

Teleoperations & ROBOTICS

The State of Play in 2025

- | Expert Roundtable
- | Analysis
- | March 2025



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WELCOME



ERF 2024

Teleoperation is a subject that's been of interest to me since, as a child, I learned about the way nuclear engineering was done at Sellafield. Things have moved on in many ways since then, and today we are seeing some really exciting applications of robotics technology in the teleoperation domain.

This white paper represents the thoughts of several of the leading experts in teleoperation today, coming from the EuRobotics Topic Group on teleoperation. I was privileged to spend several hours with them discussing the state of the art and what the future holds for teleoperation.

In a short overview like this we can only touch on a few of the key themes, and if you want to know more then join the Topic Group eu-robotics.net/telerobotics-topic-group/ or get in touch with us at Shadow Robot so we can help you navigate this exciting area of robotics!

I hope you find this as useful as I found the conversations!

RICH WALKER
DIRECTOR, SHADOW ROBOT

THE PANEL OF EXPERTS



KAROL JANIK

MANUFACTURING TECHNOLOGY CENTRE

Karol Janik is the Robotics & Automation Technology Manager at the Manufacturing Technology Centre (MTC), a key UK based Research & Technology Organisation. He leads technology strategy focusing on the widespread adoption of novel robotics and automation in manufacturing and challenging environments. This includes overseeing a portfolio of innovation and adoption activities carried out by a team of over 70 engineers and researchers. Karol has been working in technology R&D for over a decade in multiple industrial sectors including Aerospace, AgriFood, Defence, Nuclear, Space, Marine, and Sustainability across Europe and the UK. He is an active member of the European robotics community and representative for the MTC in associations such as euRobotics, ADRA, or High-Value Manufacturing Catapult (HVMC). He also acts as coordinator of euRobotics Topic Groups on Industrial Robotics & Telerobotics and as advisor to multiple large-scale R&D programmes in the UK and Europe.



ELOISE MATHESON

EUROPEAN ORGANISATION FOR NUCLEAR RESEARCH

Eloise Matheson is a robotics engineer working at CERN, focused on both mechatronics systems design, integration and testing, and teleoperation of robots used regularly in the accelerator complex for inspection, maintenance and repair tasks. Previously she worked in the fields of teleoperation, for space applications as an engineer working at ESA, and later for medical (surgical) robotics at Imperial College London where she completed her PhD. She is currently a co-chair of the EU Robotics Telerobotics and Teleoperation Working Group and a co-chair of the IEEE RAS Technical Committee on Robotics for Nuclear Environments.

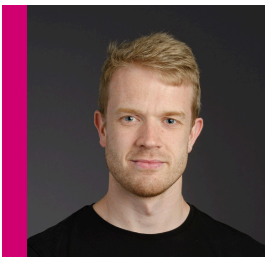
THE PANEL OF EXPERTS



DANIEL LEIDNER

UNIVERSITY OF BREMEN

Daniel Leidner received his diploma degree in communications engineering in 2010, and his M.Sc. degree in information technology in 2011 with distinction from the Mannheim University of Applied Sciences, Mannheim, Germany. In 2017 he received the Ph.D. degree in artificial intelligence from the University of Bremen, Bremen, Germany. His dissertation was honored with the Georges Giralt PhD Award as well as the Helmholtz Doctoral Prize. He is a Professor at the Institute of Artificial Intelligence at the University of Bremen and leads the department of Autonomy and Teleoperation at the Institute of Robotics and Mechatronics, German Aerospace Center (DLR), Wessling, Germany. As Co-Investigator of the Surface Avatar experiments, he investigates artificial intelligence in the context of astronaut-robot collaboration.



CHRISTOPHER MCGREAVY

EUROPEAN ORGANISATION FOR NUCLEAR RESEARCH

Christopher McGreavy received his Ph.D in Robotics and Autonomous Systems, with a focus on legged robotics, from the University of Edinburgh, and M.Sc(R) and M.Sc degrees from the University of Edinburgh and University of Birmingham respectively. He is currently a Robotics Engineer at CERN focusing on robotics for harsh environments, including control and design, with a focus on legged robots.

