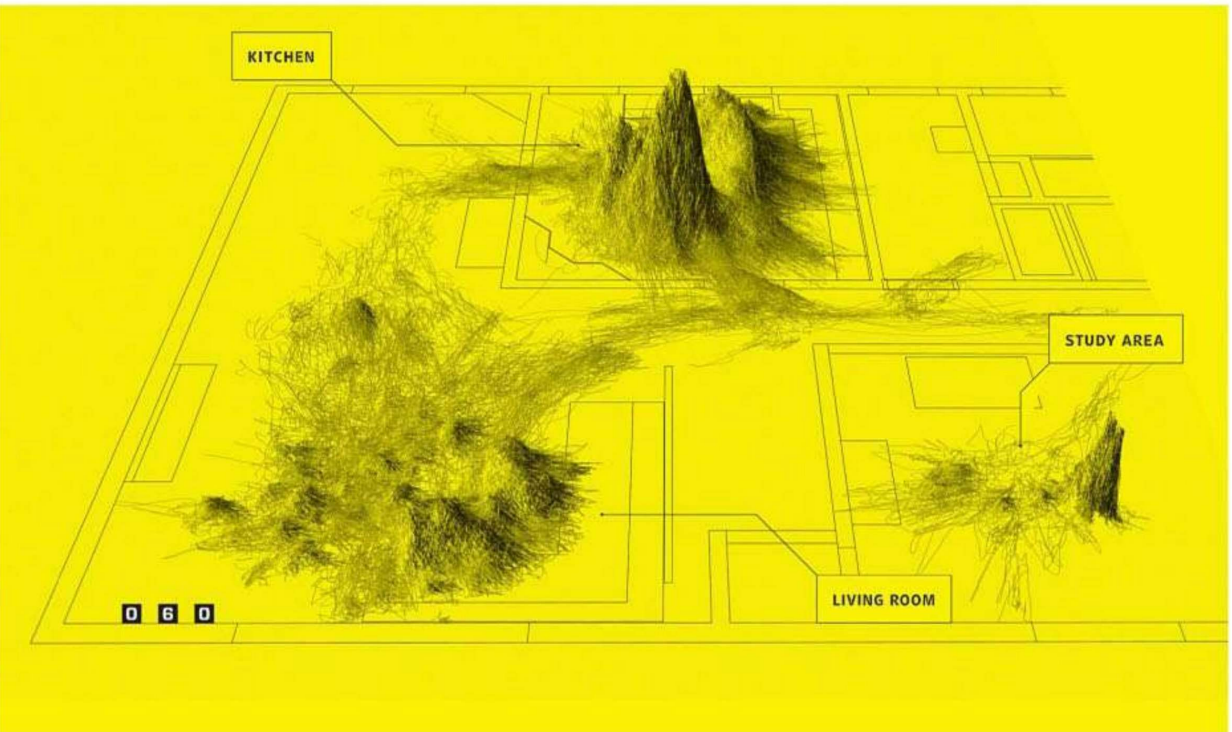


ILLUSTRATION: PHILIP DECAMP; DEB ROY

in a way that seems almost designed to help him learn language," says Roy. "We also found a surprisingly strong influence of non-linguistic context. These findings could open up new ways to approach language therapy for children."

Now Roy is expanding HouseFly beyond child development and into public spaces. "We worked with a bank and a retail store to compare transaction data with people's movements and saw what sort of thing would lead to long queues forming," he says. "Customers filling in certain forms would always lead to longer lines. The systems could then spot this and work as an early-warning system to get another clerk on the desk." **David Baker** *media.mit.edu/research/groups/cognitive-machines*

- Red lines indicate child movement over a 30-minute period
- Green lines indicate caregiver movement over a 30-minute period
- Yellow areas indicate "social hot spots" where the child is more likely to be paying attention to a caregiver's speech and actions



Deb Roy's home-recording results
This Wordscape shows data generated around 8,685 utterances of the word "water" around the house, across the three-year period

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% MEDIA LAB INDEX

2,590

Area (m^2) of BT Lab, MIT's largest

1 TRILLION

Per-second frame rate of the Media Lab's fastest slo-mo camera, developed by the lab's Camera Culture research group

200+

Undergrad lab researchers

24%

Amount of energy use cut by the lab's wristband, WristQue, which monitors its user's environment

2.4 MILLION

Number of XO laptops that the One Laptop Per Child project has delivered to children

137

Number of companies that have spun out of Media Lab research

2,745,345

Projects created on Scratch, a programming language for children created by the lab's researchers

418

Number of Media Lab research projects currently underway

$35M

The lab's annual operating budget

For sources, see Colophon (p154)

Interface floating in space

ZeroN, a hovering ball from the Media Lab, has severed its ties with gravity

Jinha Lee wants to help humans and computers interact intuitively by giving digital information physical form – and liberate it from gravity in the process. So the PhD student at MIT Media Lab's Tangible Media Group teamed up with Rehmi Post, a scientist at the Centre for Bits and Atoms, to create ZeroN, a ball which can levitate and be moved freely in space by its user. "Right now we use keyboards or touchscreens," says Lee. "Everything is in the screen. We want to bridge the gap between digital and physical."

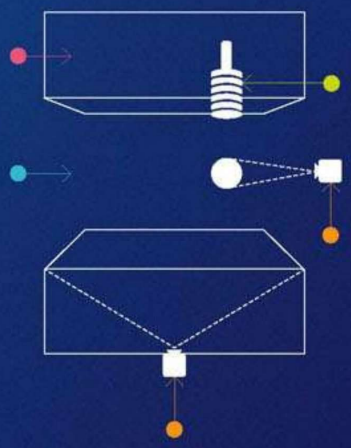
The 31mm-wide ball is controlled by an electromagnet that adjusts itself hundreds of times every second to keep it afloat. To the side is an infrared motion-tracking system built using two modified Sony PS3 Eye Cameras, which track the sphere's location, and relay information back to the controller. Reach in and move the sphere, and when you let go the magnet will hold it in its new location. The system will also record movements and repeat them, or it can digitally program the ball to travel a pre-defined path. "It's a powerful tool for creating physics simulations or modelling how nanoparticles interact," says Lee. "And it does it in a tangible way, so it's great for education and research."

ZeroN can be used to create fly-over videos of architectural models or similar tasks in 3D animation. "Looking further ahead, you could program tiny particles to fly out towards you and arrange themselves into physical objects that you could interact with." He says. "Now that *would* be exciting." **Daniel Cossins** *leejinha.com/zeron*

The ZeroN can move this ball around as if it were a planet orbiting the Sun

Hover craft: how ZeroN works

Two motors control lateral movement
An electromagnet repels and attracts the ball
Cameras track and record ball movement
The ball can move freely in this anti-gravity space



PHOTOGRAPHY: DAVID ARKY

Code for the rest of us

Sepandar Kamvar's intuitive computer language opens up new artistic possibilities

"I've always felt a disconnect between the way I thought of a computer program and the way I would code it," says computer engineer Sepandar Kamvar, who heads the Social Computing group at the MIT Media Lab. "So I wrote a language that is so close to English that it is easy to write naturally."

Called Dog, Kamvar's programming language for social applications is already in use at the Skissernas Museum in Lund, Sweden, where visitors are using it to create art. "The code will give instructions to the next visitor where to plant a tree," says Kamvar, 35. "The exhibit made from these trees will keep growing in a pattern all over the city. Dog enables these participatory experiences." Kamvar is also working with his lab colleague, composer Tod Machover (see p78), on an opera that will likely be partly written in Dog.

Kamvar joined MIT from Google, which bought his personalised search engine Kaltix in 2003. At Google, he led the team that produced services such as Personalized Search and iGoogle. "I have always been interested in the interplay between search and people," says Kamvar. **JM** *kamvar.org*

START

GIVE YOUR APPLIANCES THEIR VOICE

Your household items are now ready to talk to you. Media Lab alumni David Carr and John Kestner have developed Twine, a 60mm rubber-coated square with Wi-Fi connectivity and built-in temperature and vibration sensors that can text you when the laundry is done or send you an email if your kitchen floods.

"Twine does the hard work in terms of connectivity, so it's easy for people to work on their ideas or solve a specific problem," says Kestner, cofounder of Supermechanical, the Cambridge, Massachusetts-based design company behind the device.

You don't have to be a programmer to use Twine. Place the device on an object and use a web app called *Spool* to set up rules in plain English, such as: "WHEN vibrations stop THEN text 'the laundry is done'." The company offers extras such as moisture or magnetic sensors, and more technically minded users can use breakout boards to make their own sensors.

Twine raised $550,000 (£340,000) on Kickstarter in January 2012 (its original goal was $35,000) and began shipping its initial run of 4,000 $99 devices in September. "There are a lot of things that should be able to talk to us," says Kestner. "Twine is a simple way to jump-start that future." **Daniel Cossins** *supermechanical.com*

PHOTOGRAPHY: BRAD SWONETZ

WIRED

READER PANEL

WIRED NEEDS YOU

We are looking for excited and engaged readers to join the WIRED reader panel so they can share their opinions and give us feedback on the magazine and our tablet editions.

To join us, go to *wired.co.uk* and register for the reader panel. Every time you complete one of our online surveys, you will be entered into a prize draw for high street or online gift vouchers.

PHOTOGRAPHY: NICK MEEK

WIRED INSIDER

EVENTS, NEW PRODUCTS, PROMOTIONS AND COMPETITIONS TO LIVE THE WIRED LIFE

COMPILED BY NATALIE FUTTER

1 SHELL AND WIRED2012 COMPETITION

WIRED2012, on October 25-26, will bring together innovators, entrepreneurs, policy makers, industry leaders and experts to share ideas and build networks. In the spirit of innovation and enterprise, Shell is offering two WIRED readers the chance to win one ticket each to attend the hottest tech and networking event of the year.
To enter, visit wired.co.uk/promotions/shell

2 TECHNOLOGY VENTURES CONFERENCE

On June 22, the ninth annual Technology Ventures Conference was held in Robinson College Cambridge, by the Cambridge University Technology and Enterprise Club. Four hundred delegates attended to hear six speakers, four panels, take part in three workshops and view three exhibitions. The main topic of the conference: "Innovation in an Uncertain World".
tvc2012.cutec.org

3 OMEGA'S SKYFALL WRISTWATCH

OMEGA watches are synonymous with James Bond. To celebrate their seventh appearance in a Bond film, OMEGA has launched a limited edition Seamaster Planet Ocean 600M SKYFALL, with only a fitting 5,007 timepieces being produced. Water-resistant up to 600 metres, it can weather all kinds of storms and adventures – and we would expect no less for the wrist of Daniel Craig.
omegawatches.com

4 ENCOUNTER BY CALVIN KLEIN

Calvin Klein's new male fragrance captures the unresolved tension and desire between a man and woman, played out by the two new faces for the fragrance, Lara Stone and Alexander Skarsgård. Mixing spicy and woody tones creates a scent that is perfect for a self-assured male. Housed in a blue glass bottle with a unique shattered design gives it a sophisticated edge.
calvinkleinfragrances.com/uk

WIRED EVENTS CALENDAR

Digital Crystal: Swarovski at the Design Museum
The Design Museum and Swarovski collaborate for the Digital Crystal exhibition, examining memory in the digital age, when our relationships with objects and images are in flux. Fifteen works give a glimpse of the future.
September 5 – January 13 designmuseum.org

Corporate Entrepreneurship Awards 2012
Also at the Design Museum are the Corporate Entrepreneurship Awards, run by Market Gravity, a specialist growth and innovation consultancy. New this year is the WIRED People's Choice Award. *October 24 corporateentrepreneurawards.com*

WIRED2012
Samsung is headline sponsor of WIRED2012, where its stunning new 75" Smart TV, the ES9000, will be on display. Samsung will also invite delegates to experience the future of TV and tech over a breakfast seminar, a special talk, and opening night drinks.
October 25-26 wired.co.uk/promotions/samsungsmarttv

Pioneers Festival
STAREurope will be hosting an unforgettable startup festival for 2,500 participants, who will enjoy 60 speakers at the Hofburg Imperial palace in Vienna. They will showcase visionaries and technologies changing the future and inspiring the next wave of innovators.
October 29-31 pioneersfestival.com

Monaco Media Forum
For the seventh year, Monaco Media Forum is bringing together leaders from new and old media to discuss the future of online, broadcast and print communication. Hosted by Prince Albert II of Monaco, this offers valuable insight into the next-generation media landscape.
November 14-16 monacomediaforum.org

PHOTOGRAPHY: SUN LEE

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ALEX "SANDY" PENTLAND_
Want to predict the market? Look inside your cellphone

Adam Smith and Karl Marx were wrong – or at least, they had only half the story. The daily ebb and flow of our societies is the sum of billions of individual exchanges: people trading information, money, goods or just gossip. When we average out these billions of individual events, we obtain the familiar groupings we call markets and classes as well as statistics such as market prices or percentages of voters. These averages and groupings were the foundations for the grand theories of the Enlightenment and remain the subject of most social theorising and political reasoning.

But when we examine the detailed patterns in these billions of exchanges, we find that we can begin to explain many things that appear as random fluctuations when discussed in terms of groups and averages. Examples of such phenomena are market crashes, bankruptcies, fads and political movements. The new lens that lets us examine society in such fine-grain detail is known popularly as Big Data (see 08.12): billions of telephone-call records, credit-card transactions and GPS-location fixes. These new digital information sources let us precisely measure patterns of interaction between people, and between consumers and merchants, and then chart the patterns of experiences people have as they move about their city.

The patterns that provide the most insight have to do with the flow of information. The flow of information can be seen in telephone calls or social-media messaging, of course, but also by assessing for the amount of novelty and exploration in individuals' purchasing patterns (as seen in credit-card data) and physical mobility (as seen in GPS tracks).

Here are some examples of insights that can be gained from examination of these patterns of information flow. **Market bubbles:** Our research has shown that the richness of information flows in foreign exchange and commodity trading (measured by social-media messaging) accurately predict return on investment. This "richness" measure can vary between groupthink (everybody saying the same thing) to isolation (nobody talking). At the groupthink extreme we get financial bubbles, and at the isolation extreme there is not enough information flow for good market dynamics. In between is a "wisdom of the crowd" region with high returns. In real-world experiments, we have shown that by applying appropriate incentives we can shape the market to remain in this healthy region. **Social outcomes:** Our research has shown that patterns of information flow (measured by phone communications) can accurately predict social outcomes, such as crime and incidence of infectious disease, along with regional GDP and creative output (as measured by patenting frequency). In real-world experiments we have again shown that we can shape these information flows through appropriate incentives and gain improved outcomes as a consequence. **Growth and creativity:** Perhaps the most interesting findings are that patterns of exploration (measured by purchasing behaviour, physical mobility or communications) correlate with productivity growth and measures of creative output. We saw this most clearly in companies, but the same patterns appear to hold for cities and regions. This suggests that incentives for greater exploration and mixing of information, experiences and ideas will result in more growth and creative output.

These findings illuminate the promise of Big Data for governance and policy. When we use Big Data to look beyond aggregates such as markets, classes and parties, and instead examine the fine-grain patterns of information exchanges, we have much greater visibility and control of market behaviour and social outcomes, and can begin to set scientific, reliable policies for growth and innovation. Just as importantly, Big Data can give us unprecedented instrumentation of how our policies are performing, so that they can be quickly adjusted and revised as needed.

Alex "Sandy" Pentland directs MIT's Human Dynamics Lab

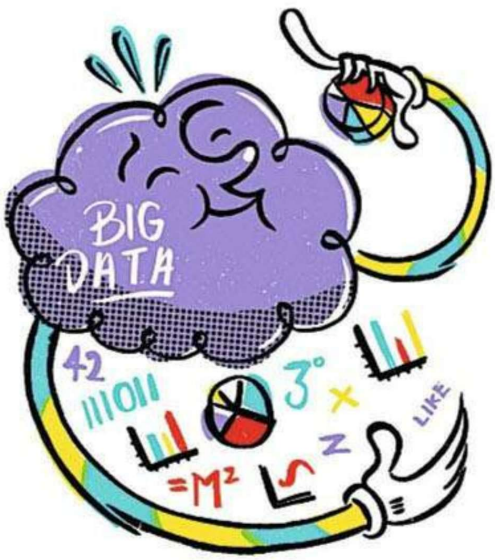


ILLUSTRATION: JOE SNOW

HENRY LIEBERMAN_

Say hello to smarter apps that fulfil your wishes

How many applications do you have on your computer? I've got 159, with 34 on the sidebar. How many apps on your phone? I've got a few 20-icon screens of apps, and after five or six more, space will run out. Where will all the apps we haven't thought about yet go? As with the trend of fossil-fuel consumption, screen-space consumption is unsustainable.

What's the solution? A desktop is like a toolbox, full of hammers and screwdrivers. It's up to me to know what tool to use for the job, use it correctly and put it away. My toolbox shouldn't have to contain every possible tool for every possible job. And what happens if something goes wrong?

The alternative is what I call "goal-oriented interfaces". The interface should be designed around what the user wants to do, rather than what the computer wants. It should be the responsibility of the system to figure out how to get the job done. It should delve into the details only if it's not sure what the user wants, or if something should fail.

One way to achieve a goal-oriented interface is through the use of natural-language input. Perfect understanding isn't yet possible, but things are improving. I'm writing this column using speech recognition. As the user thinks of more things they want to do, natural-language interfaces can scale.

Apple's Siri is the first really popular commercial broad-spectrum natural-language interface. It was preceded by more than $100 million and a decade of government and academic research in AI. It represents a tremendous achievement, and we will certainly see more like it. But, presently, Siri has its limitations. It is specialised to a small set of potential tasks. It tries to match what the user says to one of the kinds of tasks that it knows about, and then calls a conventional phone/web application relevant to the task. But Siri's expertise stops at the boundary of the application. Then you're back to the conventional interface. You can't teach Siri how to do new tasks. Siri cannot compose applications to do a multi-step job. And Siri doesn't have much ability to deal with situations where it misinterpreted, or something goes wrong.

At the MIT Media Lab, we're working on interfaces that, like Siri, are goal-oriented and use language. But we're interested in a broad spectrum of user goals, open-ended and context-sensitive interfaces, and recovery if things fail. A key ingredient is common sense. A computer will book you a plane from Boston to London, but it doesn't know you can't drive there. We're amassing a large common-sense knowledge base, and using it to figure out what "makes sense" in a situation.

Another key is to bring the power of programming to the end user. No application developer can make separate apps for everything a user might want to do. So we're going to have to give users the power to teach new capabilities to the computer themselves, without using a programming language or an "app store". Finally, no computer is going to get it right every single time. So we have to give users the ability to criticise the computer's behaviour, and fix it when it doesn't work. Just as a programmer uses a debugger, we need end-user debugging tools, to make our systems more resilient. Rather than simply filling up our screen space until it runs out, we need to start using the renewable resources of knowledge, language and human ingenuity.

Henry Lieberman is principal research scientist at the Media Lab

SEP KAMVAR_

We need more nourishing metrics than downloads

There is a Zen story about a man riding a horse galloping frantically down a path. His friend, who's sitting by the side of the road, calls out, "Where are you going?" The man replies, "I don't know. Ask the horse!"

When we build our tools, we often depend on metrics to guide development. We keep graphs of unique visitors and page views and watch them closely. This keeps us honest. It's hard to convince anybody that we're building a useful tool if our metrics show that nobody is using it.

But we must take care when we use metrics. Metrics can be like the horse in the Zen story. Once we decide on them, they have a habit of setting the agenda. As the adage goes, what gets measured gets managed.

The standard metric for a country's economic welfare is GDP. I find this strange. If the government decided to give millions of pounds to the country's richest people so that they can buy yachts from one another, that would increase GDP. So would felling national forests to build shopping malls, outsourcing the raising of children, and incarcerating large swaths of the poor.

If we temper the language a bit, we might find this description is not so far from reality.

My point is: metrics shape behaviour. Joseph Stiglitz, economist and professor at Columbia Business School, describes this mechanism nicely: "What we gather our information about, and how we describe success, affects what we strive for." Political leaders who want to grow the economy, he says, will focus policies on things that grow GDP, even when GDP does not correlate with societal well-being.

Which brings me to my second point: all metrics leave something out. Often, they leave out the most important things. In 2007, Stanford offered a course called *CS377W: Creating Engaging Facebook Apps*. The course assignment

ILLUSTRATION: JAMES GRAHAM; TY WILKINS

was to build a Facebook application that, according to the course website, would "focus on solving a problem for a broad audience". It was an intensively metrics-driven class, and the key metric was user numbers. By the metrics, the results were astonishing: during the ten-week term, the apps collectively reached 16 million users.

The flipside was that the applications themselves were underwhelming. Most of them allowed users to do things like rank the attractiveness of their friends. The substance of the applications reflected what the metric left out. If it were possible to measure the value of a user's attention, or how enriching an application is to his or her life, the course projects would likely have been quite different. But, sometimes, the important things can't be measured.

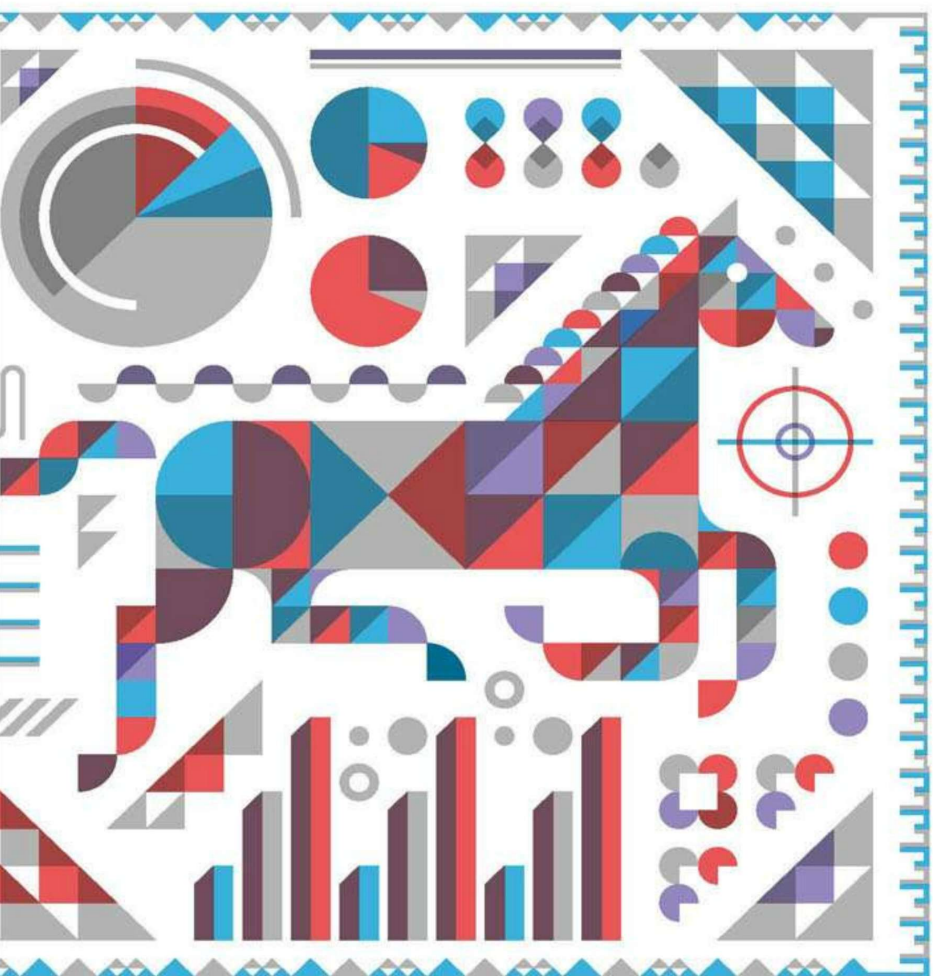
It is useful, therefore, to have missions to balance our metrics. If I were to suggest one mission, it might be: every tool should nourish the things upon which it depends.

We see this principle at varying levels in some of our tools today. I call them cyclical tools. The iPhone empowers the developer ecosystem that helps to drive its adoption. A bike strengthens the person who pedals it. Open-source software educates its potential contributors. A hallmark of cyclical tools is that they create open loops: the bike strengthens its rider to do things other than just pedal the bike.

Cyclical tools are like trees, whose leaves fertilise the soil in which they grow. At the top of the stack, all tools depend on nature and human nature. And they depend on users' attention. A fully cyclical app might use peer-to-peer data centres powered by its users, consisting of biodegradable, fertilising microprocessors. It would be open source and provide APIs to empower the creativity of builders, and a clean design and useful purpose that cultivates users' concentration. If this sounds like sci-fi, so did manned lunar vehicles in 1950, or self-driving cars in 2000. We have a tendency to achieve what we focus on.

It's difficult to build cyclical tools because the alternative is so tempting. Cyclical tools appear to be lower-power, slower-growing, and more expensive than extractive tools. But you can't measure the impact of tools on their own. You must measure them by the ecosystems that they co-create.

Sep Kamvar is associate professor of media arts and sciences at the Media Lab



ETHAN ZUCKERMAN_

Africa's hackers are today's world-class tech innovators

Growing up in the US, I didn't have much first-hand knowledge of technological progress in other countries. I assumed some countries were rich, which meant they had lots of cars, computers and electricity, whereas others were poor, which meant that most people cooked on charcoal, used kerosene for light and went through their lives without making a phone call. I'd developed a (not uncommon) cognitive shortcut: technological progress happens in parallel, so countries are high-tech or low-tech, never a blend of the two.

One trip to sub-Saharan Africa is all it takes to demonstrate the failings of this mental shortcut. Wireless ISPs were common in the Ghanaian capital of Accra before public Wi-Fi nodes were widespread in the US. My hacker friends in Lagos work from taxicabs, logging on to 4G networks. In Kenya, 70 per cent of adults use M-Pesa, a phone-based payment system, to buy groceries and send money to family. On much of the African content, telecoms infrastructure is world class, whereas transport, power and other infrastructures lag far behind.

For creative techies across the continent, this infrastructure disparity is an opportunity for innovation. In July, I visited friends in Nairobi, Kenya, at the iHub, a coworking space for the city's burgeoning software industry. I was researching an idea I'd had on a previous trip to Nigeria – a GSM-enabled smart meter that would allow generator owners to sell power to neighbours. Since Kenya has the best-developed mobile money infrastructure in Africa, I hoped my friends could introduce me to programmers who could help me make this device talk to the M-Pesa system, so that neighbours can pay each other for power using mobile phones. My friends did better than that, introducing me to a small but lively community of techies harnessing Kenyan telecoms to plug holes in the country's less developed infrastructure.

Say you're the sort of Kenyan programmer who spends hours working on your laptop at home. Your arch-nemesis is the frequent power cuts that knock your internet router and wireless hub offline. You're the target market for the BRCK, a device being prototyped at the iHub that features a battery backup for a wireless router that talks to the GSM data network to provide net access.

When the power goes off, BRCK turns on and you can code until your laptop battery gives out.

Most of the innovations that leverage Kenya's telecoms infrastructure aren't oriented towards Nairobi techies, but towards the rural poor. M-Kopa is building solar lighting that allows families to power an LED light and charge a phone. What's innovative about their product is its financial model. Families make a small payment when the system is installed, then pay via M-Pesa to keep it running. Once they've made the payments, about the cost of ten weeks' supply of kerosene, they own it. Because the system can be shut off remotely, M-Kopa bets that it will have to reclaim very few systems.

In more than two dozen villages, mobile phones are giving more Kenyans access to clean drinking water. Thanks to a program called Lifelink from Danish pump manufacturer Grundfos, villagers use an RFID-tagged fob attached to a plastic jerry can to purchase 20 litres of clean water for two Kenyan shillings (about 2p). They "fill" the RFID fob by making payments via M-Pesa.

For countries such as Kenya to emerge as economic powerhouses, they need better infrastructure: roads, ports, smart grids and power plants. Infrastructure is expensive, and takes a long time to build. In the meantime, hackers are building "grassroots infrastructure", using the mobile-phone system to build solutions that are ready for market.

The future of infrastructure in emerging nations is a mix of the planning needed to build mass-transit systems and 500-megawatt power plants, and the grassroots innovation that's allowed these countries to expand and grow thus far. What excites me most is not that farmers can obtain crop prices and mothers can call doctors. It's that there's a vast, powerful infrastructure that can be repurposed and hacked. Some of the most creative people on the continent are solving problems by using technologies in ways their creators had never expected. I think that's as likely to help Africa rise than any World Bank-funded highway.

Ethan Zuckerman is principal research scientist at the Media Lab

ALI ALMOSSAWI AND CÉSAR A HIDALGO_

Going beyond the one-bit democracy

Would democracy be any different if Benjamin Franklin, Thomas Jefferson and John Adams had foreseen the possibility of direct online participation? Would they have paved the way for new technologies? Or would they have built roadblocks to prevent the emergence of these new technological vehicles?

As with most historical hypotheticals, we will never know. We are in 2012, however, and despite the internet most countries are still stuck in one-bit democracies, where people are required to choose between two alternatives every four to six years.

People in the zettabyte age, however, are not thrilled with the outcomes of one-bit democracies. In the US, the Pew Research Center indicates that national satisfaction is only 31 per cent. In Chile, CEP reports that 47 per cent of the population do not feel identified with either the left, right or centre. The list goes on.

But who could blame people for their discontent? One-bit democracies have important limitations, including their requirement to choose candidates rather than issues. This focuses the little bandwidth available in a political system on candidates' personas rather than on relevant issues. Hence, the epidemic of stiff-haired hand-shaking machines that we call politicians is not surprising. Moreover, the large degree of fame required to be an eligible candidate limits the ability of one-bit democracies to refresh their candidate pools. Political fame is a barrier to entry, a scarce resource that a few have learned to capture.

