Cross-Industry Whitepaper Series: Empowering Our Connected World

ROBOTS BREAK OUT OF THE FACTORY: NON-CONSUMER ROBOTICS APPLICATIONS TAKE OFF

Key topics we will discuss in this paper include:

- **New technologies and initiatives in the field of robotics**
- **Role of AI in helping robotics perform better**
- **How the Industrial Internet of Things make factories and supply chains more efficient**
- **Impact of open source and cloud computing on robotics costs**
- **Drones and the world of robotics**
- **Breaking barriers with advanced mobile communications networks**

HUAWEI

INTRODUCTION

Robotics is a very active area of technology right now. There have been long-standing uses for robots since the first industrial robot was installed by General Motors in Trenton, New Jersey, USA, in 1959[1].

Today, there are established uses of robots across multiple manufacturing industries. These include automotive, aerospace, electricals/electronics and metals/machinery, food/beverages and pharmaceuticals. Outside manufacturing, robots are also used in agriculture, defense, and for moving things around in many sectors. Robot tasks include welding, cutting, materials handling, assembly, cleaning, spraying, and so on.

Statistics compiled by the International Robotics Federation indicate that 254,000 industrial robots were shipped in 2015, and the organisation forecasts that by 2019, there will be 2.6 million industrial robots deployed worldwide. Sales are predicted to grow at a CAGR of 13% over the next three years[2,3]. Robots are being installed in industrial settings all over the world.

Supporting this growth is rising research and development spend: analysts Technavio estimated in July 2016 that robotics R&D spend would increase at 17% per annum up to 2020, with most R&D spend by robot OEMs[4].

Traditional industrial robots – mechanical devices designed to replace or enhance the ability of a human to perform typically repetitive tasks in specific industrial settings – are already the most well-developed commercially.

But the industrial robot market is at the start of a wave of development where breakthroughs in other technology areas will increase the scope of what industrial robots can do and lower the cost of robot systems. These include:

- Artificial intelligence (AI) and machine learning
- Factory planning, including cooperative robot–human systems (“co-bots”) and integration with the wider supply chain
- Open-source code
- Cloud computing
- Drones
- Wireless connectivity (a key enabler of many of the most exciting changes in industrial robotics).

In factories, robots for performing manufacturing tasks such as welding can work closely with those moving materials, components and manufactured items around. Robots for logistics applications also exist within many other industries such as wholesale/retail warehouses, libraries, pharmacies in hospitals, and baggage handling in airports.

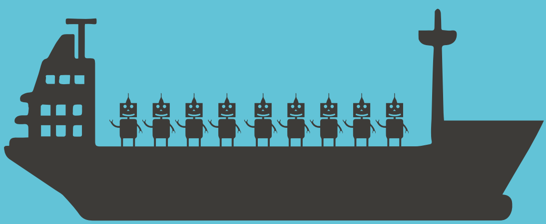
(Note – in this paper we exclude autonomous vehicles for the public highway from our definition of industrial/logistics robots, though we include autonomous guided vehicles in specific non-highway settings.)

> “It’s all about economics. The costs of the systems are falling and the capabilities are rising, we have at least 15 to 20 years where robotics will continue to expand”

- Hal Sirkin of the Boston Consulting Group, June 2016[5]

1 Unimate: The First Industrial Robot – www.robotics.org/joseph-engelberger/unimate.cfm
2 http://www.ifr.org/industrial-robots/statistics/
3 http://www.ifr.org/news/ifr-press-release/world-robotics-report-2016-832/
4 http://www.technavio.com/report/global-robotics-r-and-d-spending-robotics-market?utm_source=T3&utm_medium=BW&utm_campaign=Media
5 https://www.ft.com/content/d8d80f32-3874-11e6-a780-b48ed7b6126f

