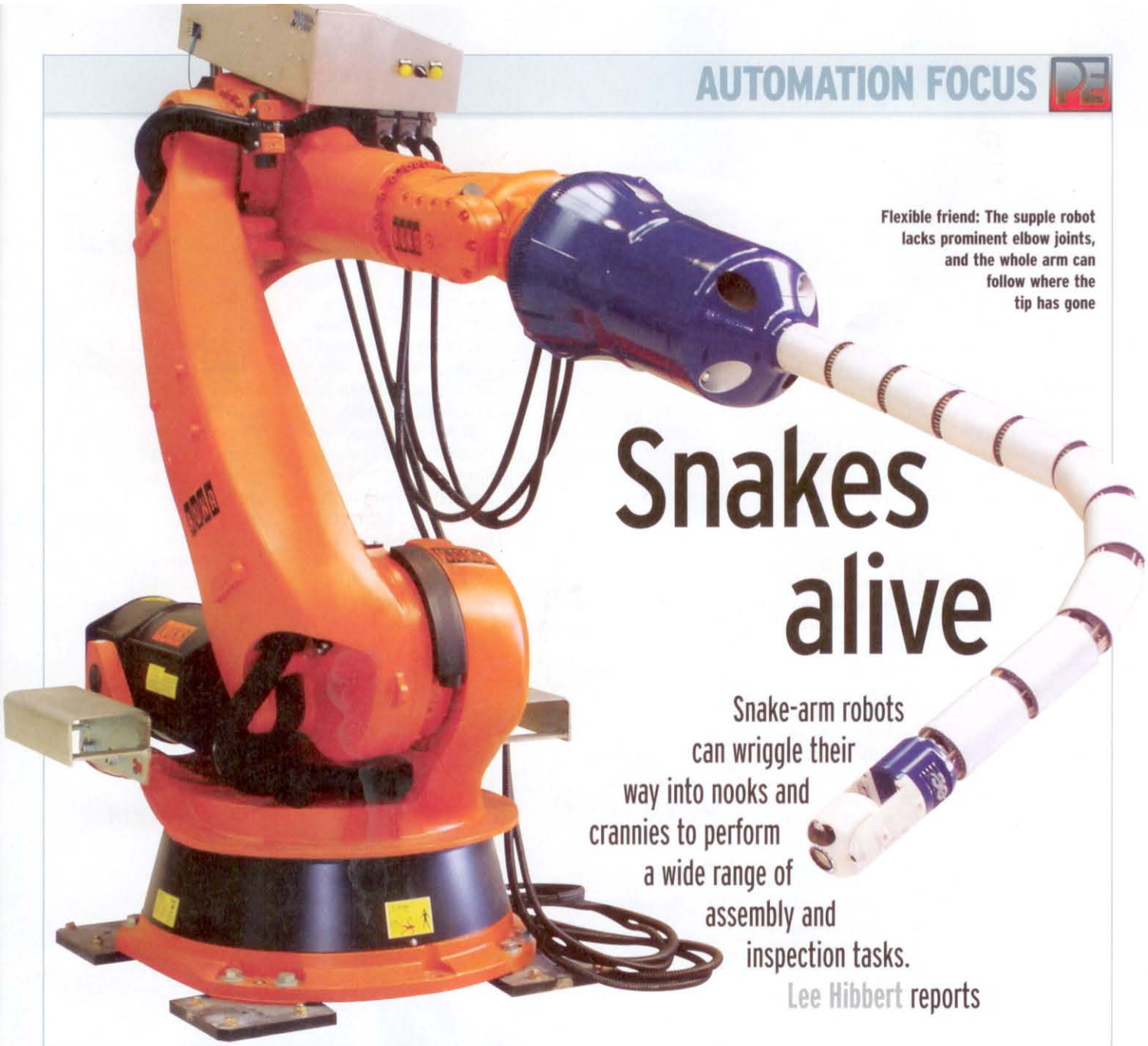


Flexible friend: The supple robot lacks prominent elbow joints, and the whole arm can follow where the tip has gone

Snakes alive

Snake-arm robots can wriggle their way into nooks and crannies to perform a wide range of assembly and inspection tasks. Lee Hibbert reports

For all the wonders of flight, the aerospace industry is behind the times when it comes to the adoption of certain technologies. Automation is a case in point: making planes remains something of a labour-intensive craft industry, with far lower levels of robot use on the assembly line than, say, the automotive sector.