INTRODUCTION AND KEY INSIGHTS

The field of robotics and teleoperation is evolving rapidly, driven by advancements in automation, artificial intelligence, and human-machine interaction. As industries increasingly turn to teleoperated robotic systems for tasks requiring precision, safety, and remote accessibility, understanding the current state of technology, its trajectory, and the challenges it faces has never been more critical.

This whitepaper presents key insights from a roundtable discussion in late 2024, hosted by Shadow Robot and featuring euRobotics leading experts from CERN, the Manufacturing Technology Centre (MTC), the German Aerospace Centre (DLR), and Shadow Robot itself. Contributors, including Eloise Matheson, Christopher McGreavy, Karol Janik, Daniel Leidner, and Rich Walker—all active in the euRobotics Topic Group on telerobotics and teleoperation—shared their expertise on the latest advancements, industry applications, and barriers to adoption.

Through this discussion, we explore the key themes outlined below. This paper highlights key opportunities and challenges in the field, offering valuable perspectives for engineers, researchers, and industry leaders looking to harness the potential of teleoperated robotic systems.

A

**TELEROBOTICS RESEARCH HAS
ADVANCED RAPIDLY UNLIKE
INDUSTRIAL TAKE-UP**

B

**A LOT OF RESEARCH HAS BEEN
DONE WITH SENSORS AND
FORCED FEEDBACK**

C

**LATENCY IS A FACT OF LIFE IN
TELE-OPERATION BUT THERE
ARE EFFECTIVE MITIGATIONS**

D

**TELEOPERATION HOLDS A KEY
TO REDUCING RISKS TO HUMANS
IN HAZARDOUS SPACES**

E

**HUMAN-ROBOT
COLLABORATION HAS PROVEN
VALUE IN ROBOTIC SURGERY**

F

**GAME DESIGN HAS
INFLUENCED USER
INTERFACES**

G

**CLASSIC AI TOOLS USEFUL BUT
ADVANCED AI CAN'T YET BE
TRUSTED**

H

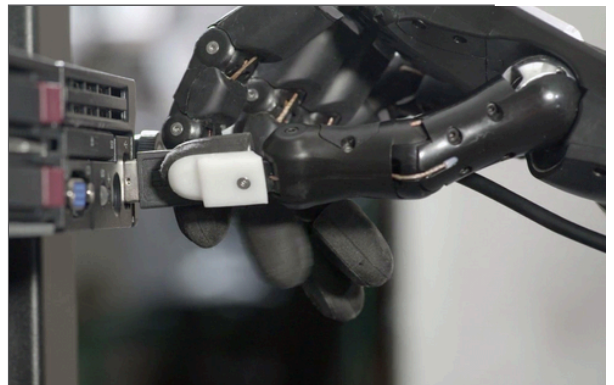
**VERIFICATION OF RESULTS
IMPORTANT AND SO IS
BALANCED REGULATION**

I

**A WIDER RANGE OF
STAKEHOLDERS MUST BE
BROUGHT INTO CONVERSATION**

STATE OF ROBOTICS HARDWARE

Telerobotics has been making big strides in recent years in research, less so in industry, with a lot of focus on telemanipulation. Taking teleoperation at its broadest, teleoperated robotics systems (largely drones) have been much in evidence 'in the real world', especially in conflicts in Eastern Europe and the Middle East. In turn, the use of those technologies in these very dangerous environments offers lessons for future deployment in peaceful applications.



Defence has a long heritage of remote control of hardware in challenging environments. In a very different setting, so has CERN. For some of the difficult aspects of teleoperation, there's a lot of call for manipulation and mapping and a clear need for precision and feedback in sensitive areas. A move at CERN towards use of touch control (haptics) and force feedback, reflects a wider industry trend, with the use of haptics controllers and high resolution gel touch sensors, integrating more force feedback into the operator's control, for safety and general situational awareness. At CERN, force feedback sensing is in the research stage although some deployment has started. The benefit comes in providing metrics to tell how much pressure is being used when turning, if surfaces are touching or how much alignment there is between them. Using sensors in the robots in this way gives the operator valuable task-level information. Eventually full deployment will lead to new levels of safety and operational availability, boosting the success of the mission at CERN.

