An academic perspective: Case study

AI POWERS THE SPREAD OF INTELLIGENT ROBOTICS – AND DEFINES ITS LIMITS

Robotics brings AI into the physical world, with developing prospects including autonomous vehicles, carebots, surgical robots and cobots. Interview with Dr Ali Shafti, Senior Research Associate in Robotics and AI, at the Brain & Behaviour Lab, Imperial College London.

QUICK READ

- Robotics transmits the data-processing and decision-making capabilities of software into the physical world.
- Autonomous vehicles are robots and therefore stand out as arguably the most economically significant field of robotics research.
- Care robots and surgical robots are other key areas of development.
- So-called “co-learning” is a potential way for robots to learn more about the context in which they are operating and move closer to human intelligence.

Dr Ali Shafti
Senior Research Associate in Robotics and AI, at the Brain & Behaviour Lab, Imperial College London

Robotics combines insights primarily from computer science, mechanical and electronic engineering and neuroscience. It aims to produce ‘intelligent machines’ capable of replicating humans’ ability to sense the physical environment, interpret and make decisions based on those stimuli in real time, then translate those decisions into actions.

Looked at from the perspective of AI, robotics therefore transmits the data-processing and decision-making capabilities of software into the physical world. In robotics, as in other areas where AI is being applied, the dominant forms of AI are based on the data-driven techniques of machine learning (ML), which have experienced a period of greatly accelerated development over the past 15 years, as discussed in our interview with Prof David Barber.

“It’s this ability to act back on the physical environment by moving something or making something happen that’s important. That defines a robot,” says Dr Ali Shafti, Senior Research Associate in Robotics and AI, at the Brain & Behaviour Lab, Imperial College London. “Up until that point the machine’s no different to a computer or a smartphone.”

Based on this definition, autonomous vehicles are robots and therefore stand out as arguably the most economically significant field of robotics research. However, the challenges of developing AI sufficiently powerful enough to allow robots to operate alongside humans in the highly complex environments that humans inhabit are significant. The dream of vehicles that can pilot themselves through a city rush hour to carry us home is more distant than some of its advocates care to admit.

Autonomous vehicles push the limits of AI

Rapid recent progress in ML has fuelled huge interest and investment in the development of autonomous vehicles, an area both carmakers and the world’s biggest tech companies are aggressively pursuing. But producing fully autonomous vehicles represents one of the greatest challenges for robotics researchers, notably because of the difficulty of developing the AI required to control them.

Dr Shafti suggests there will be big advances in autonomous vehicles over the next decade but cautions that the vision of robots driving independently alongside normal traffic and without human safety drivers on board is still decades away. The key problem, he says, is that deep learning, the variety of ML

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that dominates the visual recognition systems used in autonomous vehicles, is reaching its limits. This issue is made more difficult because so much driving takes place in extremely complex, densely populated environments that were not originally designed to accommodate cars.

"Deep learning has taken us a long way forward, but the progress is slowing down now. It's plateauing. Some of the best outcomes of deep learning have been in computer vision, particularly in real-time object recognition and labelling, which, of course, is an essential module for many autonomous systems – one example being self-driving cars. But these systems can make mistakes and are easily fooled.