But things are starting to change. European planemaker Airbus has been on the hunt for automation technologies for use on structures such as wings that are difficult to access. It has been looking for a robot that is capable of carrying out sealing, swaging and inspection activities inside a rib bay. And it is Bristol-based firm OC Robotics that has best met these requirements with its highly innovative snake-arm robot.

Rob Buckingham, managing director of OC Robotics, says: "Airbus approached us and asked us to come up with an automation solution for low-access work in a rib bay. The trials started in November last year, representing the first use of a snake-arm robot in the aerospace industry. So far, things have gone very well indeed."

Up until now, tasks such as sealing, swaging and inspection within rib bays and other areas with poor access have remained closed to automation. Manoeuvring an industrial robot through a small opening on an aircraft becomes an "eye of the needle" access problem. Even if it is possible to get a conventional robot arm inside the wing structure, carrying out work is made practically impossible because of the sharp angle at the elbow.

The beauty of the snake-arm robot is that it doesn't have prominent elbow joints. The arms are designed with a hollow bore down the centre, which can be used to take services to the tip of the arm or to turn the arm into a steerable hosepipe. The arm itself is flexible, meaning the whole device can follow where the tip has gone. It is designed to have a continuous curvature along its length, making it ideal for these tight-space applications.

The solution that OC Robotics came up with for the Airbus trials involved a snake arm

attached as a tool to an industrial robot from preferred supplier Kuka. The demonstrator snake arm has 10 segments, is 1,800mm in length and 90mm in diameter. The hollow bore is 15mm. The complete system has 27 degrees of freedom, giving the arm the flexibility to "follow its nose" into the rib bay.

The snake arm can follow a path into the wing-box either by joystick control or from a predetermined library of paths. The arm can then move in cartesian mode either by joystick control or automatically using visual servoing to ensure it is correctly aligned before beginning each task. When applying sealant, a camera on the toolpiece tracks the line of the seam to ensure accurate and even application.

"Integrating all of these elements was the real challenge," says Buckingham. "The robot, the arm, the tools and the imaging all have to be co-ordinated to work together seamlessly. This has been achieved, but there are areas that could be improved. We use digital manufacturing software to build up the programs which allow the visual servoing to be carried out. This works well but we are hoping that it can be done at a faster rate."

OC Robotics has developed three interchangeable tools for the demonstrator. These comprise an inspection tool containing several cameras; a swage tool to swage a rivet and direct the removed section into a collection area; and a sealant tool incorporating a standard-sized sealant cartridge and nozzle, with cameras to allow automatic orientation of the toolpiece to the seam.

Buckingham says: "Most of the money from the Airbus trials has been spent on developing the snake, rather than the tools. We now have a fifth-generation snake arm, and the next version will be the start of the production model. We now know exactly what is going on with the arm, and have proved that it works as expected. What we now need to achieve is repeatability at the kind of microns level required by the aerospace industry."

Even though less work has gone into the tools to date, significant progress has still been made in this area. "We have designed the tools specifically for the snake to avoid any integration issues. At the end of the day, we are a snake robot firm, not necessarily a tools company. However, saying that, all of the tools work very well and we have gone back to the established toolmaking firms to see if they want to pick up on certain ideas, license them and take them to production.

"For example, the swage tool is electrically operated through the mains or a battery, rather than the historical way of doing it pneumatically which needs a compressed-air line. So we think our tool solution in this area is more flexible."

According to Buckingham, the demonstrator for Airbus will continue to be developed until a production version is ready. This requires overcoming problems in certain aspects of maintenance and reliability. But he believes that snake-arm robots have huge potential in the wider aerospace sector, carrying out tasks such as deburring; drilling; extraction of foreign bodies; installation of components; insertion of wire looms; laser welding; leak detection; non-destructive testing; nut-running; painting; removal of liquids, gases or particulate matter; removal of swarf; and thermal imaging.

