Welcome to the personal drone revolution

By Michael Brooks

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Sophisticated, affordable airborne robot drones could soon be so commonplace that they will become our personal servants

ON THE floor of Martin Toovey's office is a stack of boxes. Their contents assemble into a small helicopter that will help decommission a nuclear reactor. On his desk sits another set of parts for a miniature aircraft destined to monitor rivers for obstructions that can lead to flash flooding.

"I was thinking of something a bit less glamorous," I tell Toovey. "I was thinking I'd stick some Velcro on the bottom and use it to get tennis balls off my garage roof."

Toovey, whose company has the self-explanatory name Build Your Own Drone, doesn't miss a beat. "You wouldn't need the Velcro," he says. "You could just pitch the copter forward. The wash from these things is easily enough to blow the balls off."

To the uninitiated, these drones look like radio-controlled toy aircraft - planes or helicopters. But with onboard computers, GPS receivers, sensors and cameras, they can follow a preprogrammed route or navigate on their own, take photos or collect data at specific locations and fly home while you, the "pilot", grab a coffee. Drones - or unmanned aerial vehicles (UAVs) as they are also known - are not so much aircraft as airborne robot slaves.

What you do with your flying robot is up to you. The next day, at dinner with a group of Toovey's drone-obsessed friends, I feel slightly shamed by the modesty of my ambition. I am sitting opposite a man who is writing a program that will allow a guerrilla graffiti artist to paint on hard-to-reach walls. He leans forward and holds up a picture on his phone showing an artist drawing on his tablet computer while, in the distance, a drone with a spray can of black paint replicates the design on a wall 20 metres up.

I declare myself impressed. "Don't be," says the programmer. "This is just a mock-up." It turns out that they had not yet made the system work reliably.

By the time you read this, though, they will have. In fact, it seems that there is almost nothing you can't do with a drone. They can hover anywhere you choose - just tap the spot on the map on your controller screen - and get themselves home should you lose touch with them. Some can negotiate tight indoor spaces or somersault like a gymnast. And thanks to an enthusiastic army of developers, hobbyists and programmers who swap ideas, circuitry and software, drones are rapidly acquiring new abilities. Farmers, mining companies, film directors and activists are already putting them to work. Drones are becoming so capable and affordable that only one question remains: what will you do with yours?

Flying smartphones

As with so many technologies, drones were inspired by military needs see diagram. Early in the 20th century, the inventor Nikola Tesla suggested using an armed, pilotless aircraft to defend the US. About a decade later, the US military watched, impressed, as a plane equipped with a rudimentary autopilot sank a decommissioned battleship. Now soldiers routinely deploy drones for surveillance or missile strikes, sending commands to them from bases thousands of kilometres away.

The personal drone revolution, however, has ridden in on the wings of consumer technology such as cellphones and gaming controllers. Smartphones have been particularly important: their small, efficient batteries, vibrating motors, accelerometers, GPS receivers, gyros and cheap memory chips have all become part of the drone make-up. "We are the direct beneficiaries of those components being mass-produced for phones," says Peter Hollands, who develops drone applications for UK-based consultancy Dale Strategies.

This has created a step change in flight capabilities. Even the cheapest drones, which cost about the same as a basic laptop computer, can be easily set up to follow a preprogrammed flight path. They will return home at the touch of a button or if communication lines are cut. They can also hover with extraordinary stability and are powerful enough, and manage battery use well enough, to carry significant payloads. You don't need to go next door to ask for a cup of sugar; with a couple of button punches, your neighbours can send round the copter with a 1-kilo bag.

It's not all about hardware, of course. The software is just as important in giving drones their astonishing capabilities. At the Massachusetts Institute of Technology, for example, the Robust Robotics group has developed an autonomous plane capable of flying a complex trajectory around an underground car park, threading a path between pillars and coming within centimetres of parked cars. "It has to work out for itself how to get from place to place, and what attitudes and velocities are required in order to do that," says Nicholas Roy, who leads the project. The plane has a digital map of the space, but no on-board camera or GPS. Instead, it uses laser rangefinders to work out precisely where it is and how to fly between obstacles at speed. Banking for turns is somewhat dicey since the plane has a 2-metre wingspan and the space is only 2.5 metres high.

Others are achieving similar aerobatic feats with small helicopters. Watching the drones at the University of Pennsylvania's GRASP laboratory in Philadelphia is breathtaking. Not only do they whizz through tight spaces, rolling onto their sides when needed, but they can form into swarms that shrink and expand in three dimensions, depending on the space available. At the Swiss Federal Institute of Technology (ETH) in Zurich, researchers have created flying robots that autonomously play tennis, build brick walls and do the robot equivalent of balancing an upturned pencil on a finger.

People power

Such extraordinary capabilities are coming to a flying robot near you. Many of the software algorithms that control these advanced drones are openly available so hobbyists can use and, in some cases, improve them. "The best open source UAVs are now near feature parity with military UAVs," says Chris Anderson, who runs two companies that help amateurs access the latest in drone technology. One of these firms, DIY Drones, specialises in open source aircraft - the most famous of which is the Arducopter, built around the Arduino processor beloved by thousands of geeks. Hobbyist drones are not quite as sophisticated or tough as military UAVs, of course - but then they cost one-hundredth as much.

Here the amateur drone community is playing a key role. It is huge and still growing, as is clear from the success of the AR.Drone quad-rotor copter. Its maker, the French company Parrot, has sold more than 300,000 of these smartphone and tablet-controlled craft since 2010. DIY Drones itself works with a community of more than 30,000 members. That means an extraordinary range of expertise is available to develop and refine UAV software. "It doesn't matter about the software you produce initially; it's about the community that develops it," says Hollands. He is part of a group that developed Matrix Pilot flight control software popular with UAV enthusiasts. "When I think of what we have put into MatrixPilot, it's literally millions of pounds worth of our time." Similarly, Mavlink, an open source communication protocol between the UAV and the ground controller, is now so good it is emerging as the industry standard, Hollands says.