KEY DATA



254
THOUSAND ROBOTS

254,000 industrial robots were shipped in 2015

2.9
MILLION ROBOTS

By 2019, there will be at least 2.6 million industrial robots deployed worldwide

17%
PER ANNUM

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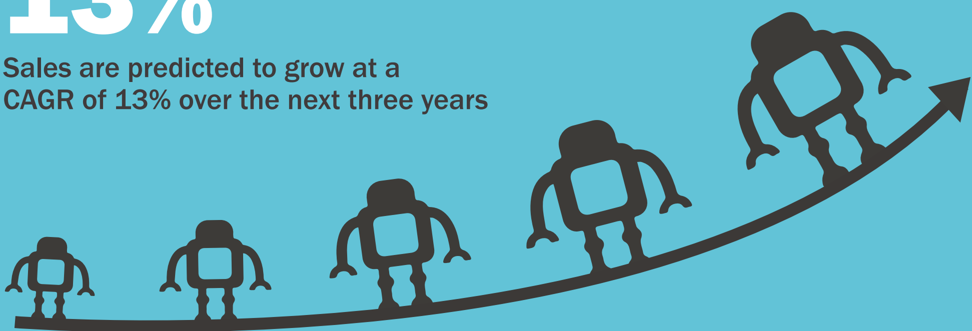


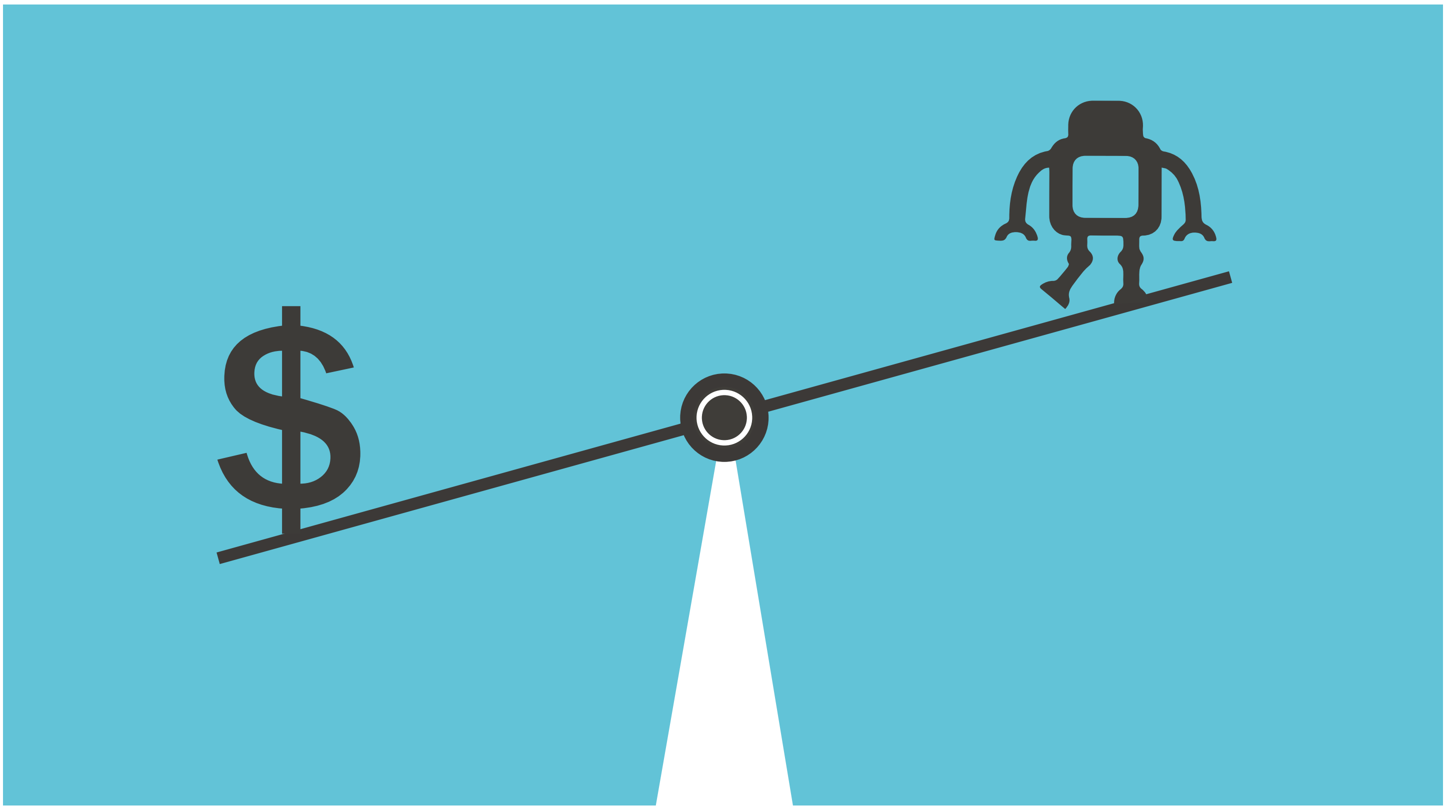
NEW TECHNOLOGIES AND INITIATIVES ARE EXPANDING THE SCOPE OF ROBOTICS IN AND BEYOND THE FACTORY

While uses for robots can be identified in very many sectors, take-up is not universal in those sectors.