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At CERN, haptics controllers and high resolution gel touch sensors put more force feedback into the operator's control.

STATE OF ROBOTICS HARDWARE

In a very different setting, direct force feedback experiments had also been carried out using a robot arm outside the International Space Station (ISS). The robot had been used on the ISS from 2005-10 before it was finally brought down and then continued to work flawlessly back on Earth. At the time the control hardware was limited: a force feedback joystick but with only two dimensions, moving left and right, back and forward. Limited in movement or not, it allowed its operator to feel the various forces the robot encountered outside the space station and to detect the differences between them with different damping settings.

A robot arm used in direct force feedback experiments outside the International Space Station for over five years was finally brought back to Earth, where it continued to work flawlessly.

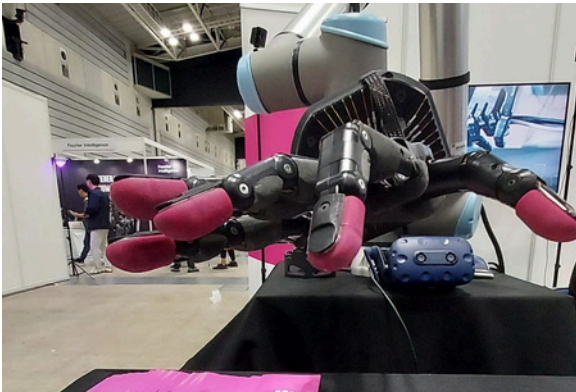
A few years on and the hardware has improved. Since 2019 three different sensing devices have been in use on the ISS: a joystick with zero force feedback but three modes of movement (left-right, front-back and rotation), used for navigation, for example, to control the robot in Rover mode. Also in use – a Force Dimension Sigma 7, offering seven active degrees of freedom, including a high-precision force feedback grasping capability - very effective for when operators need direct control of the robot. Thirdly, a touch-screen (now replaced by a laptop) for high-level commands.

High-level command is important because most of the time operators have to contend with a high time delay, sometimes only in milliseconds but usually longer, with changes to the orbit and the Earth's rotation leading to misalignments. The response has been to look for remedies via different software rather than hardware, to maintain direct control even with longer time delays. In this way operators have been able to mitigate unstable behaviour so that it's still possible to control the robot even with longer delays.

However, this becomes impractical after 2-3 seconds of delay. In theory the system will never become unstable but in practice getting interrupted feedback isn't ideal. One solution, dubbed by one contributor as a 'Monkey Island' interface, is to use simple point-and-click commands in the expectation that the robot will automatically perform the required task.

STATE OF ROBOTICS HARDWARE

There are other potential applications for remote operations especially in challenging environments, with an advanced manipulation capability using different tools on a mobile platform to carry out tasks such as basic repairs or sampling. Evidently there is an appetite for this, although current use in industry is fairly limited. The clear advantage is to be able to carry out maintenance operations remotely in dangerous or inaccessible environments. One sector where teleoperations have been most adopted and are most advanced is healthcare with robotic surgery. There are also opportunities in the pharmaceutical and biomedical sectors, both fields requiring very complex manipulation in heavily-regulated and challenging environments. For example a pharmaceutical procedure involving the human handling of very fine powders has to be carried out with hazmat suits and several transparent plastic bags at a time, one inside another, a complex, cumbersome and costly operation. In this kind of setting and in others with a comparable need for handling hazardous materials such as in the nuclear industry, developments in robotic manipulation via tele-operations hold a lot of promise.



At CERN, remote robotic manipulation has been effectively used in experiments involving the bombardment of a lead block with particles from the Large Hadron Collider (LHC) for a period of time. The block is encased in a steel box which is then drill-milled away to enable the bombarded block to be inspected with an endoscope. The procedure required two robots to perform the drilling and a third with the endoscope to inspect the very highly radioactive source material.

