Snake-arm robots are within reach of aerospace assembly applications

Quality is a high priority in the aerospace industry, yet much of the assembly work is still carried out manually because conventional robots do not offer the required accuracy. Jon Severn reports on the latest developments in snake-arm robots that, when used in conjunction with industrial robots and visual servo control, could be just what the industry needs.

La qualité est une grande priorité dans l'industrie aérospatiale, et pourtant une partie importante du travail d'assemblage est toujours réalisée manuellement car les robots classiques ne sont pas assez précis. Jon Severn présente les développements des robots à bras flexibles qui, utilisés en association avec des robots industriels et un contrôle servo visuel, pourraient répondre aux exigences de cette industrie.

Qualität hat im Flugzeugbau allerhöchste Priorität. Doch viele Montagearbeiten werden noch von Hand ausgeführt, da die bislang üblichen Roboter nicht die geforderte Genauigkeit leisten. Jon Severn berichtet über neue Entwicklungen bei Schlangenarm-Robotern, die im kombinierten Einsatz mit Industrierobotern und visueller Servosteuerung die Ideallösung für die Industrie darstellen könnten.

Both linear and rotary motion are relatively easy to achieve, with modern control technologies enabling that speed, torque (or force) and position to be predetermined with remarkable accuracy. However, creating movement along convoluted paths in three dimensions is considerably more complex, typically requiring anthropomorphic robots. Useful as they are, such robots are mainly restricted to applications where there is space available to make an approach to the target position; their bulk, in particular, means that they are seldom suitable for tasks where access is via a small aperture.

If the robot is being used for a manufacturing operation, the answer is to design the components or assembly so that they can be processed by the technologies available, which might mean that some tasks have to be performed manually. This says a great deal about the adaptability of human beings, but the result is often that people are asked to perform repetitive tasks while maintaining uncomfortable postures in confined spaces. Not only does this have implications for quality, but there is a good chance that health and safety conditions are not as good as might be desired.

This is one example of where 'snake-arm' robots can be useful. These can be used to perform assembly or inspection operations by means of suitable end effectors that are controlled and monitored via the umbilical that passes through the hollow core of the snake-arm. Alternatively, a snake-arm can be fitted to the wrist of an anthropomorphic robot arm to enable more complex tasks to be performed.

While robots have been used extensively in automotive production for over two decades, their use in aerospace has been more restricted. This is mainly due to conventional robots being unable to maintain the high absolute and relative accuracies required on comparatively large structures. While local servo control can overcome some of these limitations – by using a vision system to identify local reference points, and by adjusting the end effector's position accordingly – modern aircraft structures still have relatively limited access compared with, say, an automotive bodyshell.

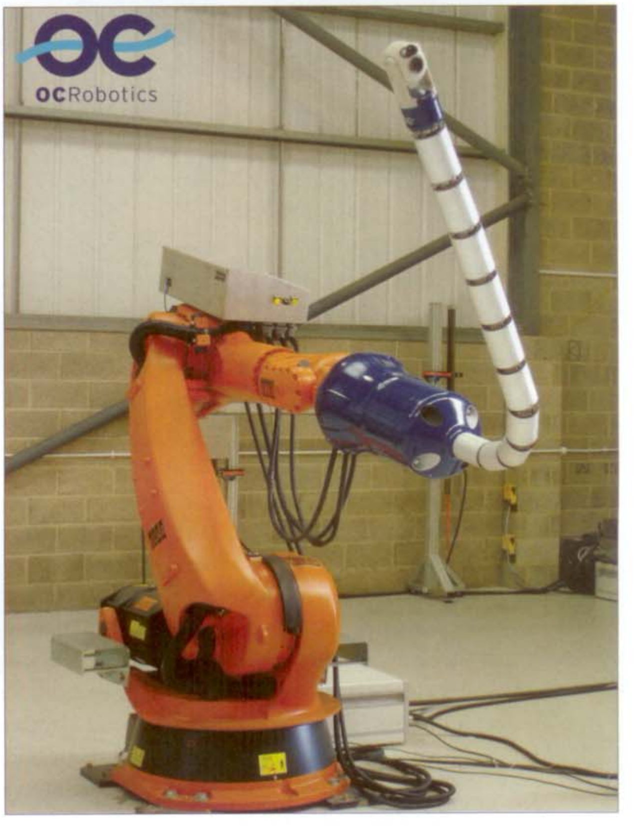

Fig. 1. OC Robotics has built a prototype hybrid robot that consists of an 'Extender' snake-arm robot mounted on a Kuka anthropomorphic arm.

Prototype hybrid

OC Robotics, which specialises in the design, development and manufacture of snake-arm robots, has been working with Airbus UK to address this problem and has now built a prototype 'Extender' snake-arm robot that is mounted on a Kuka anthropomorphic arm (Fig. 1). The idea is to create a hybrid robotic arm that can perform many of the tasks that currently require fitters to work in confined spaces that have to be accessed via small apertures. Not only are there health and safety implications for the access and work in confined spaces, but often there are fumes, dust and noise to contend with as well.