This time around, however, technology is ready to provide alternatives. The web is great at handling a large number of discussions, about different issues, in an asynchronous and decentralised manner. The web is the technological vehicle that democracy had always been waiting for, if we give it a little push.

But do we want to democratise participation to the extreme? And if so, why? Systems that limit the ability of people to decide on issues reduce people's incentives to get informed. Why learn about the consequences of immigration or the legality of marijuana, if I am only allowed to contribute one bit? If I am only allowed to select a policy bundle, wrapped in styling gel and empty promises? If my portfolio of views is not reflected by any of the available political packets, should I be happy to contribute my bit to a partial match?

We need direct online participation because people tend to own the decisions they make, more than the decisions made for them by those whom they have chosen to represent them. Direct forms of online participation will not only empower people with the power to decide, but will also help transfer the political responsibility of their decisions back to them. In direct participation, citizens can also get the blame.

Certainly, online methods will be a complement to existing social structures. There are technical issues for which direct participation might not be the best option. For other issues, however, direct forms of online participation seem natural. Examples of these include big questions – such as gay rights, abortion, gun law and the legality of drugs – and small questions, such as the construction of parks, football pitches, and other public amenities.

In future, the challenge will be to discover what direct forms of participation work best for us, and how to create active communities around them. This will involve technical challenges, but more importantly the political buy-in of pioneers in governments and mass media. Being a pioneer, however, should not be a hard decision in a world where this article will be old news in less than a century.

Ali Almossawi, an MIT alumnus, works for Mozilla Corporation; César A Hidalgo is an assistant professor at the Media Lab

ILLUSTRATION: THE TREEHOUSE PRESS

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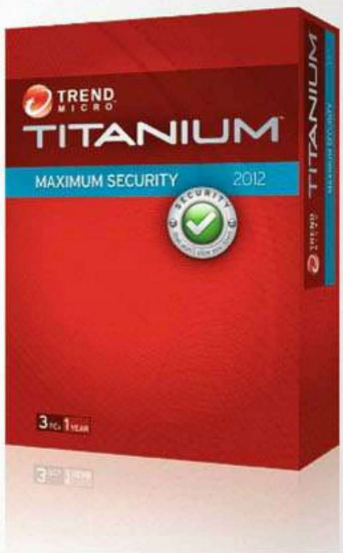

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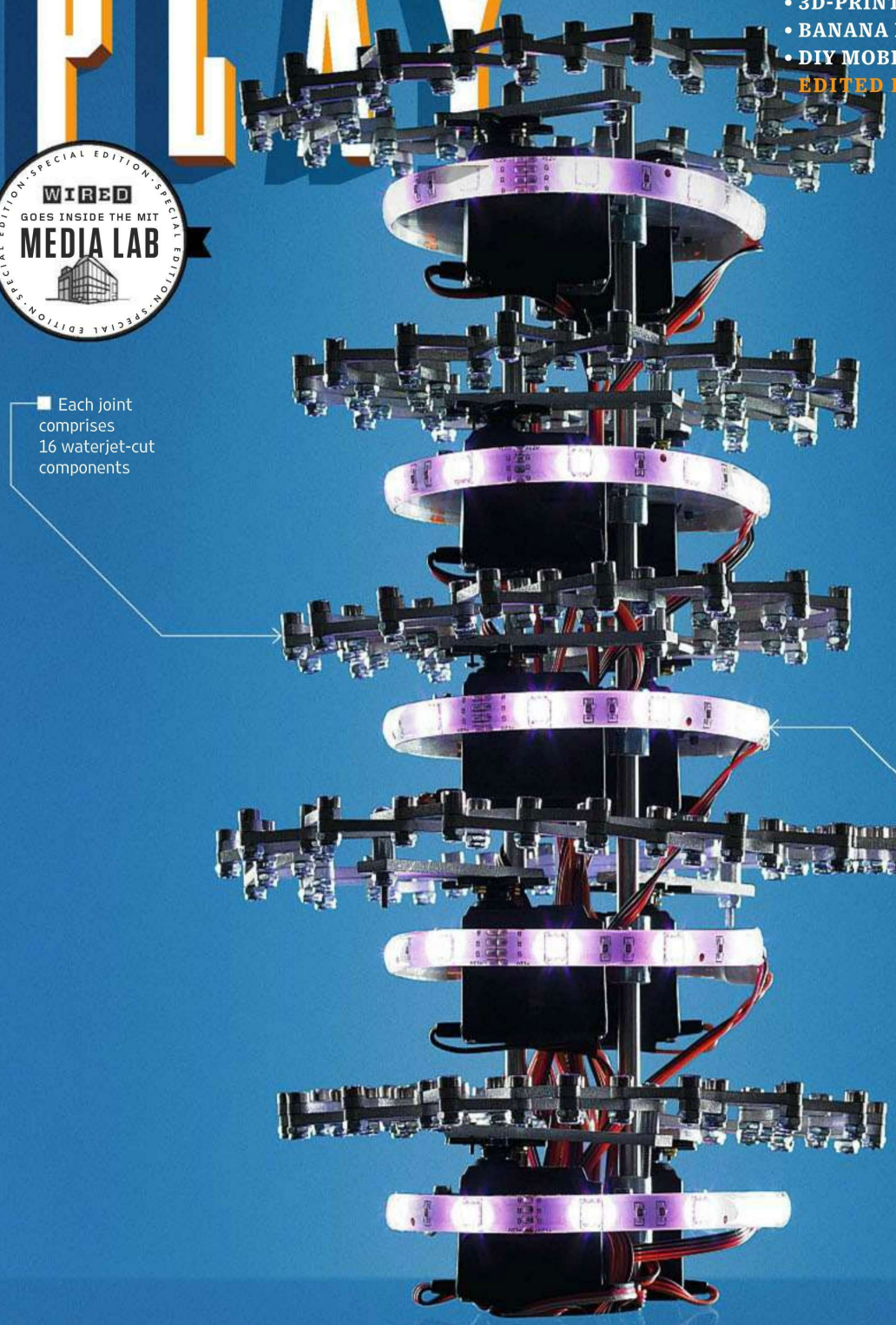
PLAY

WIRED GOES INSIDE THE MIT MEDIA LAB



GESTURE SCULPTURE

This kinetic sculpture bridges the physical and digital. "The prototype is a vase than can change shape – it has little joints that adjust their width," David Lakatos, a member of the Media Lab's Tangible Media group, says. "And once they change width, you can start creating contours – you can re-form it, in both the physical and the digital worlds." In the physical world, a sensor above the vase recognises gestures and creates a 3D model, allowing you to shape it as you would clay. In the digital world, an iPad app allows Lakatos to alter the sculpture's properties wherever he happens to be. "With the app, you can be extremely precise about how the form will change," he says. "But, ultimately, sculptors look at something, carve away at it, then look at it again. You need the 3D feeling to do that." Lakatos plans to build a series of the sculptures, which he sees as a natural next step in UI design: "We already live in a world of shape-shifting interfaces: a door that opens for you – that's a shape-changing interface on an architectural scale, because it creates a door where there wasn't one before." **TC**

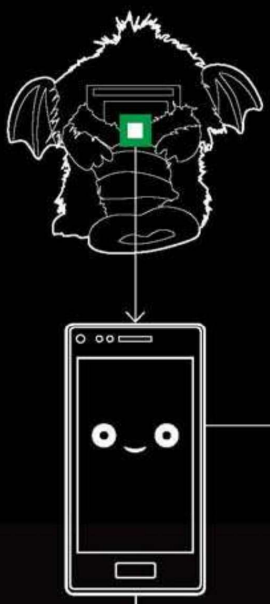
PHOTOGRAPHY: DAVID ARKY

TEACH YOUR DRAGONBOT

The Furby may have returned to toy shops, but that gibbering robo-hamster can't touch the DragonBot. This furry robot is powered entirely by an Android phone: snap yours in and it becomes an animated virtual face, capable of responding to human emotions and conversations. "Video from the camera is sent into the cloud," says Adam Setapen, project leader. "Then DragonBot asks questions about the data he sent. He doesn't store any information locally, except what type of character he is."

Earlier this year, Setapen, part of the Personal Robots group at the Media Lab, released five bots into the wild for four- to seven-year-olds to interact with. "I'm not interested in robots in the lab, I'm interested in robots outside the lab," he says. "I built this robot to be out in the world – a real-world robot. It can run for about seven hours on batteries and it always has an internet connection. It's capable of being out there, but robots are still not smart enough to be out in the real world every day. I can use all that data [from the trial] to make the robots even better."

Setapen thinks that the DragonBot will one day be "a toy for kids to learn more about robotics by programming it themselves" and cost around £200. Who knew the robot uprising would be so cute? **TC**



The phone provides sensory input (camera and microphone) and controls the actuation of the robot (motors and speakers)

Hyper musician

Tod Machover invents instruments, robot operas – oh, and Guitar Hero

In the autumn of 1978, Giuseppe di Giogno, a nuclear physicist, abandoned his research on matter-antimatter reactions to start making analogue synthesisers in a basement. His dream was to make a studio-sized synth and cover the walls and ceilings in a thousand dials: a panoply of sound sources that he could tune to create a massive noise. Di Giogno joined the faculty of the newly opened Institut de Recherche et Coordination Acoustique/Musique (IRCAM) in Paris. He soon realised the studio-synthesiser would be impossible using analogue synths or computers (then too slow). So he invented the first digital synthesiser, which eventually became the 4X system.

The problem was, no one at IRCAM knew what to do with the 4X. "That's when I found my calling," says Tod Machover (*right*). He had just arrived at IRCAM, fresh out of the elite Juilliard School of Music in New York. "I said, 'Wow, this is an instrument. And not only can you turn this programmable machine into any instrument, you can design the studio you need to make a piece. You can make it like a sculptor's studio where the sound is like clay, and whatever the basic material is for a piece, you can design it for this set of experiments." A year later, *Light*, the first piece composed on a digital synth, premiered in Metz. The next year, Machover was, at 27, director of music research at IRCAM.

Since then, he has created robotic operas, sci-fi compositions, software that lets anyone compose music, a musical exercise that can diagnose illness and the technology behind *Guitar Hero*, as well as augmenting instruments for Yo-Yo Ma and Prince. He was one of the founding faculty members of the Media Lab in 1985 and has been there ever since, heading the Opera of the Future group. Machover has been finding the edges of music and technology for more than 30 years. Now, the 58-year-old wants everyone else to do the same.

His current project, *A Toronto Symphony*, is a collaboration with the 2.7 million residents of the city to compose a

PHOTOGRAPHY: BRAD SWONETZ; DAVID ARKY

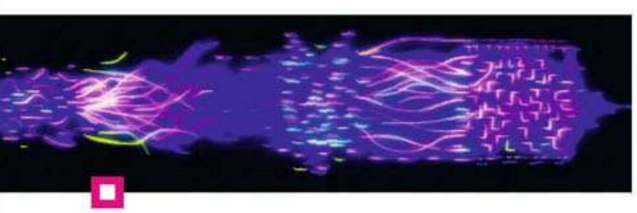
new work for symphony orchestra. His idea is to create "a new musical ecology", with input from experts and amateurs for the benefit of both. Machover started the project by publishing "launch music" – a series of chords that serve as a "genetic code" for the project – then invited locals to download the musical score, play around with it and send back their own variations. The piece will premiere in March 2013, with Machover arranging the various effluvia into a final composition. "It's not crowdsourcing, it's mass collaboration," he says. "The problem with crowdsourcing is that you can't tell where a particular sound ends up. I'm trying to build a Media Lab-like group with 50,000 people. Everyone has a role, but I guide it. It's not random. And I don't think anything quite like this has been done before, so we're inventing it as we go along."

A Toronto Symphony is ambitious, but it's only a midpoint on a trajectory that Machover has been following since the 80s and which extends into the next half-century: "Excellence and democracy have been obsessions from the beginning," the composer says.

Machover was born in 1953 in Mount Vernon, New York. His mother was a piano teacher and his father worked in the emerging field of computer graphics, but had "a sense of all things pop culture". *Sgt Pepper's Lonely Hearts Club Band*, in 1967, was a big influence. "The Beatles saw the art in multitrack recording, in remixing sources from all over the place and coming up with something new. That's when I started to wire my cello. I started thinking, how can you have the best of both worlds – the technology and the spontaneity?"

For his 1987 opera *Valis*, based on Philip K Dick's novel, he wanted to "have an orchestra that could also rehearse like a rock band". Machover ended up with two musicians, on keyboard and percussion. "And that's when we invented hyperinstruments – we've got two performers: how do we tell what they're playing, where they are in the music, what they're improvising, what the expression is, what the gesture is, and how do we use all that to add these layers?" Hyperinstruments – Machover's first project at MIT – turned out to be "a way to perform *Sgt Pepper* live. You needed an environment that understood what your intention was. And for that you needed new interfaces and new analysis software." The hypercello had sensors across its body and along the bow. By measuring the pressure, speed and angle of the player, it could aim to interpret the nuances and emotion of the player to create new, digital sounds.

Machover created the first hyperinstrument for Yo-Yo Ma. "We actually had a little accident," he says. An antenna measured the electricity in the air and fed this data into the software. But when Ma's hand went near the antenna, his body absorbed the electricity. "We'd basically invented a digital theremin." ⟶



Above: Machover's hypercello at his Media Lab workspace

Left: a visualisation of Machover's collaborative opera *A Toronto Symphony*

The star of *Death and the Powers*, a Machover opera that features a robotic, animatronic stage that gradually becomes the central character

Machover reversed the process and turned the body into the instrument, creating the Sensor Chair. Its seat was a piece of metal: "When your butt touches the metal, the electricity goes through your body... It turned out that the physical techniques and software could measure natural gestures that anyone could make." People without musical training could make sophisticated music, just by moving their body (two of Machover's graduate students spun off much of that research into *Guitar Hero* and *Rock Band*). "I realised you could make a bridge to people who love music but are very passive."

So, in 1996, Machover came up with *The Brain Opera*, for which he built an orchestra out of hyperinstruments for the public to play. "It was virtuosity for non-professionals," he says. "The next step before mass collaboration." Hundreds of instruments littered the hall of [New York's] Lincoln Center. People wandered around playing them, with others participating online, creating sounds that were edited together for a stage performance. His Hyperscore project took this another step further, creating software that allowed non-musicians to compose entire symphonies by abandoning traditional music notation (you can download it at hyperscore.wordpress.com).

The mass collaboration of *A Toronto Symphony* is the next step, but it's nowhere near the end. "There are all kinds of things we haven't even begun to imagine that will be valuable in music. There'll always be a place for the perfectly crafted song, the definitive performance. But a large part of music is going to be some kind of collaboration. Up until today, we judged music by how a combination of sounds appeals to the most number of people. One of the most important new branches is going to be to personalise music so that there is maximum impact for you, your genetics, your physiology, your psychology. Depending on how you're feeling, it plays differently. It may play on its own, but I also think there's going to be a role in between the basic music materials and the listener – somebody in the middle fine-tuning it."

Machover is now interested in measuring responses to music that occur within the brain and body (he's working with a tissue specialist at MIT, along with MIT's Buddhist chaplain, to study how vibration travels through the human physique). "We're working on vocal techniques that everybody can do to send vibrations to different parts of your body... We're designing an experience where you start out singing in a series of private rooms and end up in room with ten people."

Machover "doesn't know how it will shake out. This is a 50- to 100-year progression. Something big could happen. The real question is how to make music itself – something grand and good – and how people participate in that, without making it cheesy." **TC** *Tod Machover is a speaker at* WIRED2012 *in London on October 25-26 (wiredevent.co.uk)*

PHOTOGRAPHY: DAVID ARKY; CHRIS CRISMAN

GENIUS OF THE LAMP

The desk lamp is being reinvented. LuminAR turns a standard incandescent bulb into a robotic digital information device. "Imagine what happens when an everyday object such as a light becomes a computer," says Natan Linder, who leads the project. The LuminAR bulb packs in a Pico projector, camera and wireless computer, turning any desktop into a gestural user interface, and can be screwed into any standard fitting. The LuminAR lamp is a robotic arm that can find a clutter-free section of your workspace on which to project, or open different apps on separate parts of the desk. "You can augment objects from the top, interfaces can disappear and appear when you want – a touchscreen can't do that," says Linder. Still in prototype, it's backed by Intel. It may not be long before you can swap your desktop for a desk lamp. **TC**

The LuminAR lamp can be used to scan an object on your desk

Then the LuminAR can project the scan back on to any surface

WIRED

#2 ACCESSORIES SPECIAL

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1 G-STAR RAW BROGUES

G-STAR has pulled off a style coup, mixing black denim with a leather body, white laces and a terracotta-toned heel in these new brogues. Smartly playful, these shoes are ideal for the man who likes to make a statement. Attention to detail enhances the luxurious-but-street feel, which runs through the G-STAR footwear collection. *g-star.com*

2 DIESEL BESCA BELT

Rocking a bold vintage look, Diesel's Besca belt is real leather with an aged silver metal buckle. Its embossed logo looks subtle, but gives the belt that unquestionable cool factor that Diesel has owned for decades. An essential part of any man's wardrobe, this versatile belt will compliment most outfits, whether smart or casual. *diesel.com*

3 BURBERRY HOUND UMBRELLA

This is not your standard umbrella – it is a truly unique item that will actually make you wish for more rain. Burberry has created a work of art in this ultra luxurious Hound Handle umbrella. It features a sartorial college-striped canopy and a distinctive resin handle that has been moulded and handcrafted by an Italian artisan. *burberry.com*

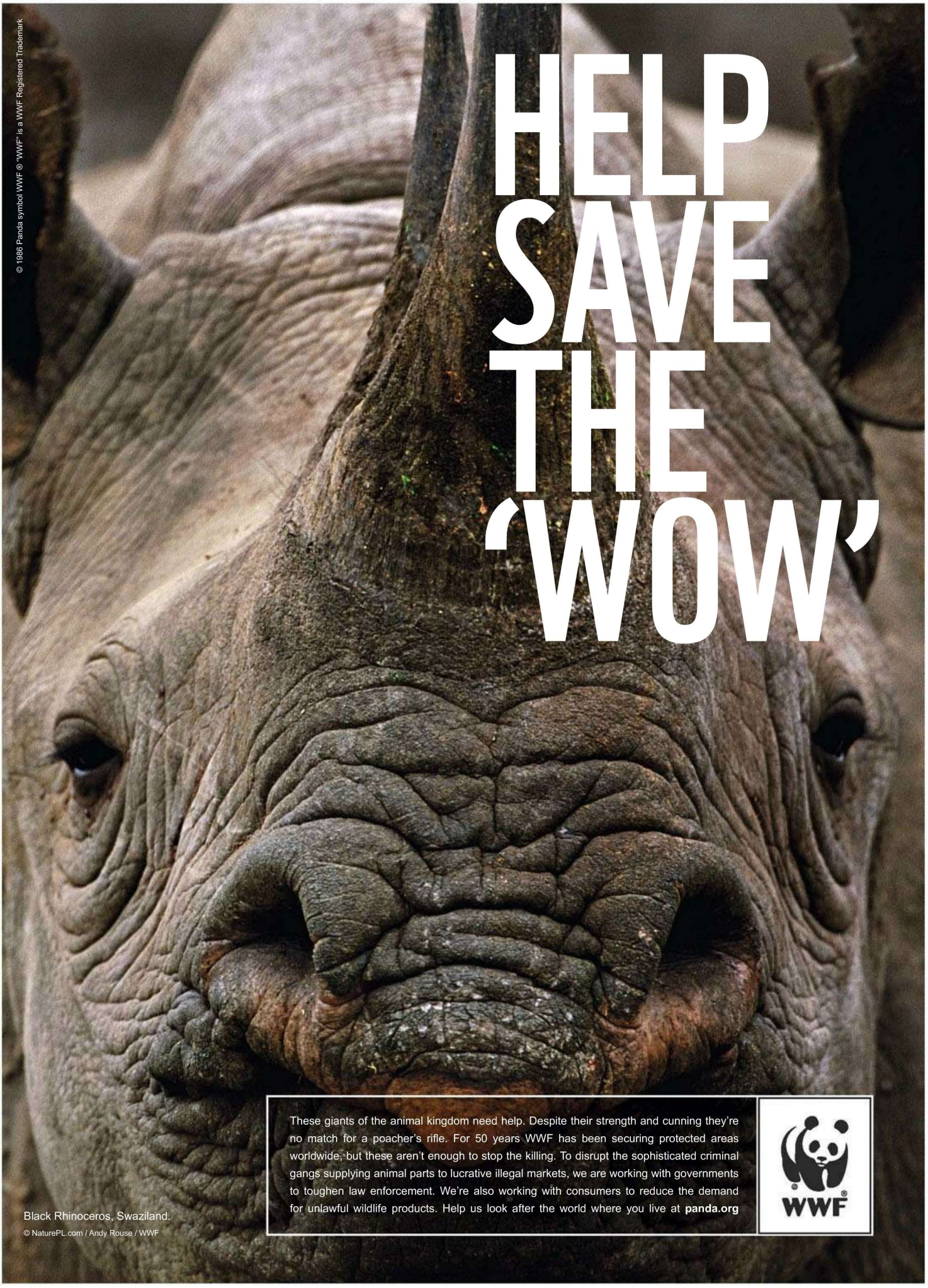
4 Z ZEGNA TABLET CASE

Ermenegildo Zegna is a brand that exudes sophistication and luxury, and its Z Zegna accessories range, which includes this fine iPad case, is no exception. Made from black grained leather with a copper zip, it creates a very chic look. Zegna has perfected the art of pairing their suave clothing line with slick matching accessories. *zegna.com*

5 HUGO BOSS CUFFLINKS & DRESS STUDS

Cufflinks are essential for sharp dressing – so Hugo Boss has crafted the perfect addition to any sophisticated shirt with this cufflink and dress stud set, from its BOSS Black label. The Simony Stud Set 3P has a simple, classic silver and black design that works perfectly for the man who wants to look stylish any time of day. *hugoboss.com/uk/en*

PHOTOGRAPHY: SUN LEE



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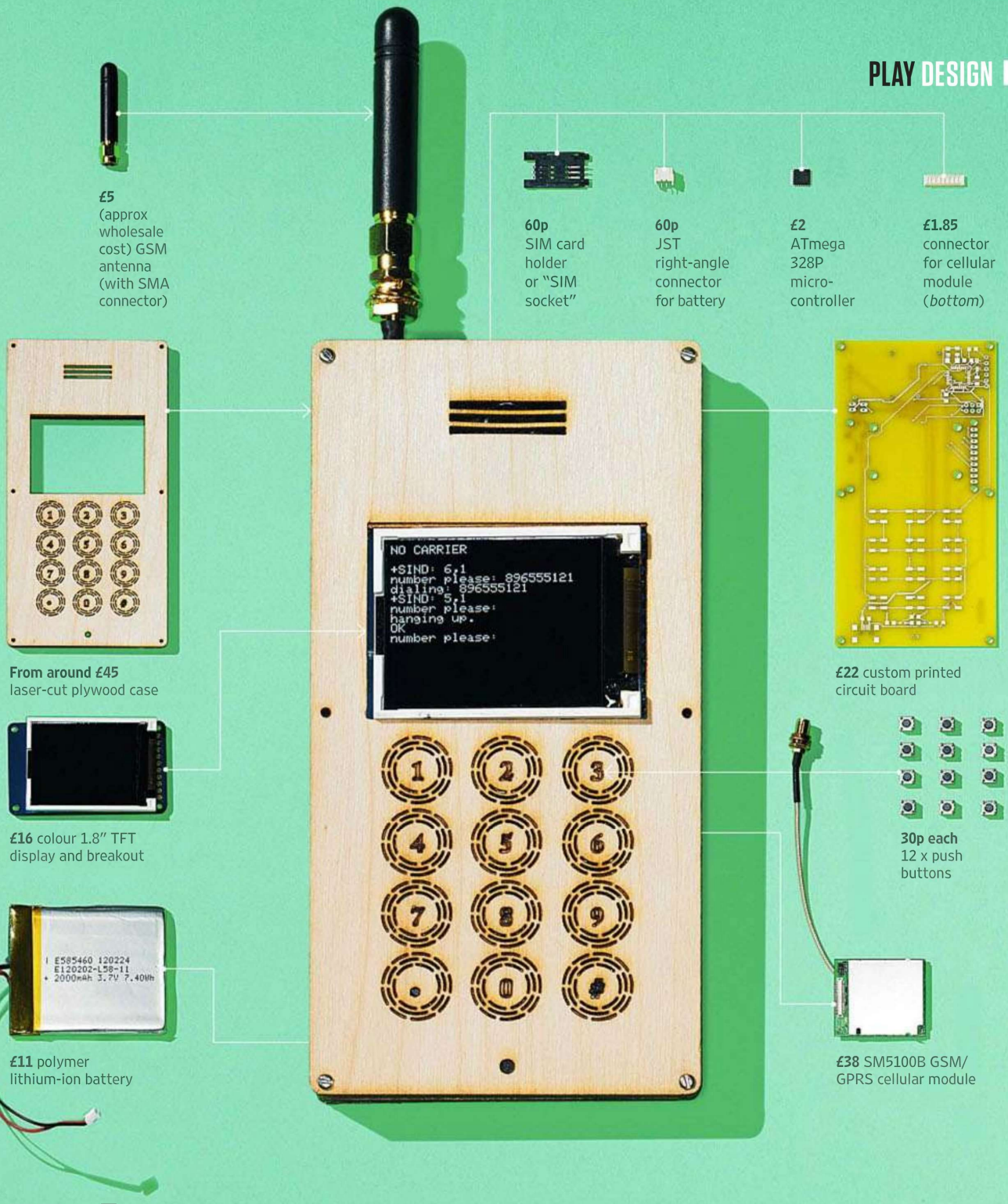


Make your own mobile phone

Fed up with too much functionality? Maybe it's time to build a handset from scratch

Here's your next mobile-phone upgrade: the one you make yourself. David Mellis, from the MIT Media Lab's High-Low Tech group, created the DIY Cellphone to "encourage a proliferation of diverse mobile phones". The open-source prototype was built from a variety of standard electronics components, costing around $150 (£100): "it's just pieces that can be put together."

The phone contains a custom-built circuit board ("some challenging soldering," Mellis, 32, says), inside a laser-cut plywood case, and takes any standard SIM card, thanks to a SM5100B GSM module; the colour display is a 160 x 128 pixel TFT from Adafruit. Version 1.0 can make and receive calls, but Mellis, a software developer for the Arduino platform, plans to add text messaging and an address book to the next iteration. "Will it eventually play *Angry Birds*? Maybe. I want to get it to the point where I can carry it as my main phone."

If you want to build your own, the source code, circuit designs and case-design files can be downloaded from the damellis/cellphone library on GitHub. Collaboration is welcome: "I want to work with other designers to come up with cool, different ideas." Watch out, Apple. **TC**

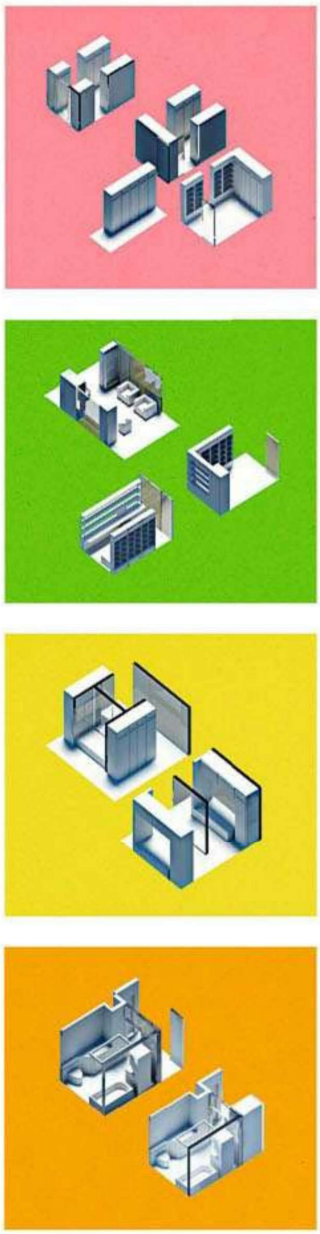
PHOTOGRAPHY: DAVID ARKY

Interior redesign

MIT's Changing Places group can help you transform your gym into a bedroom in time for dinner

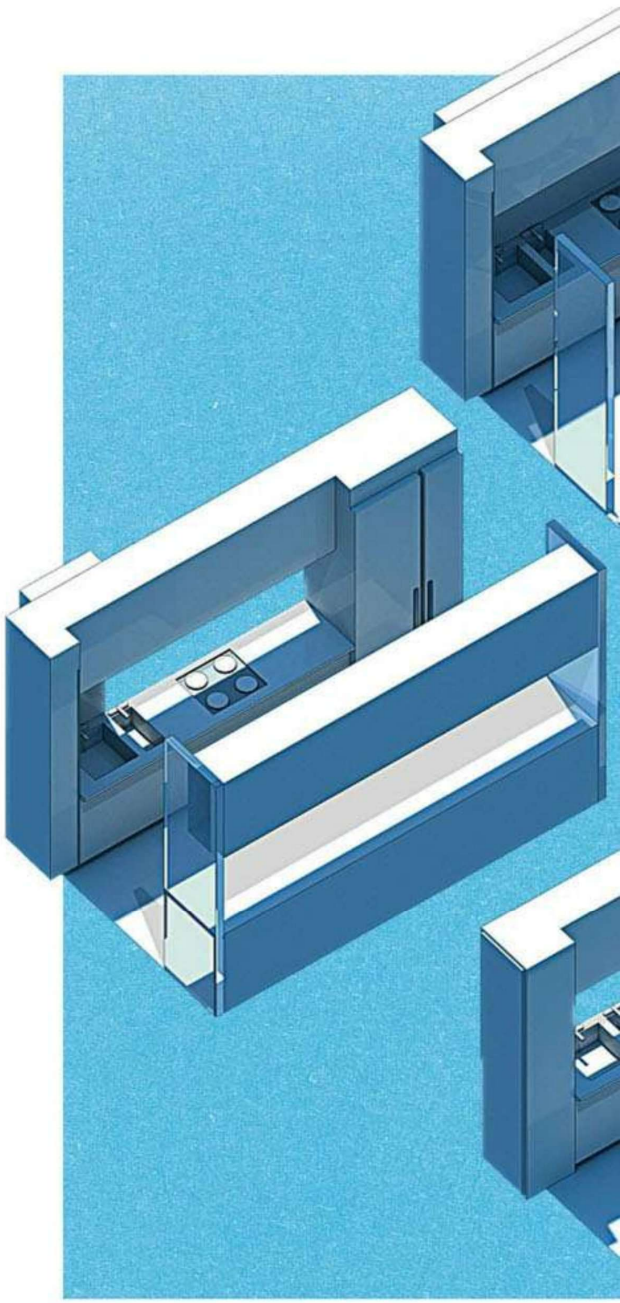
You can trick out your flat with all sorts of furnishings, but the structure itself isn't particularly customisable. Until now, that is. The Media Lab's Changing Places group wants to personalise your home according to design preferences or even the time of day. The group's Home Genome Project breaks down a flat into a set of building blocks (such as the components of a kitchen and living room) or "genes" which can be combined in different ways. Then a design recommendation engine, based on proprietary algorithms, matches customer profiles to complete designs, allowing what it calls "mass customisation".

