Robotics and autonomy

From space robots to applications in daily life

Robots are an integral part of our world, with mostly non-autonomous systems providing support in practically every aspect of modern life. These robots are used in industry, surgical procedures, and the household, with more autonomous robots developed for space and deep-sea applications which are more detached from human activities. Dr Sirko Straube and Professor Dr Frank Kirchner from the German Research Center for Artificial Intelligence (DFKI) seek to translate the greater autonomy of maritime and space applications to the human sphere, opening possibilities for fruitful interactions between man and machines.

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The term 'robot' often evokes images of the highly intelligent and humanoid mechanical systems described in books, films, and popular media. The reality of modern robots is more complex, with robotic systems such as food-preparation devices, smart vacuum cleaners, rehabilitation exoskeletons, drones, and industrial robotic arms already in use, and more applications proposed in almost every sphere of human experience.

ROBOTS AND AI

Computer algorithms designed to perform tasks normally requiring human intelligence, like speech recognition, decision-making, and language translation, collectively referred to as artificial intelligence (AI). AI has become increasingly advanced in recent years, with algorithms even able to beat human players at strategic games, such as Go and chess, through trial and error learning. The most recent advances also include the likes of AI systems (such as ChatGPT) that boost the application of AI in everyday life and also function as a booster for robotics technology.

Robots are made of real-world hardware – a body, mechanical components, electrical circuits, sensors to monitor conditions and flag when changes occur, and actuators to receive signals and perform actions – all connected through a composition of software programs. Modern robots are often developed in tandem with integrated AI software to produce intelligent robotic systems with varying degrees of autonomy.

KEEPING ROBOTS AT A DISTANCE

In collaboration with colleagues from social sciences, Dr Sirko Straube and Professor Dr Frank Kirchner from the German Research Center for Artificial Intelligence (DFKI) used the Delphi method of progressive and iterative questionnaires to determine how people perceive different types of robotics applications, from household tasks to space exploration. Participants' responses to robotics and AI were overwhelmingly positive, with only one in five viewing them negatively, and only one in ten seeing robots as unnecessary for society.

However, a few considered AI and robotics to be reliable and error-free. Responders were also much more critical of robot use in private homes and care than in the context of deep-sea or space exploration. The team suggest this might show a preference for using robots far away from human settings. Emotional considerations could also be a factor, as care-giving is often associated with empathy, a characteristic not commonly associated with machines.

HOW AUTONOMOUS ARE ROBOTS?

Autonomy is a key aspect of any robotic system. Developers tend to classify robots as non-autonomous if they are fully controlled by human operators, semi-autonomous if they use AI to operate independently in certain tasks but require human help in some cases, and fully autonomous if they can plan, replan, and react appropriately to their environment in real time, without the need for human input. In reality, most current systems still involve a degree of human support. The level of autonomy depends on the environment, the task in hand, and the context of the operation.