Further complexity involved the presence of cooling liquids, plus dust from the milling, and the need to move metal parts around without damaging surrounding surfaces or spreading radioactive material. Retrieving the robot intact for future use was a further consideration. All of this involves multiple robots working together, with their respective operators working in coordination to carry out what becomes a time-consuming and delicate operation.

In pharma, the human handling of very fine powders involves hazmat suits. It's complex, cumbersome and costly. In this kind of setting, developments in robotic manipulation via tele-operations hold a lot of promise.

SOFTWARE - INFLUENCE OF GAMES

Game design is important for telerobotics. As well as the 'Monkey Island' style interfaces previously mentioned, there are several examples from surgery robotics involving the use of screen interfaces that would be familiar to gamers. At the German Aerospace Center DLR, a student designer's knowledge of game design enabled researchers to gain a fresh third-person perspective through the use of a game engine (Unity) to recreate the space working environment, complete with spacecraft and landing site, to provide an effective simulation.



This enhanced the researchers' awareness of the environment and gave them an improved capability to find solutions to errors when these occurred. The view from DLR is that this is just the tip of the iceberg and that game design offers huge potential for the future.

With the advantages that such multi-user perspectives offer, gaming's collaborative possibilities read through to other non-gaming scenarios where experts can log into a virtual space to help an operator physically performing a task. Tele-surgery is one example of this 'expert in the loop' approach. Something comparable is now also emerging in the world of transport, where some self-driving car companies are effectively deploying robot taxi with backup taxi-driver-by-teleoperation-as-a-service dropped in.

"If you can have your operator somewhere far away, you really open up your workforce and your possibilities. We saw this from one of our robotics working groups where they were almost offering robots-and-operators-as-a-service. That starts to be quite interesting. With cloud-based control as well, you can operate robots from anywhere in the world."

ELOISE MATHESON, CERN

DEALING WITH LATENCY

The question of latency goes hand in hand with tele-operation. Dealing with delay in networked environments, how much can be tolerated and accommodated, and the tools used to manage this – these are all part and parcel of the tele-operation environment. The use of fibre-optics, tethered communication and advanced mesh networks effectively remove the issue of latency or reduce it to a manageable level. Volumetric video streaming is another game-changer, enabling a work environment such as an inspection and maintenance task to be viewed immersively from several angles in real time. With data compression, too, latency issues can be managed.

Experience in the lab is promising but security concerns are real and this often limits industrial deployment to cabled settings, with the use of wireless viewed with considerable caution.



Bandwidth is another consideration. Developments in 5G and 6G offer the prospect of very high bandwidth. Meanwhile, working with low bandwidth is a present reality. One solution is to build models of the environment and then to render these virtually. Volumetric streaming has been used to slash bandwidth requirements, producing very good visuals but using 95% less data.

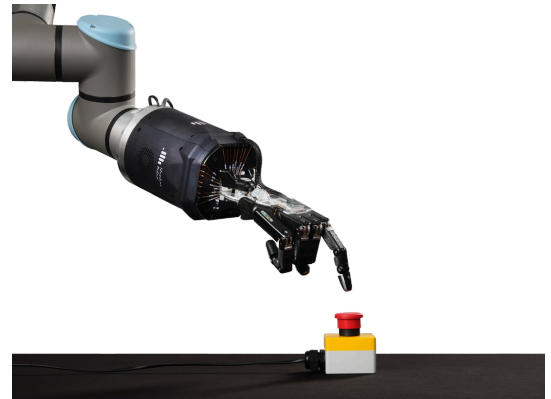
Another example is [Cybathlon](#), a platform that challenges teams from all over the world to develop assistive technologies suitable for everyday use with and for people with disabilities. In this setting the term 'low bandwidth' has an added sense of referring to the limited scope for movement of people suffering various kinds of motor impairment. With a combination of AI, image recognition, user intention recognition and a smart control algorithm, people can use the robot as an extension of themselves.

At CERN, which controls its robots over a 4G network, latency is an operational reality but one for which there are some workarounds, so that even when problems with varying data rates arise, there is enough data arriving so that the operator can always make the next decision.

