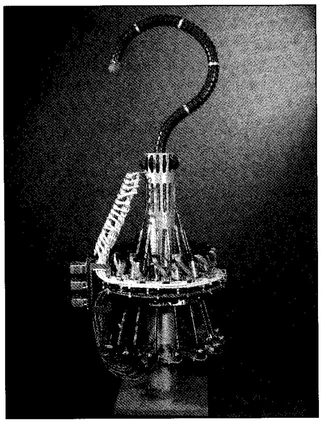
EOD GAZETTE



Reaching the Unreachable.

Using snake-arm robots

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On the 1st. January 2002 OCRobotics Ltd launched a new type of robot; called snake-arm robot (S-AR).

To date most other robots have been designed to work on the outside of objects, or to work in free space. For instance, robots are now an expected part of any car assembly line; welding, painting or inserted components. Robots are also commonly used for general pick and place tasks in a wide variety of industries. In contrast, snake-arm robots are designed to work on the inside of objects, or in situations where free access to the work site is not guaranteed. They are designed to reach locations that are unreachable using standard techniques. They can also access areas that people cannot reach or where people do not want to go.

The idea of snake-arm robots is not new. The earliest citations in patents refer back to the 1890's. This is not surprising. It has long been the ambition of engineers to be able to reach into a complex structure using the available access in order to inspect or repair components. Keyhole surgery and the use of endoscopes for minimally intrusive surgery is now common best practice and has demonstrated clear advantages to both patients and those agencies who pay for healthcare.

This ability to reach into complex structures is also driven by observations of natural systems. Many images spring to mind - an elephant ponderously exploring a hollow log and then picking it up as if it were a twig - a swan's neck curving down to graze on pondweed - the tentacles of an octopus grasping a rock - a snake slithering through undergrowth or sliding through a hole in a wall.

The factors that make the S-AR technically viable, 50 years after the most significant patents are; the state of computer technology, the availability of materials and components and a variety of needs from commercial to military and surgical. Research conducted in the 1980's and 1990's has now been brought to a stage where the fundamental mathematical control problems have been resolved.

Applications for the S-AR are vast and the manufacturers are investigating uses in the aerospace industry for in-wing inspections and maintenance tasks and on-wing engine inspections and repairs. In the commercial aircraft industry a key driver is aircraft utilisation, so opportunities to inspect components prior to dismantling, or indeed instead of dismantling have a great appeal and could also reduce the effect of any further problems being created by the dismantle and rebuild process.

Similar applications are being investigated with international companies and institutions working on the maintenance and decommissioning of nuclear powered installations.

Applications in surgery are numerous and would include ventriculoscopy (a branch of neurosurgery), colonoscopy (the colon is part of the large intestine), oesophagael (the oesophagus is part of the alimentary canal - throat to stomach) and spinal surgery. In fact, the S-AR combines the best features of a flexible endoscope with the contollability of a rigid probe.

The applications in EOD, IEDD and counter-terrorism are equally forthcoming. A S-AR can follow a path through a car window, down into the footwell and beneath the seat, it could equally gain access to the engine compartment from underneath the vehicle. S-AR's can be used to delve into piles of rubble equipped with cameras or sensors. Using the hollow bore, suitable equipment can be exchanged without the removal of the S-AR, obviously reducing the risk of initiation, detonation or collapse of the immediate environment.

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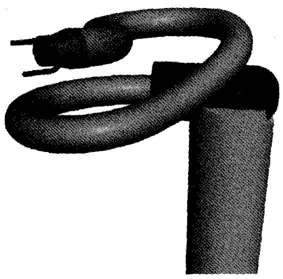
The surgical applications made the most significant impact on the design of the arm. Satisfying these criteria has produced an arm that is ideally suited to a dirty, wet, hostile environment.

All devices will comprise three components, which can be seen in Figure 1. The first component is the flexible arm; the second is the drive unit; the third is the payload - either cameras, tools or sensors.These can be either fixed components of an arm or can be interchanged by means of a tool changer.