Not radical enough? Then try the CityHome – a reconfigurable apartment. "It's space on demand," says Changing Places student Hasier Larrea. Living rooms transform into dinner-party spaces, or a bedroom becomes a home gym: Larrea claims that it can make the living space of a 78m² home three times bigger. The project relies on moving, transformable walls. Larrea has built a prototype moving wall and says the real thing isn't too far off: "The technologies are here. We're just at an early stage." It gives a whole new meaning to moving house. **TC** *cp.media.mit.edu*



Rooms recalibrated by Changing Places:

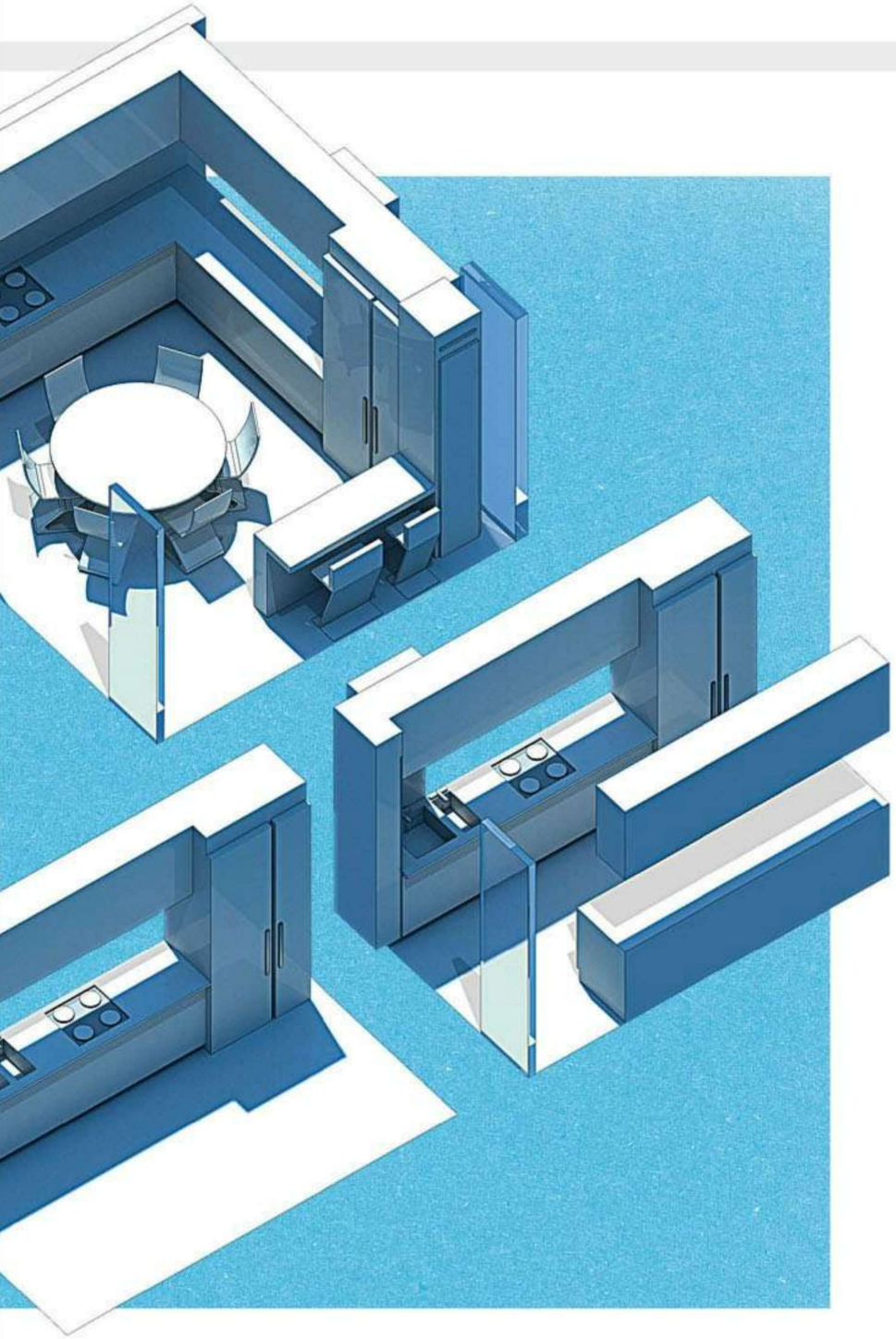
- Walk-in wardrobe
- Study/office
- Dining room
- Bathroom
- Kitchen



NOTES PREDICT VOTES

It's official: Republicans like country music. So says The Echo Nest, a music intelligence company with more than a trillion data points on 34 million songs in its database. Brian Whitman, cofounder and CTO of the MIT spinoff company, wanted to see if musical taste matched a person's political affiliation. So he combed The Echo Nest's Taste Profiles – a complete record of a user's music library and listening habits, which can be combined with social-media accounts – to identify US-based users who self-reported as either Republican or Democrat (being enthusiastic about Barack Obama online would identify a user as Democrat-aligned, for instance). If they offered conflicting allegiances, they were discounted. Whitman then fed these examples of Democrat and Republican Taste Profiles into The Echo Nest to see if it could predict the political class of a new, unknown Taste Profile ahead of next month's US election. He found Republican tastes easier to predict than Democrat: "Overall, for every ten unique musical types Democrats listen to, Republicans listen to just seven," he wrote in a blog post. Lastly, Whitman created a "highest confusion list" – artists who were reliable predictors of neither Republican nor Democrat – topped by The Beatles. Who knew the Fab Four would end bipartisanship? TC *the.echonest.com*

ILLUSTRATION: QUICKHONEY; LIAM KEATING



ARTISTS WHOSE FANS ARE CORRELATED TO DEMOCRAT:

1. **Rihanna**
2. Jay-Z
3. **Madonna**
4. Lady Gaga
5. **Katy Perry**
6. Snoop Dogg
7. **Chris Brown**
8. Usher
9. **Eminem**
10. Bob Marley

ARTISTS WHOSE FANS ARE CORRELATED TO REPUBLICAN:

1. **Kenny Chesney**
2. George Strait
3. **Reba McEntire**
4. Tim McGraw
5. **Jason Aldean**
6. Blake Shelton
7. **Shania Twain**
8. Kelly Clarkson
9. **Pink Floyd**
10. Elvis Presley

ARTISTS WHOSE FANS ARE HARDEST TO PREDICT:

1. **The Beatles**
2. Marilyn Manson
3. **The Rolling Stones**
4. Johnny Cash
5. **Pantera**
6. Alice in Chains
7. **Paradise Lost**
8. Moonspell
9. **Fleetwood Mac**
10. Tiamat

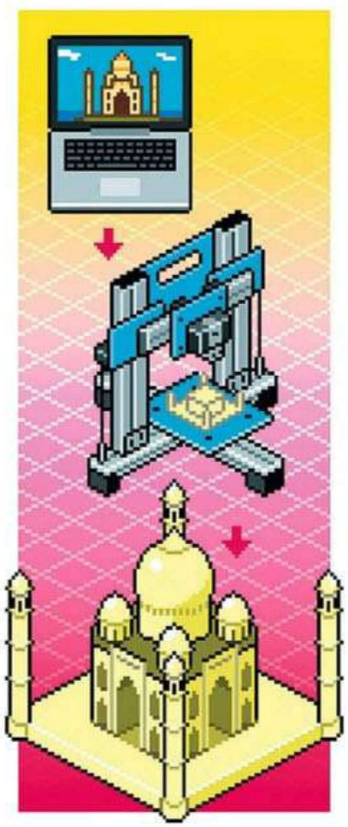
MINECRAFTED

Want to learn computer-aided design (CAD)? Play *Minecraft*. "[*Minecraft* creator] Notch hasn't just built a game," Cody Sumter, part of the Human Dynamics group at the Media Lab, says. "He's tricked 40 million people into learning to use a CAD program."

Minecraft players construct elaborate virtual structures; Sumter created a program that allows users to bring these into the real world using 3D printers. Players build their digital monuments – whether they're the USS *Enterprise* or the Taj Mahal – in the game itself. Then they place obsidian, diamond, gold and iron blocks at set points to define the 3D area to be printed.

Minecraft.Print() recognises this area, then renders a standard model file for printing, either on professional 3D printers or personal printers such as MakerBot and RepRap. The intention is to turn *Minecraft* into a gateway program to more professional CAD software. And, according to Sumter, "*Minecraft* has something that is lacking in actual CAD programs – fun."

TC *minecraftprint.com*



Design from life

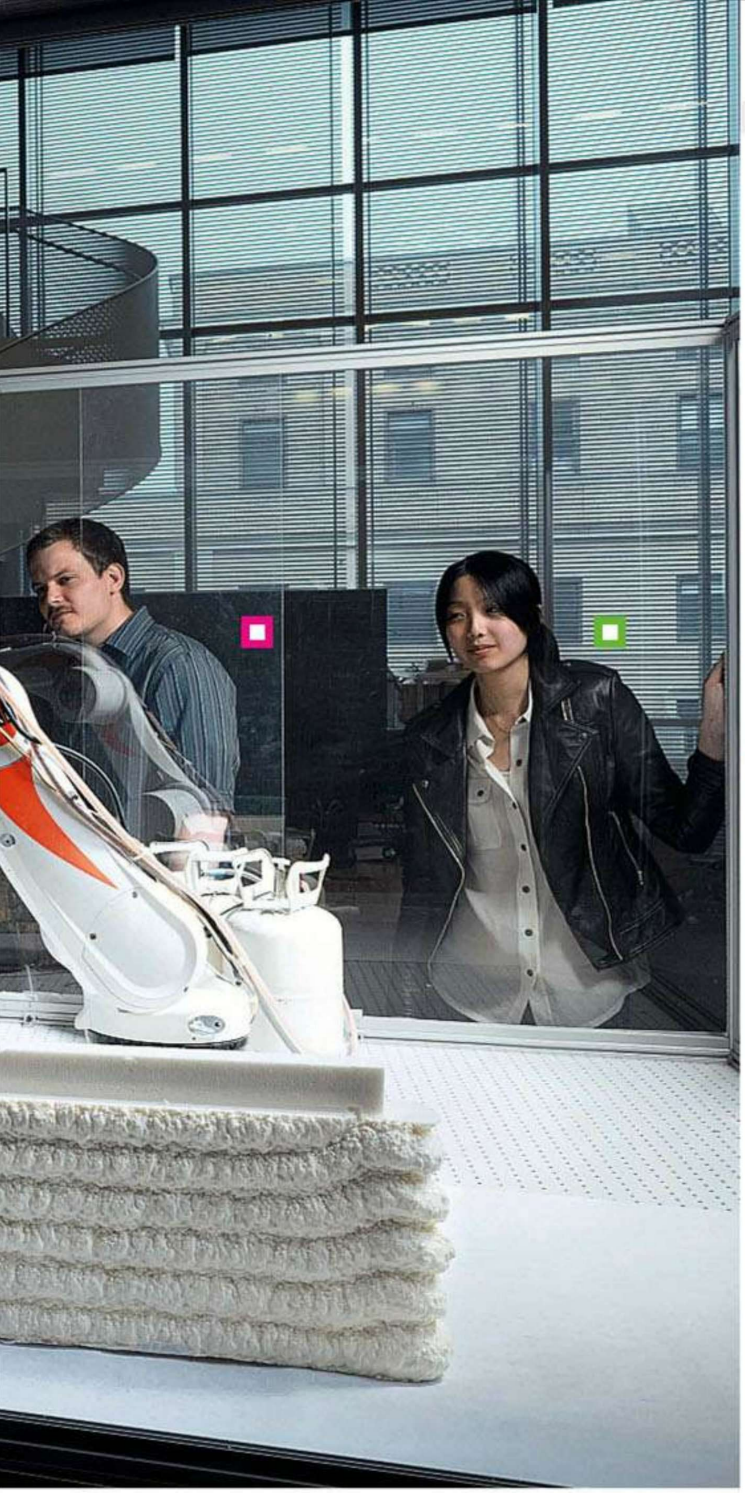
Bone and silk are inspiring Neri Oxman to invent new ways of construction

This robot-arm is 3D printing its own home – inspired by human bones. "We can't print with calcium," Neri Oxman says. "So the idea is to print with concrete but vary its density as a function of the load, much as bone does." The robot prints and mills an expanding foam that doubles as a mould for concrete walls, and as an insulating layer; Oxman hopes that the printing process will eventually include wiring and plumbing.

Oxman, a designer and architect who heads the Mediated Matter research group at the Media Lab, is stealing nature's best design principles and applying them to architectural creations. Each of her graduate students is exploring a biological system and matching it with an existing digital fabrication technology, such as computer numerical control and 3D printers. "Look at spiders," Oxman says. "They use about eight different properties of silk for different functions. The spider is like a multimaterial 3D printer."

Spiders turn out to be a theme of the lab: the Spiderbot project takes it cues from a spider's web. It's a 3D-printing gantry you can strap to your back and carry: four cables, each with a motor, attach to trees and can lift four tonnes between them, meaning the system can print over 3,370m^3, even in

PHOTOGRAPHY: CHRIS CRISMAN.
ILLUSTRATION: ROBIN BOYDEN



challenging terrains. Oxman calls it the "largest 3D printer in the world". If combined with the bone-inspired building project, it could print out architectural structures anywhere, on demand. Another project, CNSilk, investigates silk as a building material. "My ambition is to print a tent-sized silk cocoon within a year."

Within ten years, "we'll see completely different construction technologies," says Oxman, who recently showed some of her work at the Pompidou Centre in Paris. "[That building] signifies everything we're moving away from – the culture of assembly, with each material providing a different function. That's my dream – to build at the scale of the Pompidou, but celebrate this approach." **TC** *media.mit.edu/research/groups/mediatedmatter.*

For more of Neri Oxman's work, see p112

■ Oxman's team examines a section of wall printed and milled by a robotic arm

HIGH-SPEED HOOPS

How hard does star US basketball player Kobe Bryant dunk? Add aerospace tech to a basketball net and you can find out, right down to the joule.

The Slam Force Net, by MIT researchers Dan Novy and Santiago Alfaro, quantifies dunks. The pair replaced the string net with carbon-impregnated silicon rubber used for O-ring drive-belts in the aerospace industry. Its electrical resistance changes as it stretches; this change is measured to derive a calculation of how much energy, in joules, the dunk adds.

Researchers can also use the net to recognise different types of slams by looking at multiple inputs such as resistance and time. "The equation can tell the difference between a fast-moving ball and a slower-moving ball that is in contact with the net much longer," Novy says. "These dunks could conceivably have the same amount of energy but are characterised totally differently."

The US National Basketball Association used the net in a dunking competition at its annual All-Star game in Orlando, but Novy and Alfaro are looking at other sports too: "It could be worked into a soccer net to tell you where the ball hit and again derive an angle and velocity to be overlayed in 3D space, in real time," says Novy. Hitting just the back of the net may no longer be enough. **TC** *media.mit.edu/research*

Shine a light on coding

Programmer Jennifer Jacobs turns computer algorithms into easily fabricated designs

Jennifer Jacobs doesn't just make lamps: she codes them. "The goal of this project was to write an application that allows someone to describe an object through code, and then fabricate that object," she says.

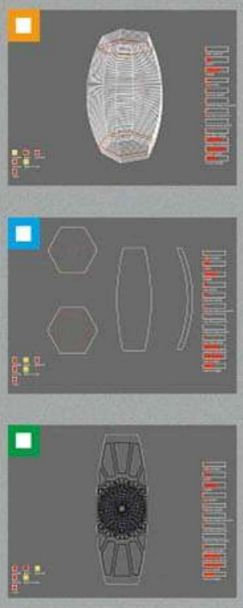
Codeable Objects is a library for Processing (a popular open-source programming language invented at MIT) that lets users design artefacts using simple code and geometry. Users set the width and height of a lamp, say, in the code itself: when it's compiled, a 3D representation of the object is revealed. The 3D graphical user interface lets people tweak the object using sliders.

But it's in the intricate patterns on the lamp that code comes into its own. A program, created by Jacobs, allows users to describe complex patterns. Entering polar point co-ordinates gives simple patterns but, by using programming conventions such as a four loop, "you can quickly iterate and get interesting effects – you can go easily from a circle to a spiral". The program uses an algorithm based on a Voronoi diagram – a geometric subdivision of space, and a form common in nature, whether in butterfly wings or nautilus shells – to generate the patterns.

The program automatically breaks the object down into its constituent parts, for computer numerical control milling or 3D printing, and then assembly. All the source code is available for download on GitHub.

The result is what Jacobs, 27, calls "'design on the fly' – this idea that I don't have to conceive an object and then, if I realise I've got it wrong, start all over again." **TC**

hlt.media.mit.edu/?p=2254



When the code is compiled, a 3D model is generated

Another preview shows the 2D parts to be cut

A third view shows decorative lamp patterns

PHOTOGRAPHY: DAVID ARKY

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The magic fruit

Anything can be a computer input with MaKey MaKey

Typing on a standard qwerty keyboard can be boring. Typing on a ripe mango, however – now that's infinitely more interesting. MaKey MaKey is a kit that can make such surrealist dreams come true by turning conductive objects into computer keys and buttons. Alphabet soup becomes a drum kit, bananas transform into piano keys – you can even draw a game controller on to a piece of paper using a pencil, and use it to play *Pac-Man*.

"It's a different way of connecting the physical world with the computer," says Mitchel Resnick, who heads the Lifelong Kindergarten group where MaKey MaKey originated. The kit exploits the fact that by touching things you complete electric circuits. The MaKey MaKey circuit board connects to your computer via a USB cable. Then attach any object to the board using a crocodile clip. When you touch the object, you complete the circuit, and the circuit board sends a message to your computer, which thinks that MaKey MaKey is a standard keyboard or mouse. You can assign up to 18 mouse and keyboard inputs to any object.

The pair raised $568,000 (£360,000) on Kickstarter for the project – 22 times what they asked for. "It makes the world your construction kit," adds Resnick. A few bars of Adagio for banana, anyone? **TC**

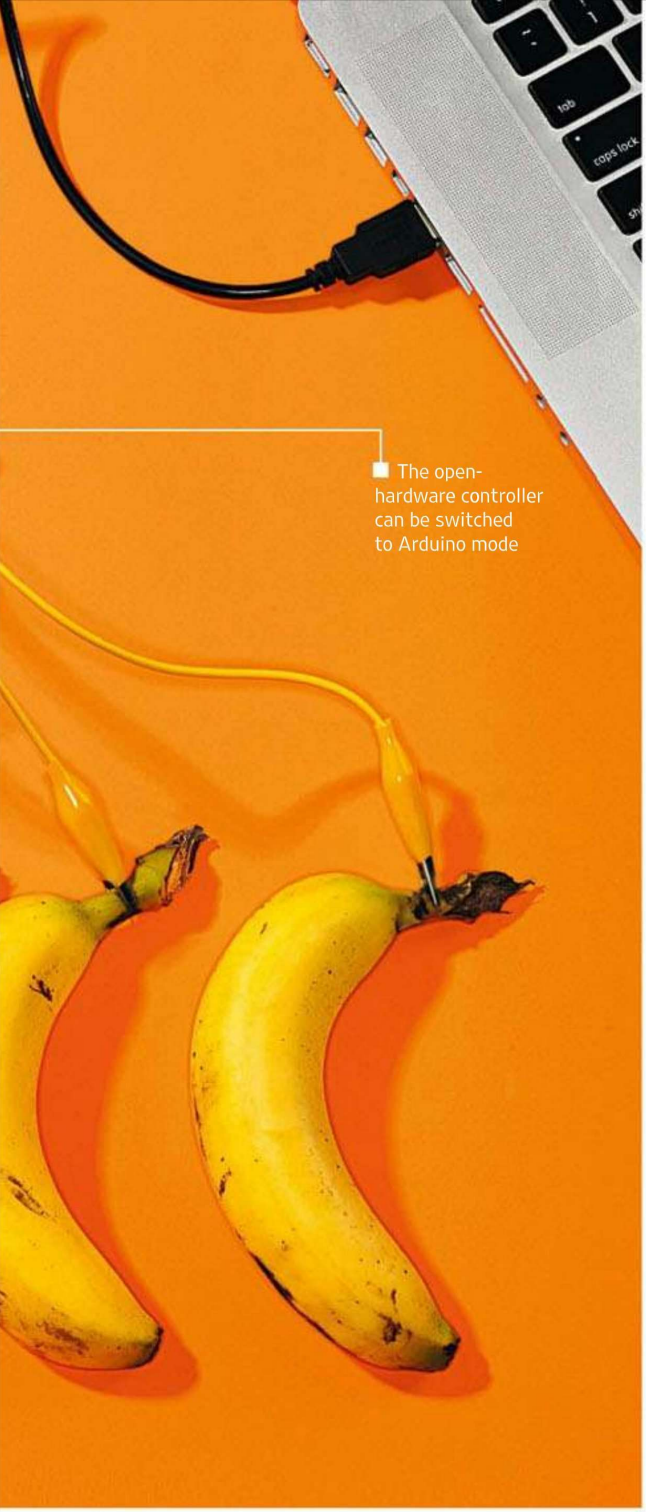
MaKey MaKey is available to order for $39.99 from makeymakey.com

PHOTOGRAPHY: DAVID ARKY; BRAD SWONETZ; SPENCER LOWELL

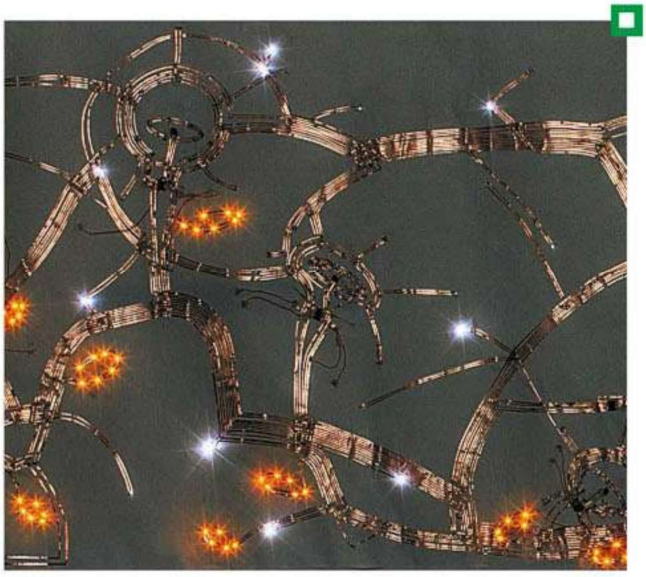
PHYSICAL PIXEL ART

Can you copy and paste in real life? Marcelo Coelho and Jamie Zigelbaum wanted to do exactly that with *Six-Forty by Four-Eighty*, an interactive light installation. "A lot of the experience people have with computers happens through displays, through screens," Coelho says. "So we created these pixels that are physical objects." Each "pixel" is a self-contained unit, with a circuit board, microbattery, controller, an RGB LED and wireless communication system inside. Touch one pixel and it changes colour. But if you hold one pixel down a little longer, then touch others, the colour of the light transfers to them. "The digital information they carry gets transferred through your body," Coelho says (with some artistic licence). The largest incarnation of the project comprised 220 pixels and the duo are now pushing the processing power of their art: "I'm locating the pixels in space, so that you can display videos and animations," Coelho adds. We're waiting for the physical version of *Minecraft*. **TC**

■ *Six-Forty by Four-Sixty* turns copy and paste into a physical function



The open-hardware controller can be switched to Arduino mode



MODERN ART IS A BREEZE

Ever think paintings are a bit static? Jie Qi, from the High-Low Tech Media Group, took a traditional Chinese paper painting of a dandelion field and made it interactive: blow on the white puffs (backlit by LEDs) and the seeds fly off to make new flowers. The piece, called *Pu Gong Ying Tu*, is part of Qi's Programmable Paintings series. "I fell in love with how simple yet magical this interaction was – because the technology made sense and was somehow very human," he says.

Underneath the painting is a layer of circuitry, comprising microcontrollers, LEDs and microphones, that "listens" for the wind. The circuits also look like a work of art: "I created the electronics based on the painting," Qi says. "Basically, I tried to draw as much as possible with the circuitry, to make the electronics match the aesthetics of the painting." TC

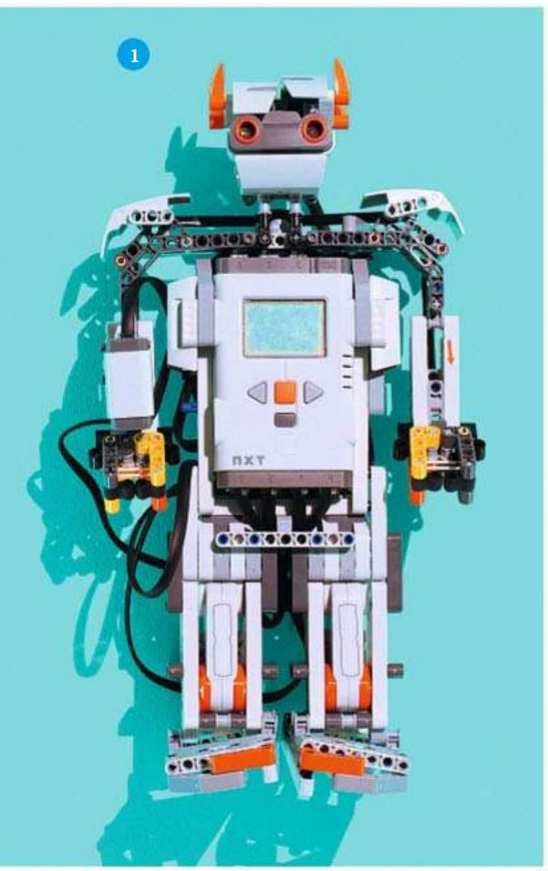
The façade of *Pu Gong Ying Tu*, Jie Qi's interactive painting

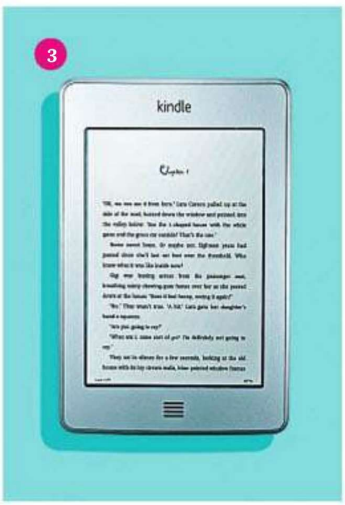
The layer of circuitry that lies underneath the artwork

Lab list

MIT'S GREATEST HITS

You may not be able to buy a hyperinstrument or folding car just yet, but many of the Media Lab's research breakthroughs have already made it to mass market. WIRED selects five of MIT's best-known spin-offs.





PHOTOGRAPHY: WILSON HENNESSY

1 LEGO FOR GENIUSES

In 1998, Media Lab researchers embedded tiny computers in LEGO bricks. LEGO adapted the tech to create the Mindstorms range, which lets you build and program your own robots. *mindstorms.lego.com*

2 NON-STOP ALARM CLOCK

Alarm clocks' snooze buttons are laziness enablers. Not Clocky's, though. Hit snooze and this former MIT class project will jump off your bedside table and wheel maniacally around your room. *$39 nandahome.com*

3 PAPERLESS READER

Can't decide between a Kindle, Kobo or Nook e-reader? Whichever you choose, the electronic "ink" that makes all three devices legible is produced by E Ink Corporation, which spun off from the Media Lab in 1997. *eink.com*

4 LOW-COST LEARNING

More than 2.4 million children and teachers now have the low-cost, low-power XO laptop as part of the One Laptop Per Child project. The semi-flexible XO-3, designed by Yves Behar, is in development now. *one.laptop.org*

5 RIFFS AND REVOLUTIONS

The Media Lab spawned both *Guitar Hero* and *Rock Band*, and thus more than $1 billion in sales, creating one of gaming's biggest genres. New download-only title *Rock Band Blitz* requires no instruments, just rhythm. *rockband.com*

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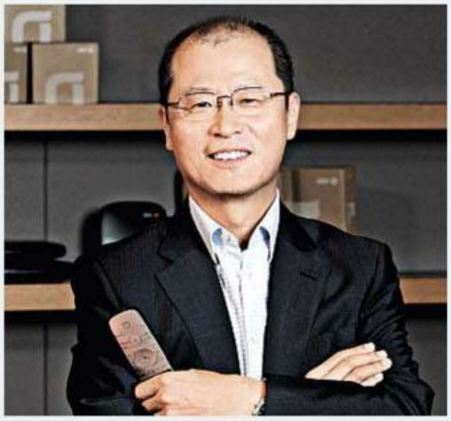

THE BRAND GOES PHYSICAL

A NEW PRODUCT IDENTITY FOR KT

As the world's most wired nation, Korea sets a pace with its internet speed and connectivity that few nations can match. For KT, Korea's leading telecoms provider, the future is a fascinating thing. Its next challenge? A way of bringing the devices associated with connectivity out of hiding – making

YUNG KIM, LEADER OF THE NEW KT PRODUCT IDENTITY PROJECT

Yung Kim is senior executive vice president and chief strategy officer at KT (*above*). Having earned his Masters in microwave engineering and modern optics at University of London, he has led exciting initiatives in marketing, R&D, M&A and innovative business for some of the world's biggest telecoms players, including BT. He joined KT in 2009, bringing a wealth of experiences and insights. WIRED asks him about the project's impact.