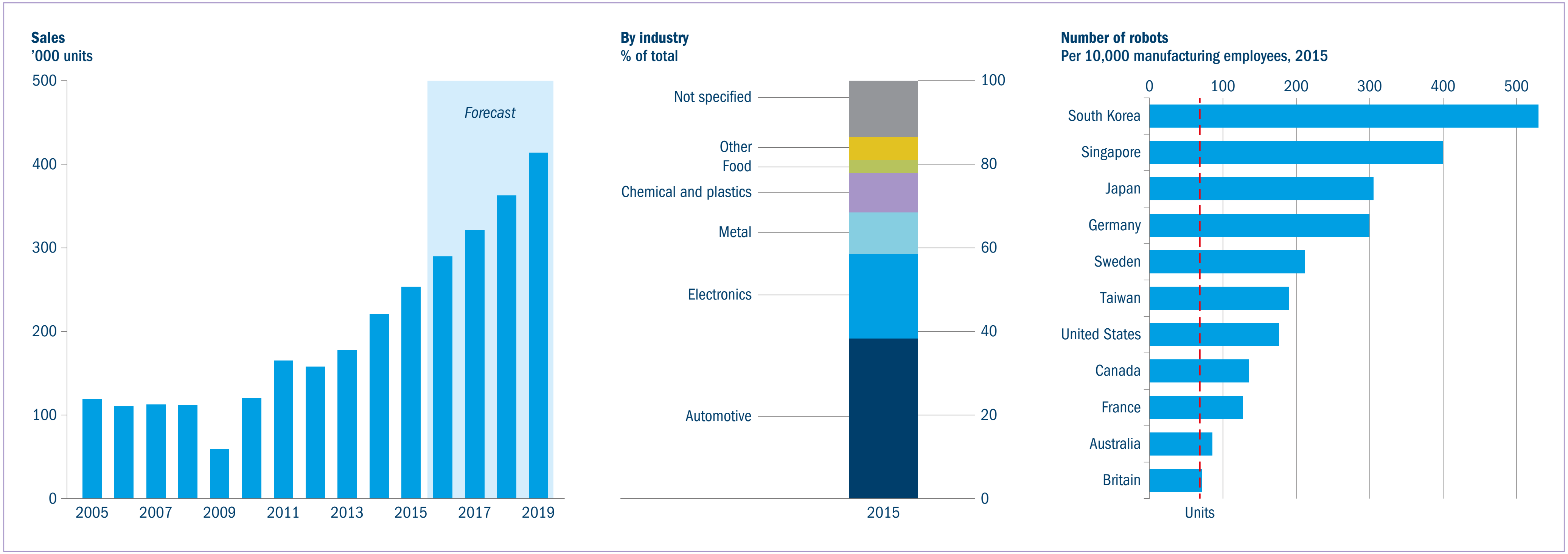
"There's a famous example where, if you put a few small stickers or a small graffiti drawing on a stop sign, it will be mistaken for other signs such as speed limits. That wouldn't happen with a human because we understand the context. The system doesn't – it's just looking at pixels. It's not intelligent beyond the very specific task it is trained for, so it sees a slightly disfigured sign and is easily fooled into thinking it is not a stop sign.

"Having an autonomous car operating in the same environment as a non-autonomous car is a very difficult problem. There's a lot of talk but there are no real examples of an autonomous car operating extensively without a safety driver in a mixed environment. That alone, to me, shows that we're way behind on this."

The most likely intermediate stage of development is to designate certain traffic lanes or zones of cities for autonomous cars in order to avoid the challenges of letting robots drive alongside humans, he suggests. In the long term, however, he believes that the shift to autonomous cars will greatly reduce injuries and deaths on the roads and will create major benefits by enabling autonomous vehicles to communicate with each other. This will allow for optimal traffic management, as vehicles are all connected as a network and in constant communication, leading to the possibility of higher vehicle density while retaining efficiency and speed.

"Imagine arriving at a multistorey car park, getting out of your car and leaving the car to go and park itself. That's a lot of time saved and a lot of optimisation gained. Cars can park much tighter to each other because, when you want to summon your car, the others will all move out of the way so it can come out."

The life robotic: global industrial robots



Source: International Federation of Robotics.

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Other key areas of development in robotics

Robots have been used in industry for decades, but more recently they have started to advance into other real-world settings. Two areas of development stand out.

Social and care robots

Dr Shafti believes that robots designed to interact with and monitor people who are lonely or suffering from conditions such as dementia will start to spread in the near future. This is one of the few areas of robotics where it will be relevant to create anthropomorphic whole-body robots, which many wrongly assume is a central goal of researchers in the general field of robotics.