In part this is related to the relative costs of specifying, acquiring, deploying and operating robotic systems on the one hand, and local cost of human labour.

Robotics systems have traditionally been an expensive upfront cost. For some applications, the costs of the "end effector" (the application-specific device that goes on the end of the robot arm) and "peripherals" (for instance transport systems on which robots may run, or communications networks) can significantly add to the cost.

In most cases, programming the robot to do what is required and to respond appropriately in different scenarios can be a significant cost. These issues are now being addressed by developments in several areas of technology.



AI, MACHINE LEARNING AND DEEP LEARNING ENABLE ROBOTS TO PERFORM BETTER

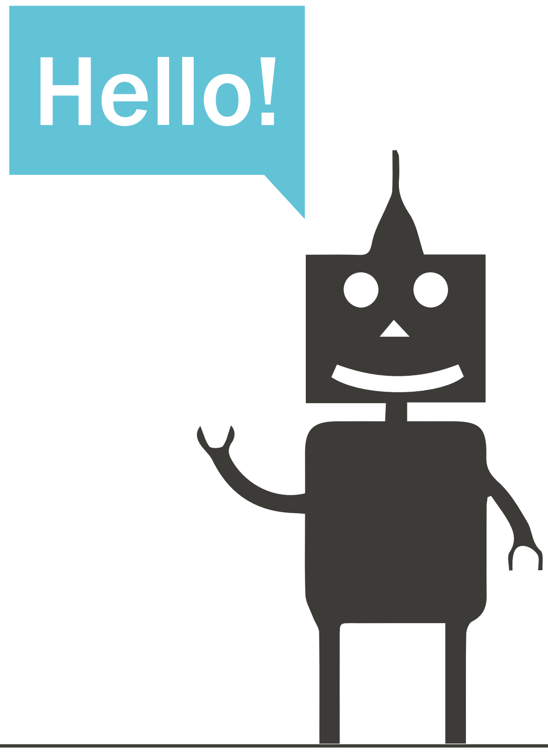
The idea of teaching robots to do a task, rather than programming a control system to achieve the same task, has been developed over the last ten years or so, as the academic field of Artificial Intelligence (AI) has become commercialized.

Increases in the power and affordability of computer processing (coupled with fast networks) have been so great that consumer applications such as Google Now, Apple's Siri and Microsoft's Cortana can understand questions posed by users, find the relevant answers, and respond in natural language within milliseconds.

Within the broad AI domain, machine learning describes the use of algorithms (of various kinds) to help computers to interpret data and make decisions based on the data. They can be "trained" to understand when their decisions are right or wrong so that their decisions get better over time. Machine vision systems and email spam filters are among applications that have used this approach. Deep learning refers to the use of multi-layered artificial neural networks that enable the training to be carried out on a huge scale, with the result that decisions are very much better. An example is the Go-playing robot Alpha-Go that defeated world champion Lee Se-dol in 2016, or more usefully, systems that can examine MRI scans and identify indicators for illnesses.

Using machine or deep learning, a robot can become better able to complete a task, or to undertake a new one, through an improved awareness of its environment and the context of the task. These approaches will also reduce the need – and cost – to program robots for each new task. This in turn creates the possibility of more flexible industrial robots able to cope with changes in factory configurations and shorter production runs, and capable of optimizing the processes that they are required to perform.

Access to the compute power required for machine and deep learning is greatly enhanced through high-speed networks and the use of cloud resources.