There is still some work to do before the capabilities of the best lab drones can be replicated in the real world, says Rafaello D'Andrea, who runs the Institute for Dynamic Systems and Control at ETH Zurich. "The next step is to really make them robust," he says.

One reason that drones perform so well in the lab is because they can take advantage of technologies that would be impractical outside. University labs often use ground-based sensors such as cameras to improve navigation, for example. GPS technology can give a drone feedback on its position 10 times per second, but an array of cameras tracking the drone can send signals 20 times as often, says Vijay Kumar of the GRASP lab. This means camera-based navigation can be more accurate.

Another lab "cheat" is that much of the number-crunching for flight control is done by computers on the ground. That processing could be done by an on-board computer, but it would make the craft bulkier. As Kumar puts it: "Bigger means less agile - there's no free lunch."

In the end, though, solving all the technical problems won't be enough to set UAVs free. "We're very much boxed in by the law at the moment," Hollands says.

By law, in the US, Europe and Australia, drones can only fly up to an altitude of 120 metres or so, away from buildings and people, and within line of sight of their operators. It's a highly restrictive scenario, but there is growing pressure for the rules to change. Demand is rising for UAVs to be deployed in search-and-rescue operations, for monitoring crowds at sporting events and for traffic surveillance. And when military drones return to the US and UK from service in Afghanistan, their operators will need aerial playgrounds to keep their hands in.

As a result, regulators are looking at ways to make broader UAV use possible. The US Congress has charged the Federal Aviation Administration with opening airspace to UAVs by the end of 2015. Personal drones will be given a boost in the next year, when the FAA is due to pass a rule that will allow bigger UAVs, weighing up to 25 kilograms, to fly. It's a good start, says Jerry LeMieux, founder of the web-based Unmanned Vehicle University, which trains UAV pilots and engineers. The market for small drones will expand fastest, he says, with the new rules enabling all kinds of commercial applications such as aerial photography. "My prediction," he says, "is that the UAV industry will grow to a trillion dollar business over the next 20 years."

Eye in the sky

Not everyone has to wait for a change in the law. Some 50 organisations are already authorised to fly drones in US airspace, and several law enforcement agencies have special permission to deploy large UAVs for patrolling remote areas such as the Arizona border with Mexico. Kumar thinks swarms of small police drones could be a common sight in cities before long. "I would be surprised if you don't see these used within a year or so," he says, adding that they are too valuable a tool in search and rescue, or first response by law enforcement agencies, to delay their roll-out. "If there's a gunshot in a city block, we could deploy 20 of these and surround the area," he says. "We can do that before any police officers get to the scene. Maybe we'll lose some, but what's a few drones if you can save a life?"

His optimism is fuelled by what he perceives as an acceleration in people's acceptance of a robotic future. California, he points out, has just welcomed driverless cars onto its roads. "That's a landmark," he says. "And if cars can operate autonomously, why not planes?"

The short answer is the third, and biggest, hurdle UAVs must overcome: an inability to detect and react to unexpected obstacles, especially flocks of birds, other UAVs and piloted planes. "Sense and avoid has to improve dramatically," Hollands admits.

Here, it seems, our love for gadgets might help. Microsoft's Kinect motion-capture system, developed for videogaming, is showing itself to be a rather useful tool. "It will be a complete game-changer in robotics," Roy says. His team has equipped one of their machines with a Kinect sensor that enables it to map out its environment and so avoid all the potential obstacles in a room.

Not that it's a perfect solution. It doesn't help if, for instance, another drone pops into the room and starts flying around. Avoiding such obstacles requires more elaborate kit, such as laser rangefinders. They have a range of 30 metres, six times that of the Kinect but they also cost 30 times as much.

This won't necessarily be your problem, however. So get ready: your imagination could unleash the personal drone revolution. "Just as with the PC, the real innovation comes from putting the technology in the hands of regular people, who will find applications we've never dreamed of," Anderson says.

One such idea comes from the people behind the Swedish file-sharing website The Pirate Bay. Chased by corporations for allowing users to share copyrighted material, they have now suggested putting servers kilometres up in the air, hovering outside any national jurisdiction. It's more of a thought experiment than a realistic possibility, but it gives a flavour of what drones might bring. For example, it's already possible to turn a drone into an airborne cellphone mast.

More feasible is the application that the team at Matternet, a start-up based in Palo Alto, California, has in mind. The company wants to create a drone-based service delivering vaccines, antibiotics and other medicines to remote parts of Africa or Asia, bypassing the poor or non-existent road network in these areas.

And then, more mundanely, there are a host of commercial and other applications. House sellers could soon include aerial shots of their property as standard. Hollywood directors might no longer have to fork out to rent a helicopter for a bird's eye view of a car chase; instead, they could use footage captured by camera-packing quadcopters. Fire services will be able to scour the interiors of potentially hazardous burned-out buildings without sending crew in, and steeplejacks will inspect chimneys without erecting a scaffold. Environmental campaigners will be able to find out exactly what industrial complexes are emitting into the air right above them.

"There's no limit to it," Toovey says. "If you can think of an application, you can probably get a drone to do it." And you can do it in your own special way. Whatever Toovey says, I like the Velcro idea, and I'm sticking with it.

Michael Brooks is a consultant for New Scientist and author of The Secret Anarchy of Science