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University in Houston, Texas. "Large populations of robots are advantageous because they allow you to approach these same problems, but in fundamentally different ways."

Engineers have been tinkering away on distributed algorithms that can co-ordinate robotic swarms for more than a decade. McLurkin has already taken a significant step: he's deployed a swarm of more than 100 robots that can co-operatively explore new territories and even move objects around. But there's a catch. The swarms can only do so if those territories are immaculate rooms with no cracks wider than a hair, and those objects are covered in Velcro, which, conveniently, the robots are, too. Most perfectly smooth floors aren't in need of exploration, however, and there aren't many Velcro-covered objects in the world that need to be moved. But McLurkin thinks swarms running on his algorithms could be released into the wild next year – with a little help from the maker community.

At the end of 2012, McLurkin will crowdsource his robots to academic research labs and "hackerspaces" – DIY meccas packed with professional-level shop equipment for communities of dues-paying techies. The robots will be equipped with McLurkin's programmable multirobot operating system, which allows them to interact with one another and the environment, and thus behave as a co-ordinated swarm. The foundational hardware has the basics: a couple of computers, a radio, two motors, a gyro-accelerometer, a sound and light system, and enough infrared receivers and transmitters to communicate with eight other robots nearby, all of which are packed into the size of a small stack of CDs.

With the skeleton and the brains ready to go, it's up to the hackers to cobble together the skin and the viscera – McLurkin doesn't have any interest in being in the hardware business. They can add sensors for different odours, claws for gripping, small bulldozer blades, or wheel configurations that allow exploration in rough terrain, or even equip the bots for swimming. McLurkin envisions more futuristic applications arising from the increasingly sophisticated DIY crowd banging away at the hardware while he continues to optimise the software – his bread and butter – to co-ordinate larger and larger groups. Collections of thousands of robots could soon be building houses, inspecting pipes, disposing of domestic and municipal waste, finding land mines and even being built into engines and spacecraft to perform regular maintenance. McLurkin can make them swarm; the crowd can turn the swarm into something useful.

Lizzie Buchen is a science writer based in San Francisco

HAND-LOCK

Movement and hand position will replace passwords on smartphones – accelerometer data is harder to fake.

had formed the Li-Fi Consortium to raise awareness. Haas became Li-Fi's poster boy, lauded at the 2011 World Technology Awards.

At the 2012 Consumer Electronics Show in Las Vegas, Casio, a serious Li-Fi player, swapped data between two phones ten metres apart. The first had a large spot on its screen which rapidly changed colour. The receiving phone's camera sensor pointed at it and decoded the information. Casio says that similar spots could be added to TV commercials and electronic billboards to transmit a URL.

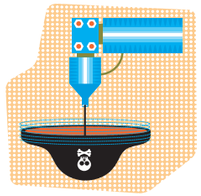
Haas has since texted a "LightMessage" to an unmodified Android device at a data rate of 2.5Kbps – much faster than Casio's 10bps. Data speeds are accelerating all the time. The Li-Fi Consortium targets 10Gbps, enough to comfortably download an HD movie.

Marketing is next. Haas and fellow academic Gordon Povey have launched a company called PureVLC, with investment from the smart-lighting industry. They hope to exploit a perceived crisis in the radio spectrum, the frequencies which carry phone calls and data.

Experts including Martin Cooper, inventor of the mobile phone, say fears are exaggerated, but the evolving phone industry cautiously welcomes Li-Fi. Indeed, Povey insists high-speed VLC will be integrated in several mobile devices by 2014. "Let me boldly predict that a volume product [from us] will be on the market by late 2013," he says.

Meanwhile, Casio has launched a free VLC app called *Picapicamera*, which allows users to share photos without using email addresses, text messages or social media usernames.

Michael Watts is a former editor at the Financial Times *who now writes on technology, business and travel*



PIRACY GOES 3D

In 2013 3D printers will fall below £350, creating a new challenge for copyright and intellectual-property laws: the pirating of physical goods through the sharing of CAD files.

As WIRED went to press, The Pirate Bay's "Physibles" category mostly consisted of gaming figures and a Mark Zuckerberg head. But look out for simple (and slightly more tasteful) commercial objects appearing soon.