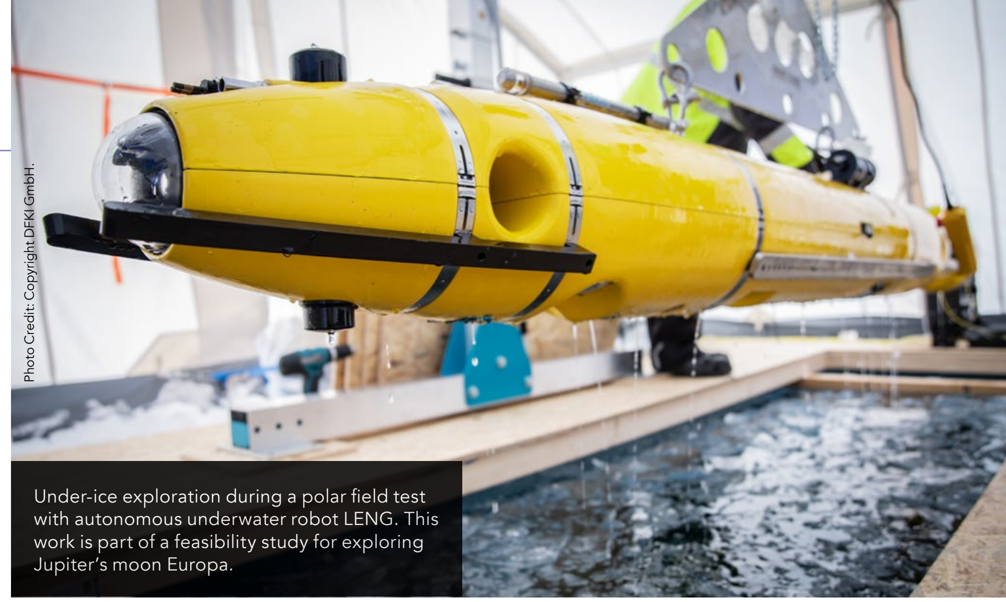
Straube and Kirchner stress that autonomy is useful in highly uncertain scenarios. When a robot is placed on the Moon or Mars, it will naturally be exposed to situations where standard procedures might not work. In that case, a non-autonomous robot would wait for human input to continue its task. A robot equipped with a certain level of intelligence could analyse its surroundings and decide on an action without the need for outside input.

EXPLORING HARSH ENVIRONMENTS

Intelligent robots show great potential for use in hazardous or inaccessible environments. Robots could be sent to the deep sea or planetary surfaces to create maps, obtain samples, and build, inspect, and maintain infrastructures. Search and rescue robots could enter hazardous and unstable areas such as earthquake sites to search for survivors and provide useful footage, reducing risks posed to human rescue teams.

Robot autonomy is evaluated using field tests in different scenarios. For example, in an analogue for similar sites on the Moon and Mars, the researchers found that highly mobile robots exploring lava caves in Tenerife orientated themselves by generating landmarks, planning, simulating, and executing their actions as they mapped the caves. However, they still required help when their return path was blocked, or sensors malfunctioned. This calls for engineering a next generation of robots that are more robust.

The researchers also propose systems with different robots working together with humans using exoskeletons and teleoperation, which are closer to real situations in which autonomous robots could be deployed. Significant human–robot interaction and high levels of autonomy would be required in these cases.



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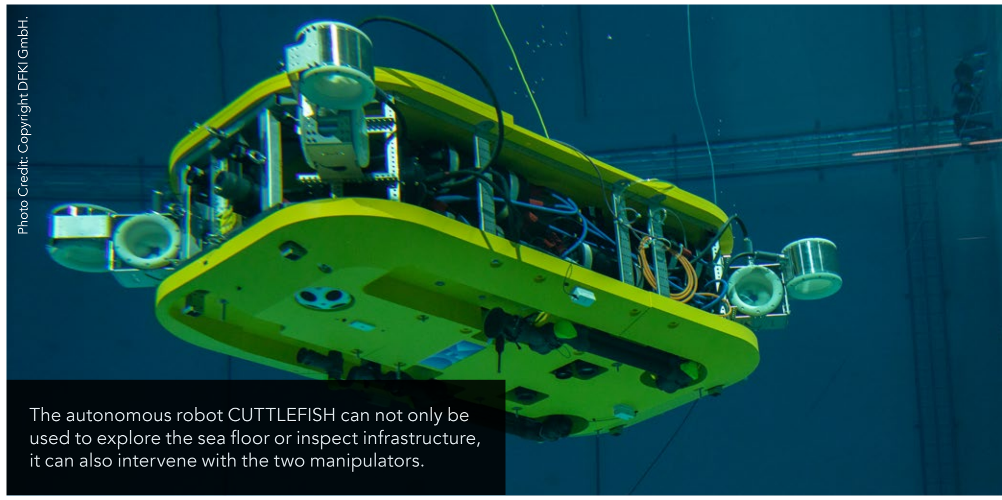
Under-ice exploration during a polar field test with autonomous underwater robot LENG. This work is part of a feasibility study for exploring Jupiter's moon Europa.



