Legged robots need more testing before real-world use

When it comes to the evolution of mobile robots, it may be a long time before legged robots are able to safely interact in the real world, according to a new study.

Led by a team of researchers at The Ohio State University, the study published recently in the IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS) 2022 describes a framework for testing and characterizing the safety of legged robots, machines that, unlike their wheeled counterparts, rely on mechanical limbs for movement. The study found that many current legged robotic models don't always act predictably in response to real-life situations, meaning it's hard to predict whether they'll fail -- or succeed -- at any given task that requires movement.

"Our work reveals that these robotic systems are complex and, more importantly, anti-intuitive," said Bowen Weng, a PhD student in electrical and computer engineering at Ohio State. "It means you can't rely on the robot's ability to know how to react in certain situations, so the completeness of the testing becomes even more important."

As mobile robots evolve to carry out more diverse and sophisticated tasks, many in the scientific community also note that the industry needs a set of universal safety testing regulations, especially as robots and other artificial intelligence have gradually begun to flow into our everyday lives. Legged robots especially, which are often made of metal and can run as fast as 20 mph, could quickly become safety hazards when expected to operate alongside humans in real and often unpredictable environments, said Weng.

"Testing is really about assessing risk, and our aim is to investigate how much risk robotics currently presents to users or customers while in a working condition," he said.

While there are currently some safety specifications in place for the deployment of legged robots, Weng noted that there isn't yet any common agreement on how to test them in the field.

This study develops the first data-driven, scenario-based safety testing framework of its kind for legged robots, said Weng.

"In the future, these robots might have the chance to live with human beings side-by-side, and will most likely be collaboratively produced by multiple international parties," he said. "So having safety and testing regulations in place is extremely important for the success of this kind of product."

The research, which was partly inspired by Weng's work as a vehicle safety researcher at the Transportation Research Center, which partners with the National Highway Traffic Safety Administration, takes advantage of sample-based machine learning algorithms to discern how simulated robots would fail during real-world testing.

Though various factors can be used to characterize a robot's overall safety performance, this study analyzed a set of conditions under which the robot would not fall over while actively navigating a new environment. And because many of the algorithms the team used stemmed from previous robotics experiments, they were able to design multiple scenarios for the simulations to run.

One trial focused on studying the robot's ability to move while performing tasks at different gaits, such as walking backward or stepping in place. In another, researchers tested whether the robot would take a tumble if it was periodically pushed with enough force to alter its direction.

The study showed that while one robot failed to stay upright for 3 out of 10 trials when asked to slightly speed up its gait, another could remain upright over 100 trials when pushed from its left side, but fell over during 5 out of 10 trials when the same force was applied to its right side.

Eventually, the researchers' framework could help certify the commercial deployment of legged robots and help establish a safety benchmark for robots created with different structures and properties, though Weng noted it'll be a while before it can be implemented.

"We believe this data-driven approach will help create an unbiased, more efficient way to make observations of robots in the conditions of a test environment," he said. "What we're working towards isn't immediate, but for researchers down the line."

Co-authors were Guillermo Castillo and Ayonga Hereid of Ohio State, and Wei Zhang of the Southern University of Science and Technology in Shenzhen, China. This work was supported by the National Science Foundation and the National Natural Science Foundation of China.

Quantum physicists make major nanoscopic advance

In a new breakthrough, researchers at the University of Copenhagen, in collaboration with Ruhr University Bochum, have solved a problem that has caused quantum researchers headaches for years. The researchers can now control two quantum light sources rather than one. Trivial as it may seem to those uninitiated in quantum, this colossal breakthrough allows researchers to create a phenomenon known as quantum mechanical entanglement. This in turn, opens new doors for companies and others to exploit the technology commercially.

Going from one to two is a minor feat in most contexts. But in the world of quantum physics, doing so is crucial. For years, researchers around the world have strived to develop stable quantum light sources and achieve the phenomenon known as quantum mechanical entanglement -- a phenomenon, with nearly sci-fi-like properties, where two light sources can affect each other instantly and potentially across large geographic distances. Entanglement is the very basis of quantum networks and central to the development of an efficient quantum computer.

Today, researchers from the Niels Bohr Institute published a new result in the journal*Science*, in which they succeeded in doing just that. According to Professor Peter Lodahl, one of the researchers behind the result, it is a crucial step in the effort to take the development of quantum technology to the next level and to "quantize" society's computers, encryption and the internet.

