Left hand doesn’t know what the right hand is doing...

So, which is it? Many hands make light work, or the devil finds work for idle hands? I suggest that ever since Zog got his fingers burnt lighting a prehistoric fire, there have been metaphors, aphorisms, homilies and parables involving hands. Too often in our lives we rely on our hands to make discoveries, from checking to see if something is harmful (is that electric fence on?) to finding out that something else is good to eat (should cheese be squishy?). It is no surprise, then, that when we created our first robots we had to provide them with a manipulator or ‘hand’ to fiddle with whatever we could see.

The development of unmanned ground vehicles (UGVs) makes for an interesting evolutionary model, especially in terms of adaptation to environmental pressures. In the early days it was enough to send a ‘wheelbarrow’ down range and ‘make bad thing go away!’ either by firing a disruptor at it, or packing it with enough counter-charge white noise to make it a distant, if noisy, memory. Over time this became the necessary evolutionary path for the UGV. Adaptations made it lighter, faster, able to cross rougher terrain, and to communicate remotely with the base unit in a variety of ways.

Only when this was achieved, arguably in the last five to six years, did the evolutionary pressure fall on the manipulator – having improved our ability to move through our primordial soup we desired to the ability to impact it: our flagella started turning into limbs. This is the current challenge for UGVs. At one end of the scale is the revolutionary dexterity of Shadowrobot’s Shadowhand, and at the other is the brute force of Proyteca’s Super Aunav (that has a habit of ripping car doors off). There is a plethora of possible pathways but evolutionary pressure from explosive ordnance disposal (EOD) experts and, to a far lesser extent, hazmat technicians has yet to force the choice of direction.

The key questions are: what do we want the manipulators to do, and what is the best format for them? This is, of course, a bit chicken and egg: it is no good the operator deciding that he wants robots that can gently lift an egg when all the technology can do is make finger omelettes. That said, both EOD people and hazmat technicians would like to have greater dextrous control. For EOD purposes this could be anything from the ability to place a radiography system more accurately to opening a bag, while the hazmat team would probably like to be able to turn a valve without pulling it off the pipe or to put a lid on a barrel.

What comes out of all this is that it would be really handy [Groan! Ed.] to have two manipulators. Massive increases in delicacy (or smashing!) are possible when two hands work. In our lifetime we could go from ‘Rock-em, sock-em robots’ to ‘Real Steel’.

© RE2
together. This can apply whether the aim is to steady an object, when you want to unscrew something, or to interact with it another way, for instance when one hand bends while the other twists. Technology has now matured enough for this to be a viable evolutionary direction, and while one hand/arm is likely to remain the near term favourite, it might be that sometimes there is a case to be made for two hands being better than one.

**Handyman, handier robot**

Various companies out there offer two arms/hands, and two of the leaders are RE2 and HDT, the latter being best known in CBRN for its filters and colpro tents but also with a burgeoning robotics element. Both of these companies state that they have developed their twin arm variants in response to requests from EOD operatives.

RE2 has its highly dextrous manipulation system (HDMS), and Jorgen Petersen, president of RE2, explained that the need for a complex relationship with a device had driven a craftier approach. “HDMS was originally designed for EOD teams. They are the primary customer for mobile robotic arms to date, and as such drive the design requirements for systems like HDMS. Single, low-dexterity manipulators significantly limit the tasks that can be performed, but by supplying two arms more complex tasks, such as unscrewing the cap off a pipe bomb, can be accomplished. We wanted to provide the same level of dexterity, speed, and strength as a human torso and arms. Although HDMS was originally designed for the military EOD market, public safety EOD also need this capability, as well as other markets such as harvesting in the agricultural sector or assisting patients in the healthcare market.”

Kent Massey, director of advanced programmes at HDT Robotics, stated that it was not just a matter of having two arms, but of having two smart arms. Improvements in the sensitivity and capability of arms and manipulators have meant that instead of compounding the problem you have doubled the solution.

“The Adroit arm comes very close to matching the dexterity, speed, and strength of a human arm and it also has a ‘sense of touch’ just like a human arm. Every joint in the Adroit arm has very precise strain gauges that measure the forces at that joint, which means we can very precisely control how firmly it grasps an object. For instance, operators can remotely grasp a detonator and extract it, without risking an explosion caused by crushing the detonator. Dual-arm systems also provide the strength to dig up a 155mm projectile and lift it out of the ground. Our Adroit arm weighs less than 23kg, while a 155mm projectile weighs over 50kg. “Opening doors was also a requirement,” Massey continued. “The dexterous force-sensing and compliance of the Adroit arm allows it to turn door knobs and pull open doors almost as quickly and easily as a person can. The single arm version had to lift over 20kg and the dual arm version had to lift over 50kg, and we easily exceeded both of those requirements. Current EOD arms are very slow, so we had to move faster than 90 degrees per second in every joint and we exceeded that requirement by about 150%.”