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The autonomous robot CUTTLEFISH can not only be used to explore the sea floor or inspect infrastructure, it can also intervene with the two manipulators.

> ***For the foreseeable future, humans will remain a key component of robotic missions in space and the deep sea.***

ROBOTS IN SPACE

The Moon, Mars, and Jupiter's moon Europa are key targets for intelligent robotic exploration. The Moon is our nearest planetary body and presents several options for habitation and exploration. Autonomous robots could potentially be employed to build a base on the Moon, which could be used as a starting point for exploring more distant bodies.

Missions to Mars would likely involve exploration, mapping, and sampling of potential resources and determining sites for future infrastructure. The timescales for communication between Earth and Mars are prohibitively high due to distance, making robot autonomy even more important. The robots employed must operate independently without waiting for remote human intervention.

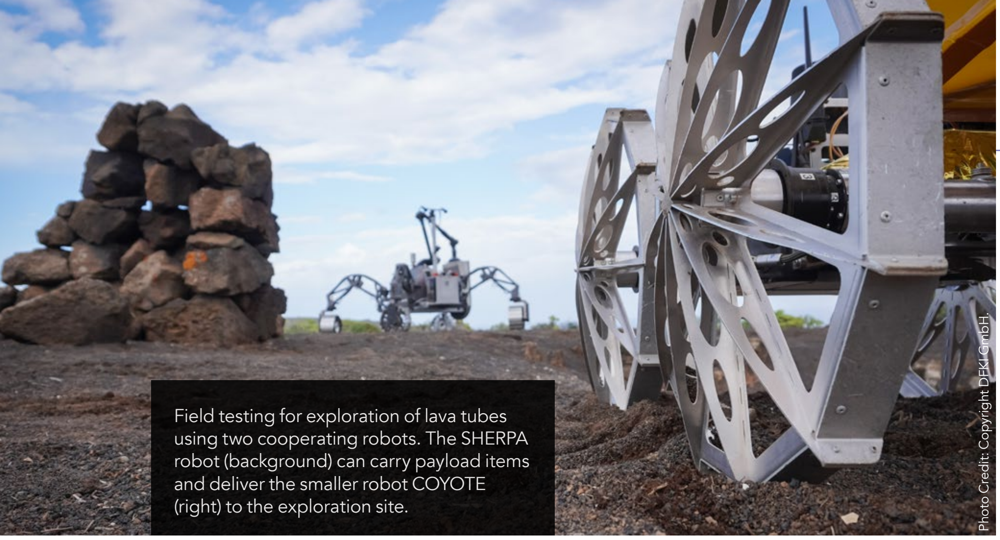
Scientists suspect there may be a deep ocean under a thick ice layer on Europa that could contain life. For this even more distant mission, after landing a probe and digging through the ice, aquatic robots would be an ideal exploration tool. These aquatic robots would necessarily be autonomous, as human intervention would not be practical in this case.

With this in mind, the researchers developed an autonomous aquatic vehicle for this type of mission that could fit into an ice drill, navigate autonomously, use no energy to dive, search the seafloor, and autonomously dock on return to the probe for data transfer. Autonomy is as crucial for deep-sea robots as in space because communication is difficult and unforeseen challenges such as shifts in currents can occur.

HUMAN–ROBOT INTERACTIONS

For the foreseeable future, humans will remain a key component of robotic missions in space and the deep sea. For example, humans and robots could share tasks for maintenance of space stations such as the International Space Station (ISS), in which humans can either directly control robots through teleoperation or instruct them to perform tasks. In this scenario, robots would not just be a tool, but an assistant to the human.