Flexible Arm

An arm comprises a number of sections that in turn contains a number of segments, the shape of each section is controlled by a set of wires. This method of control means that there are no active elements within the arm. This flexible arm can be of almost any length and diameter. It can also be made up of any number of sections. In order to specify an arm, two further pieces of information are required - the total curvature of the path to be followed and the payload to be delivered. Perhaps counter-intuitively snake-arm robots can carry significant payloads with good repeatability.



All devices can have substancial bores, this means that all services can be carried internally. This in turn means that the external surface of the arm is basically smooth making the arm very simple to seal. A fully sealed arm offers the opportunity for applications for NBC, hazardous or corrosive materials and sub-aqua operations. Sensing and dealing with UXO in extreme low vision conditions, such as muddy water, with the minimum of disturbance is one application for a S-AR, which could equally be used for covert observation operations the same day, merely by cleaning down and changing the tools.

There are two further distinct advantages that come from an arm design that does not include any active elements. First, the arm is inert in terms of EMC, although tools carried at the end of the arm would need to be carefully screened. Second, the arm is relatively cheap and can therefore be regarded disposable or sacrificial. This is particularly important as the arm can be connected to the drive unit by means of a quick release mechanism which then enables easy exchange of arms. This allows different sized arms to be fitted to the mother drive unit, greatly increasing the range of tasks that can be undertaken using the same drive unit. The exchangeability of the arm unit means that a range of variously equipped arms can be held in readiness and that repairs under field conditions are easily achievable.

Drive Unit

The drive unit comprises the motors and actuators that pull each individual control wire, each wire must be independently pulled in order to control the shape of the S-AR device. Whilst this design requires a large number of motors, each individual wire drive unit is identical. This makes it possible to optimise the design for size, weight, economy and quality control. An individual wire drive unit is also so simply exchangeable that it avoids lengthy, expensive or complex repair operations.

A secondary feature of this drive system is that if a control wire or wire drive unit becomes damaged, the software can adapt by effectively absorbing the damaged unit into the adjacent operational segments. This means there are no catastrophic failure modes. In addition absolute encoders and breaks mean that power can be switched off and back on without the need to re-initialise, in effect the arm can carry on where it left off.

The specifications in this table are all achievable.

Length	0.5m	2m	3.5m	10m
Diameter	6mm	70mm	120mm	120mm
Payload	10g	2kg	50kg	2kg
Total curvature	180degrees	450degrees	270degrees	720degrees
Bore diameter	2mm	40mm	75mm	75mm

Tools and Sensors

A Snake-Arm Robot is a delivery system. The software has been designed so that the operator is not concerned with controlling the arm but instead controls the movement of the sensors or tools. Clearly the computer has to be able to warn the operator when it is no longer possible to move in a particular direction because the arm is at full reach, but the intention is to make operation as intuitive as possible.

The tools can be controlled in Cartesian coordinates with respect to the tool or world coordinate frame, or for instance, the coordinate frame of a UXO. The main operator interface is by joystick, although the ability to programme moves offline is also available.

The range of tools and sensors that can be carried is directly influenced by the task being carried out. Cameras, abrasive water jet cutting tools, disruptors, shaped charges, powered torque drives and welding torches can all be applied, limited only by available size, payload and repeatability required. S-AR's are designed to be flexible and hence they do not have the ultimate rigidity of a standard robot, however uncompensated deflections under full load are in the order of half the diameter of the arm and repeatability of better than 1mm is achievable.

This level of repeatability when coupled with visual feedback from a tip-mounted camera is adequate to achieve all but the highest precision tasks.

Conclusions

Snake-Arm Robots offer significant advantages over current robot technology, particularly in their ability to withstand harsh conditions and reach into limited access spaces. This combination is set to increase the range of routine remote operations that can be considered in hostile or dangerous environments.

The next stage in the development of snake-arm robot technology provides significant opportunities for potential users. The detail of what an arm needs to carry, how it needs to be controlled and the subtleties of converting a good product into an essential tool for everyday use can only be worked through with people experienced in the art. We are enthusiastic to engage in discussions to ensure the snake-arm technology becomes a widely available tool for use in the EOD and IEDD communities. Resources are available for those who have a specific immediate requirement and snake-arms can be built on an individual bases once final specification have been agreed.