WIRED: What is the background to this product identity project?
Yung Kim: When I first joined KT, we offered a variety of devices which were very different in look and feel. Most customers wanted to hide them and keep them out of sight. This was not only detrimental to our competitiveness, but also got in the way of customer satisfaction. After all – we want customers to be proud of our equipment. The optimum solution was to make them easier to recognise as well as more approachable. At its heart, the project is all about a consistent design quality. Building up product identity and developing fine design takes time and resources, so in the short term it looks like a cost burden. However, in the long term, design consistency actually contributes to cost saving and creates a product that connects with the consumer.

W: How did you ensure the project's success?
YK: First, by putting together a dream team of in-house experts in design, marketing and industrial engineering (*opposite page, top inset*). Second, by working with Matthew Cockerill, associate design director at design and innovation company Seymourpowell, and his team (*opposite page, lower inset*). They were really outstanding – full of passion and ideas.

W: How have customers reacted to the new designs?
YK: I myself was surprised by their reaction. In the process of creating the Product Identity, and even before that, we made sure to take on board customer feedback. Being surrounded by so many IT devices, it became apparent that what our customers needed was high-tech functions, but with an approachable, de-tech aesthetic. We identified ten key customer insights, and worked tirelessly to resolve each one. The positive response from our customers shows our efforts paid off!

them something we don't instinctively want to put behind the sofa or under our desks. These things tend not to get the same attention to detail that is lavished on more visible products, so KT got to work on a new set of design guidelines to create devices that are consistent in every detail, from the basic shape to the smallest button, switch and screw. No mean feat when you consider that KT boasts a family of over 56 types of product, from IPTV set-top boxes and remote controls, to power adaptors and connector cables.

It's a laudable project. To be truly fit for purpose, a product should also be sympathetic to its environment; looking the part as well as acting it. KT's design policy team worked with the design team at Seymourpowell to create a flexible new design language – one that could be modified consistently in size and proportion to suit each product.

KT's design policy team worked with product design agency Seymourpowell to create a new design language that could be modified consistently right across its product family

KT's in-house design policy team, Sey Koh, Jaehee Lim, Sooyeon Kang and Kihwan Kyoung Seymourpowell's dynamic design team, Nick Sandham, Matthew Cockerill and Jamie Cobb

FROM THE TEAM AT

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THIS MONTH: 11.12
- **SKETCH CIRCUITS**
- **WIN AT *ROCK BAND***
- **UNDERSTAND A SMILE**

ILLUSTRATION: JAMES YAMASAKI

HOW TO...

EXPERIMENT ON YOUR BABY

New parents often seem surgically attached to their camera when their baby is born, but MIT professor Deb Roy went a few steps further: he set up dozens of fixed cameras and microphones in his home and recorded his infant son for 15 months continuously. Roy's motive was purely academic – he wanted to use the data to trace infant language development in his lab, the Cognitive Machines Group. He explains how to design an experiment to observe your own child learning to talk. **MV** •→

HOW TO...

EXPERIMENT ON YOUR BABY... CONTINUED

1 HARDWIRE YOUR HOME
To understand how baby talk evolves, you need to design a data-capture method that doesn't get in the way of everyday life. No handheld cameras or short-life batteries, but an embedded system that can run itself. "I chose to install microphones and cameras up in the ceiling of our home," says Roy. "We had 11 cameras and 14 microphones distributed in every room of the house."

2 CAPTURE EVERYTHING
It's important to eliminate human biases. That means no editorial decisions in what you capture – you want to record as much as possible. Roy collected about ten hours of footage a day in every part of the home that his son occupied between the age of nine months and two years. "We estimate we recorded somewhere between 70 and 80 per cent of his waking hours," explains Roy.

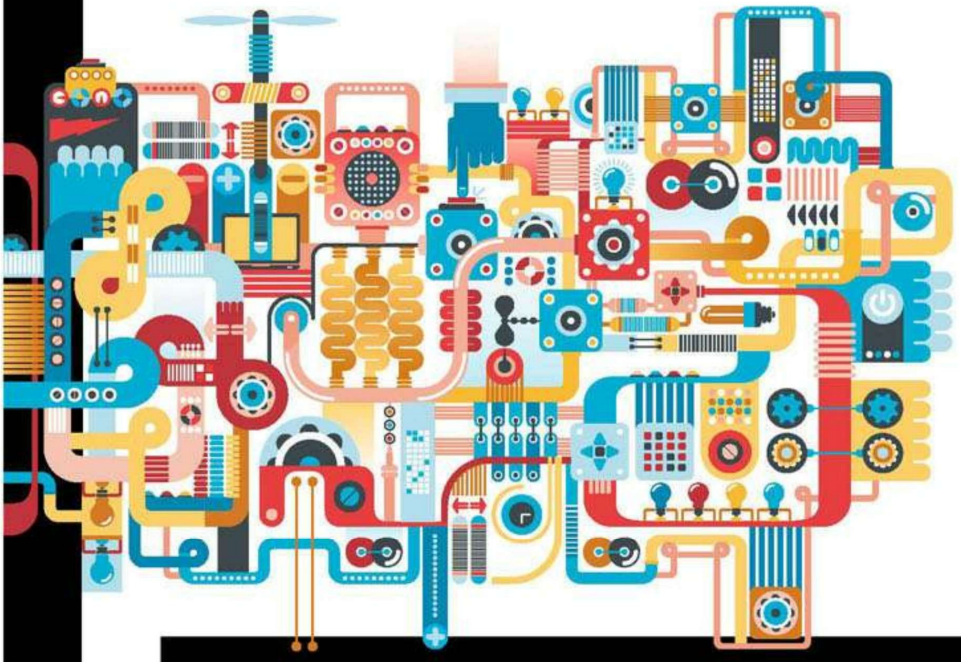
3 LOOK FOR PATTERNS
Roy's team approached the data by building wordscapes: a visual showing the physical context of every word in his son's vocabulary. "If you can see what your child is doing when he hears a particular word, it provides complementary information," says Roy. He found that if his son heard a word in the same visual context several times, it would be picked up far more quickly.

4 CAST YOUR NET WIDER
If Roy's conclusions hold true for not just his son, but for other children, then his research has implications for youngsters struggling to learn language. "Structured games and visual activities could be better formats to learn words easily," he says. To draw overarching conclusions, you need to expand your dataset by recording different babies.

HOW TO...

SKETCH CIRCUITS

Circuitry is technical, but it can also be artistic. "You can build circuits straight on to paper, even in a spiral notebook," says Jie Qi, a member of the High-Low Tech Group at the Media Lab. Here he explains how to draw your connections. **TC**



HOW TO...

WIN AT ROCK BAND

Think *Rock Band* is child's play? The popular videogame was a spin-off from music research at the Media Lab. Its creator, Alex Rigopulos, CEO of Harmonix Music Systems, explains how to enhance your riffs and rise up the charts. TC

LAY OFF THE JACK DANIEL'S
Sure, staying sober will dent your rock 'n' roll credentials, but, according to Rigopulos, "Playing your best requires lightning-fast reflexes, which are rapidly diminished as you enhance your bloodstream with booze."

USE OVERDRIVE WISELY
Use Overdrive mode when it helps you the most: while you're streaking and during passages with lots of notes. But don't save it for too long – if your Energy Meter is maxed out, use it at the earliest decent opportunity.

IT'S ALL ABOUT STREAKS
Don't assume that choosing the highest difficulty level is your path to the highest score. (More notes hit = higher score, right?) "You're better off playing a lower difficulty level that you can totally crush."

HIT OVERDRIVE AS A TEAM
"When you've got four players, all streaking to max multiplier, and then all of them enter Overdrive simultaneously, the exponential score accumulation becomes absolutely explosive."

1 GATHER YOUR KIT

You'll need LEDs for surface-mount technology – the small components you see on circuit boards – to lie flat against your page. And get a power supply too: "Coin cell-batteries are great because they're flat and provide just the right amount of power for LEDs without overpowering them," says Qi. Last, find some conductive copper tape.

2 SKETCH YOUR CIRCUIT

"Trace the footprints of your components directly on to the paper [in pencil], then connect the dots between these footprints to draw in all the connections in the circuit." To light the LEDs, connect them by drawing lines from the + end to the + end of your power supply, and the – ends of the LEDs with the – end of the cell.

3 CONNECT WITH COPPER TAPE

"Now you're ready to turn your pencil sketch into an actual functioning circuit." Tape the conductive copper tape over the lines connecting the components. If the tape is too wide, cut it thinner with scissors. Soft copper tape can be curved by folding."But don't fold too many times or it will break."

4 MAKE PAPER SWITCHES

Place the two ends of the switch (the traces that will be connected and disconnected) next to each other in parallel. Use a third piece of conductive copper to bridge these traces. "Between the parallel traces and the bridge, place a paper space with a hole large enough to expose the two parallel traces when someone presses the button."

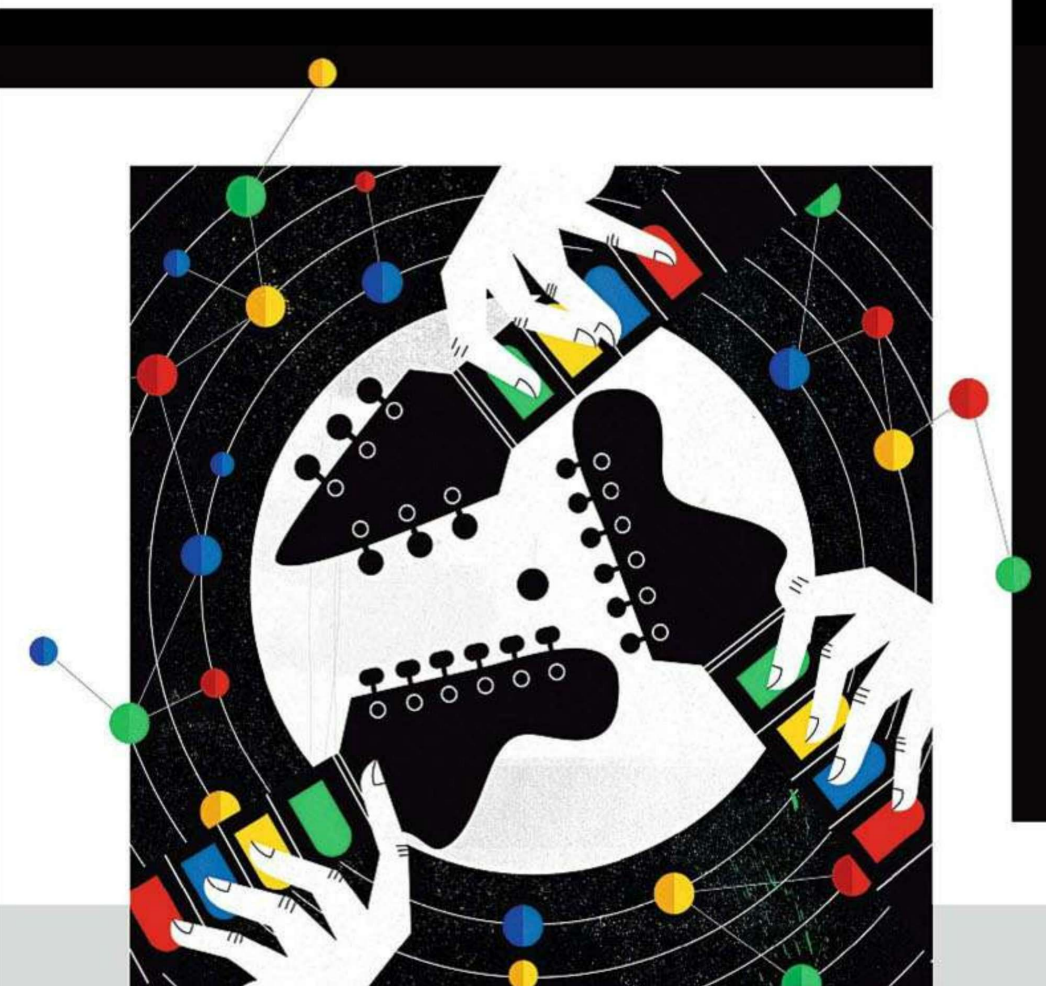
5 PLACE THE COMPONENTS

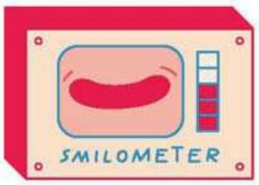
Once you've finished laying down the circuit connections and switches, place the components over the copper traces. "For LED circuits, you can simply tape the LEDs on to the copper traces to make the connection," explains Qi. "For more complex circuits with many connections, solder your components to the copper traces."

6 ADD SOME POWER

All you need now is power. "You can create a simple battery holder by folding a corner of your paper and using a binder clip to secure the battery in place." There's a tutorial at *hlt.media.mit.edu/?p=1149* and one for a creating a separate battery pouch at *web.media.mit.edu/~jieqi/?p=50*

ILLUSTRATION: FERNANDO VOLKEN TOGNI; DALE EDWIN MURRAY; FICKLE FATE





HOW TO... UNDERSTAND A SMILE

If a computer can spot a fake smile, so can you. Last May, MIT researcher Ehsan Hoque trained a machine algorithm to analyse smiles. "Our algorithm was almost twice as good as humans at identifying fake smiles," says Hoque. Here are some tips on how to spot a fake, from Hoque's machine. MV

1. VIDEO TRUMPS STILL PICTURES

Hoque's machine is shown a video clip of a smile. The algorithm then plots how smiles progress through time, and breaks them down into three individual components. So don't judge straight away: watch the smile as it develops.

2. IDENTIFY THE PEAK

The algorithm sifted through 35 smile videos, and was trained to observe how long smiles stay at their peak; real smiles are sustained for about six seconds, it found, whereas fakes have significantly shorter peaks.

3. TRACK SMILE PROGRESSION

Hoque's algorithm was able to spot and sort two categories of smiles. Genuine smiles build up gradually to a peak and then fade slowly, whereas fake ones plot as a sharp spike on the graph: rapid build-up and quick fade.

4. BUILD A SMILE CATALOGUE

Once more data has been collected and analysed, Hoque wants to build a library of smiles. His group is not just curious about real and fake smiles, but other kinds too, "such as nervous ones, polite ones or frustrated ones," he says.

NEGROPONTE 2.0

Message: Oh, lost count… From: Nicholas Negroponte
To: editorial@wired.co.uk Subject: Anti-disciplinary

In his first column for US WIRED, in 1993, Nicholas Negroponte refused to be distracted by HDTV – predicting instead the ways a digital revolution would alter how we consume content. Now, in a historic return to the magazine, he explains why MIT's Media Lab is so vital.

The digital world creates convergence, overlap and blur in previously separate, distinct and crisply defined areas. Simple definitions, such as being inside or outside something, being part of or not part of something else, being for or against just about anything… all of these are suddenly subject to reinterpretation. Today, "either/or" is "both/and" in so many different ways. All things digital commingle where and when they never have before. Examples: work and home, reader and author, education and entertainment, container and content.

The medium is not the message. The message is the message and can be rendered in many ways. For example, books are not about paper, but about narrative, created with the basic DNA of digital life, binary digits. Since 1948 we have called them bits (most people think the word is much older).

Whatever the post-digital world may be we know it is a fuzzy world, with blurred definitions and overlapping disciplines As recently as ten years ago, academic and research aspirations included being interdisciplinary or multidisciplinary, words usually used to describe the *avant-garde* of higher education. Today, by contrast, the very idea of disciplines is coming apart, in favour of a less compartmentalised and a more imaginative and more creative world. Said differently perspective is more valuable than IQ.

Salon des Refusés

The idea to build the Media Lab first came up in the autumn of 1979. It was generally considered a fool's errand. Nevertheless, the process of doing it, of pulling together the constituent parts, was frictionless. MIT had no schools or departments that laid claim to education, journalism, graphics film, animation or human-computer interface design. So putting them all under one roof was easy.

But why bother?

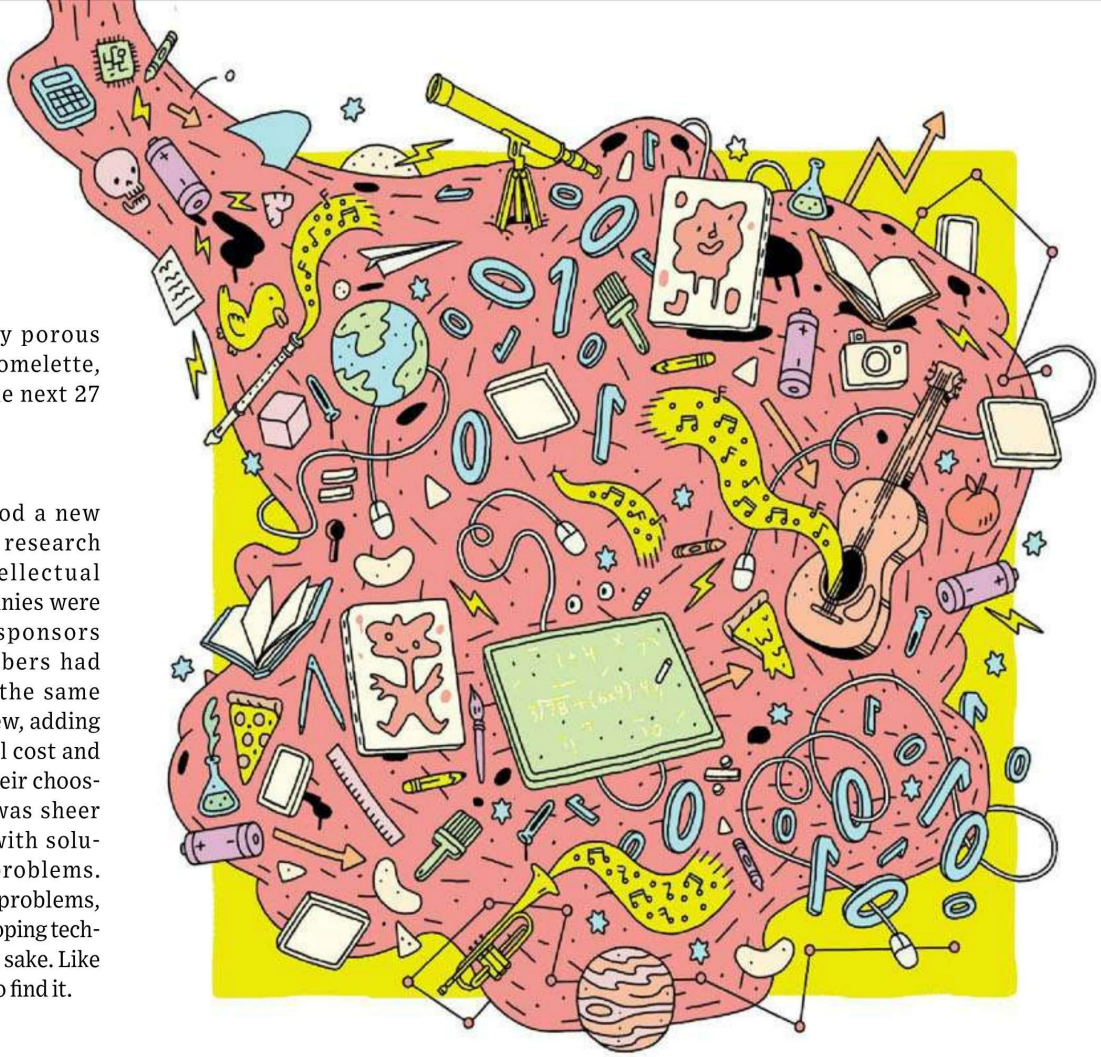
The answer is simple and was simple, even all those years back. "Computers are not about computing, but everyday life." This 32-year-old statement is, hands down, my most widely quoted.

By extension and less quoted then and now, new ideas in computer science would come from the applications, not from basic science. New ideas would emerge from creative uses and users, from a heterogeneous collection of edgy, unorthodox people. In the case of the Media Lab, those people came from various parts their home departments. In that sense, the founding faculty was a veritable *Salon des Refusés*. Misfits.

In October 1985, we moved into a brand new building, specially designed by IM Pei. At the opening ceremonies, Steve Jobs was our keynote speaker and Martha Stewart was our caterer. Michael Crichton spoke at the event as well. Did we know where we were going? No. But we knew it would be orthogonal to the mainstream, contrarian and follow an "omelette theory of life".

What I mean by that is: the pre-digital world was like a fried egg, with that

PHOTOGRAPHY: GETTY IMAGES. ILLUSTRATION: KELSEY HEINRICHS



commingle and create a very porous world. Life would become an omelette, instead of a fried egg. Over the next 27 years life did just that.

Solutions without problems

Over the course of that period a new economic model for funding research evolved around shared intellectual property. Simply stated, companies were members of a club versus sponsors of "directed research". Members had privileges; all members had the same ones. From the lab's point of view, adding members had a low incremental cost and faculty worked on projects of their choosing. The reason this worked was sheer numbers. The lab was filled with solutions without knowing the problems. Seriously. We were not solving problems, but inventing solutions and developing technology, in many cases for its own sake. Like a gold mine, companies just had to find it.

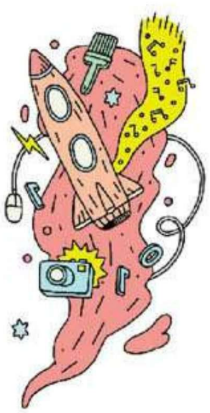
Cyberneticist Warren McCulloch characterised the difference between a dog and a human. When pointing, he said, the dog looks at the tip of your finger and the human looks in the direction in which you are pointing. Media Lab projects pointed. *Quod erat demonstrandum.*

Said differently: the best vision is peripheral vision.

Some sponsors made millions by looking in that direction. Others did not. The same project that was viewed with delight by one company might be viewed as boring to another. But what all companies saw was a passion, in faculty and students, living proof that love is a better master than duty.

Two giants influenced the Media Lab: Marvin Minsky and Seymour Papert. Minsky cofounded the field of artificial intelligence and Papert laid the foundation for learning in the digital age in his book, *Mindstorms*. Together they brought not only deep thinking but the idea of thinking about thinking itself.

Both men believe that computer programming is a way for children to learn about thinking and that the iterative process of debugging (a computer program) is the closest approximation a child will get to understand and see his or her own learning. This view of education, so-called constructionism, lived in the lab from the earliest days. Call it learning by doing. However, this simple idea all but fell off the table over the past quarter century of educational technology, while people and companies made more and more applications to be "consumed" by children and teachers alike.



Today, programmes such as Khan Academy, Coursera and MIT's own edX are, in my opinion, blindly focused on teaching, not learning. Course correction is needed. Pun intended.

Some things will not happen in an economy driven only by markets. And that is the reason you need a Media Lab

Innovation versus invention

The Media Lab is about ideas, about inventions, about breakthroughs in science. These should not be confused with entrepreneurship or innovation, two equally important but different elements of a vibrant society and strong economy. Not all ideas make startups and almost all startups make small ideas. While the current trend in academia, especially in business schools, is to be entrepreneurial, it can lead to small thinking – and usually does.

When I think of the Media Lab, what it has done and what it should do in the future, I remind myself that normal market forces are important, but not enough. Some things will not happen in an economy driven only by markets. And that is the main reason you need a Media Lab.

If industry can do what we are doing, we should not be doing it.

Nicholas Negroponte is the chairman emeritus of MIT's Media Lab. He was the first investor in WIRED *magazine in 1992, after founder Louis Rossetto pitched him at TED. A $75,000 investment for ten per cent of the magazine led to a regular back-page column – the first of which we revisit on p156*

ILLUSTRATION: KELSEY HEINRICHS

WORLDWIDE INITIATIVES

India
Good all-weather roads are vital to connect, support and help communities. Shell InstaPave Systems offer a simple and cost-effective way to seal gravel roads in rural communities – making a proven and immediate difference to health, education and economy.

Italy
Shell's trackside lab with Ferrari's Formula One team is a hub for the quest for gasoline performance. Improvements on the race track often become improvements on the road.

Canada
Trucking firms and other industries are looking to liquid natural gas (LNG) as a cleaner burning fuel. It's around 30 per cent cheaper and more efficient than regular diesel. Shell is lending its expertise to develop LNG engine maintenance and set up LNG fuelling stations.

Brazil
Brazilian sugar-cane ethanol produces around 70 per cent less CO_2 than regular petrol. Raízen, Shell's joint venture with Cosan, makes more than 2bn litres of ethanol a year (a number expected to double). Raízen specialises in renewable sugar-cane production methods.

France
It was a French team that won the all-time record in the Shell Eco-marathon challenge, which invites students from around the world to design, build and test energy-efficient cars to see who can go the furthest on one litre of fuel. They managed an amazing 3,771km.

ILLUSTRATION: NEIL STEVENS

#2: SMARTER MOBILITY

INTELLIGENT MOVEMENT

EMBRACING CHANGE AND INNOVATION

Smarter Mobility embraces a broader spectrum than you might at first think. Above all, it requires a shift in perspective that considers both macro and micro. This means looking at smarter use of products as well as the products themselves, infrastructure as well as fuels, total engine efficiency as well as fuel, and commercial as well as personal transport. This approach allows Shell to use human ingenuity, innovation and technology to meet mobility needs while limiting environmental impact.