In space, DLR sees the use of large language models and chat agents as a game-changer for operating in conditions of high latency. The scenario given was of an astronaut orbiting Mars trying to resolve a problem with a robot. Instead of waiting up to 40 minutes for an answer from the ground, the astronaut could type a query into chat, ask the AI why the robot cannot carry out the function, and get a simple answer immediately.

PHYSICAL SAFETY AND SECURITY

One aspect of safety in a scenario involving robots is about making sure that the human in the loop understands what is and isn't happening in a given setting, what can and cannot happen and then making a decision to proceed or not based on that understanding and a situational assessment. There are work-space design considerations, too - how much or how little space is needed so the operator can perform a task effectively without having to worry about what's happening beyond the immediate scope of operation.



Other fail-safe features, for example in a multi-camera set-up, may include a robot only being able to go forward when the forward camera is turned on. Here, the keynote is safety by design.

And in the background there is the essential groundwork of planning the whole mission and making all the risk assessments needed, deciding how much data an operator needs and what efforts are required of the operator in turn. At the same time, how much can be automated and how processes can be made to work autonomously using teleoperation are other areas where safety decisions are made.

In conditions where latency is a factor, and high-level commands are given but the robot deals with the rest, safety and security are high on the operator's list of considerations. In more complex systems, the robot has to make some decisions on the ground. Actuation- and impedance-based controls may be built in, for example to prevent high-impact collisions. Decisions about the best balance between system- and operator-determined controls need to be finely judged, depending on the application, and always with the understanding that risk is never zero.

At CERN, as might be expected, for every intervention there is a very detailed set of risk analyses, safety procedures and mitigation strategies. The presence of risk is accepted, the risk minimized and backup strategies brought into play if something does go wrong.

HUMAN-MACHINE COLLABORATION

Once a mission is planned, risk assessments completed, mitigation plans put in place and resources gathered together, what's the role of tele-operation in the human-machine collaboration that follows?

For continuous or high-frequency 'business as usual' procedures, one approach is to automate as much as possible and operate with some form of shared control, perhaps with computer vision capability, with an operator supervising and making certain decisions.

Another more bespoke approach is to review the mission plan and then decide the best way to handle the challenges, risks and mitigations. This may involve one robot with a team of people looking after different camera streams and everybody with their finger on the pulse sharing control. Or it might involve one person managing multiple systems – mainly supervising and only intervening when needed. These are different scenarios but they each rely on human-machine collaboration, with safety and efficiency as priorities every time.

When non-specialists are involved, it's important to get people to think in the right way about what robots can do. CERN is such a multi-faceted organization that robotics can be used in many different ways. With their interfaces, procedures and training the engineers aim to make the system as easy as possible for non-experts to use. One part of this is to adopt a protocol that operators leave the robots in a state so that people from other parts of the organisation can use them for their own particular operation. This requires a variety of interface design, plenty of iterations and a lot of education of non-specialists about the robot's capabilities.

There's an element of training and educating around what is possible and what is not possible. You need to make sure the robot's functionality is really understood because when you don't come from robotics your experience or your impression of what robotics can and can't do is very, very different.

ELOISE MATHESON, CERN

In space, at the ISS, remote control has been part of operations for a long time, while robots are a more recent arrival, with the two now used in combination. Working with robots forms part of an astronaut's training but given everything else their training has to cover in a short time it does not make them robotics experts, hence the need for the human-robot interface to be as intuitive as possible. In fact 'gamifying' the interface, making it intuitive and easy to use, has not stopped astronauts from being able to carry out often complex experiments or even showing other astronauts how to use it successfully for themselves

AI AND AUTOMATION INTEGRATION

There are various beliefs about what AI can or can't do, when it will be able to do it, and what's already possible. From the view-point of the robotics engineer there's a natural curiosity about what the classical AI or 'lower-case ai' tool-box has to offer, especially on reliability, repetition and on-time delivery.

The consensus view was that "lower case" AI offers several tools, some are within easy reach, and of these, perception stands out. One example: it may not be easy to understand whether a robot 'knows' what it sees but by using an AI overlay the operator can get a really good idea of how much of an environment a robot understands.