It should be remembered that part

‘Number Five stupid name... want to be Kevin or Dave!’

Putting two arms on a robot suddenly humanises it ©HDT
THINK NEXT GENERATION
THINK INTEROPERABLE
THINK TALON

Flexible, Capable and Ready

- IOP-compliant
- 3DOF arm
- JAUS AS4 compliant
- Ethernet backbone

Learn more about TALON V by scanning the QR code or visiting our website at http://www.qinetiq-na.com/talonV

PROVIDING CBRN SOLUTIONS IS OUR COMMITMENT

Biological and Chemical Detection

50 years experience in the development, production and sale of gas masks and filters for the military and civilian markets.

Individual Protection

Provide a complete range of decontamination systems for vehicles, aircraft, sensitive equipment and personnel.

Collective Protection

Decon

Visit us at

EURONVAL (Paris – FRANCE)
October 21-31, 2014
Booth C29

CBRN COVERAGE (New York – USA)
October 28-30, 2014
Booth 314
of the attraction of robots is being able to put them in harm's way, and while that might include dealing with a specific device, it can often mean the surroundings as well. This might involve a fission surplus at a reactor, or equally it might be matter of dealing with a leaking pipeline underwater; the potential to do two things at once during ‘suicide’ missions is an attractive proposition!

One hand doesn’t know what the other is doing

A challenge for the two handed robot is the two handed robot operator. Currently many operators struggle with moving the robot and the manipulator simultaneously, as the camera shakes, the viewpoint needs to shift and they need to make sure that they don’t get the commands of their left and right hands mixed up. Bearing in mind that one controller does movement and arm, what sort of controller and user is needed for a two handed robot?

Both manufacturers admitted that there have to be fundamental changes to the way that the user controls the new robot. “Traditionally, robots have been controlled using switches/dials or simple joysticks as in the Xbox controller,” said Pedersen. “These inputs are mapped to individual joints of the arm or to the robot’s mobility actuators,” he continued. “In recent years, some robot manufacturers have been offering ‘fly the gripper’ control, where a joystick maps to the axes of a Cartesian plane. In this way, the operator only controls the gripper and the inverse kinematics software algorithm determines how to move each joint of the arm to create the desired gripper position and orientation.

“When an arm becomes highly dexterous it can have eleven to sixteen degrees of freedom, and controlling arms using inverse kinematics does not work well if there are multiple solutions for any given gripper position and orientation. We therefore developed our imitative controller (IC) to enable a single operator to intuitively control two dexterous arms simultaneously. This is a scaled replica of the arm to be controlled with robotic gripper controllers (RGCs) at the end of the IC arms that represents the grippers.

“Our IC is a modular device that can be custom configured to match any robotic arm. To further enhance the operator’s effectiveness we are currently developing haptic feedback for the IC. This new capability will make the operator feel as though the HDMS is an extension of his or her own body. As an operator instructs the arm to grip an object, the force from that grasp at the gripper will be transmitted back to the RGC.”

The RE2 team is happy that the system of slaving human arm and hand is fairly intuitive and can be taught very quickly (they have suggested less than a minute), and by adding more buttons onto the RGC (besides open and close) the operator can control the UGV and manipulators. Kent Massey from HDT Robotics agreed that the challenge could seem overwhelming, but there are solutions. “We have shown that a single operator can maneuver the robot while operating both arms and aiming the camera, all with a ruggedised, lightweight operator control unit (OCU) and a head-aimed, helmet-mounted display provides video. The operation is intuitive and immersive. We have used a cyber-glove with arm tracking to control our prosthetic arm. Although this solution is fairly intuitive once it is fine-tuned, it is surprisingly cumbersome to implement and does not work well outdoors. Ruggedising this solution for use in the field does not seem practical at present, which is why we developed a compact, rugged master/slave controller.”

While nature has not seen fit to give us three, eight or twelve arms, human evolution will probably hold back that of UGVs, too. Whether it is through an IC that fits onto the operator’s arm, or a cyber-glove with arm tracking, there is the fundamental fact that we have only two arms and hands, and if we want to try and control something with more than that there are always going to be limitations.

The moving finger…

It is not just hands and arms that cause operator problems but also the pointy end [Honestly! Ed.]. There tend to be two or three digits on the end of a traditional manipulator, yet is this the right number? Humans and other primates evolved four fingers and a thumb for very specific functions, yet none of the evolutionary pressures that led us down that path involved unwanted explosives! It could be that three is the right number, or it could equally be eight and two thumbs per hand! If we task orientate, rather than fixate on the finger-hand-wrist combo, is it not possible that UGVs will evolve differently to humans?