One simple idea: getting vehicles to slow down. New Shell marine lubricants are designed to help cargo ships to run slower and smoother, meaning a reduction in fuel consumption. Other projects find Shell developing fuel-saving tips for drivers; inventing light, strong polymers for use in car manufacture; with its partner in Brazil producing renewable sugar-cane ethanol fuel; and new preparations that allow companies to mix and lay "foam" asphalt at lower temperatures – all generating big savings in energy expenditure. Shell is working hard to keep you moving – in the right direction.
To learn more, visit shell.com/letsgo

SHELL AND MOBILITY

The number of cars on the road is expected to triple by 2050. Cost, technology, government policies and environmental concerns are all converging. Shell's "Smarter Mobility" programme is developing a variety of fuels and techniques to help meet the growth in energy demand while helping to limit transport CO_2 emissions and increase fuel efficiency.
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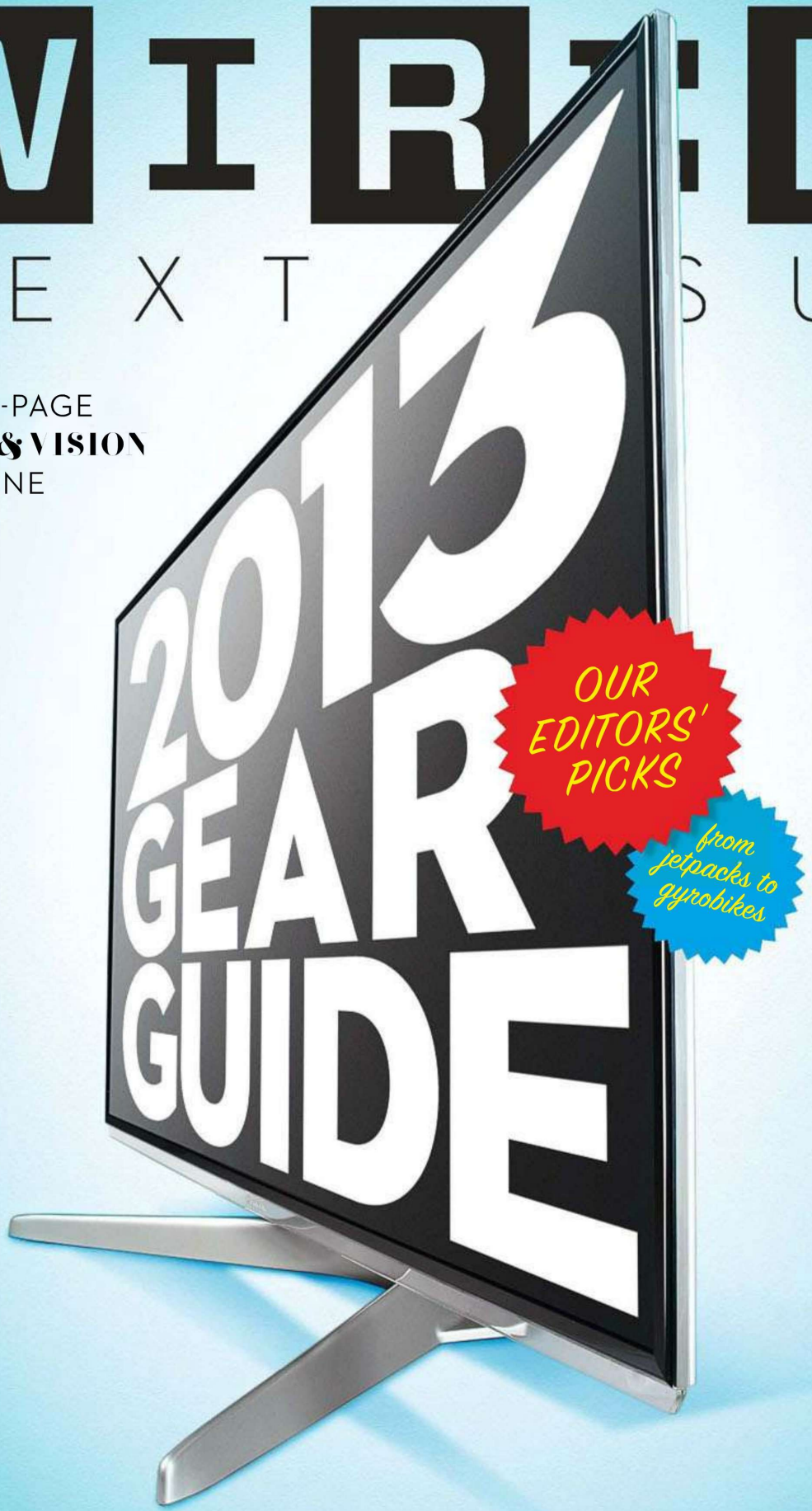
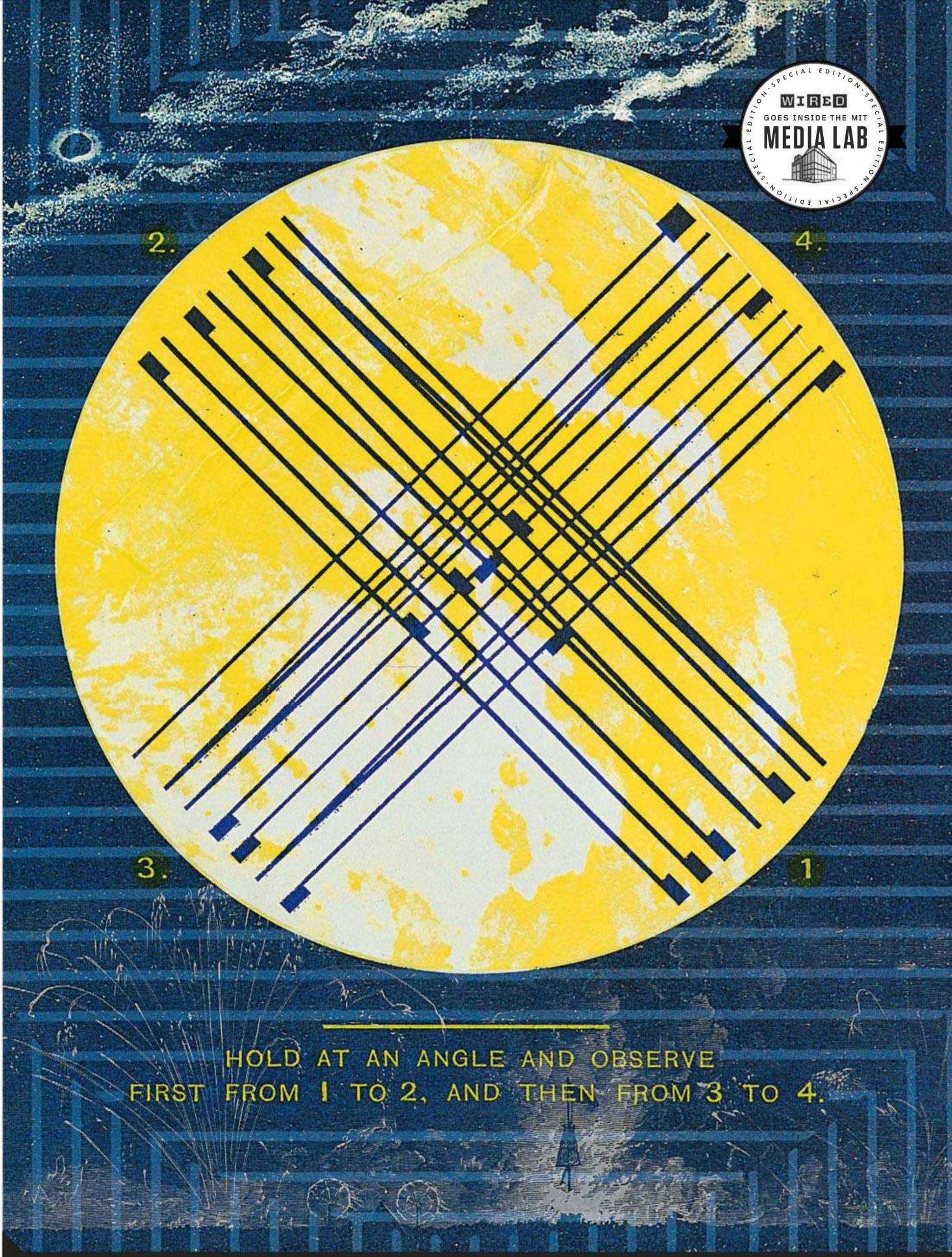


PHOTOGRAPHY: CHARLIE SURBY

OUR ANNUAL WISHLIST



COLLAGE: MARK LAZENBY. BASED ON ANAMORPHIC TYPOGRAPHIC OPTICAL ILLUSIONS FROM THE 19TH CENTURY. CREATED USING OLD PAPERS, ENGRAVINGS AND HAND-DRAWN LETTERING

FEATURES/11.12

OPEN UNIVERSITY

JOI ITO PLANS A RADICAL REINVENTION OF MIT'S MEDIA LAB – WITH THE BUILDING AS JUST ONE HUB ON THE NETWORK

Joi Ito, 46-year-old director of MIT's Media Lab since last September, has just selected the faculty's newest outpost: the troubled streets of downtown Detroit. "I was in a rough neighbourhood there yesterday, where there are miles and miles of bombed out buildings, and it just blows your mind to see a bunch of kids building urban farms," he says back in his office in Cambridge, Massachusetts. "They have no streetlights. If you connect a streetlight to the grid, it gets controlled by the city and regulated. So they're thinking, how can we create solar-powered low-cost streetlights, as that will lower crime? They have a maker space in a church, a place where the kids can learn how to build a computer, a bike shop where they can learn how to do repairs. The kid who runs this place, Jeff Sturges, is awesome. So I'm going to make him a Media Lab fellow. We plan on giving him full access to the Media Lab and sending a bunch of Media Lab people to Detroit to work with local innovators already doing stuff on the ground."

By DAVID ROWAN
Photography: CHRIS CRISMAN

Welcome to Ito's vision for opening up the 27-year-old Media Lab, one in which – for example – urban agriculture might be researched in Detroit; the arts in Chicago; coding in London; and in which any bright talent anywhere, academically qualified or not, can be part of the world's leading "antidisciplinary" research lab. "Opening up the lab is more about expanding our reach and creating our network," explains Ito, appointed director in April 2011. His prior career spans venture capital and angel investing, Creative Commons and the Mozilla Foundation, nightclub DJing and cofounding the first Japanese internet service provider – but he never actually earned an academic degree. Although, as Ito sees it, the formal channels of academia today inhibit progress. "In the old days, being relevant was writing academic papers. Today, if people can't find you on the internet, if they're not talking about you in Rwanda, you're irrelevant. That's the worst thing in the world for any researcher. The people inventing things might be in Kenya, and they go to the internet and search. Funders do the same thing. The old, traditional academic channel is not a good channel for attracting attention, funding, people, or preventing other people from competing with you.

"Being open, you're much less likely to have someone competitive emerge and you're also much more likely to find somebody who wants to come to work with you. Innovation is happening everywhere – not just in the Ivy League schools. And that's why we're working with you guys [at WIRED] too – in the old days, academics didn't want to be in popular magazines. Openness is a survival trait."

By opening up the Media Lab, Ito hopes to move closer towards his goal of "a world with seven billion teachers", where smart crowds, adopting a resilient approach and a rebellious spirit, solve some of the world's great problems. His is a world of networks and ecosystems, in which unconstrained creativity can tackle everything from infant mortality to climate change. "We want to take the DNA [of the lab], the secret sauce, and drop it into communities, into companies, into governments," he says. "It's my mission, our mission, to spread that DNA. You can't actually tell people to think for themselves, or be creative. You have to work with them and have them learn it themselves."

The lab, opened in 1985 by Nicholas Negroponte and former MIT president Jerome Wiesner as part of MIT's School of Architecture and Planning, was intended from the start to foster antidisciplinary thinking. It was, according to a 1984 briefing document by Negroponte, "designed to be a place where people of dramatically different backgrounds can simultaneously use and invent new media, and where the computer itself is seen as a medium – part of a communications network of people and machines – not just an object in front of which one sits." The same document – written the year the Apple Mac was born – stated: "Today, computers are awkward, if not debilitating, to use. The average so-called personal computer arrives with unreadable documentation, the bulk and weight of which usually surpass that of the machine itself." So how does the lab remain relevant in an era of sentient, voice-recognising and multi-sensor-embedded smartphones?

The Media Lab timeline

1985
Media Lab (cofounded by Nicholas Negroponte and former MIT president Jerome Wiesner) opens in an IM Pei building

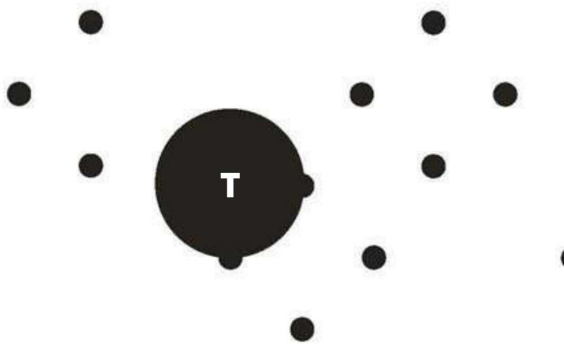
1990
The lab demonstrates the world's first real-time, moving synthetic hologram

1994
The lab posts the web's first electric postcard where text and image are "mailed" via the net

1995
Harmonix is founded by lab alumni Alex Rigopulos and Eran Egozy. It developed *Guitar Hero*, *Rock Band* and *Dance Central*

1996
Patent filed for e-ink, now used in e-readers such as the Kindle. CSound is developed – it's capable of delivering an entire Beethoven symphony over the internet in about ten seconds and rendering it in real time at CD quality

1998
Launch of LEGO Mindstorms, developed in collaboration with the lab. MPEG-4 is released by the International Standards Organisation, featuring Media Lab's Structured Audio sound-processing tech



o Ito, that role is not about creating spun-out products – although celebrated products spawned by the lab include *Guitar Hero*, the Kindle, the XO laptop, LEGO Mindstorms, and the foldable CityCar. As Ito sees it, the lab's mission "is to come up with ideas that would never be able to occur anywhere else because most places are incremental, directed and disciplinary". And that means turning the lab into a platform rather than a physical place.

PHOTOGRAPHY: CHRIS CRISMAN, BRAD SWONETZ

The atrium of MIT's Media Lab (*left*) and Nicholas Negroponte, July 31, 2012 (*opposite*)

message – a lot of the kids at the Media Lab today don't want to make more money, don't want to become immortal, they just want to figure out how to fix this unhealthy system we have. There are lots of kids who are not happy with this massive consumerism, this unsustainable growth, but who have really smart science and technology values. That's a type of person we can draw into what I think will become a movement."

And that will come from pursuing distinctly unconventional research goals. "We aim to capture serendipity. You don't get lucky if you plan everything – and you don't get serendipity unless you have peripheral vision and creativity. [Conventional] peer review and scholarship play by predetermined rules – that five other people agree that what you're doing is interesting. Here, even if you're the only person in the world who thinks something's interesting, you can do it. Our funding model allows our students to do anything they want without asking permission. It's like venture capital: we don't expect every experiment to succeed – in fact, a lot are failures. But that's great – failure is another word for discovery. We're very much against incrementalism – we look for unexplored spaces, and our key metrics for defining a good project are uniqueness, impact and magic."

During a two-day "Sponsor Meeting" at the lab in late April – open to a few hundred Media Lab friends and financial backers, ranging from BT to Bank of America, Hasbro to Hallmark Cards – Ito set out some of his key principles. These included: "Encourage rebellion instead of compliance"; "Practice instead of theory"; "Constant learning instead of education"; "Compass over map". "The key principles include disobedience – no one ever won a Nobel prize by doing as they're told," he explains later. "And it's about resilience versus strength – you don't try to resist

"Nicholas comes from a slightly top-down, design-led background. I come from a very unorthodox community-building place – Creative Commons, Mozilla, Witness, Global Voices – which are all about creating movements. To me there's a science to community building. If you extend the Media Lab as a network, and bring in different types of partners and nonprofits, and create more diversity, the lab itself could become a mission, a movement. People think of the lab as a lot of smart people in a really cool-looking building making really cool gadgets. But I want it to have a much stronger normative political

2000
Walter Bender succeeds Nicholas Negroponte

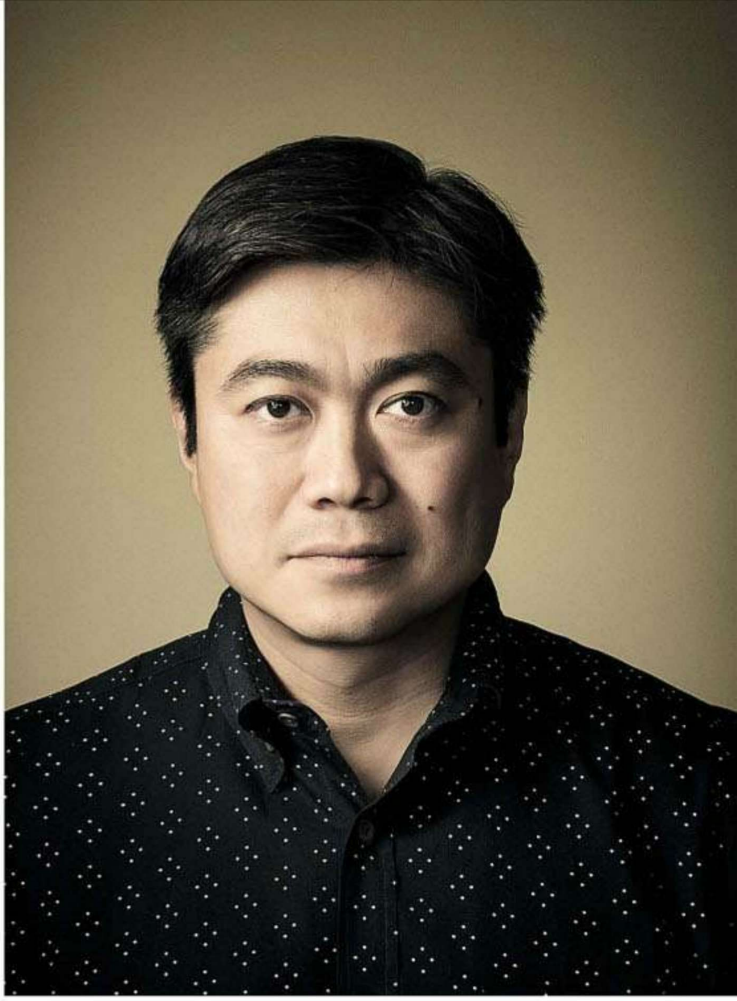
2001
Media Lab Europe opens in Dublin

2002
Minority Report uses the lab's gesture-recognition tech

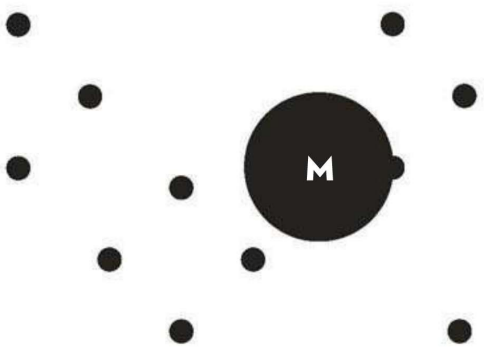
failure, you allow failure and bounce back. And compass over map is important – you need to know where you're going, but the cost of planning often exceeds the cost of actually trying. The maps you have are often wrong. These principles affect and apply to just about any organisation."

Because all the rules have been torn up. "Today any kind of science that's used to predict the future becomes useless. The world is no longer incremental or linear. A lot of risks come from the periphery, not what you're focused on. In the old days, you needed hundreds of millions of dollars and armies of people to do anything that mattered. Today a couple of kids using open-source software, a generic PC and the internet can create a Google, a Yahoo! and a Facebook in their dorm room, and plug it in and it's working even before they've raised money. That takes all the innovation from the centre and pushes it to the edges – into the little labs inside the Media Lab; inside dorm rooms; even inside terrorist cells. Suddenly the world is out of control – the people innovating, disrupting, creating these tools, they're not scholars. They don't care about disciplines. They're antidisciplinary."

Ito himself is a product of the periphery. Born in Kyoto, he moved as a child to Canada and then Michigan. Although he attended Tufts and the University of Chicago, he dropped out before completing a degree, frustrated at the limitations of conventional teaching. Yet, partly through his research-scientist father, he had access to academics while growing up: "When I was in high school most of my learning came from college professors – I'd just email professors in Berkeley and MIT. I figured out a way to cobble together an education using academic institutions without actually getting a degree. So I'm an antidisciplinary self-made academic. Because I've come from the outside, I'm more focused on learning than education."



Joi Ito, prophet of the virtual community, whose early-stage investments include Twitter, Flickr, Kickstarter and Last.fm



2005
Negroponte announces the "$100 laptop" at the World Economic Summit in Davos, Switzerland

2006
Frank Moss succeeds Walter Bender as director

2007
World's first robotic ankle-foot prosthesis prototype is introduced

2008
Nexi (*opposite*) – a mobile, dextrous, social robot – makes her debut

y problem is I'm interested in everything – I have a lack of focus," says Ito. "But my bug turns into a feature at the lab. Because the Media Lab is interested in everything. My main skill is connecting and trading contacts. When you have 350 random projects and 26 groups and 75 members [at the lab], the director needs to create context, make connections, pull the pieces together. My favourite thing is managing communities and creating energy. That's really what the Media Lab is – it reminds me of an open-source community like Mozilla." He knows he will have succeeded when "the Media Lab name is as ubiquitous as the word internet".

He has convened an advisory council made up of friends and contacts, including TED's June Cohen ("It's no accident that June is one of our advisers. There's a lot we can learn from TED, the way the branding works and the platforms"); Greylock's Reid Hoffman; writer Seth Godin; Alberto Ibargüen of the Knight Foundation; Michelle Kydd Lee of the CAA Foundation; and – his mentor on "wisdom" – Peter Gabriel. So who sets the lab's broad priorities? "I'm working with the faculty to come up with the things they're interested in," Ito says. "The seven billion teachers, or Tod Machover wanting to make the eighth art – these initiatives we're building on internally. But we'll also need the funding. Probably a third of my energy goes towards fundraising. So the priorities will be set by what are three to six big stories. One of the problems we have right now is there are 26 groups and 350 projects. The ones that become priorities will be those that can attract the funding, but also have the uniqueness, impact and magic. There's also pattern recognition: when you go mushroom hunting, you can't focus or you won't spot the mushrooms. It's when you stop looking that the mushroom patterns pop out. A lot of the priority setting isn't about laser focus. It's that combination of execution and peripheral vision. Part of our job is about picking priorities that others don't do – if you can do what you do anywhere else, you shouldn't be at the Media Lab. You have to be a true misfit."

Ito, who married Mizuka Kurogane four years ago in Japan, has pledged to travel less – two years ago, a WIRED Infoporn (10.10) showed that between January 1, 2009 and April 5, 2010, he was away from home for 372 out of 460 days. "This year I barely left Boston for six months," he says. "I'll probably start travelling more again, but not as intensely as it used to me. Before, my job was running around mostly making connections. Now at the Media Lab I pick the colour of

PHOTOGRAPHY: CHRIS CRISMAN, SPENCER LOWELL

the furniture and make hires – lots of face to face stuff." He's also on various boards, including those of *The New York Times*, the Knight Foundation and the MacArthur Foundation.

What about resistance to change as he imposes his ideas? "Surprisingly, knock on wood [he laughs], people are excited about the direction we're going. I listen a lot, I'm not pushing the lab in a direction it doesn't want to go. My background is community development. And MIT as an institution is trying to constantly reinvent itself. So far so good. We'll see if it's a honeymoon period or long-term relationship."

Ito was originally rejected for the role because he lacked academic credentials. "The search committee said out of courtesy that I should send him an email appreciating his interest but that he didn't qualify," Nicholas Negroponte recalls over breakfast at the Charles Hotel in Cambridge. "Six months later, we came up empty, with no candidate. And Joi's name floated back to the top of the list. I sent Joi an email – where are you? He said, I'm in the Bahamas. I said get your ass up to MIT as soon as you can. He came two days later."

Negroponte, director from 1985 to 2000, had been no fan of Ito's predecessor, Frank Moss, who took over in 2006 from Walter Bender. "They brought in the wrong person," Negroponte says bluntly. "The lab went through a five-year period like the dark ages." So when Ito was appointed, Negroponte wanted the press release headlined: "University dropout named director of Media Lab". "But," he says with raised eyebrows, "the fact that he didn't have a degree was buried near the last paragraph. That's the good Peter Thiel – if you do drop out and do something creative, more power to you."

What does Negroponte – the original investor in and a columnist for WIRED 20 years ago (see page 145) – see as the lab's role today? "It has at least three roles," he says. "To do what normal market forces do not do; market forces are great for what's not important in your life. In an organisation like Media Lab, you can take a level of risk that's unparalleled. You can start 40 projects of which only two succeed. VCs can't do that; corporate research can't do that – because you have this other product line called people. The most interesting ones who come out of the lab have worked on projects that failed. And the third role is its antidisciplinary nature. It's been the only part of MIT that's a lab and an academic department – we're really church and state. It worked."

What importance does he accord to commercial spinoffs? "Very small." Take littleBits (WIRED 10.12), founded by Media Lab alumna Ayah Bdeir, which produces modular electronics kits and in which Negroponte is an investor. "Whether littleBits succeeds or not is inconsequential. I hope she succeeds, as an investment. But startups are perforce small – you've got to focus, the blinders get narrower. By definition it's not big thinking. I don't measure success by a list of 50 things that were born at the Media Lab – e-ink; that's not important. The important part is that people were looking at electronic paper, at display techniques – and whether that particular one worked, it brought us reflective displays in general, and the e-book. It had bigger effects."

Why does he think that efforts to create overseas spinoffs of the lab proved unsuccessful? "There was an attempt to take it to Japan, Germany, Sweden, France, Spain, Ireland, India – you think we'd learn our lesson. None of them took. In the US, there are half a dozen [institutions] that call themselves media labs. And none of them is like it at all. The idea clearly isn't 'generalisable'. It's the uniqueness of MIT – it's both porous like Swiss cheese, and has an absence of other departments. So nobody when we founded it said, 'Wait a minute, I do that.' When we decided to call it the Media Lab, I remember a meeting in 1983 – 'You mean media, as in TV, newspapers?' When I said yes, the answer was: 'It's all yours. Good luck.'"

What big problems does Negroponte – founder of the One Laptop Per Child project – believe the lab can help solve today? "The biggest is eliminating poverty. How do you have a world of infinite zero-cost energy, infinite zero-cost education, how do you make a creative society – all these seemingly unrealistic things? Whatever path you take, you know the answer is through technology. In a world where technology is increasingly a bad word, it is up to an organisation like the Media Lab to keep pushing that technological envelope. In our original [1984] paper, it says the Media Lab will be the place where the invention and creative use of new media happen together. Video and TV were invented by engineers, thrown over the fence and used. Photography by contrast was invented by photographers. The entire evolution of photography was led by the people who creatively used it. My argument back in 1980 was that computer science would be like photography. Which at the time was near heresy."

So if he were starting from scratch today, what would be different? First, he says, he would abolish academic tenure. "A terrible thing." Research priorities "would be in synthetic biology, not computing. I'd fill the building with Ed Boydens, and would look to where nature and science inform each other. I'd look in places where Neri [Oxman] spends her time. The fact that she, Ed Boyden and Hugh Herr work together is amazing. I'd look to that for inspiration, whether the lab is a platform, a school of thought – but probably not a huge campus building. The days of institutions may be over – it would probably not be a building if we started today." Ito disagrees. "The building and the space and the core faculty are really important – they're the custodians of the DNA," he says.

"The lab will be a network. You'll find the lab and its fellows, its affiliates, all over the world. I've just picked Billionaire Boys Club designer Christopher Bevans as a fellow of the lab; you'll be able to touch the Media Lab a block away from you in London, in all kinds of networks. Instead of just having large companies as our members, we'll have other academic institutions, and governments, and philanthropists, and arts bodies. You'll see more of the Media Lab in every kind of area."

David Rowan is the editor of WIRED. *He wrote about Rakuten in 09.12*

2010
The new Media Lab building, designed by Maki and Associates, opens

2011
Joi Ito becomes Media Lab director

2012
Hiriko, the commercial version of the lab's folding, stacking electric car, is introduced in Brussels MV

Nexi, the social robot developed by Cynthia Breazeal of the Lab's Personal Robots group

PHOTOGRAPHY: **YORAM RESHEF**

BY **MADHUMITA VENKATARAMANAN**

Natur archi

In May this year, the Centre Pompidou in Paris opened MIT designer Neri Oxman's exhibition *Imaginary Beings: Mythologies of the Not Yet*. The collection consists of 18 pieces that Oxman calls "wearable mythologies": objects you can wear to augment your ordinary, human capabilities. Inspired by Argentinian poet Jorge Luis Borges's *Encyclopaedia of Fantastic Zoology*, each of the prototypes is based on a mythical beast and encapsulates a magical ability such as the capacity to fly, or the secret of invincibility. Oxman designed the pieces using Israeli company Objet's multimaterial 3D-printing technology. Objet's printer, known as the Connex 500, was able to manufacture the garments to a 600 dots-per-inch resolution. "We could vary colour, material properties and shape at the 16-micron scale," says Oxman, who worked closely with Objet to customise its technology specifically for this collection. Although she takes advantage of the latest innovations, Oxman says mythology is the real inspiration of all modern design. "It's a projection of the future," she says. Here's a selection of WIRED's favourite fairy-tales of tomorrow.

Neri Oxman, founder of MIT's Material Ecology Design Lab, transposed the super powers of mythical creatures into designs for a series of garments realised by advanced 3D printer and exhibited in Paris

e's tect

Drawing its inspiration from Franz Kafka's novel *Metamorphosis*, this flexible corset – ***Kafka*** – represents an insect's soft torso shell combined with "armour' (a human spine). It is 3D-printed in malleable rubber-like material, with leopard's spots. The ornate, soft-printed texture covering the shell is informed by the curvature of the armour. Denser patterns appear in regions of high curvature, such as those surrounding the joints, providing more flexibility.

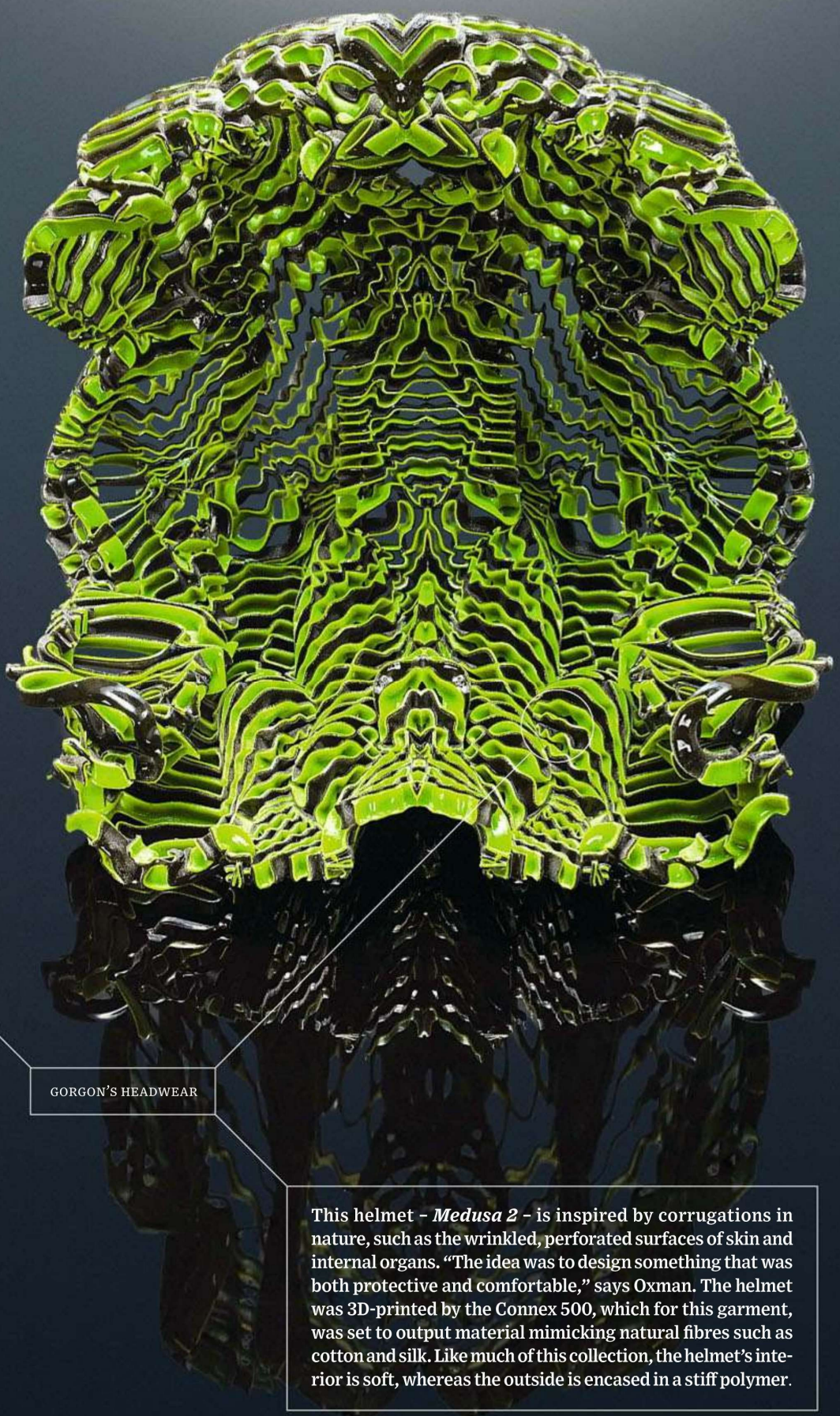
INSECT CORSETRY

This shock-absorbent helmet, ***Minotaur Head with Lamella***, is designed to vary in thickness, based on anatomical and physiological data derived from CT scans of human skulls. Data derived from images of hard tissue (skull) and soft tissue (skin and muscle) from the intended wearer informs helmet thickness and material composition. This ensures that it offers precisely attenuated protection for individual skull shapes, which can vary widely from person to person.