Vision, perception and semantic segmentation for object recognition are all very useful tools that help robots to make more decisions about the environment. The use of AI for perception in particular is becoming an automatic choice.

Meanwhile, at CERN, work to improve the integration of large language models into high-level control has also proved to be useful in tackling issues arising from latency and also from the user interface. This provides a relatively simple tool that's fairly easy to use. AI tools have also been used to assess legged robots' stability using learned methods ('Don't walk this way. You'll be less safe than if you walk this way...'). Classical methods are also effective, but integrating more semantic knowledge allows the robot not to make decisions about operations in a certain environment but at least advise or make suggestions to the user.

A big part of the inclusion of AI is to absolutely not forget the user. One of the most annoying things about modern UIs is stuff like when you're using MS Word and it starts thinking it knows better than you and that gets very frustrating... There's a fine balance to be struck. The AI needs to be useful and not overtake the user.

CHRISTOPHER MCGREAVY, CERN

AI AND AUTOMATION INTEGRATION

For industry, the view from MTC is that 'classic' AI can help with planning and also with routine tasks – manipulation, navigation, highlighting objects of interest and so on. This very usefully removes some of the human work-load, freeing the operator to do less hands-on work and to focus on decision-making. However there is still some way to go before we can expect to see the useful deployment of advanced AI tools in scenarios that are of serious practical application for robotics in real-world industrial scenarios.



Leaving aside considerable safety, ethical and regulatory hurdles, part of the challenge for AI in industry is access to relevant specialised data. While large language models have been fed with huge amounts of data, it seems unlikely that industrial concerns operating in highly competitive environments will willingly give away their proprietary data to make AI better.

We know that AI can tell an apple from a watermelon, that it can recognise gearbox A from gearbox B. So as an assistant in some use cases AI might be very helpful. But a lot needs to be improved to let it help you with intention- or fault-recognition. Are these models capable of saying 'You shouldn't be doing that' or 'This is going wrong'? We're nowhere near that.

KAROL JANIK, MTC

VERIFICATION AND REGULATION

A project owner, commissioner or sponsor may well not focus on the technical specifics of how an operation is conducted, but will have an interest in both verification – are these the right results? – and in regulation – have we obtained these results in a way that satisfies regulatory requirements?



At CERN, emphasis is placed on the verification of results obtained via machine learning algorithms in a range of operations, not only those using robots. Beyond a binary success or failure call, verification probes degrees of tolerance in the grey areas – how right (or wrong) is a little bit right or wrong? Inevitably there's an element of judgement that's far from easy to call.

Trust. It's a towering topic of contemporary concern for a host of institutions – and it is, too, for developments in technology, not least robotics and AI. Concerns about controlling the tech and its uses have led to highly cautious safety protocols which some researchers believe are restrictive and inconsistent in comparison with the safety regimes governing uses of more established technology in other settings. Clearly robots can be dangerous if they are used in the wrong way, but with telepresence control and teleoperation, there are built-in measures to prevent danger in the first place.

Take trains. The only thing separating you and me from several thousand tons of steel is a painted line on the platform. Imagine if trains were invented today and how difficult it would be to get them on the rails, because safety regulations grow and grow. For robots, you need a fence, an emergency stop, or the robot's arm cannot move while the base is moving... At some point we need to work towards standards that are actually attainable by companies and researchers.

DAN LEIDNER, DLR (GERMANY SPACE AGENCY)

VERIFICATION AND REGULATION

Training and licensing operators to work with robots should provide many of the necessary safeguards. Concern about restrictions are in no way voiced from a sense of disregard for safety, but reflect instead a real fear that those restrictions may become so tight that they create a barrier to adoption of robots, leading service providers considering the use of robots in healthcare and other sectors to look instead for alternatives to avoid what they may see as an additional burden of regulation.



Education plays a part in reducing the risk that insurmountable regulatory barriers will impede the wider adoption of robots. In the UK there is ongoing work to raise awareness among national regulators in several industrial sectors about what robots and autonomous systems can do.