"Automation in the aerospace industry is bound to increase," he says. "Most of the big players in the sector have automation research budgets. Most of these firms are aware of what we can do, it's a fairly small community and we are getting well known. We've had talks with Boeing, Bombardier and Lockheed, to name but a few. OC Robotics might be a little dot in a huge industry but we have the potential to get much bigger."

Other industries that have issues of restricted access include the defence, nuclear and general industrial inspection sectors. OC Robotics is also on the fringe of the medical sector, in so much as the human body can be viewed as a confined space. It is looking at the potential of using its robots in what is known as natural orifice surgery, whereby a miniature robot could go in through the mouth. This would allow surgeons to operate on the abdomen with no incision, therefore reducing the chances of infection by superbugs such as MRSA.

SINUOUS SHAPE SNAKES AROUND OBSTACLES

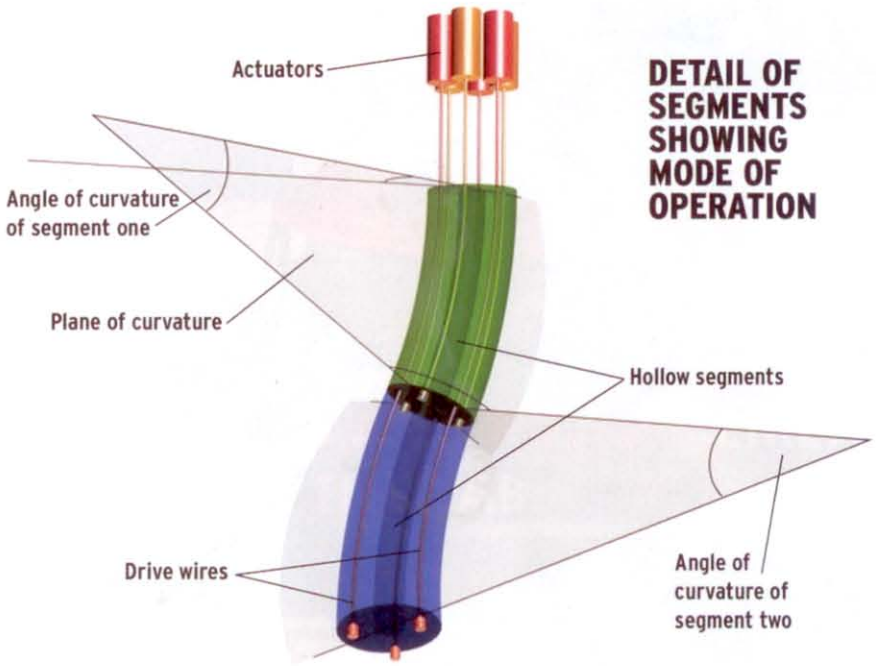
According to Andrew Graham, co-founder and technical director of OC Robotics, a snake-arm robot can be compared to the human spine in so much as it comprises a large number of vertebrae. It is a tendon-driven arm with wires terminating at various points along its length. The result is that the curvature of each segment can be independently controlled.

Graham explains: "A motor is used to control the length of each wire independently. The control software calculates the necessary lengths of all the wires to produce the desired shape. The operator uses a joystick to drive the tip, while the computer does the maths to make the arm follow. This tip-following capability enables a snake-arm robot to avoid obstacles and follow its nose into complex structures."

All OC Robotics' snake-like manipulators have a hollow bore that runs the length of the arm. This means all services can be carried within the arm so that the external surface is smooth and continuous. It also means that the arm can be used as a steerable hosepipe or a vacuum cleaner.

"At the base of the arm, the actuator pack is a modular drive system that uses electric motors and actuators to control the length of the drive wires. All actuators are the same to reduce complexity and cost of ownership," says Graham.

A snake-arm robot can be tele-operated or programmed offline. It can be controlled in three modes: path-following, using a joystick and tip-mounted cameras to follow a path with the whole device following the tip; cartesian motion, moving the tip in tool or world coordinates; and joint mode, moving individual joints.



DETAIL OF SEGMENTS SHOWING MODE OF OPERATION