Hybrid teams could be formed in the future, in which robots and humans act as autonomous partners fulfilling a task. These applications require the development of technologies that provide effective communication between human and robotic team members. This type of human–robot cooperation will also be crucial in developing intelligent robotic solutions in healthcare and industrial



Field testing for exploration of lava tubes using two cooperating robots. The SHERPA robot (background) can carry payload items and deliver the smaller robot COYOTE (right) to the exploration site.

Photo Credit: Copyright DFKI GmbH

settings, where effective and precise communication is essential.

THE LEAP TO INDUSTRY

Although robots have the potential for widespread industrial applications, there are several barriers to transferring the results obtained in space and deep-sea exploration to industry. Different levels of knowledge transfer can be required for certain applications, from details on individual software and hardware parts, complete robotic frameworks or systems, to the robotics and AI knowledge needed for a particular use.

A research institute such as DFKI does not deliver products, but rather assists with knowledge transfer into applications, for which resources are normally provided by industrial partners, and occasionally, public bodies. The introduction of AI and robotics technologies in a company takes significant time and resources, and sometimes, also initiates transformative processes in the company itself. Here, a research institute like DFKI can become a strong partner in accompanying this process by providing the relevant technology building-blocks, helping to gain the required knowledge and competence with the company, and providing infrastructure for testing and evaluation.

ROBOTS IN EVERYDAY LIFE

In standard industrial applications, such as a robotic arm in a factory, operating conditions are highly controlled. However, a fully autonomous robot used in everyday life would need to interact with people in constantly evolving scenarios. It must act independently, learn, solve complex tasks, and react to unpredictable situations, and its proximity to humans means that it must be reliable and safe.

As the human environment places high demands on the physical, mechanical, and electrical hardware and AI software of an intelligent robot system, the next generation of robotic systems developed for everyday use will be semi-autonomous rather than fully autonomous. These robots will have some independence, such as the capacity to navigate around obstacles, with humans controlling complex decision-making and activities.

Semi-autonomous robotic systems present many possibilities within care settings, and researchers have developed adaptive robotic motorised beds with a robotic arm and sensors to adjust bed position depending on need, and intelligent exoskeletons worn by neurology patients for their rehabilitation.

THE DAWN OF AUTONOMOUS ROBOTICS

Due to the ever-evolving nature of the field, it is difficult to determine when fully autonomous robots will be available for use in human settings. Several promising robotics systems developed for hazardous situations present high levels of autonomy, and Straube and Kirchner suggest that their autonomy and cooperation could be transferred to applications in the human sphere. More research and development is required to ensure the reliable operation of autonomous robots in complex human environments to eventually realise the dream of robots and humans working together as a team.