The ability to use natural language processing to enable conversation between humans and robots is central to this area of robotics and recent advances have brought the widespread use of social robots significantly close, he says. "There's an accelerated push to develop intelligent social robots and I think in the next decade or so we're going to start seeing people suffering from loneliness or social anxieties, as well as those with conditions such as dementia, having these types of robotic systems in their home." As well as providing company, these systems will be able to monitor human behaviour and aid people with declining cognitive abilities, for example, by reminding them to take essential medication.

Surgical robots

In laparoscopic surgery, robots are becoming established, the leading producer being Intuitive of the US, whose Da Vinci machines are the most advanced on the market.

These master-slave systems allow a surgeon sitting at a terminal to make extremely precise movements, translating a hand movement of several centimetres into a far smaller movement of the surgical instrument inside the patient. They also provide multi-tool instruments, allowing surgeons to operate through a single keyhole incision, rather than the three required in manual surgery.

Dr Shafti says current computer vision research in surgical robotics has been focused on issues such as enabling

3D vision and automated recognition of organs and features or defects from camera images. This allows surgeons to gain a lifelike view inside the patient, instead of the 2D, hard to recognise screen images they currently rely on. Researchers are also adding haptic feedback to these systems, so that surgeons can sense how hard or soft organs and tissue inside the patient's body are, possibly indicating the presence of a tumour, for example.

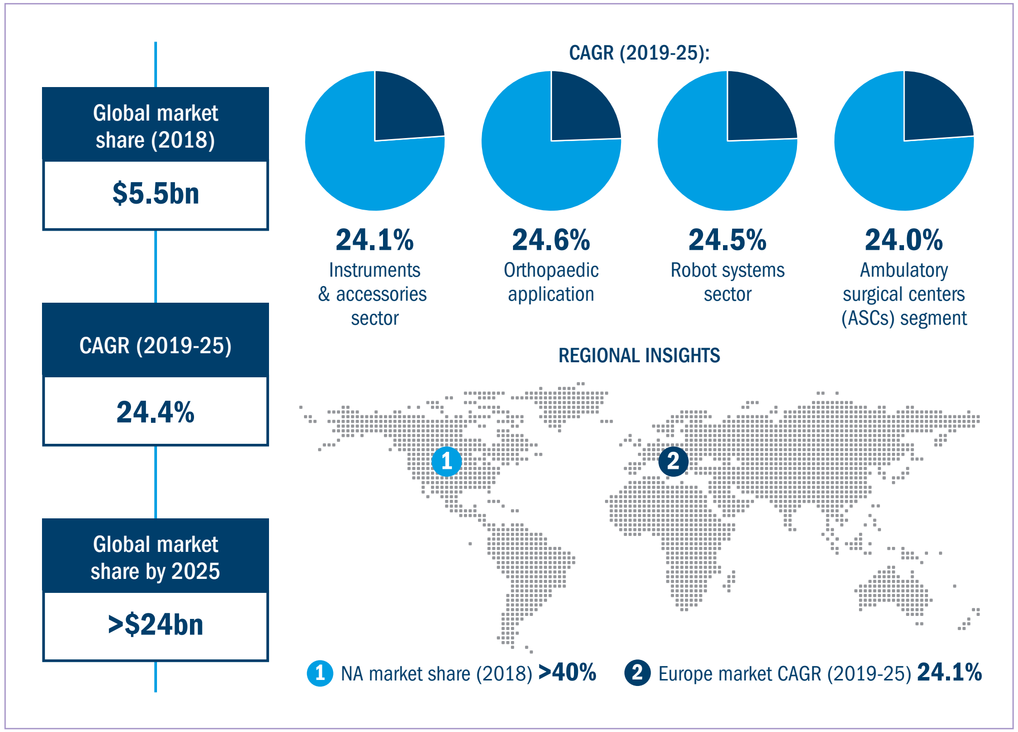
However, the major barrier to the take-up of surgical robots is likely to be the professional conservatism of senior surgeons, he says, who have spent decades operating manually and prefer familiar methods. Ultimately, surgeons are likely to be trained to operate both manually and using robots, at which point adoption would spread more rapidly.