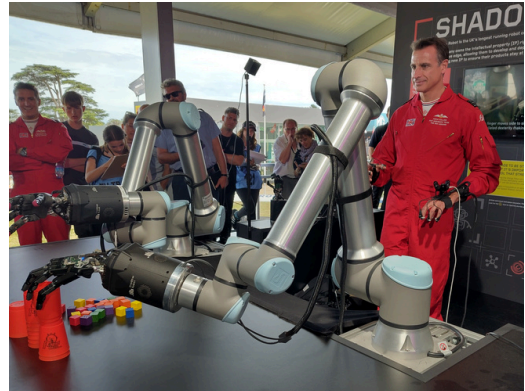
Provided it is recognised that each sector has its own regulation and there is a willingness to work at the regulators' pace, results can be promising, with regulators found to be open to change.

We demand from machinery much more than from human operators. We had a good example of a manufacturing company with an awful process where human operators were dipping stuff in hot wax full-time and could quite easily be burned. It's easy to automate, but so difficult to fulfil the requirements of the Machinery Directive that they'll just keep having people there.

KAROL JANIK, MTC

TELEOPERATIONS - COMING SOON

Discussions around the next technology to land inevitably lead to talk of autonomous vehicles, which have long been on the horizon but never quite seem to get much closer. Autonomy is a tantalising prospect, whether for cars or other robotic applications, but the reality is that for some time to come, robots will not yet be sufficiently well developed to operate autonomously in highly – perhaps even infinitely - unpredictable human environments. There still needs to be a human controller in the background.



Looking to the future, the use of generative AI for 3D designs or modelling could be feasible, if not yet to create a full working design then at least to provide a start point. Developments in software may provide the key – a familiar refrain in robotics – although there's also work still to be done to improve the hardware and make robots more robust. Improvements are made all the time, of course, but the advances may seem small-step and incremental.

Sometimes it's necessary to look up from the work-bench and reflect on how far recent advances in robotics applications have come already. For example, the advance of robotic surgery, once the realm of fiction, can already be counted in terms of millions of procedures already completed. At CERN, tele-robotics is used every day to fix things that are otherwise unfixable by humans, an impressive fact. Of course, CERN is exceptional as a cutting-edge research environment. A scan around other sectors produces a quick list of applications where robots are already playing significant roles, for example, by carrying out inspection and maintenance tasks in hazardous settings or performing fast-pace pick-and-place activities in warehouses.

At space launch sites and in nuclear installations, robots have been used successfully to check if something has gone wrong in locations where humans cannot go, providing information that can then be used to rectify errors.

TELEOPERATIONS - COMING SOON

Another example in a different setting is the collection and clean-up of ammunition from the Second World War on the Baltic sea-bed, another highly hazardous and inaccessible environment but one for which robotics holds the key.

Sometimes the pace of adoption of robots – or resistance to their use – is governed by socio-economic or cultural rather than technological factors. An example was given where workers in a challenging work environment were reluctant to see robots introduced for the most dangerous aspects of the operation because they feared they would lose their bonus for hazardous working.

Conversely a German trade union unexpectedly spoke out in favour of robots in the workplace because they helped keep pay rates up for their members, perhaps contrary to expectations. UK trade unions have a similar positive outlook because in their analysis, the use of robots leads to better, safer jobs.

At major events like the European Robotics Forum it's good to freshen up discussions by looking beyond the reliable regular contributors to hear other voices.

These may be end-users for whom telerobotics is a tool rather than the main focus of their work. Interesting perspectives could also be expected from trade unions and regulators. Speakers from less obvious domains like ocean monitoring or solar farms may very often come with interesting stories, very useful questions and ideas for requirements to help their work that could lead to new developments in robotics.