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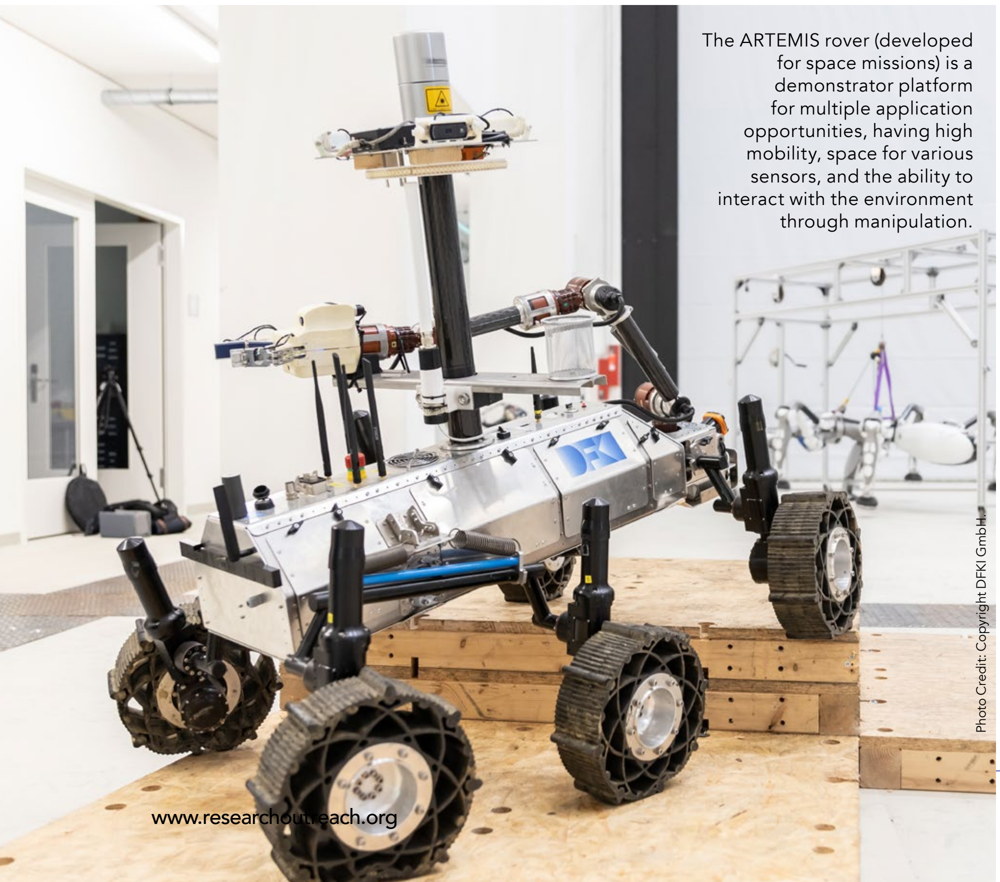

The ARTEMIS rover (developed for space missions) is a demonstrator platform for multiple application opportunities, having high mobility, space for various sensors, and the ability to interact with the environment through manipulation.

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Behind the Research

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Research Objectives

The researchers explore the current robotic systems and their sustainable expansion into future industrial applications.

Detail

Bio

Dr Sirko Straube studied neurobiology and computer science at the Albert-Ludwigs-University Freiburg, Germany (2005). After completing his dissertation about human object recognition (2009), he joined the Robotics Innovation Center in Bremen, Germany, first at the University Bremen – later at DFKI GmbH, leading projects focused on human–machine interaction, machine learning, hybrid teams of humans and robots, and advanced training for companies. Since 2015, Sirko Straube is the institute's deputy head. His core interests are in cooperation of industry and research, successful knowledge transfer, and bringing more transparency about current AI-trends into public awareness.

Dr Frank Kirchner is an Executive Director of the German Research Center for Artificial Intelligence, Bremen, and is responsible for the Robotics Innovation Center – one of the largest centres for AI and Robotics in Europe. Founded in 2006 as the DFKI Laboratory, it builds on the basic research of the Robotics Working Group headed by Kirchner at the University of Bremen. There, Kirchner has served as the Chair of Robotics in the Department of Mathematics and Computer Science since 2002. He is one of the leading experts in the field of biologically inspired behaviour and motion sequences of highly redundant, multifunctional robot systems and machine learning for robotics control.

Funding

The work is most often supported by funding from the federal state of Bremen, national ministries like BMBF, BMWK, or research funding from the European Union. With direct funding from industry, the technology is then transferred into application.

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Personal Response

What could limit the future level of autonomy for robots used in the human sphere?

" The most important fields currently limiting higher autonomy levels are the following:

1. robustness in function (albeit acting in a dynamic environment);
2. perceiving the context of action and adapting the action appropriately;
3. learning from errors and the reasons for their origins.

Only when robots are equipped with these, they will be able to act in everyday life on a long-term scale. If not, they will only be able to work on specific tasks or with major limitations.

The more humans and robots work together, the more the interaction between the two comes into play. Humans are experts in interaction while robots still have typically fewer interaction possibilities, which has to change to a large degree. "