This body suit, ***Leviathan 1***, is named after the ancient sea serpent that acted as the gatekeeper to Hell, according to the *Book of Job*. "The wriggling serpent is reimagined as armour for the human torso," says Oxman. Composed of a thin, stiff shell, the piece is designed as a single continuous surface with cuts in it, allowing flexibility. ***Leviathan 1*** is produced in two 3D-printed materials: soft on the inside, tough and rigid on the outside.

SERPENTINE BODY ARMOUR

In nature, this type of yellow/green and black colouration (known as aposematism) denotes a warning. It achieves the opposite effect of camouflage, increasing visibility, and is a trick used by some poisonous snakes.



GORGON'S HEADWEAR

This helmet – ***Medusa 2*** – is inspired by corrugations in nature, such as the wrinkled, perforated surfaces of skin and internal organs. "The idea was to design something that was both protective and comfortable," says Oxman. The helmet was 3D-printed by the Connex 500, which for this garment, was set to output material mimicking natural fibres such as cotton and silk. Like much of this collection, the helmet's interior is soft, whereas the outside is encased in a stiff polymer.

The ***Remora*** is a pelvic corset, based on the parasitic fish once believed by the ancient Greeks to have the ability to stop ships from moving. The fish's first dorsal fin is a sucker-like organ with slats that allows it to attach to the skin of larger marine animals. This girdle also has "suction cups" which attach to the body. It promotes circulation when worn one way; by reversing the structure and wearing it on the outside "the wearer is able to attach the pelvic region to rough surfaces," Oxman says.

PARASITE-INSPIRED GIRDLE

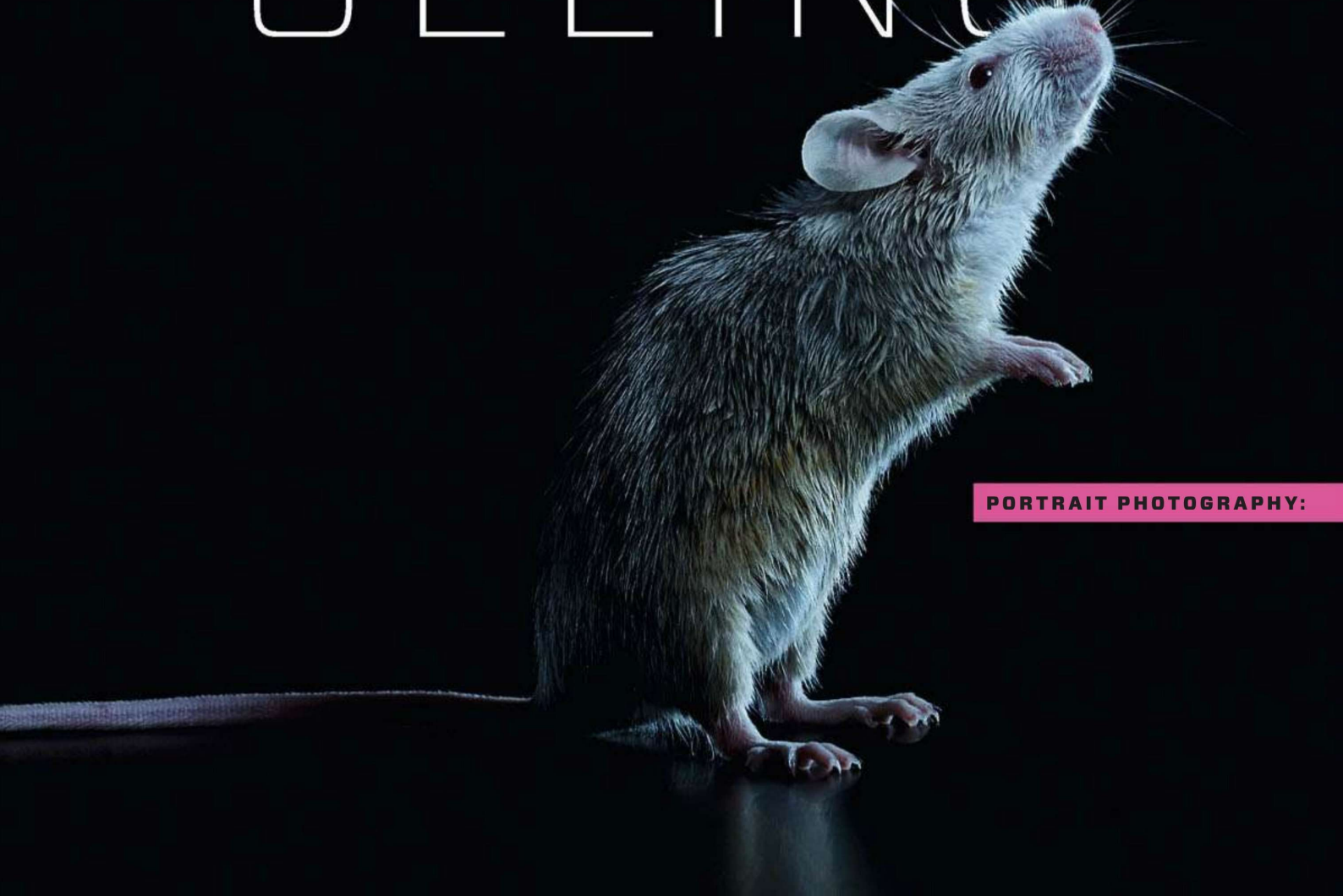
MATERNITY SUPPORT FROM THE GODDESSES

This pregnancy corset, ***Gravida***, is named after the Latin for pregnant and is intended to represent ancient fertility goddesses such as Aphrodite (or Venus) and Freya. "This object offers support for the female belly as it expands," Oxman says. The wrinkled, elastic corset comprises two surfaces: an external armour shell and an internal soft membrane. This maximises the retention of warmth in cold environments while providing support and flexibility as the body transforms. W

ED BOYDEN, AN ENGINEER TURNED NEUROSCIENTIST, MAKES TOOLS FOR BRAIN HACKERS. IN HIS LAB AT MIT, HE'S BUILT A ROBOT THAT CAN CAPTURE INDIVIDUAL NEURONS AND USES LIGHT POTENTIALLY TO CONTROL MAJOR DISEASES – ALL IN HIS QUEST TO 'SOLVE THE BRAIN'

BY ED YONG

SEEING

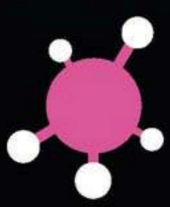


PORTRAIT PHOTOGRAPHY:

STILL LIFE: ANDY BARTER

THE LIGHT

CHRIS CRISMAN



TO BREAK INTO A NEURON WITHIN A LIVING BRAIN, YOU NEED A GOOD EYE, EXTREME PATIENCE, MONTHS OF TRAINING, AND THE ABILITY TO SUCK WITH GENTLE CARE.

HERE IS HOW IT WORKS

A MOUSE LIES IN FRONT OF YOU, BRAIN EXPOSED. YOUR MISSION IS TO IMPALE ONE OF ITS NEURONS WITH THE MICROMETRE-WIDE TIP OF A GLASS PIPETTE.

An electrode in the pipette measures the resistance at its tip, and relays the signal to a monitor. You're watching out for the subtle spikes that tell you that the tip has struck cellular gold. When it is in place, you suck on a rubber tube connected to the pipette – gently at first, to form a seal, and then slightly harder to create a small hole.

If it works, you now have full access to the neuron's inner workings. You can inject a dye through the hole to map the cell's many branches. You can measure its electrical activity as it communicates with its neighbours. You can suck out its contents to analyse the chemicals inside it. If you did that for hundreds of connected neurons, you could start to understand the molecules and electric pulses behind the rodent's thoughts, emotions and memories.

Or at least you could if this technique, known as patch-clamping, were not so frustratingly hard. Getting an electrode to impale a single neuron is difficult enough in a dish. Doing it on a living animal is so tedious and arcane that only a few dozen people in the world can pull it off. And forget about studying networks – to date, the record for the most individual cells patch-clamped in a live brain is two. In an age when brain scanners can produce vivid portraits of mental activity and 3D printers can fabricate organs, patch-clamping seems like an anachronistic relic from a different time. But no more – a technique that has stayed the same for over 30 years is being brought into the 21st century by Ed Boyden.

Boyden, 33, makes tools for brain hackers. From his lab at MIT, he is building technology that will vastly expand the range of experiments that other scientists can pull off. His latest invention is a classic example: a robot that patch-clamps as well as a human scientist, with none of the fatigue or variability. It works all day. It does not need lunch breaks. It has transformed a technique that had only been mastered by an elite few into something that anyone can do, and hundreds of labs are queuing up to buy or make an auto-patcher of their own. Boyden published a description of the robot in May this year. He says, "After our paper came out, I got an email saying, 'I just spent a year learning how to do that. Thanks. There goes that'."

Before Ed Boyden graduated, he had already won a competition to design a submarine that could navigate an underwater maze by itself

oyden has a gentle demeanour but speaks so rapidly that he keeps a treasury of tea at hand to soothe his throat. "I tend to forget to breathe," he says. His ideas flow as quickly as his words. "Even among that elite group [at MIT], Ed stands apart. His ambition is audacious," says Craig Forest from the Georgia Institute of Technology, Boyden's partner on the auto-patcher project. Other colleagues agree. "It's regular to hear him say something like, 'I want to solve the brain.' Period. Nothing after that," says Anthony Zorzos, one of Boyden's graduate students. "But for a guy who says things like that, he's pretty down to earth."

"Solving the brain" is as difficult as it sounds. A cubic millimetre of brain tissue can house 100,000 neurons, sending signals across a billion connections in mere thousandths of a second. This cross-talk is what turns a lump of spongy tissue into the most sophisticated computer in existence. It is also impenetrable to modern methods. We can zoom out to scan broad regions encompassing millions of cells, or zoom in to dissect the traits of individual ones, but the intermediate world of circuits still eludes us. Boyden likens our current technology to studying one pixel on a computer screen at a time. "Even if you buy a million screens, you won't understand how a computer works by looking at that one pixel," he says. "I'd rather have one computer and look at everything in it." The auto-patcher is one of the tools that Boyden is developing to observe neural circuits in detail, to better understand how the brain computes.

But voyeurism is not enough. Boyden is also designing tools to tweak, trigger and silence neural circuits, offering a degree of control that neuroscience has always lacked. For a long time, studying the brain meant finding correlations. Scientists measured how blood flow or electrical activity changed as we carried out mental tasks, and they noted how injuries and disease affected those abilities. But to establish causality, you have to stimulate neural circuits, as well as watch them. A movie, drug or electric shock will do the trick, but we need tools to stimulate specific sets of cells, not vast swathes of neurons.

The most famous of these is the one that made Boyden's name: optogenetics. By implanting neurons with light-sensitive proteins called opsins, harvested from algae, microbes and other creatures, scientists can stimulate or silence them with a simple optic fibre. Boyden pioneered optogenetics in 2005, with Karl Deisseroth from Stanford University. Now, it is used by thousands of scientists around the world.

The opsins can be loaded into neurons within just one part of the brain, or into neurons that secrete a certain type of signalling chemical. Flash the right set and you can steer an animal's movements, send it to sleep or make it aggressive. Silence the right ones and you could potentially calm the hyperactivity that accompanies epilepsy and Parkinson's disease. "I'm wary of using the term revolutionary but I don't think it's an overstatement for optogenetics," says Robert Desimone, director of MIT's McGovern Institute for Brain Research and one of Boyden's collaborators. "It has affected virtually every lab working in neuroscience."

In Boyden's endgame, neuroscientists will use these tools to observe and control large networks of neurons at once. Imagine recording the activity of thousands of cells as a memory is

formed, and then triggering the same pattern of activity to see what happens. These are the experiments that Boyden is working towards. With a background in physics and electronics, he brings an engineer's mindset to the messy world of brain science. "The premise I put to people who start in my group is: assume the brain is solved in 50 years, and that we'll need to invent lots of new tools to get there. What are those tools, and which one should we work on now?"

The tools he builds are varied, but all of them are meant to be easy to use, and to accelerate the process of discovery. Many scientists are content to slowly chisel away at the bounds of our knowledge, but Boyden is building jackhammers for them to wield.

"Imagine all possible neuroscience experiments," he says. "You could pick a brain region, a type of cell, a behaviour and a disease. You might study how the interneurons of the cerebellum are involved in spatial memory or Alzheimer's. There are billions of such experiments. If you're going to solve the brain in 50 years, doing billions of PhD theses isn't how you go about it."

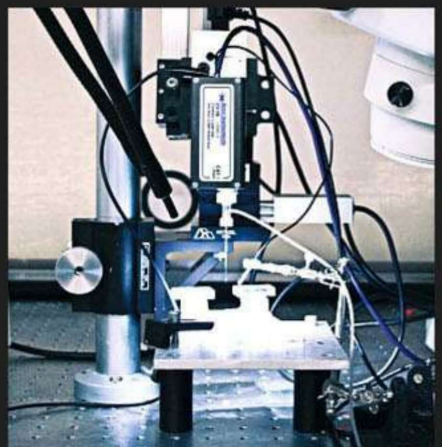
That is exactly the kind of attitude that neuroscience needs, according to Desimone. "Ed comes in from the outside and shakes things up," he says. "You keep on asking yourself: why didn't people in the field come up with that?"

Clockwise from main picture: a pipette touching a neuron; a mouse with an optical fibre in the brain; and the rig where the patch-clamping takes place

Boyden was interested in big philosophical questions from an early age, and he knew that to answer them, he needed a solid scientific training. Fortunately, his high school – the Texas Academy of Mathematics and Sciences – was connected to the University of North Texas, and all the students could attend lectures and labs in their final two years. Boyden spent a few days a week working with Paul Braterman, a chemist obsessed with the origin of life.

"It was eye-opening that someone with a beaker and a fume hood could try to test these theories about how life began billions of years ago," he says.

By the time he joined MIT as an undergraduate in 1995, Boyden's interests had shifted to include engineering, physics and computer science and, in particular, how the world computes and processes information. In his final year, Boyden spent a few weeks at Bell Labs. Surrounded by former physicists who had switched to neuroscience, he spent several weeks trying to develop ways of understanding the brains of singing birds. "It was total immersion in a community that was trying to hack the



brain," he says. The brief encounter set Boyden on his path. "At MIT, I was interested in the physics of computation, but that seemed too broad," he says. "Neuroscience was a subset of that." This, then, is all you really need to know about Boyden – he decided to try to "solve the brain" because it seemed like a more tangible and realistic problem.

Richard Tsien as a graduate student, to look at how the brain stores memories of movements. "I wanted to do my time," he recalls. "A lot of my friends who did engineering wanted to do neuroscience, but went back to start another dotcom company after a year. Biology is so messy, slow and painful. You need to learn to be patient and tolerant of extreme failure."

Raymond and Tsien taught him those qualities, and gave Boyden the freedom to pursue the many side projects bubbling inside his brain. A good thing too, for one of these would change the field.

At Stanford, Boyden bonded with Karl Deisseroth, another of Tsien's students, who was about to finish his PhD and start a psychiatric residency. They spent several late nights brainstorming ways of mapping and controlling specific circuits in the brain. It would not be enough to electrify thousands of neurons into action; they wanted a way of exciting specific cells of their choosing.

In 2002, Gero Miesenböck at the Memorial Sloan-Kettering Cancer Center in New York showed this could be done with light-sensitive molecular machines. He infused mammalian neurons with three proteins from a fruit fly's eye, so that a burst of light would make them fire. His technique was the first true example of optogenetics, and proved light could drive neural activity. But it was unwieldy. The three proteins had to be balanced at exactly the right levels, and took seconds to influence neurons – a glacial pace in the millisecond-fast world of the brain. Boyden and Diesseroth knew that to create a tool others would use, they needed a fast, self-contained machine.

As it happened, a freshwater alga called *Chlamydomonas reinhardtii* has been using just such a machine for billions of years. *Chlamydomonas* looks like a microscopic green marble, and it relies on sunlight to make its own food. It tracks the nearest light with an eyespot, containing an opsin called channelrhodopsin-2 (ChR2). Like other opsins, ChR2 is a machine for converting light into electricity. It consists of seven tightly clustered columns that open into a pore when they are hit by blue light. The pore stays open for just a few milliseconds, long enough to let in a flood of positively charged ions. This creates a voltage.

Here was the neural controller that Boyden and Deisseroth wanted and the timing could not have been better. ChR2 was discovered in 2002, just as Deisseroth was about to start his own laboratory and Boyden was finishing his PhD. The duo had languished upon their dreams of neuron control for a few years, but Miesenböck's paper showed that others were thinking along similar lines. "It kicked us back into the game," says Boyden. The duo got a copy of the ChR2 gene, and used a harmless virus to smuggle it into mammal neurons. The infected neurons manufactured copies of ChR2 and became sensitive to blue light.

HOW DOES OPTOGENETICS WORK? OPTOGENETICS TECHNIQUES ENABLE RESEARCHERS TO ACTIVATE OR SILENCE SPECIFIC NEURONS USING PULSES OF LIGHT. HERE'S HOW THEY DO IT.

1. BUILD A SYNTHETIC CHR2 GENE

A synthetic version of the ChR2 gene, found in green algae, is built. This opsin gene codes for a light-sensitive channel that responds to blue light.

2. PUT THE GENE INTO A VIRUS

Next, the synthetic gene, which has a DNA "postcode", is inserted into a virus, which acts as a messenger when injected into an animal's brain.

3. INFECT YOUR SUBJECT

Once inside the brain, the (harmless) virus infects multiple neurons. The gene is expressed only in a subgroup of these, as marked by the postcode.

4. FIRE BLUE LIGHT INTO THE BRAIN

A pulse of blue light can now be fired into the brain. Neurons containing the light-sensitive channel open up and start firing electrical impulses.

5. MEASURE NEURON RESPONSE

When specific neurons are active, behavioural and physiological responses can be measured. Different opsin genes vary the responses. MV

Supreme confidence, not arrogance, is Boyden's hallmark. "I once let him borrow my car," says Jennifer Raymond from Stanford University, one of his PhD supervisors. "It was pretty new, and had manual transmission. I gave him the keys and 15 minutes later, he came back and said, 'How do I do the shifting?' I said, 'You can drive a stick, right?' He said, 'I've read about it.' I asked for the keys back."

It was this fearlessness about jumping into new areas that led Boyden to Raymond's group in the first place. Bell Labs had inspired him, but he realised that he needed some hardcore biological training to bolster his engineering nous. In 1999, he joined Raymond and

PHOTOGRAPHY: MCGOVERN INSTITUTE FOR BRAIN RESEARCH AT MIT.
ILLUSTRATION: SPUTNIK ANIMATION

In hindsight, there were many reasons why this should not have worked. But it did, and on the very first go. At 1am on August 4, 2004, Boyden patch-clamped a ChR2-infused neuron, shone blue light on it and watched it fire. Somehow, an algal protein had just the right qualities to turn on a mouse neuron. "All the stars aligned evolutionarily," he says. But Boyden is modest about his contribution and notes that other labs published similar and more extensive papers in the following months. "The idea was very much in the air," he says. "If we hadn't made the discovery, someone else would have."

ventually the duo published their results, and the publication of that first paper in August 2005 triggered a huge interest in both optogenetics and Boyden himself. He spent just a year as a postdoctoral researcher in two Stanford labs ("No single lab can contain Ed," says Raymond) before returning to MIT in 2006 to launch his own group. He became a professor a year later. These days, his team – the Synthetic Neurobiology Group – is around 30-strong, and involved in dozens of collaborations.

His current academic home at MIT's Media Lab looks like a standard molecular biology lab where engineers have run amok. Benches full of the usual beakers, plastic tubes and pipettes, also have screwdrivers protruding from them. Every piece of equipment has been jerry-rigged. On a whirlwind tour, Boyden points to a simple microscope riddled with accessories. "Laser, more lasers, a monochrometer, a xenon lamp," he says. Then, after a pause: "I don't even know what these are."

Boyden's laboratory spaces are scattered around two floors and a dozen rooms. He walks between them at a brisk stride, taking in a playground of high-pressure water-cutters, 3D printers, holograms, X-ray microscopes and gardens of robotic flowers. "There's a lot of very thought-provoking stuff around," he says. "If I'm writing, I try to walk around every hour or so. I walk past these flowers and, for a few minutes every day, I'm thinking about robots."

Boyden's former partner Deisseroth is also at the top of his game. His Stanford lab has become a conveyor belt for high-impact publications, where optogenetics is used to study everything from fear to memory to mental health. Post-docs emerge from it plated in academic gold. With Deisseroth's background in psychiatry, the goal of using optogenetics to treat mental disorders is never far from his mind. Boyden, meanwhile, has focused more on improving the tools he helped to create. He sees clinical work as important, but also as slow and expensive. "If we did both invention and clinical work, we'd keep on improving tools and the in-house clinical people would always play catch-up," he says. "Instead, we really focus on making the best tools possible, and collaborating with others on their application."

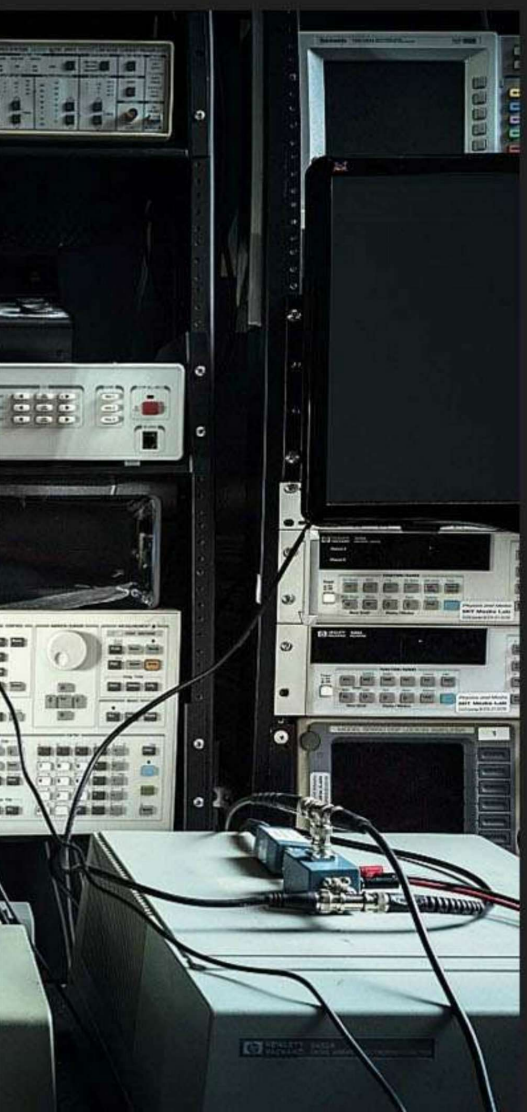
These tools include an expanded palette of light-sensitive opsins. Together with Xue Han – then his partner, now his wife – he showed that two microbial opsins, halorhodopsin (Halo) and archaeorhodopsin (Arch), can silence neurons when exposed to yellow light. Combine these with ChR2 and you can flip neural circuits on or off with bursts of blue and yellow. Boyden is still mining the tree of life for more opsins, especially those that respond to red light. Red penetrates deeper into the brain and it's less likely to accidentally trigger a blue-sensitive opsin such as ChR2 by mistake, since it sits at a far end of the visible spectrum. And Boyden has just received a grant from the US Defense Advanced Research Projects Agency (DARPA) to

scour the genomes of plants for other light-activated proteins – not just gates like the opsins, but also hinges, motors and other molecular machines.

Boyden also moved optogenetics from rodents, flies and worms into primates. Together with Han and Desimone, he was the first to successfully load ChR2 and Arch into the brains of macaque monkeys . A monkey's immune system is more likely to tell us if our body would launch harmful offensives against these microbial and algal proteins. Their brains are much also larger than a rodent's, making them tougher to impregnate with opsin genes and harder to illuminate with optic fibres.

The delivery of light is a big issue. It is cumbersome enough to have a mouse tethered to a laser by an optic fibre, and it is downright unfeasible to expect the same of a human. Again, Boyden is on the case. Together with his former student Christian Wentz, he has developed a wireless optogenetics helmet. It weighs less than a gramme, contains 16 LEDs for flashing opsin-infused neurons, and is powered by magnetic fields produced by a distant transmitter, which can plug into a laptop's USB port.

PHOTOGRAPHY: ALAN HORSAGER; EOS NEUROSCIENCE



If you talk to scientists about optogenetics, words such as "transformative" and "Nobel" get bandied around a lot. If you talk to Boyden about it, you realise that he would be dissatisfied with pioneering just one revolutionary technique in his lifetime. "Optogenetics is a great tool but by itself it won't solve the brain," he says. "You can control things, but if you can't observe what's going on, you won't fully understand it."

Observing the brain is the goal of the auto-patcher project. Patch-clamping is the ultimate technique for neural voyeurs – a way of connecting the dots between the electricity coursing through a neuron and the biochemistry going on inside it. Boyden and Craig Forest's student Suhasa Kodandaramaiah spent four months learning how to patch-clamp a single neuron in a living brain (making him the only person at MIT who can) and just under two years writing a script that would do the same.

Left: Boyden in his lab. *Above, top*: a blind mouse is unable to detect the lit exit, but Boyden's blind, optogenetic mouse (*below*) can still find the light

The robot can clamp single neurons as well as a skilled human can, and the team have already upgraded it to deal with several cells. It is still a challenging task, but the team have already doubled the previous record by clamping four neurons at once. Boyden adds, "I like to think of 'dynamic connectomics', where we can see how connections change, second by second, minute by minute, throughout changes in attention, learning, diseases and so on."

Others have been quick to realise the robot's potential. "At the Society for Neuroscience meeting in Washington DC in November, over 100 people left me their email and asked me to contact them as soon as this is commercially available," says Forest. "We also talked to Pfizer and they said this could allow them to test how drugs affect neurons in a living brain." Forest has created a start-up called Neuromatic Devices to sell the patch-clamping robots, but Boyden has no ownership of this or any other company that has spun out of his work. He has made the instructions for building an auto-patcher, like those for his optogenetic techniques, freely available online. "I just want to move the field along as fast as we can," says Boyden.

Boyden is also working on other ways of mapping the connections between neurons, by delivering precise bursts of light to optogenetically enhanced cells. One such tool, known as the waveguide array, is the work of his student, Anthony Zorzos. It is a grid of 100 needles mounted on a stamp-sized square. Each one funnels light from a central laser down parallel tracts and beams them outwards at ten individual points, shining on the neurons nearby.

In Boyden's dreams, all of these tools would eventually converge in a "brain co-processor" – a mechanical sidekick for the mind. "Imagine you had a stroke or Alzheimer's and lost a fraction of your brain," he says. "Could you have a machine that would read out info from the brain, compute what the missing part should have done and enter that information back in?" All of his tools fit within this framework, including techniques for reading information from neural circuits (the waveguide and auto-patcher) and entering data back into them (optogenetics). This is what "solving the brain" looks like: we would know so much about neural computations that we could duplicate them. We could stop epileptic seizures in their tracks by detecting telltale patterns of brain activity and blocking the neurons involved. We could abate the risk-taking urges of drug addicts or the long-term fears of people with post-traumatic stress disorder. We could boost our problem-solving abilities.

Such goals may be distant and optimistic, but they keep Boyden excited. In the meantime, he has more pressing concerns. His wife has just given birth to their second child, Athena. She is on newborn duty, while Boyden looks after their two-year-old son, Edward. Even by his standards, it is a busy and chaotic time. By day, he is building tools that allow us to engineer the brain. By night, he is caring for the two brains that he personally helped to build.

Ed Yong wrote about mapping the Amazon in 03.12

GIANT

HUGH HERR BEGAN HIS SEARCH FOR THE PERFECT PROSTHETIC IN 1982. FINALLY, HE'S FOUND THE RIGHT FIT

BY MADHUMITA VENKATARAMANAN

STEPS

PHOTOGRAPHY: CHRIS CRISMAN

STILL LIFE: DAVID ARKY

HUGH HERR KEEPS SIX PAIRS OF LEGS IN HIS CUPBOARD.

Most days, he wears a set of bionic ankle-and-foot devices which are motorised, making them ideal for walking long distances. When trail-running, he swaps them for large C-shaped carbon legs ("Just like the ones Olympic sprinter Oscar Pistorius wears," he says). And for climbing he's got at least four different types. Some are designed for rocky cliffs and others for specific tasks: rubber feet for vertical walls, tapered blades to penetrate rock fissures and crampon-claws for icy surfaces. "I am made of aluminium, silicon, carbon composites and titanium," the 48-year-old says. "Depending on my activity, I can adapt."