MOLECULAR RAM

Random-access memory (RAM) is physically large and uses a lot of power, which is why smartphones have so little of it. Next year will bring a big step towards portable devices with laptop-like amounts of RAM, as a "molecular-memory transistor", developed by a team at Tel Aviv University, goes into manufacturing trials. Standard RAM consists of a capacitor whose charged state represents 1 or 0, and a transistor to read it. The Tel Aviv team has found a carbon molecule, C_{60}, that can act as both.

TECHNOLOGY

CURVY DISPLAYS

A new kind of glass, just 100 microns thick and as flexible as plastic film, will mean that monitors and tablet displays no longer have to be flat.

Willow glass, developed by Corning, can withstand the temperatures of up to 500°C that are part of high-end-display manufacturing. They can then be wrapped around any shape, opening the way to screens that give a more immersive viewing experience. Willow glass is also thinner than the plates currently used in many tablet displays, which will make the next generation of portable devices lighter too.

LI-FI SWITCHES ON

WITH AN INCREASINGLY BUSY RADIO SPECTRUM, WE WILL LEARN TO SEND DATA OPTICALLY. BY MICHAEL WATTS

It's still a fledgling, with much early hype, but next year should bring a commercial breakthrough for "Li-Fi", the adopted term for describing high-speed, optical wireless communications using electronically adapted LED lights (see WIRED 02.12). The technology of visible light communication (VLC) has come a long way from Alexander Graham Bell's Photophone, which in 1880 sent a shaky voice message by modulated light using a parabolic mirror. Researchers now view Li-Fi as a complementary, short-range alternative to Wi-Fi, with light instead of radio waves. It's cheaper, greener, much faster than Wi-Fi and more secure, because light cannot penetrate walls; nor is there RF interference and possible radiation leakage; and the LEDs are (until modified) ordinary bulbs.

True, its range is far less, so it may be best for communicating in confined or potentially dangerous locations, such as hospitals and petrochemical plants, on aircraft and under water, where radio frequencies are restricted, for smart control in the home or for navigating large buildings such as warehouses and museums (point your Li-Fi device at a painting and it will give you its details). Other possibilities include uplinking computers and mobile phones via streetlamps and electric shop signage. As long as LED light is present, either direct or reflected, any house, office or public building could, theoretically, become a Li-Fi hotspot.

Li-Fi works by linking a modem via a high-speed cable to a source that transmits light modulated at many hundreds of megabits per second. The flickering signals, too fast to be detected by human eyes, transmit data to light-sensitive receivers – such as a smartphone camera.

Li-Fi's progress has been dizzying. In July 2011, Harald Haas, a German professor at Edinburgh University, was the first to publicly demonstrate how to turn semiconductor LEDs into broadband wireless transmission systems. Within months, international companies led by Fraunhofer

VLC parts: two multi-chip LED elements, an LED with lens, and an LED lighting module

SPOT ILLUSTRATION: GILLIAN BLEASE

ANGEL TECHNOLOGY

BEHAVIOURAL ECONOMICS HAS FOUND NEW WAYS TO NUDGE US. BY SENDHIL MULLAINATHAN AND SAUGATO DATTA

Our essays do not have nearly as many typos as they once did. We can resolve arguments about matters of fact in a matter of seconds. We do not get lost on the road nearly as often as we used to. All of this is thanks to technology. Spell checks, Wikipedia and GPS devices have made us more attentive writers, less glib conversationalists and superior navigators. Technology has made us more efficient. But in 2013, technology will change us in another way: it will also make us more angelic.

What time did you wake up this morning? And what time did you intend to get up? This daily struggle is almost a comical tug of war. Your angelic side sets the alarm clock with enough time to go for a workout and read the paper. But when it rings, your devilish side says, "Go on, sleep a little longer." Now, thanks to neuroscience and experimental psychology, we know this tug of war is a very real struggle between an impulsive self and a far-sighted self. But the devil has an accomplice in this tug of war. The snooze button, by its very design, lures us into an unproductive cycle of eight-minute naps.

Angel technologies recognise this and redress the imbalance. Clocky, designed by Gauri Nanda, at the time

The £26 Clocky alarm clock runs away and hides if you don't get out of bed quickly enough

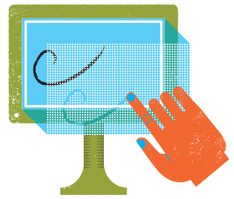
a graduate student at MIT Media Lab, is an alarm clock with a different kind of snooze button. When you hit it, Clocky jumps off the nightstand and rolls to a random corner. When it goes off again, you have no choice but to get up. Clocky allows your angelic, virtuous, early-rising self to overcome its slothful counterpart.