Massey thought that that could happen, but didn’t see much chance for a fistful of fingers more. “The crucial advantage of the human hand is the opposable thumb. Just like a human hand, the thumb of our end-effector can rotate from a top pinch against the side of the forefinger, to an opposition pinch with the tip of the thumb against the tip of the forefinger, to a cylindrical grasp where the thumb tip passes between the forefinger and middle finger. This dexterity allows the end-effector to pick up and use almost any tool meant for humans. For instance, the Adroit arm can pick up a cordless drill and independently actuate the trigger.

“Our decision to have only three fingers (thumb, forefinger, and middle finger) was based on ruggedness and cost. We have built five fingered hands, but the finger mechanisms are tiny, making them delicate and very expensive. Our five fingered hand costs $250,000, whereas our three fingered hand costs a small fraction of that, and is far more robust. In certain circumstances, a specialised end-effector could have some benefits, but going down that path results in dozens and dozens of highly specialised end-effectors. We believe that generalised, anthropomorphic end-effectors that can use existing EOD tools make better sense. Using three fingers, our Adroit end-effector can handle almost any object a human hand can manipulate, although picking up a needle and thread and threading the needle is beyond our abilities - at least for now.” Good news for seamstresses and tailors at least!

RE2 has also flirted with a five
The future in CBRN Personal Protective Equipment for European first responders. The IFREACT Consortium is pleased to invite you to its end conference in Brussels 16 December 2014, 10.00 – 16.00 at Crowne Plaza Brussels - Le Palace, Rue Gineste 3, Brussels 1210, Belgium.

IFREACT (Improved First Responder Ensembles Against chemical, biological, radiological or nuclear Terrorism - http://www.ifreact.eu/) funded by the European Union’s 7th Framework Programme for research, technological development and demonstration, has developed a family of protective ensembles, comprising new skin and respiratory protection solutions for first responders involved in CBRN mass casualty events.

In addition to the presentations of these ensembles and add-ons, participants will be shown a video from the field exercises. A discussion session will also be organised to complete the conference. This event includes lunch and is free for European first responders, academics, industrialists and government departments/agencies tasked with defending against CBRN attacks.

Book your place for the IFREACT final conference via enquiries@cbrneworld.com
We look forward to seeing you there!
fingered hand, but similarly has settled for a thumb and two fingers. As Pedersen explained: “The majority of grippers available have two fingers and although this style of gripper is relatively inexpensive, it is limited in the tasks it can perform. More dexterous, three-finger grippers are in development and are beginning to enter the market, but while some of these are actively controlled they are not very strong. They include underactuated designs that provide more powerful conformal (human-esque) grasping, and these conformal grippers are typically linkage or tendon-based, echoing human anatomy.

“These new conformal hands, such as RE2’s conformal end effector (CE2), can be scaled to the size of a human hand while still retaining their power-to-weight ratio. Full five-finger hands are also in development, but the extra capability for each additional finger beyond three is still being researched. An alternative to one generic dexterous hand is to have a tool box of end-effectors that can be rapidly swapped out at the wrist. For example, one robot may carry a two-finger gripper, a drill, and a cutter and be able to automatically change tools within seconds.”

**Reaching for the future**
The technology seems to be maturing fast - and I would encourage readers to visit both companies’ websites and see for themselves (http://www.hdtglobal.com/products/robotics/adroit-manipulator-arm/ for HDT and https://www.youtube.com/watch?v=Q17XxTHkWgk for RE2).

Neither manufacturer sees size as too much of a challenge since systems are scalable, the downside comes in the weight the system can lift - a small chassis means light loads [or toppling over… Ed.]. The challenge will be finding enough users with this requirement to bring down the cost of ownership, including training. Many operators simply want to pack the device with white noise and watch it disappear. The skills needed for manual neutralisation are rarely taught. While we have televisually grown up on ‘red wire, blue wire?’ this is seldom the reality, and a robot that is capable of more needs an operator that is, too.

The military needs a battle space where the damage caused by a device being exploded is more costly than the robot, arms and operator training. In terms of operational military scenarios that clearly fits with an improvised nuclear device (the archetypal low frequency-high impact event) but few others, but it does fit neatly into civilian scenarios. Major sporting events and high value (in terms of money and culture) buildings come out positive in the counter-charge vs robotic neutralisation cost-benefit analysis. The question is whether there is enough evolutionary pressure for these systems to become main stream with a lower price point. Time will tell; and it wouldn’t be the first time that a predator suddenly appeared to make sense of evolutionary potential!

---

‘Yes [Number Five], disassembled all over the place!’

_There is a cost benefit analysis to be done on sending smart robots to deal with dumb bombs_ ©DoD
Run, walk, or sked to
8th Annual CBRNe World Congress and Exhibition
Growing Closer, staying distinct: merging civilian and military response to CBRN and IED threats
27 - 29 October 2015
Rosen Plaza Hotel, Orlando, Florida
A Falcon Communications event
www.cbrneworld.com/events