Herr's love of physical exercise is purely recreational. At his day job as director of the Biomechatronics Group at MIT he researches the mechanics of movement and builds high-performance robot legs. His goal: to blur the lines between human disability and human augmentation, using technology.

Herr's desire to design leg prostheses began in 1982 when a climbing accident left the then-17-year-old a double amputee. Although he was walking within months of his accident, the prostheses available in the early 80s were limited and inflexible. "Because I was desperate to climb again, I was pushed into fashioning my own limbs and testing them on myself," he says. Herr, who now has 14 patents related to prosthetic limbs, including a computerised knee and the BiOM ankle and foot, arrived at MIT in 1993 as a graduate student in mechanical engineering. His favourite phrase, he says, is: "There is no such thing as a disabled person, only disabled technologies."

The Biomechatronics lab addresses physical interfaces between humans and machines, and how these might be enhanced. Herr's team studies how best mechanically to attach prosthetics and braces to bodies, builds smart limbs that can adjust to a person's individual gait, and connects prosthetics back to the nervous system so that mechanical limbs can detect motor intent in the wearer.

Currently, Herr is working on the first problem: how to build a socket that attaches a robot limb to a person without inflicting pain. "If you ask a hundred leg amputees about the number-one problem they want solved, a hundred will say the socket," Herr says. "Millions of people are in pain, all because an advanced socket should exist and it doesn't." Modern sockets are simple carbon composites that are moulded into the shape of an amputee's stump using sculpting techniques. "We are dynamic creatures, so our interfaces can't be fixed," Herr says. He is currently working with Media Lab colleague and assistant professor of media arts and sciences Neri Oxman (see p68) to build a flexible socket embedded with pressure sensors that can change shape when the stump swells or shrinks. In tests conducted on walking amputees, a prototype has reduced pressure from the socket by 20 per cent, according to Herr.

Oxman, who is an architect and designer, is Herr's climbing partner and has worked closely with him

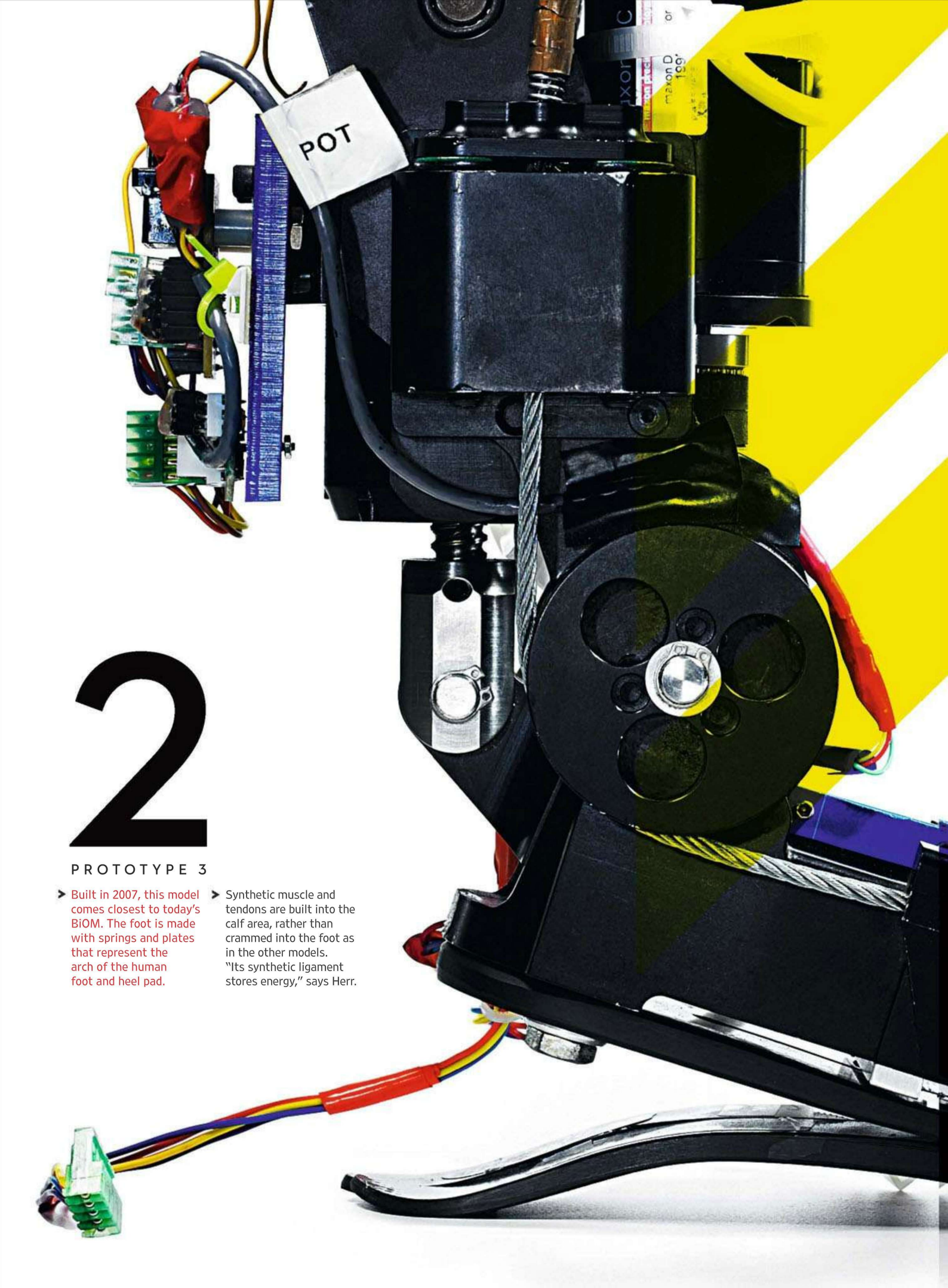
> The ankle-foot contains nine sensors, including one to gauge position of the ankle joint, a heat sensor, three accelerometers and three rate gyros, which senses the foot's angle.

THIS PROTOTYPE ANKLE-FOOT, ALONG WITH THOSE OVERLEAF, WAS DISCARDED BY HERR. BUT EACH IS A MILESTONE ALONG A JOURNEY TO CREATING THE BiOM PROSTHESIS (SHOWN ON THE PREVIOUS PAGE)

1 PROTOTYPE 6

Built in 2008, this version has its electronics fully exposed. "We decided to hang the brains and guts on the outside so we could access them quickly and make changes," says Herr.

The key feature of this 2008-built prototype is its synthetic version of the human subtalar joint, located towards the back of the foot. The joint allows the ankle to twist.



2

PROTOTYPE 3

- Built in 2007, this model comes closest to today's BiOM. The foot is made with springs and plates that represent the arch of the human foot and heel pad.
- Synthetic muscle and tendons are built into the calf area, rather than crammed into the foot as in the other models. "Its synthetic ligament stores energy," says Herr.

since 2008. "He is a rare kind of thinker, because he can translate big visions into a set of detailed protocols," she says. The two are also working together on designing an exoskeleton with a spiderweb structure, to enhance climbers' athleticism. "The suit would be made of many springs – as you stretch your muscles, the suit will also expand, turning your body into a giant, moving spring," says Oxman.

Herr also runs a company called iWalk, based in Bedford, Massachusetts, that commercialises and sells the BiOM ankle-and-foot prosthesis. Priced at about £45,000, the BiOM contains three microprocessors and 12 sensors that measure force, pressure and motion. With each step, a motor powered by a 25V battery and a set of springs provide the wearer with an extra push, replicating the work of human calf muscles and the Achilles tendon. Sensors adjust the position of the foot, reducing the amount of energy required to walk and giving the wearer a natural-looking gait. "We've managed to dynamically capture how a real foot and ankle behave, at least on level surfaces," Herr says.

IN HERR'S VIEW OF THE FUTURE, PROSTHETICS WILL SOON BE SUPERIOR TO, AND MORE COVETED, THAN BIOLOGICAL LIMBS

Will Borden can relate. The 40-year-old high-school history teacher from Cambridge, Massachusetts, lost his right leg in a car accident in 1993. He was fitted with a J-shaped carbon-fibre foot that proved adequate: held fixed at a 90° angle, it allowed him to walk, run and even play tennis. In 2008, he was the one of the first people to test an early prototype of the BiOM. "I could immediately feel its power," he says. "I started walking faster and faster, it felt like a race between my human and my bionic side." The flexible ankle joint means Borden can now walk to and from work without tiring, and the socket is far less painful. "It's exhilarating," he says.

Next, Herr wants to design a bionic brace for people with damaged knees. He says a wraparound knee brace will allow users to walk and run without injuring their joints. The brace's functionality can be programmed to individual specifications – ideal tightness, pressure or force – using a mobile phone. "In a decade, one will commonly see people jogging with a robot strapped on – either to prevent injury, or to heal it," Herr says.

In Herr's view of the future, prosthetics will soon be superior to, and more coveted than, biological limbs. "He doesn't see disability, just beauty," Borden says. Playing out Herr's prophecy is athlete and double amputee Oscar Pistorius, who ran at the London 2012 Olympic *and* Paralympic Games in the summer. In 2008, Herr was the biomechanics expert testifying for Pistorius's case at the Court of Arbitration for Sport in Switzerland, causing the court to overturn an International Association of Athletics Federations ban imposed on Pistorius competing against able-bodied athletes. Herr continued to be the South African athlete's supporter and scientific adviser throughout the 2012 Games. "I was in London in August to watch Oscar compete," he says. "The atmosphere was electric." Pistorius came second in his 400m Olympic heat, reaching the event's semi-final, but didn't qualify for the main event. Herr's prediction of athletes' prosthetics becoming superior to biological limbs doesn't look like coming true just yet, but it only may be a matter of time.

> The prototype's curved foot plates can bend and lay flat on the ground. "If I stood on the side of a hill, it would bend to be flat," says Herr. "It behaves like the real thing."

> It contains a 200W motor to mimic a calf muscle and a pulley mirroring an ankle joint. The pulley is connected to a box containing synthetic ligaments.

3

PROTOTYPE 5

- This 2007-built model is very similar to the sixth prototype. "I stuffed the tendon and calf muscle into the foot region," says Herr. "They looked nothing like a biological foot."
- The prosthesis contains a release spring that mimics the human heel. Despite this addition, it only produced 300W of power, not sufficient for normal walking.

FORWARD MARCH: UNUSED PROTOTYPES FROM THE VAULTS

The BiOM prosthesis is the latest in a long line of ankle-foot prototypes, worked on by Herr and his team. "We spent millions of dollars going down several expensive rabbit holes until we perfected our design," says Herr. Here are six of his team's early efforts, all of which helped them to hone, test and build their preferred working prosthetic in 2008.

PROTOTYPE 1, 2004
This early model has an electronic damper that creates resistance to motion. "One of my flawed ideas," says Herr. "The damper adds weight and size, and is unnecessary when you have a large motor."

PROTOTYPE 4, 2007
This was the lab's first attempt at packing the calf muscle and Achilles tendon into the foot region to make the prosthetic more compact. "A disaster," says Herr. "It was far too heavy; it weighed close to 3kg."

PROTOTYPE 2, 2005
This dummy contained a new type of motor – a pancake motor – made to work like a real ankle. But it didn't look like one. "Aesthetically and functionally, humans don't like fat ankles," says Herr.

PROTOTYPE 5, 2007
This prosthetic (*see left*) proved unsuccessful in walking studies, although it was displayed at the Museum of Modern Art in New York in 2008, as part of the Design and the Elastic Mind exhibition.

PROTOTYPE 3, 2006
The structure of this prototype (*see p120*) was too high, making it hard to fit the "average" amputee. "I worked out how to make the final version shorter by limiting the range of ankle movement," says Herr.

PROTOTYPE 6, 2008
This prosthetic contains a brushless motor, three micro-processors and nine sensors. It also has springs to emulate the Achilles tendon and the subtalar joint, but these proved to be unsuccessful on test.

EMOTION MACHINES

PHOTOGRAPHY:

EVAN KAFKA

INSTEAD OF COMPUTERS THAT CAN REPLACE US, WHY NOT MAKE ONES THAT UNDERSTAND US? WELCOME TO ROS PICARD'S TOUCHY-FEELY WORLD OF EMPATHIC TECH

BY

ADAM HIGGINBOTHAM

woman – and, worse than that, a blonde – Rosalind Picard was determined to have nothing to do with the study of emotion. Twenty years ago, for a young research scientist in the male-dominated world of electrical engineering, there were already enough stereotypes working against her. Studying something as irrational as emotion could only open her to ridicule. After years of chip design at Bell Laboratories in Holmdel, New Jersey, her research was as cold-blooded as that of any of her peers: content-based retrieval, modelling machine architecture and building algorithms to enable computers to see. This was a central part of the quest to build a true artificial intelligence which, like many at the time, Picard believed could be achieved by reproducing the higher functions of the human brain – the visual cortex, the auditory cortex – that were involved in most perceptual experiences.

But, prompted by reading *The Man Who Tasted Shapes*, neurologist Richard Cytowic's case study of synaesthesia in which the subject's strange sensory episodes took place while his cortex was shutting down, she began to doubt that perception was as straightforward as she had thought. Picard had became intrigued by the idea that the limbic system – traditionally regarded as the most ancient part of the brain and the home of memory, attention and emotion – could have a role in the process. Reading more, she learned that emotion not only affects what goes into the memory, but also guides perception by helping make choices between different stimuli – determining what we find interesting. The more Picard discovered about the limbic system, the clearer it became that any attempt to build a perceiving computer that did not take account of emotion would fail. "I realised we're not going to build intelligent machines until we build, if not something we call emotion, then something that functions like our emotion systems."

Still, Picard didn't want to be associated with work on emotion; she tried to talk colleagues into it, but failed. Eventually, she reluctantly took on the work herself and in 1995 circulated a tech report she called Affective Computing, arguing the importance of integrating emotions into the machine environment. In the radical environment of the Media Lab, this was just the kind of work she was expected to do: one colleague appeared in the doorway of her office shaking a copy of it and approvingly declaring it to be "crazy".

Elsewhere, the reaction to her ideas was just as she had feared; her manifesto was rejected from every peer-reviewed publication she submitted it to. In 1997 one reviewer suggested it was better suited to an in-flight magazine. Later that year, at the Conference on Computer Vision and Pattern Recognition, an annual event that attracts specialists in the field from all over the world, she overheard a group of scientists discussing her. "That's Rosalind Picard," they said."She used to do respectable work."

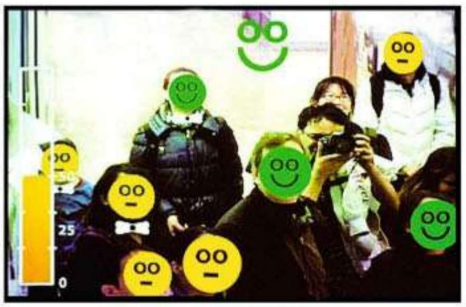
Today, Picard's tech note, and the book she followed it with in 1997, are credited with creating an entirely new field of study – one now significant enough to require its own journal. From her office overlooking the yawning meeting space of the Media Lab's East Laboratory – a two-storey-deep romper room scattered with experimental equipment and bric-a-brac – she now oversees the Affective Computing research group. With a team of ten graduate students working on projects as disparate as "emotional social prosthetics" for autistic children, and robot sponsors for recovering drug addicts, for more than a decade the group has been pioneering work in emotion measurement and communication technology. Last year, Picard and her Media Lab colleague, Egyptian-born computer scientist Rana El Kaliouby, spun off a private company, Affectiva, to exploit emotion-recognition technology for use in advertising and marketing.

In the years since she first conceived the term "affective computing", Picard says that the aims of artificial-intelligence research have evolved subtly but profoundly. Both in Picard's lab and in the field at large, work has moved away from perfecting machines that are intelligent for their own sake, towards building those that can use emotional intelligence to help us solve problems. Today, her research group concentrates on creating tools that help computers understand human emotions, not to try to mimic them. This has the added benefit of shifting research away from the pursuit of a goal – computer consciousness – that threatened to make humans obsolete. "We've decided it's more about building a better human-machine combination," Picard explains late one afternoon in June, "than it is about building a machine where we will be lucky if it wants us around as a household pet."

In the beginning, much of the work of the Affective Computing group was focused on making computers easier for humans to get along with. "Computers were frustrating," Picard says. "Human/computer interaction is intrinsically natural and social. I thought, we're trying to build intelligent machines, but people emote at machines and machines have been unintelligent in not responding to it."

Human beings have long had unreasonable expectations of computer empathy. Regardless of how rationally aware we might be that they are boxes of components processing information, we interact with computers as if they are people – and become very exercised when the machine doesn't respond in kind. In a 2010 Intel survey, 80 per cent of people admitted having become frustrated with their computer, while 33 per cent described seeing a colleague shouting abuse at theirs; 24 per cent admitted hitting their screen or keyboard. "I love the story of the chef in New York who threw his computer in a deep-fat fryer," Picard says. "There was a guy who fired several shots through the monitor and several through the hard drive. You don't do that because you're having a great experience."

Picard's favourite example of computers' lack of emotional intelligence is Clippy, the relentlessly perky animated paperclip employed as an onscreen assistant in many iterations of Microsoft Office – and infamously detested by users. Clippy materialised, unbidden, each time the software suspected you needed assistance – with writing a letter or spelling a word – bursting with cheerful suggestions, paying no regard to how busy or bad-tempered the user was, and even when repeatedly sent away insisted on doing a little dance before departing. "That is emotionally unintelligent behaviour," Picard says.



A live feed rigged up in a corridor of MIT measures the emotions of casual passers-by in real time

Clippy proved so unpopular that Microsoft approached the research group to find ways in which he would know when he was unwelcome. The team devised a squeezable mouse with pressure sensors designed to detect tension; in one demonstration a student tried to address a letter to a Mr Abotu, a name the software repeatedly insisted on changing to "Mr About". As the software registered the student's grip tightening in fury, Clippy appeared and observed, "It seems as if you're frustrated. Should I turn off AutoCorrect?"

The squeezable mouse was one of many tools the Affective Computing group devised at the end of the 90s to enable machines to read emotional cues better. These included spectacles that could detect a frown and a hat with a camera to scan facial expressions. There was also something named the "galvactivator", a glove that measured the electrical current conducted between two points on the skin, which increases with sweating, to provide an index of emotional arousal. Back in 1999, MIT students used the galvactivator to enhance *Quake* – plugged into a modified version of the game, it made characters leap backwards when it registered players' shock. But the interface it provided was far more significant than this use suggests: the wearable biosensors created then have become the basis of the most far-reaching applications yet to emerge from Picard's lab.

FACING THE AUDIENCE

IN ORDER TO MEASURE THE EFFECTIVENESS OF A COMMERCIAL, AFFDEX GAUGES THE VIEWERS' EMOTIONS USING SOPHISTICATED METRICS THAT ANALYSE EVEN NUANCED FACIAL EXPRESSIONS

CAPTURE Expressions are caught, analysed and incorporated into the dashboard results

INTEGRATION Ads are combined with emotion traces and metrics for intuitive, interactive analysis

ANALYSIS Automatic breakdown and examination of segmentation through survey integration

SYNCHRONY Emotion traces are tied to the advertisement for moment-by-moment insight

In her office on the second floor of MIT's Media Lab building, Picard shakes out a small plastic bag over her desk. Picking through a selection of grubby-looking towelling sweatbands, she alights on a dusty pink one, decorated with a bow. "Ah," Picard says, "there's the one I could have worn to that cocktail party the other night." Inside each of the bands is a prototype of Affectiva's Q Sensor – a metal and plastic lozenge slightly larger than a box of matches – that records electrodermal response and wirelessly transmits the data to a laptop or smartphone. Until now the only way to gather such data has been through fingertip electrodes, which can only be worn for up to 20 minutes at

a time. But the MIT team's wearable and durable biosensor now makes it possible to map an individual's stress levels in real time, for weeks at a stretch. Picard and her students have been enthusiastic guinea pigs, providing thousands of hours of information about their emotional states; when WIRED arrives, the first thing Picard does is strap on a sensor, which streams data to the computer on her desk. Picard knows how her nervous system reacts to REM sleep, parties, being ill and giving presentations; she can show you in detail how she reacted to taking her son on a Six Flags rollercoaster for his birthday (she found getting the boy and his friends to the theme park more stressful than anything that happened inside its gates).

> 'I REALISED WE'RE NOT GOING TO BUILD INTELLIGENT MACHINES UNTIL WE BUILD, IF NOT SOMETHING WE CALL EMOTION. THEN SOMETHING THAT FUNCTIONS LIKE OUR EMOTION SYSTEMS FUNCTION.'

But the team's most extensive field tests of the sensor so far have been with autistic children. On most parts of the autism spectrum, sufferers have the same limitations in their interactions with others that humans encounter with computers. They lack empathy and find it hard to read the social and emotional cues of others. For many, communicating their feelings is impossible; many have language difficulties; some simply cannot speak. One of the worst symptoms of this emotional opacity is the apparently sudden and inexplicable onset of what Picard calls "challenging events" or "meltdowns", in which the children express frustration by biting or hitting themselves or others. These episodes can seem all the more unexpected because they're often preceded by apparent calm. As the child grows up the meltdowns can be increasingly dangerous to themselves and others; some parents find no alternative to committing their children to institutions where their violent outbursts can mor easily be managed. But in an ongoing trial with a group of 15 children at the Groden Center for Autism Research in Providence, Rhode Island, the Affective Computing group is using the Q Sensor to reveal the hidden meteorology of these emotional storms.

The biosensors showed that, far from arriving abruptly, meltdowns were the climax of gradually rising stress levels, which, in these often hypersensitive children, caused a sensory overload and shutdown – which gave them an appearance of placid relaxation. If the stress continued, the child's readings finally spiked into meltdown. By monitoring a child's readings in real time through the sensor, one can isolate and remove these causes of the stress as soon as they appear.

Biosensors created for the galvactivator glove are widely used

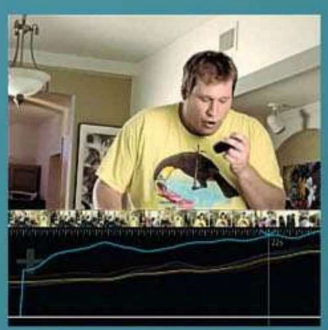
The light that the Q Sensor can shed into the minds of autistic people may also save lives. Picard cites a boy, treated by research pioneer Ted Carr, who had very limited language and was, Picard says, "unable to get his words to match his thoughts". The boy would often respond to stress or pain with self-injury, banging his head against a wall to calm himself – the action released soothing endorphins into his bloodstream. When one day the boy's head-banging began to increase unexpectedly, his carers had no explanation until he was hospitalised with acute appendicitis, and died. "This boy had no way of describing his pain," Picard says, and gestures to her own Q Sensor reading slowly tracking across the monitor in front of her. "This goes up with pain. What if someone had seen this signal go through the roof and said, 'What's going on?', and taken him to be checked out?"

The Affectiva offices are on the second floor of a bland two-storey red-brick building on an industrial estate next to a dentist's surgery in the Boston suburb of Waltham. When WIRED visits in the summer, the company has been installed for six months, but the empty bookshelves and unmarked whiteboards in rows of deserted offices suggest hiring is still under way. In the conference room, Rana El Kaliouby flips open her MacBook to demonstrate her invention, the company's flagship product: Affdex, a cloud-based application that makes it possible for practically any digital device to read human emotions.

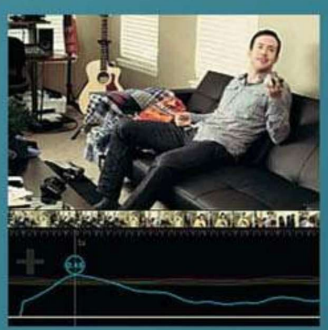
Like the Q Sensor, Affdex was proved in the crucible of autism research. In 2001, El Kaliouby – whose master's thesis at the American University in Cairo had been written on an elementary facial-tracking system

MEASURING THE MOOD

AS THE COMMERCIAL UNFOLDS, THE VIEWERS' RESPONSES ARE MEASURED AND SHOWN AS A GRAPH BELOW THE SCREEN. ANALYSTS CAN TOGGLE BETWEEN GRAPHS

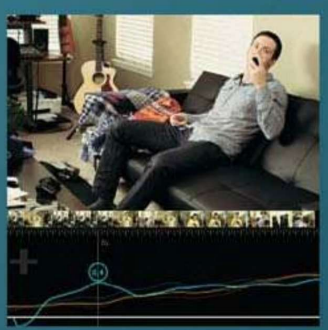


SMILE The viewer is amused by the narrative from the start



SURPRISE A twist in the story causes a spike in the graph

CONFUSION A simple scenario keeps confusion levels low



VALENCE The steady line shows that viewers are relaxed

for computers – began conducting doctoral work at Cambridge University on developing an emotionally intelligent machine that could read faces. She knew nothing about autism until, giving a lecture in which she discussed the difficulties of teaching a computer to recognise expressions and map them to emotional states, an audience member said that the problems sounded just like those experienced by his brother. "My brother is autistic," he said.

Fascinated by the possibility that she could borrow from autism theory to build an emotionally intelligent machine, El Kaliouby contacted Simon Baron-Cohen, head of the Research Centre in Cambridge. Baron-Cohen – a cousin of comedian Sacha – was building a taxonomy of the emotional states that people can communicate using their faces, and had created a video database of six actors performing 4,000 permutations of 24 different emotions – not only happy or sad, but also more nuanced states such as confused or seductive. He was using the videos in a study, teaching autism sufferers to interpret the expressions, to ease their interactions in the outside world.

El Kaliouby wanted to use them for much the same thing, except that her pupil was a computer. She wrote software that enabled the machine to analyse the video images, and lock on to 20 different feature points on the faces of the actors. The computer then mapped the patterns of pixels it saw to identify individual expressions – composed of face tilts, nose wrinkles, eyebrow raises – and codify groups of those expressions into emotional states classified by Baron-Cohen. "And then I realised," says El Kaliouby, "wouldn't it be so cool if we took that technology – that's now trained using all this data – and applied it to improved human communication."

Her first thought was to use the system to create a device that could provide autistic children with the social feedback they couldn't perceive for themselves. This was the conception of the "emotional social-intelligence prosthesis", or ESP – a series of wearable devices, culminating in a pair of glasses with a webcam and an LED built into the frames. In conversation, the webcam pointed at the face of anyone the wearer spoke to, providing a real-time feed of their expression and head movements for streaming analysis by El Kaliouby's software. The LED gave the wearer feedback about the meaning of the listener's expression – engaged (green), neutral (amber) or bored (red) – with an accuracy of up to 88 per cent. Eventually, the capabilities expanded beyond basic emotions, to embrace, for example, the subtleties of "thinking" (brooding, choosing and judging). By employing machine learning, the more expressions it saw, the more accurate it became. El Kaliouby christened it Mindreader.

ATTENTION The arrival of the attack dogs grabs the viewer

In 2004, Picard and El Kaliouby met when Picard was included on the committee for El Kaliouby's dissertation, and the two began collaborating almost immediately. Two years later, El Kaliouby joined her at the Media Lab, and they embarked on a five-year study using their core technology – the Q Sensor and Mindreader – with the children at the Groden Center. Each year, the team presented their results to visiting commercial sponsors of the Media Lab, and each year they heard the same thing: the autism work was impressive, but the technology had potentially more far-reaching applications in marketing and product testing. "We realised, wow, this could very well go beyond autism," El Kaliouby says. "This could help people around the world communicate. This could help bridge the gap between consumers and businesses."

Picard and El Kaliouby believed the best way to fulfil this potential was by drawing more students into the research programme, and went to Frank Moss, then director of the Media Lab, for permission to expand it. He refused. If they really wanted the tools they had developed to reach as many people as possible, he told them, they should spin off their own business. Reluctantly – they wanted to conduct research, not run a company – in 2009, they agreed.

Affectiva was launched last summer, offering both the Q Sensor and Affdex

as market-research tools, in collaboration with Millward Brown, the agency that handles ad testing for many *Fortune* 500 companies – to analyse viewer response to commercials. Graham Page, now head of Millward Brown's neuroscience practice, had spent almost ten years looking for technologies that could be used to improve their testing processes, but found many shared the same problem: "A lot of the methods that neuroscientists use don't translate well out of the lab. They're often cumbersome, or require devices that you have to strap on people's heads or around their chests," he says.

But Affdex was exactly what he had been looking for. Affectiva began with a pilot project in March this year based on recording the faces of viewers watching three TV ads broadcast during the Superbowl, which they streamed online; in the second quarter of 2012, they worked on 200 more commercials, for clients including Intel, Unilever and Coca-Cola.

In the conference room at Affectiva, El Kaliouby launches Affdex on her laptop and, with a couple of clicks, the webcam light winks on. After a camera check, as the machine makes sure my face fills the frame and is well enough lit to be analysed, a commercial for Doritos begins: two hefty frat-boy types in their living room; one complains that the other has eaten all the crisps. "Relax, bro-chaco," he replies, "this new phone I got will get us anything we want." He demonstrates, by asking the phone to send more Doritos, and then a sombrero, which magically plink into existence around him. His friend takes over: "Send three hot, wild girls."

"Sending three Rottweilers," replies the phone. Uh-oh. After the punch line – three women in low-cut outfits left in the suddenly deserted room, asking, "So... why are we here again?" – there's another pause while the machine transfers the video of my face into the cloud for processing, inferring emotional state from my expressions. It then presents its analysis of my reaction on a five-layer graph mapping a video strip of the ad against fluctuating emotion tracks: smile, surprise, confusion/dislike, attention and valence, or the intensity of feeling. My response is apparently close to the global average: a slowly rising track of smile and surprise, peaking with the appearance of the barking dogs; broadly, the ad is a success.

But there are subtle regional variations, inferred from IP addresses: it went down better in California than in Middle America. "We love our Siri-enabled phones out West," says Avril England, Affectiva's head of marketing. "Common-sense midwesterners don't have a lot of time for that flim-flam."