"We can now control two quantum light sources and connect them to each other. It might not sound like much, but it's a major advancement and builds upon the past 20 years of work. By doing so, we've revealed the key to scaling up the technology, which is crucial for the most ground-breaking of quantum hardware applications," says Professor Peter Lodahl, who has conducted research the area since 2001.

The magic all happens in a so-called nanochip -- which is not much larger than the diameter of a human hair -- that the researchers also developed in recent years.

**Quantum sources overtake the world's most powerful computer**

Peter Lodahl's group is working with a type of quantum technology that uses light particles, called photons, as micro transporters to move quantum information about.

While Lodahl's group is a leader in this discipline of quantum physics, they have only been able to control one light source at a time until now. This is because light sources are extraordinarily sensitive to outside "noise," making them very difficult to copy. In their new result, the research group succeeded in creating two identical quantum light sources rather than just one.

"Entanglement means that by controlling one light source, you immediately affect the other. This makes it possible to create a whole network of entangled quantum light sources, all of which interact with one another, and which you can get to perform quantum bit operations in the same way as bits in a regular computer, only much more powerfully," explains postdoc Alexey Tiranov, the article's lead author.

This is because a quantum bit can be both a 1 and 0 at the same time, which results in processing power that is unattainable using today's computer technology. According to Professor Lodahl, just 100 photons emitted from a single quantum light source will contain more information than the world's largest supercomputer can process.

By using 20-30 entangled quantum light sources, there is the potential to build a universal error-corrected quantum computer -- the ultimate "holy grail" for quantum technology, that large IT companies are now pumping many billions into.

**Other actors will build upon the research**

According to Lodahl, the biggest challenge has been to go from controlling one to two quantum light sources. Among other things, this has made it necessary for researchers to develop extremely quiet nanochips and have precise control over each light source.

With the new research breakthrough, the fundamental quantum physics research is now in place. Now it is time for other actors to take the researchers' work and use it in their quests to deploy quantum physics in a range of technologies including computers, the internet and encryption.

"It is too expensive for a university to build a setup where we control 15-20 quantum light sources. So, now that we have contributed to understanding the fundamental quantum physics and taken the first step along the way, scaling up further is very much a technological task," says Professor Lodahl.

The research was conducted at the Danish National Research Foundation's "Center of Excellence for Hybrid Quantum Networks (Hy-Q)" and is a collaboration between Ruhr University Bochum in Germany and the the University of Copenhagen's Niels Bohr Institute.

New method to control electron spin paves the way for efficient quantum computers  
Quantum science has the potential to revolutionize modern technology with more efficient computers, communication, and sensing devices. Challenges remain in achieving these technological goals, however, including how to precisely manipulate information in quantum systems.

In a paper published in *Nature Physics*, a group of researchers from the University of Rochester, including John Nichol, an associate professor of physics, outlines a new method for controlling electron spin in silicon quantum dots -- tiny, nanoscale semiconductors with remarkable properties -- as a way to manipulate information in a quantum system.

"The results of the study provide a promising new mechanism for coherent control of qubits based on electron spin in semiconductor quantum dots, which could pave the way for the development of a practical silicon-based quantum computer," Nichol says.

**Using quantum dots as qubits**

A regular computer consists of billions of transistors, called bits. Quantum computers, on the other hand, are based on quantum bits, also known as qubits. Unlike ordinary transistors, which can be either "0" (off) or "1" (on), qubits are governed by the laws of quantum mechanics and can be both "0" and "1" at the same time.

Scientists have long considered using silicon quantum dots as qubits; controlling the spin of electrons in quantum dots would offer a way to manipulate the transfer of quantum information. Every electron in a quantum dot has intrinsic magnetism, like a tiny bar magnet. Scientists call this "electron spin" -- the magnetic moment associated with each electron -- because each electron is a negatively charged particle that behaves as though it were rapidly spinning, and it is this effective motion that gives rise to the magnetism.

Electron spin is a promising candidate for transferring, storing, and processing information in quantum computing because it offers long coherence times and high gate fidelities and is compatible with advanced semiconductor manufacturing techniques. The coherence time of a qubit is the time before the quantum information is lost due to interactions with a noisy environment; long coherence means a longer time to perform computations. High gate fidelity means that the quantum operation researchers are trying to perform is performed exactly as they want.

One major challenge in using silicon quantum dots as qubits, however, is controlling electron spin.