Angel technologies won't just help us get up in the morning. They can save millions of lives. Some of the world's toughest diseases – HIV, diabetes, tuberculosis, cardiovascular disease – all face a behavioural problem: even the most effective medication can't work if people don't take it. Half of those prescribed tuberculosis medication in the developing world do not take their pills. Nearly three quarters of all lower-limb amputations could have been prevented if people were better at taking their diabetes medication. Yet most of these people intended to take their pills: it is just that the devil of disorganisation or forgetfulness triumphs over the angel with which it competes. Enter GlowCaps, a pill bottle that does everything from flashing if not opened often enough to calling our phones to remind us to order refills of chronic medication. This angel tech is having remarkable success where decades of education and exhortation have failed.

The possibilities are endless, and the stable is growing. How about a wallet to control your wasteful spending? The Proverbial Wallet from MIT's Media Lab "swells" with your bank balance and becomes physically harder to open as you run short on money. How about help sticking to your New Year's resolutions, whether going to the gym or quitting smoking? A website called StickK allows you to stake your own money against these goals to motivate yourself to keep up the hard work. Over 150,000 people have used it so far. Cyber-loafing? Several apps, such as *Freedom*, let you control the amount of time you spend online.

In every sector – from government to business, from the biggest firms to the smallest non-profits, from banking to healthcare – angel technologies that use behavioural science will help people run their lives better. We are at the beginning of a hockey stick. Look out for angel tech everywhere around you in 2013. *Sendhil Mullainathan is scientific director, economic mobility, and Saugato Datta is vice president for international development at the behavioural-psychology consultancy ideas42*

SPOT ILLUSTRATION: GILLIAN BLEASE



ULTRAFINE GESTURES >

Kinect has spawned many uses beyond gaming, but it works better with big body movements than tiny gestures. In 2013 we will use our fingertips to control our computer screens, with motion-capture devices such as The Leap from Leap Motion (available in February). These use VGA cameras to detect movement anywhere in a three-dimensional space in front of the screen, allowing the user to open and close windows, copy files and move items around simply by gesturing in the air.

GlowCaps vastly improve medication adherence – it can contact your mobile phone to send reminders

THE SELF-ASSEMBLING MACHINES

THE PREMISE OF *TRANSFORMERS* IS LEAKING USEFULLY INTO THE REAL WORLD, WITH SHAPE-SHIFTING MACHINES JUST AROUND THE CORNER. BY SKYLAR TIBBITS

We are all taught at an early age that DNA is the fundamental building block for life. However, until recently, "building block" only meant life's key ingredients, and not "DNA LEGO". Over the past few years scientists and engineers have been releasing a slew of extraordinary nanoscale technologies that utilise DNA as a literal building material that assembles itself. This has been coined structural DNA nanotechnology, or DNA origami, and is producing nano self-assembly machines for circuits, biomedical devices and DNA-alphabets.

Self-assembly systems take a jumble of components and order them into something more organised, simply through the interactions of the components themselves.

These self-building DNA structures are extremely exciting at small-scale. However, it is now becoming clear that this phenomenon is scale-independent and can be utilised for *Transformers*-like self-assembly at even the largest of scales. This is a new construction mindset and will be the basis for a self-assembly toolkit for bricklayers, furniture-makers and spaceship-builders.

The ingredients that make self-assembly possible at all scales are an elegant mix of interdependent forces:

Blueprints: the step-by-step instructions for building.
Building blocks: components with a minimum of two states: on/off, flexible/rigid, active/static etc.
Energy: thermal, electric, sound, mass/gravity etc, required to assemble the parts and enact the blueprints.
Error correction: to ensure accurate structures.

In a recent development translating folding protein into a tangible, hand-held educational toy, we have turned the components of self-assembly into a simple, single unit: Crambin, a protein strand that folds on its own. The strand includes a sequence of links, representing the amino acids or the blueprints for assembly. Each link has unique fold angles and a pivoting mechanism, demonstrating independent building blocks with a folded/unfolded state. The designed folding