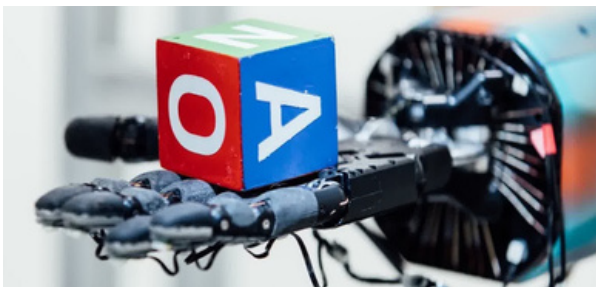
CASE STUDY

OVERVIEW

OpenAI researchers wanted to explore simulated and machine learning using their robotic system called DACTYL in which a virtual robotic hand learns through trial and error.

To put these human-like strategies to the test in the real world, they needed a dexterous robot hand in order to transfer their data onto and test performance.

These human-like strategies were then transferred to Shadow's Dexterous Hand in the natural world enabling it to grasp and manipulate objects efficiently, no fine-tuning needed.



PROJECT NAME - DACTYL

CLIENT NAME - OPENAI



PROJECT :

OpenAI were able to create Dactyl, a system for manipulating objects using a Shadow Dexterous Hand. OpenAI place an object such as a block or a prism in the palm of the Shadow hand and ask Dactyl to reposition it into a different orientation; for example, rotating the block to put a new face on top. The network observes only the coordinates of the fingertips and the images from three regular RGB cameras.

Dactyl learns to solve the object reorientation task entirely in simulation without any human input. After this training phase, the learned policy works on the Shadow Dexterous Hand without any fine-tuning.



CHALLENGES

Working in the real world.

Reinforcement learning has shown many successes in simulations and video games, but has had comparatively limited results in the real world. By using our Dexterous Hand, OpenAI were able to test Dactyl on a physical robot.

High-dimensional control.

The Shadow Dexterous Hand has 24 degrees of freedom compared to 7 for a typical robot arm.

Noisy and partial observations.

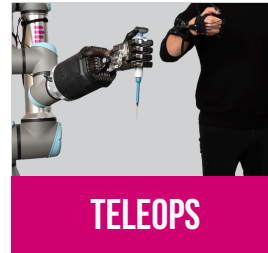
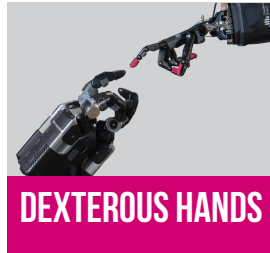
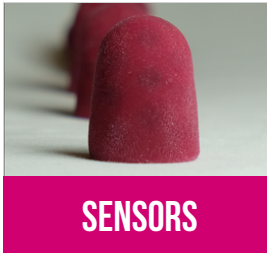
Dactyl works in the physical world and therefore must handle noisy and delayed sensor readings. When a fingertip sensor is occluded by other fingers or by the object, Dactyl has to work with partial information. Many aspects of the physical system like friction and slippage are not directly observable and must be inferred.

Manipulating more than one object.

Dactyl is designed to be flexible enough to reorient multiple kinds of objects. This means that our approach cannot use strategies that are only applicable to a specific object geometry.

ABOUT SHADOW ROBOT

Shadow Robot is a pioneer in robotic systems, specializing in highly dexterous robotic hands and teleoperation systems. Known for pushing the boundaries of robotics innovation, the company collaborates with leading organizations, including NASA, [Google DeepMind](#), and MIT. Shadow Robot's flagship product, the Dexterous Hand, features 24 movements and 20 degrees of freedom, making it one of the most advanced humanoid robotic hands globally.



Shadow Robot are also available as consultants for robotics projects, as they use their near 30 years of experience in the space to help you achieve your goals by utilising robotics solutions. One of such consultancy projects (working with Google DeepMind) has resulted in the creation of DEX-EE, the most robust robot hand on the market.

The company emphasizes customization and quality, tailoring each system to client needs and providing robust support throughout the project lifecycle. It also stands out for its commitment to ethical robotics, refusing to sell products for military applications and focusing on “robots for good.” Shadow Robot has received numerous accolades, such as the Queen’s Award for Enterprise and the AI Global Awards.

Products and solutions from Shadow Robot are widely applied in research with a focus on healthcare and hazardous environments, empowering industries to explore advanced robotics capabilities.



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