**Controlling electron spin**

The standard method for controlling electron spin is electron spin resonance (ESR), which involves applying oscillating radiofrequency magnetic fields to the qubits. However, this method has several limitations, including the need to generate and precisely control the oscillating magnetic fields in cryogenic environments, where most electron spin qubits are operated. Typically, to generate oscillating magnetic fields, researchers send a current through a wire, and this generates heat, which can disturb cryogenic environments.

Nichol and his colleagues outline a new method for controlling electron spin in silicon quantum dots that does not rely on oscillating electromagnetic fields. The method is based on a phenomenon called "spin-valley coupling," which occurs when electrons in silicon quantum dots transition between different spin and valley states. While the spin state of an electron refers to its magnetic properties, the valley state refers to a different property related to the electron's spatial profile.

The researchers apply a voltage pulse to harness the spin-valley coupling effect and manipulate the spin and valley states, controlling the electron spin.

"This method of coherent control, by spin-valley coupling, allows for universal control over qubits, and can be performed without the need of oscillating magnetic fields, which is a limitation of ESR," Nichol says. "This allows us a new pathway for using silicon quantum dots to manipulate information in quantum computers."

Autonomous steering system keeps human drivers engaged

Autonomous driving technologies have already been integrated into many mass-produced vehicles, providing human drivers with steering assistance in tasks like centering a vehicle in its lane. But the little data available on automated driving safety shows that placing too much control of a vehicle in the hands of automation can do more harm than good, as disengagement by human drivers can increase the risk of accidents.

"Current vehicles on the market are either manual or automated, and there is no clear way of making their control a truly shared experience. This is dangerous, because it tends to lead to driver over-reliance on automation," explains Jürg Schiffmann, head of the Laboratory for Applied Mechanical Design in the School of Engineering.

Now, researchers from the lab have collaborated with Japanese steering system supplier JTEKT Corporation to develop and successfully road-test a haptics-based automated driving system that integrates different modes of human-robot interaction. The researchers hope that their approach will increase not only the safety of automated driving, but also social acceptance of it.

"This research was based on the idea that automation systems should adapt to human drivers, and not vice versa," says EPFL PhD student and JTEKT researcher Tomohiro Nakade, who is also the first author on a recent paper describing the system published in the *Nature*journal *Communications Engineering.*

Nakade adds that a good metaphor for the new system can be drawn from a transportation mode that predates automation: "A vehicle must be open to negotiation with a human driver, just as a horseback rider conveys his or her intention to the horse through the reins."

**Interaction, arbitration, and inclusion**

Unlike current automated driving systems, which use only cameras for sensory input, the researchers' more holistic approach integrates information from a car's steering column. It also encourages continuous engagement between driver and automation, as opposed to current automated systems, which are typically either switched on or off.

"In automation in general, when humans are just monitoring a system but not actively involved, they lose the ability to react," says Robert Fuchs, a former EPFL PhD student who is now an R&D general manager at JTEKT Corporation. "That's why we wanted to actively improve driver engagement through automation."

The researchers' system achieves this thanks to three functionalities: interaction, arbitration, and inclusion. First, the system distinguishes between four different types of human-robot interaction: cooperation (the automation supports the human in achieving a goal); coactivity (the human and automation have different goals, but their actions impact one another); collaboration (human and automation assist one another in achieving different goals); and competition (human and automation activities are in opposition).

Next, as the driver operates the vehicle, the system arbitrates, or moves between different interaction modes depending on the evolving situation on the road. For example, the car might switch from collaboration to competition mode to avoid a sudden collision threat.

Finally, and still within the same control framework, the system integrates an 'inclusion' function: it recomputes the vehicle's trajectory whenever the driver intervenes -- by turning the steering wheel, for example -- rather than perceiving it as an override and switching off.

**A practical solution**

To test their system, the researchers developed experiments involving a simulated virtual driver and a human driver using a detached power steering system, a full driving simulator, and even field tests with a modified test vehicle. The field tests were carried out with the participation of five drivers on a JTEKT test course in Japan's Mie prefecture, by connecting the researchers' system to a standard sedan via an external controller.

The researchers specifically tested drivers' experiences of steering smoothness and lane-changing ease, and their results confirmed the system's significant potential for increasing comfort and reducing effort for drivers through collaborative steering.

"This is a very practical concept -- it's not just research for research's sake," says Schiffmann, adding that the software-based system can be integrated into standard mass-produced cars without any special equipment. "It's also a beautiful example of a fruitful partnership between our lab and JTEKT, with whom EPFL has collaborated since 1998."