Collaboration vs replacement

Robotic arms have been used in industry for years, but only in the past decade have they become safe enough to leave the segregated areas they had previously been confined to and operate in the same space as humans. Advances in sensing and mechanical engineering to prevent potentially fatal collisions have made this development possible.

The result has been rapid growth in the adoption of these 'collaborative robots,' or 'cobots,' in industry over the past few years. Key producers include Universal Robots of Denmark, Munich-based Franka Emika and Kuka, a Chinese-owned company also based in Germany. The latter is an established maker of old-style industrial robots, but has also moved into cobots. The arrival of robots that can safely work next to humans

Surgical robots market



Source: https://www.gminsights.com/industry-analysis/surgical-robots-market. March 2019.

> “I believe the next big thing is having humans more involved. In human-in-the-loop methods, you don’t put humans aside and have everything run autonomously end-to-end. The system runs autonomously but there’s a human within the loop being asked to monitor and intervene, which allows you to optimise for the human.”

represents a major advance in the technology and opens up large new markets for robotics manufacturers in many more industrial settings.

However, the appearance of collaborative robots also opens the way for robotics to develop using the ‘human-in-the-loop’ methods that Dr Shafti specialises in. He argues that human-in-the-loop approaches provide better outcomes, both for society and in terms of the development of robotics.

“Deep learning is reaching its limits and people will have to come up with the next big thing,” he says. “I believe the next big thing is having humans more involved. In human-in-the-loop methods, you don’t put humans aside and have everything run autonomously end-to-end. The system runs autonomously but there’s a human within the loop being asked to monitor and intervene, or collaborate in real-time, which allows you to optimise for the human. This is the way to make progress happen faster and with fewer negative effects on human lives.”

Combining human and robot intelligence, Dr Shafti believes, will create an intermediate stage in the development of robotics, where tasks that humans are less suited to such as repetitive actions, heavy lifting and accurate, precise movements that are physically difficult or tiring can be performed by robots, while humans use their knowledge and experience to direct the activity. This means that less general robotic intelligence is required, which in turn means existing intelligent algorithms can already be adapted and deployed to work with humans towards better work environments, while reducing the need for high computer power and its resulting carbon footprint. “Trying to have robots learn and generalise how to work in factories is not yet feasible with end-to-end deep learning approaches, and would also be very computationally heavy, consuming a lot of power. We should look into other methods.” he says.

This vision of the medium-term future of robotics envisages a two-way process in which robots augment human capabilities without fully replacing them, while over time the robots learn through the process of working alongside humans and become able to perform more complex tasks. So-called ‘co-learning’ is an area of keen interest among robotics researchers, who see it as a potential way for robots to learn more about the context in which they are operating and, in doing so, move closer to what we would think of as human intelligence.

Dr. Shafti biography

Dr. Shafti is a Senior Research Associate in Robotics and Artificial Intelligence with the Brain and Behaviour Lab at the Department of Computing & Department of Bioengineering, Imperial College London.

He studies physical collaboration and interaction between humans and intelligent robots – or embodied AI. He looks into making these interactions intuitive and natural for increased synergy, and augmented capabilities on both sides, leading to explainable, trustworthy and productive human-robot interaction. To this end, he implements machine intelligence in the context of robotics, while conserving the role of human intelligence as an essential part of the action/perception loop and the interaction.

He researches methods in robotics, machine intelligence and human behaviour analytics, as well as ways to integrate the outcomes through human in-the-loop methods. He has applied these findings in different scenarios, including collaborative robots, assistive robots, and autonomous vehicles.

Shafti has a PhD in Robotics from King's College London, where he focused on human in-the-loop physical human-robot interaction.

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