Three different end effectors have been designed for use on a 100 mm diameter

Fig. 2. The prototype snake-arm has the flexibility to enable it to enter the rib bay of a wing-box.

snake-arm that has a bore of 25 mm. The first is a tool that swages rivets and directs the removed section into a collection area; the second is a vision inspection instrument with several cameras and lights to illuminate the workpiece; and the third is a sealant applicator. Both the swage and sealant tools are also equipped with cameras so that they can operate under visual servo control. Other end effectors could also be developed for drilling, deburring, extracting foreign bodies, removing swarf, installing components, inserting wiring looms, nut-running, painting, non-destructive testing, and removing liquids, gases or particulate matter. It has to be remembered, however, that the end effector should ideally be no wider than the snake-arm's diameter and have a length that is not greater than 1.5 times the diameter, otherwise the full benefits of the highly manoeuvrable snake-arm concept may not be enjoyed.

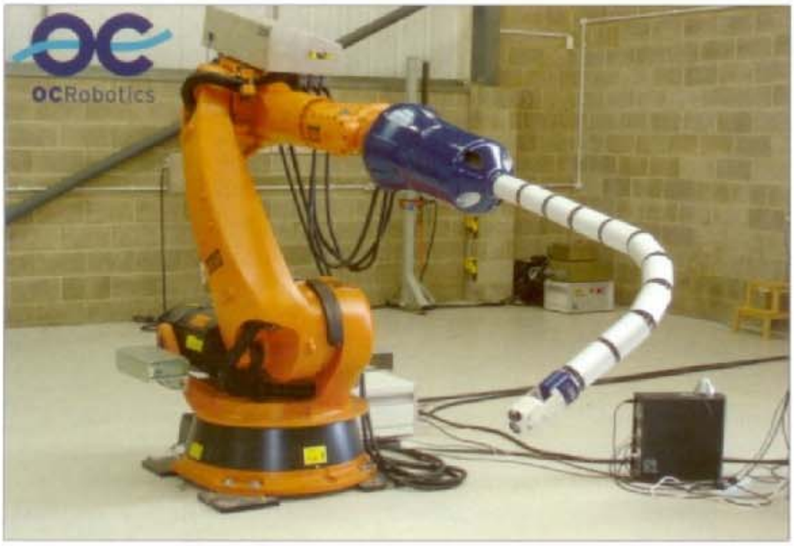

Fig. 3. The snake-arm's wrist joint design enables the tooling to be changed quickly, plus the arm itself can easily be removed and replaced on the actuator pack.

The prototype arm has ten segments and measures 1.2 m long. Compliant joints between the segments mean that the arm will not cause damage if it inadvertently collides with the structure through which it is navigating, and further research is underway to create a sensitive 'skin' that will, amongst other things, detect such collisions. With 27 degrees of freedom, this snake-arm has the flexibility to enable it to enter the rib bay of a wing-box (Fig. 2). Clearly it would be impossible for a human operator to control all of the 27 degrees of freedom to enable the tip of the robot to be moved as required, with the 'body' of the snake-arm being continually adjusted in such a way as to follow the path taken by the tip. Software developers at OC Robotics have developed an interface that enables the robot to be controlled manually by a joystick or, alternatively, the snake-arm can be made to automatically follow a pre-programmed and optimised path. Built into these control systems is a means by which the Kuka robot acts in 'slave' mode to position the base of the snake-arm wherever it is required in order that the tip of the 'master' snake-arm can follow the desired path.

Once the snake-arm is in approximately the correct position, it can be moved in 'Cartesian mode' by means of the joystick, or it can be aligned automatically for a particular task by means of visual servoing. Importantly, the control algorithms take account of this additional movement when the arm is withdrawn, as the path will not be identical to the insertion path.

In the prototype snake-arm, the wrist joint has been designed to enable the tooling to be changed quickly, plus the arm can be removed and replaced on the actuator pack in the event of any damage (Fig. 3).

So far the prototype has been demonstrated on a mock-up of a rib bay and has been shown to be capable of performing the type of task that would be required in an aerospace application; precise replications of specific tasks have not yet been tested. Nonetheless, it seems that snake-arm robots are capable of undertaking tasks that are currently performed manually. More importantly, however, aircraft designers may find themselves given the freedom to design more efficient assemblies that do not need to be compromised to allow access for fitters.

Snake-arm robots are made up of a number of rigid segments separated by compliant joints. Each segment has two degrees of freedom and is typically controlled by three wires that act in a similar way to tendons, with the length of each wire determined by a servo-controlled motor or linear actuator housed within the actuator pack at the base of the arm. While the prototype snake-arm for aerospace applications has 10 segments, others have been designed with fewer segments and up to 20. Regardless of how many segments the arm has, the movement is such that the second, third, and subsequent segments all follow exactly the same path as that taken by the tip. ■