The appeal of the technology to the giant corporations is simple: it's a window into the minds of consumers. Once, ad testing agencies relied upon focus groups to contemplate what they'd seen, and code their reactions using scores out of ten on a piece of paper. But this was an often unreliable process, as each individual's interpretation of their own feelings is subject to the vagaries of self-awareness, memory and self-censorship, or what El Kaliouby calls a "cognitive filter". Affdex circumvents that filter, so test subjects unconsciously reveal themselves before the merciless eye of the computer.

In follow-up interviews about the Superbowl ads, some viewers reported that they didn't realise they'd done anything with their faces. "You don't think you're reacting, but you're giving some signs, whether it's furrowing your brow, leaning in, or tilting your head," England says. This has produced some surprising results. El Kaliouby cues up a TV commercial for a women's body lotion recently launched in India. The ad is simple: a man returns home to find his wife in the garden, where she draws his attention to her bare midriff with a tinkling charm dangling at her waist. He reaches out, touches her stomach and – bingo – is captivated by how smooth her skin feels. Cut to pack shot.

In March this year, Affectiva tested the commercial on Indian women, using both Affdex and conventional interviews. When asked to recall what happened in the advertisment, many women failed to mention that the woman's husband had touched her skin, suggesting that it was unmemorable and therefore ripe for trimming; the majority of those that did said that they found it offensive and that it should be removed from the broadcast version. Because, El Kaliouby explains, "this is a conservative culture – you don't show skin, or the guy touching his wife." Affdex told a rather different story. "When you looked at the participants' facial expressions, it was the exact opposite. A lot of the women were smiling. They *clearly* liked it." In April this year, the clients launched the campaign in India, using the full spot that the survey group had claimed to disapprove of. "If they hadn't used our technology for that particular test," England says, "they would have axed that scene for sure. And that scene is probably the most memorable."

In the US, Affectiva is now extending testing into longer formats: Sony recently employed the company to read audience responses to movie trailers, and Nielsen may use the system for TV ratings. Disney, England tells me, is considering using Affectiva's tools to product test all of its content. Taking El Kaliouby's face-reading system beyond the confines of the Media Lab has not only made the technology commercially viable; deploying its machine-learning capacity in the wild has also made it exponentially more perceptive.

Before Affectiva launched, it had taken El Kaliouby six years to show her system 1,000 separate clips of human faces. "Now we have about 90,000 in our platform," she says. "Around 54 million facial frames. And it's all global. Chinese faces, Indian faces, Russian faces: it keeps learning." Increasing the scale of samples from those measured in hundreds to the tens of thousands has led to a dramatic jump in accuracy – from 75 per cent in some expressions to more than 90 per cent; the machine can now detect any expression of disgust in 97 per cent of cases.

'We're trying to build intelligent machines. But people emote at machines and machines have been unintelligent in not responding'

The box that reads minds

The unobtrusive Affectiva Q Sensor constantly tracks the wearer's stress levels and transmits the data to a laptop or smartphone in real time. A graph shows simultaneously, allowing analysts to tally levels of skin conductance with physical exertion.

Rosalind Picard wears a Q Sensor at her desk in her office at MIT. When she started at MIT, working in a field as unscientific as emotional responses was for her "absolutely something to be avoided"

And the growing saturation of the world with webcam-equipped devices now means that computers that can read feelings may soon be unavoidable. In India, the Affectiva team was taking a four-year-old Nokia mobile into shopping malls and homes to run Affdex tests. "There are about four billion smartphones out there already," England says. "That's a lot of cameras."

If Affectiva realises its ambitions for its technology, it will add a striking new dimension to the ways in which, as social media and digital interaction tighten their grip on the globe, we all communicate with one another. "Everyone is increasingly attached to some form of technology – whether their mobile phone, tablets or laptops – for an increasingly large portion of their communication," England says. "And yet emotion is not being transferred to this format. We can really enrich these interactions in a way that's innately human – with emotional content that's more sophisticated than an emoticon or a 'like' button."

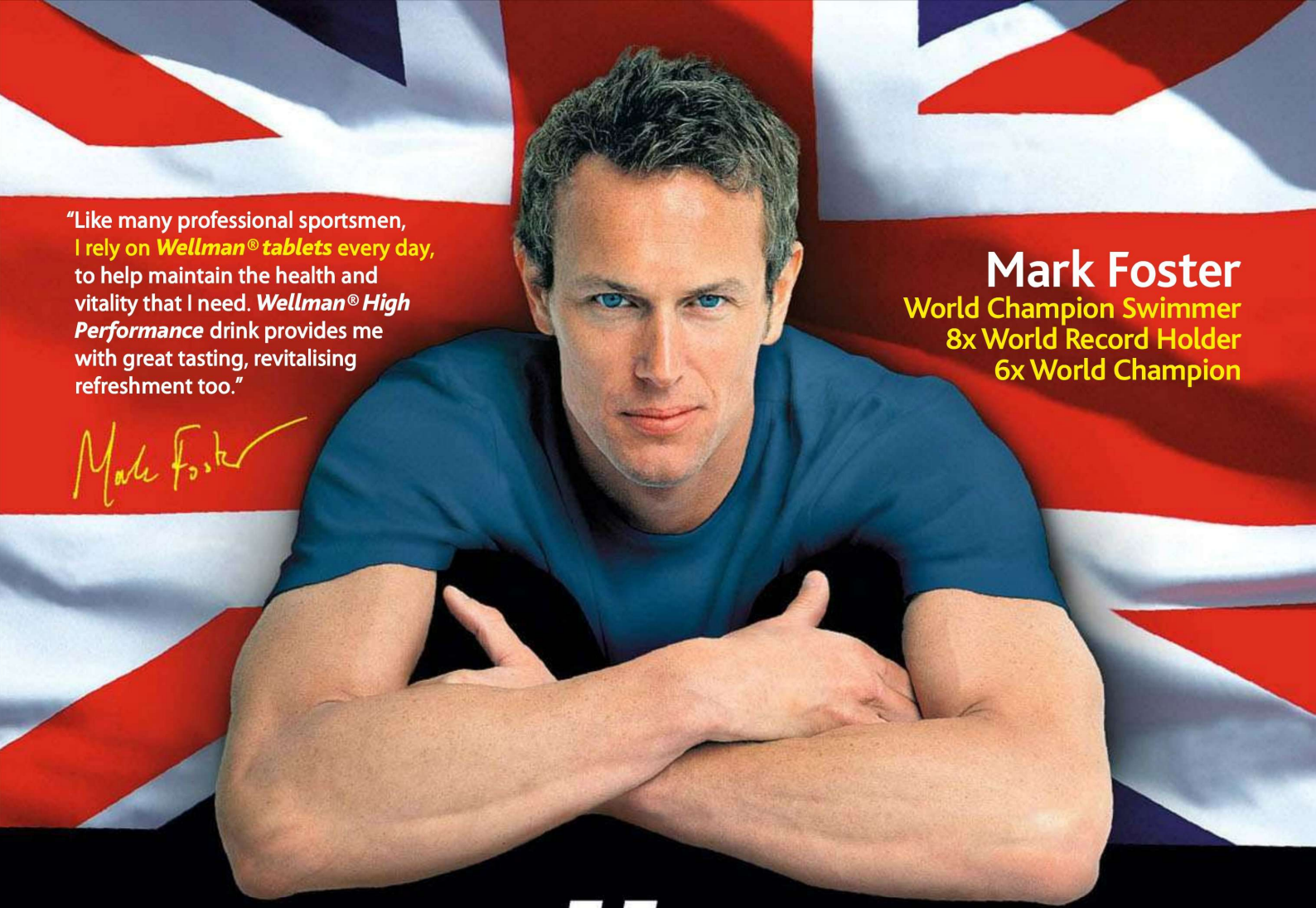
At the moment, what England is talking about is allowing Facebook or YouTube to read your expression as you watch a video of your friend's new baby and immediately post your reaction online. Picard, naturally, sees wider and more significant applications.

She is well aware of the potential dangers of the technology – the US National Security Agency has already expressed a discreet interest in her work – but says that Affectiva is focused on an ethical and open use of affective computing. "Our mission is to enable the communication of emotion when people want to opt in – not the extraction from them of things that they may not want to share." Yet she has a convincing example of how the face-reading system might be used anonymously to help bring more peaceful solutions to political problems. During the Arab Spring – when El Kaliouby was at home in Cairo – both she and Picard were struck by the gulf between what Hosni Mubarak was saying on television and the negative reactions of everyone El Kaliouby knew. "Mubarak was still talking to the people as if they liked what he was saying. What were his advisers telling him?" Picard asks. "If people had been able to Affdex their faces watching his speech – scowling, with asymmetric smiles and grimaces – then we would have a way to aggregate that very powerful feedback."

Since Picard first publicly outlined her notions of what affective computing could be in 1995, digital machines have become ever more intimately enmeshed in our lives. Picard's lab continues to find ways in which that process will only intensify. In the meantime, the goal that originally inspired her remains as far away as ever: the realisation of a true artificial intelligence is as remote now as it was 15 years ago. But Picard has no problem at all with this.

"Which would you rather invent? I want to invent the thing that enables us all to have better experiences in life. To better understand one another, to have deeper relationships, to help people who have an illness that has been misunderstood," she says. "I don't want to be the one who invented the thing that makes me feel like a dog."

Adam Higginbotham wrote about Chernobyl in 06.11



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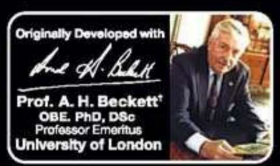
Vitamin supplements may benefit those with nutritionally inadequate diets. † Professor Beckett is not cited in the capacity of a health professional, but as a product inventor and former Chairman of Vitabiotics.

Boots vitamin awards 2011 winner



Britain's leading supplements for specific life stages

40 YEARS VITABIOTICS
SCIENCE OF HEALTHY LIVING

ADWELCONP 23-07-12

TEST

LAB RESULTS THIS MONTH: 11.12
- ACTION CAMERAS
- TABLETS FOR KIDS
- SELF-HEATING FOOD

EDITED BY JIM HILL

SPORT SHOTS

Tough, compact cams get rated for rugged outdoor adventuring

The GoPro HD HERO2's case also makes it water-resistant to 60 metres

PHOTOGRAPHY: SUN LEE; CORBIS

COOKING WITHOUT GAS

	HOT PACK	HOT CAN	HEATER MEALS	FOODIEZZ	WAYFAYRER
NET WEIGHT OF FOOD	300g	400g	300g	300g	300g
ENERGY IN KJ	1,572	1,380	1,545	1,752	1,524
CALORIES IN KCAL	375	328	369	414	363
CHEMICAL REACTANTS FOR HEAT	Calcium oxide, aluminium and water	Water and granular limestone	Magnesium and iron powder combined with salt water	Calcium oxide and water	Sodium carbonate, aluminium and water
PROTEIN PER PACK	27g	9.6g	14.4g	18.9g	20.7g
CARBOHYDRATE PER PACK	27.6g	53.6g	25.2g	29.7g	36.9g
FAT PER PACK	17.4g	8g	23.4g	24.3g	14.7g

HOW WE RATE **1.** A complete failure in every way **2.** Barely functional – don't buy it **3.** Serious flaws – buy with caution **4.** Downsides outweigh upsides **5.** Recommended, with reservations **6.** A solid product with some issues **7.** Very good, but not quite great **8.** Excellent, with only a few niggles **9.** Nearly flawless – buy it now **10.** Metaphysical product perfection

CHEESE & TOMATO RAVIOLI

Push the spike provided into holes at the top of the can and the meal heats up in 12 minutes. The sides get very hot quickly so you can't pick it up straightaway, but it is the most fuss-free heating system on test. The pasta texture seems acceptable, but the sauce tastes quite sugary. Although this has the lowest saturated-fat content of all the meals we tested, it includes 16g of sugar (about three teaspoons).

WIRED Free from artificial colours, flavours and preservatives

TIRED Reduced protein and fat mean it's less filling

£3.99 hotcan.com

LAMB CURRY

Simply pour the sodium water provided into the outer pocket, fold over and leave for 12 minutes. The curry has good amounts of sauce and meat. The "lamb" is actually mutton and although high in saturated fat, it does provide iron. While some of the spices have anti-inflammatory properties, the meal has quite a few chemical preservatives.

WIRED Good portion of meat

TIRED Mutton dressed as lamb

£6 cotswoldoutdoor.com

BREAKFAST

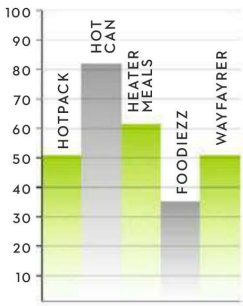
To heat this meal you have to press down hard in the middle of the box until the lining "softens", but it's difficult to tell instantly whether it has been activated. This has the highest calorie content of the meals, so is great for energy, but it features mostly saturated fat because of the types of meat used.

WIRED White beans, which provide slow-release energy and fibre

TIRED Additives and preservatives; looks revolting

€18 (pack of three) foodcase.nl

TEMP WHEN HEATED (°C)



BEEF STEW & DUMPLINGS

You need to have 40ml of water to use this meal, which means not all the tools for the job are provided. However, the meat was tender and the dumplings big – as wide as a 50p piece. The stew is quite watery and the meat content is only 22 per cent. The meal is 95-per-cent fat free – good if you're trying to lose weight but not if you're on an active camping trip.

WIRED Tasty and filling dumplings

TIRED No water included; more of a snack than a dinner

£5.50 millets.co.uk

PHOTOGRAPHY: SUN LEE; DAVE LIDWELL. WORDS: EMILY PECK

CAMPING CUISINE

You don't need a stove but are self-heating meals worth it?

MEATBALLS & PASTA

This comes with a small pouch of water, which triggers an exothermic reaction to heat the food. It also has a plate, on which to serve the meal, and cutlery. Douglas says that the meal supplies about a third of your daily protein, with an average calorie content for a ready meal. The pasta provides refined carbohydrates, which means it's more likely to boost your blood-sugar level and energy. There is no information about fibre content, salt or sugar on the packet.

WIRED Good balance of meaty protein and carbohydrates

TIRED Bland sauce and little nutritional information

£33.50 (pack of six)
hotpackmeals.co.uk

HOW WE TESTED

With the help of Becky Douglas, a nutritionist from Champneys, we chose five self-heating meals and analysed their ingredients, heating system, nutritional merit and taste. "Even a soggy-looking camp dinner will supply the energy needed to survive days in the wild," says Douglas. After a full day's boot camp and hike, we prepared each dish in the damp English countryside to measure serving temperatures, cooking times and consider their restorative value versus pack weight.

LIGHTS, CAMERA, MOTION

Designed for action, which of these cameras spun when taken for a spin?

If dry land isn't your thing, the JVC GC-XA1 camera is waterproof to up to five metres

JVC GC-XA1

This offers an interesting USP: Wi-Fi, which lets you use your PC, Android or iOS device as a viewfinder. Although the concept is sound, the execution is fiddly – prone to an unexplained connection error – and Mac OS isn't supported. But it's a fine camera: small, impervious to hazards (temperatures as low as -10°C, dust, water and impact) and capable of capturing 1080p video that's not far off the high quality of the GoPro's footage. Like the GoPro, it sports a broad range of video modes.

WIRED Tiny and tough
TIRED Unreliable Wi-Fi

£299.99 jvc.co.uk

READY FOR THEIR CLOSE-UPS

	JVC GC-XA1	GOPRO HD HERO2	DRIFT HD	OREGON SCIENTIFIC	VEHO MUVI HD10
MAX VIDEO RESOLUTION	1080p/30fps	1080p/30fps	1080p/30fps	720p/30fps	1080p/30fps
DATA STORAGE	SD card up to 64GB	SD card up to 32GB	microSD card up to 32GB	microSD card up to 32GB	microSD card up to 32GB (4GB supplied)
SCREEN	1.5" LCD	Basic setting display	1.5" LCD	None	1.5" LCD
DIMENSIONS	74 x 53 x 35mm	42 x 60 x 30mm	104 x 50 x 33mm	85 x 40 x 40mm	80 x 47 x 19mm
WEIGHT	126g	70g	120g	120g	81g

OREGON SCIENTIFIC

Sturdy and waterproof without the need for an extra case, the Oregon Scientific ATC Mini appears to be a steal. However, its performance leaves a lot to be desired: the 720p video runs at a slow 30fps, but that's nothing next to the washed-out colours, vast amounts of grainy noise in low-light shots and the colour banding instead of smooth gradations from light to dark.

WIRED Low cost; rugged case

TIRED Grainy video unsuited to low light

£119.99
uk.oregonscientific.com

GOPRO HD HERO2

GoPro has become the go-to brand for action cameras. After putting the Outdoor Edition of the HD HERO2 through its paces, we can see why: it's tiny, sturdy, simple to use and its footage is a degree above anything else in this test. Images are sharp, colours vivid and the contrast is deep. The low-light footage displays relatively little noise, and this is the only camera here that shoots at up to 120fps for smooth ultra-slo-mo playback. Even the stills look punchy and crisp.

WIRED Sharp and stable video

TIRED Lack of inbuilt display

£299.99 gopro.com

DRIFT HD

You'll need a £41.99 case to make the Drift HD fully waterproof but its simplicity is appealing. An LCD aids shot composition, and the rotatable lens allows you to mount the camera on its side. The case affects usability, making the buttons unresponsive to anything but the firmest push. Of the two mid-priced cameras, though, the Veho is champion in almost every area.

WIRED Simple controls and an easy set-up

TIRED Clumsy waterproof case

£165
driftinnovation.com

HOW WE TESTED

To find out how these action cameras coped with fast motion, dirt, vibration and the occasional whack, we enlisted the help of motocross rider James Jadell. We were chiefly interested in the quality of the video footage each camera provided. But the final scores also take into account user-friendliness, portability and robustness.

VEHO MUVI HD10

Despite being cheaper than the JVC and GoPro (even with the £59.95 waterproof casing), the Veho's footage isn't too far behind in terms of clarity and colour. It's not so good in low light, with distinct graininess. The lens's 160° field of view doesn't capture as much as a full fisheye, and the sensor is slower to react to sudden changes in brightness. But overall this is a solid camera.

WIRED Vivid colour and clarity

TIRED Fussy touch controls

£149.95 veho-uk.com

PHOTOGRAPHY: SUN LEE; DAVE LIDWELL. WORDS: SAM KIELDSEN

TABLET TABLE

	ARNOVA	LEXIBOOK	VTECH	APPLE	LEAPFROG
OS	ANDROID 4.0	ANDROID 2.2	PROPRIETARY	iOS	PROPRIETARY
DISPLAY	7" 800 X 480	7" 800 X 480	5" 480 X 272	9.7" 2,048 X 1,536	5" 480 X 272
MEMORY	1GB RAM/4GB STORAGE/ MICROSD TO 32GB	256MB RAM/4GB STORAGE	2GB STORAGE /MICROSD TO 32GB	1GB RAM/16-64GB STORAGE	4GB
CONNECTIVITY	WI-FI, USB	WI-FI, USB	USB	WI-FI, BLUE-TOOTH 4.0, 30-PIN DOCK CONNECTOR	USB, CARTRIDGE
AGE RANGE	4+	6+	4-9	NOT SPECIFIED	3-9

INNOTAB 2

The InnoTab 2 features a rotating camera, a motion sensor and a cartridge slot for expansion – similar to the LeapPad2. Rubberised corners are a nice touch, but less welcome are the slow loading times, which led to bored testers. Being less reliant on pricey cartridges (a LeapPad2 downside), and its excellent personalisation options make the InnoTab 2 ideal for younger kids.

WIRED Friendly voice
TIRED Slow loading

£85 vtechuk.com

Essentially a good-value, modern Android tablet that's dressed up in kids' clothing, this is ideal for older children to whom you don't want to lose your iPad. Ice Cream Sandwich 4.0 OS is up to date and looks good, if sparse, compared to iOS. However, the child-friendly apps lag behind the iTunes and the parental controls are fairly limited. It also doesn't come bundled with a case – an essential for younger users. Overall, though, this is a great first tablet.

WIRED Runs the latest Android OS
TIRED Case is extra

ChildPad, £99 arnovatech.com; case £9.99 amazon.co.uk

LEXIBOOK FIRST TABLET

rubberised soft surround is the only sign that this tablet designed for kids. s a fairly straight skin of the out-of-date Android 2.2 with a few extras. Our testers were left nonplussed the awkward vigation and hated the unresponsive uchscreen. Even the price isn't that great there are higher spec Android tablets r £100, such as the Kocaso M1050, while Google's Nexus 7 is a mere £60 more.

WIRED Rich features
TIRED Poor screen

£95 argos.co.uk

HOW WE TESTED

To help us to assess the tablets, we enlisted the help of three target users, Mia (5), Lois (7) and Henry (9). After they had spent several hours playing, we interviewed them and awarded scores for the tablets based on educational value, ruggedness (after a one-metre drop test), quality of apps available and ability to entertain.

APPLE IPAD WITH M-EDGE SUPERSHELL

All kids love iPad – but it's not exactly built for rough handling. The SuperShell closed-cell foam protector adds much-needed toughness, but the screen remains unprotected. The iPad's parental controls are limited, so it's not ideal if you're wary of your child using it alone. Apps are plentiful, cheap and lots of fun.

WIRED Quality apps
TIRED Expensive

iPad (16GB, Wi-Fi) £399 apple.com; M-Edge SuperShell £30 medgestore.com

PHOTOGRAPHY: SUN LEE; DAVE LIDWELL. WORDS: SIMON MUNK. A FULL APOLOGY FOR USING COMIC SANS CAN BE FOUND ON P140

EARLIEST ADOPTERS

Five screened ways to leave children to their own devices

LEAPFROG LEAPPAD2 EXPLORER

The new LeapPad features a series of useful upgrades: doubled memory (now 4GB), front and back cameras and an improved processor speed of 550Mhz. Apps, including quite complex stuff such as the *Nintendogs*-a-like *PetPad*, *Cartoon Director* and the games, run quickly and smoothly. But the catch is the cost of the cartridges, which provide most additional apps, with some selling for as much as £25.

WIRED Speedy processor

TIRED Expensive cartridges and apps

£90 leapfrog.com

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Most expensive object in the office this month:
An URWERK "Zeit Device" – valued at a fairly reasonable £595,000. We should probably check our insurance policy...

Overheard this month:
"If James Blunt can do it, [associate editor] Tom Cheshire can."
"Just so you know, I'm going to San Francisco for dinner. But I'm coming straight back again."
"It's the greatest WIRED logo ever. It's like a supergroup."

Arrivals and departures this month:
Fond farewells: Duncan Geere, wired.co.uk's news editor; Jack Dyson, promotions' senior copywriter. Best of luck.
Welcome hugs: Ian Steadman, wired.co.uk's new staff writer.

Crimes against typography:
The use of Comic Sans in the Test section (p153) was due to it being pre-printed on the building blocks which belong to the art director's daughter, Bella. Her father finds the presence of Comic Sans *in his own home* to be immensely upsetting, but they were a gift from a member of the family, and at two years old Bella does not yet know better. WIRED is still very sorry, though. We promise never to do it again.

Mouse lures, in order of most to least effective:
Butter; a Kit Kat; another mouse (opposite sex); peanut butter; a Milky Bar; leaves.

Most tattooed contributor:
Photographer Spencer Lowell, who satisfies WIRED's strict criterion of combining strong design with solid, evidence-based scientific thinking.

Extra credit:
Special thanks to all our friends at MIT – this issue would not have been possible without your thoughtful input and endless assistance.

MIT photography datastream:
Total number of shoots: 41, all occurring between July 27 and August 16.
Tightest scheduling: 39 of the shoots took place between July 27 and August 3.
Most shoots on one day: eight.
Most rescheduled shoot: MindRider (p27) – four times.
Shortest shoot: MindRider (p27) – nine minutes.
Longest shoot: Nexi (p24) – five hours.
Largest oyster consumed: 70mm x 50mm – force-fed to the art director by photographer Chris Crisman.

Sources for the WIRED index [p62]:
[1] [2] [3] [4] [5] [6] [7] [8] [9]
All statistics supplied by the MIT Media Lab.

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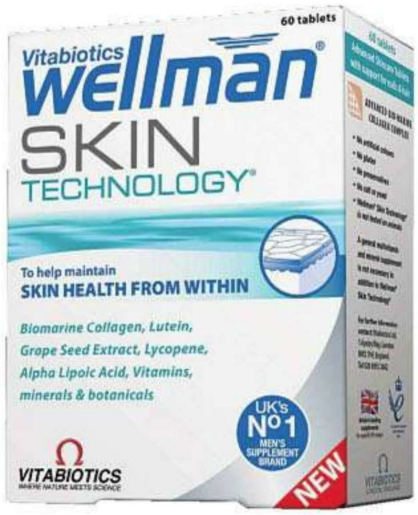

Vitabiotics Wellman Skin Technology is from the UK's number 1 men's supplement brand and has been developed to help men stay looking their very best. It includes nutrients such as niacin (vit.B3) and biotin which contribute to the maintainace of normal skin health. It also includes lycopene, lutein esters, alpha lipoic acid, green tea and grape seed extract.

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Tivoli Audio PAL BT. The original Tivoli Audio PAL is a multi-selling premium, portable analogue radio. The PAL BT sees the little portable "come of age" - now complete with Bluetooth technology. The result is an incredibly flexible, portable radio. A rechargeable, built-in battery is included in the price and the water-resistant unit is able to wirelessly communicate with Bluetooth-equipped audio devices!

The PAL BT is ideal for those who want to share the music stored on for example, Bluetooth-equipped phones.

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NEGROPONTE 1.0

NOTES FROM THE PAST
WIRED 1993 REVISITED

Message: 1.0 From: Nicholas Negroponte
Subject: HDTV – What's wrong with this picture?

Nicholas Negroponte, cofounder and first director of the Media Lab, was a monthly columnist for US WIRED between 1993 and 1998 – writing that informed his 1995 bestseller, *Being Digital*. Here we reprint his first, highly prescient column, from January 1993, issue 01.01.

During the late 60s, a few visionary Japanese asked themselves what the next evolutionary step in television would be. Their conclusion: higher resolution. They postulated that the move from black-and-white to colour would be followed by filmic-quality TV, which would be followed by 3D TV. They proceeded to develop something called Hi-Vision by scaling up TV as we know it in the analogue domain.

Around 1986, Europe awoke to the prospect of Japanese dominance of a new generation of television. For totally protectionist reasons, Europe developed its own analogue HDTV system, HD-MAC, making it impossible for Hi-Vision, which the US backed at the time, to become a world standard.

More recently, the US attacked the HDTV problem. However, this occurred at a time when it was possible to think about TV in the digital domain. The perseverance of a few has resulted in the US being the sole official proponent of a digital process – but we blew it by rooting our thinking in high definition.

The truth is that all these systems (currently under consideration for a national standard by the Federal Communications Commission – which President Clinton could then change) were constructed on the premise that increased image quality is the course to be pursuing. This is not the case.

Prime time is my time

What is needed is innovation in programming, delivery, and personalisation of content. All of this can be derived from being digital. The six-o'clock news can be not only delivered when you want it, but it also can be edited for you and randomly accessed by you. If the viewer wants an old Humphrey Bogart movie at 8.17pm, the telephone company will provide it over its twisted-pair copper lines. When you watch a baseball game, you'll be able to do so from any seat in the stadium.

As intelligence in the television system moves from the transmitter to the receiver, the difference between a TV and a personal computer will become negligible. It can be argued that today's TV set is the dumbest appliance in your home. As the television's intelligence increases, it will select video and receive signals in "unreal time". For instance, an hour's worth of video could be delivered over fibre to an intelligent TV in less than five seconds. All personal-computer vendors are adding video capabilities, creating the de facto TV set of the future. While this view is respected, it is not yet accepted worldwide.

Reckless nationalism

TV is so bound in culture that even some very democratic countries legislate the number of hours that foreign programming is allowed on their domestic channels. Less democratic nations use TV for propaganda and control. This blending of the cultural with the potentially political has crept into the technical arena and, for a variety of gratuitous economic reasons, we are presented with the likely nightmare that Japan, Europe and the United States will go in totally different directions vis-à-vis TV.

The front cover of US WIRED issue 01.01, January 1993

However, my bet is that 1993 will be the year these diverging courses correct themselves and converge, with Europe, Japan and the US collaborating. Why am I optimistic? For several reasons, all relating to one question: where is the action?

Nintendo, Sega, Apple and IBM – not your TV makers – will present us with a burst of multimedia products in the home very soon.

At least 200,000 direct broadcast satellite receivers, fully digital, will hit the stores in time for Christmas. And cable operators are trying to get digital TV even sooner than that. Namely, there will be an outpouring of digital video services that have absolutely nothing to do with HDTV, and they will be in place long before action can be taken on any FCC decision if, in fact, one is made.

Finally, a small band of multinational people are making progress in the standards arena. The roots of digital/video harmony reside in the Motion Picture Experts Group, MPEG, which is a bona fide part of ISO, the International Standards Organisation.

As scalable as the US Constitution

The biggest reason to be optimistic is that the digital world is tolerant of change. We will not be stuck with NTSC, PAL and SECAM, but we will command a bit stream that can be easily translated from one format to another, transcoded from one frame rate to another. The digital signals will tell your intelligent TV what to do with them.

Digital is a licence to grow. The manner in which memory and features are added to your PC or organiser will be the same for your TV. When people argue over the number of scan lines in the future, one can rest assured they are discussing the most irrelevant pieces of the puzzle. What they should be talking about are the consequences of being digital and the changes that will affect the delivery of information and entertainment. The future of video is no different from that of audio or data; it will be a bit stream.

To read a brand new WIRED *column by Nicholas Negroponte, see p101*

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