INDUSTRY 4.0 AND THE INDUSTRIAL INTERNET OF THINGS MAKE FACTORIES AND SUPPLY CHAINS MORE EFFICIENT

BY 2019, THERE WILL BE 2.6 MILLION INDUSTRIAL ROBOTS DEPLOYED WORLDWIDE

ACCORDING TO THE INTERNATIONAL ROBOTICS FEDERATION

Most robots are deployed in factories, and factories are undergoing a major change as industrial automation systems become more sophisticated, and the robots within them change to fit into a vision of a more flexible, more connected manufacturing environment – essentially, “smart manufacturing”. While industrial robots have long been used in factories to undertake repetitive, dangerous or physically demanding manual tasks, industrial efficiency can also be improved by using robots that complement human workers in factories, rather than replacing them. For instance, factory workers assembling equipment can be assisted in their work by “co-bots” bringing them parts for assembly at the right time, loading parts into machines, or lifting heavy objects. Industrial robots are changing as they become part of a more flexible automated manufacturing workplace.

Current industrial robot arms sacrifice flexibility for reliability: once wireless connectivity can match the performance of a wired connection, and be shielded from interference from activities such as welding that generates RF noise, future factories will see AGVs with integrated robot arms.

The idea of Industry 4.0[6] (begun in Germany in 2011) presents a vision of connected machines and systems that enable businesses to create intelligent networks throughout the supply chain, with the use of autonomous systems for tasks such as maintenance, reconfiguration of factory workspaces, and self-organizing logistics networks. Simultaneously, the concept of the Industrial Internet of Things has emerged (see for example the work of the Industrial Internet Consortium[7]), which broadens the concept to include an architecture beyond the factory itself.

“The manufacturing industry is undergoing profound transformation, and robots will be critical to revolutionising factories and driving new opportunities. KUKA plays a central role in promoting and developing smart manufacturing solutions in Germany and across the world [and] we’re confident our strategic partnership with KUKA will enable Huawei to lead the way in helping global manufacturing enterprises transform their factories and gain significant competitive advantages from realising smart manufacturing.”

- Ryan Ding, Executive Director and President of Products & Solutions, Huawei

6 - www.plattform-i40.de/
7 - https://www.iiconsortium.org/

OPEN SOURCE AND CLOUD COMPUTING LOWERS THE COST OF ROBOTS

Robots designed for industrial and logistics applications in the past have been expensive. As in many other areas of technology, there is the potential to increase the efficiency and reduce the cost of industrial robotics by using open source software, and by centralising some processes in the cloud, using shared resources and making use of fast, reliable network connections.

An important piece of open source software in the robotics context is the ROS (Robot Operating System). Begun at Stanford University's Artificial Intelligence laboratory in 2007, the ROS project is now managed by the Open Source Robotics Foundation[8] . A project to apply ROS to manufacturing robots – ROS-I[9] – is led by SwRI and Fraunhofer IPA.

Many business and consumer services and processes have been revolutionised by the shift of computing and storage from local devices to distributed resources accessed from the cloud. Robotics is likely to be similarly impacted. For instance, the availability of low-cost, scalable compute resources has enabled the rapid development of artificial intelligence (AI) and machine learning which as we saw earlier in this paper, have important applications in the development of robotics.

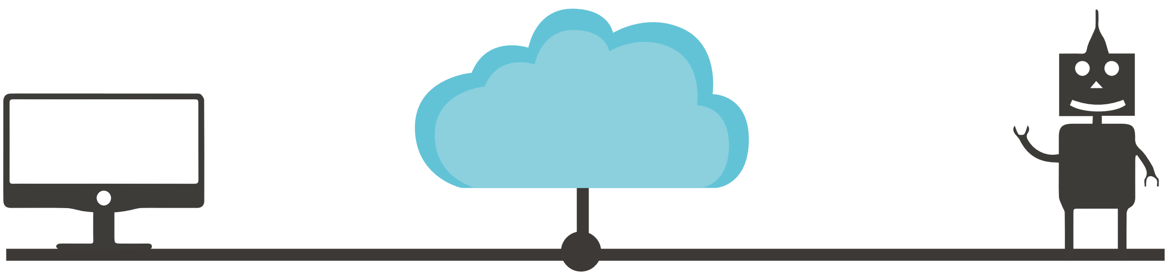
Economies of scale can be achieved using shared resources, but successful cloud-based services demand a good match between the requirements of the service and the ability of the communications network to deliver access to those resources. The network performance can be considered in terms of its reliability, data throughput, latency, and security.

In the case of robotics, it is important to understand where the cloud is appropriate. For instance:

- Controlling a robot's motion (and that of its end effector), which relies heavily on sensors and feedback, is best performed locally rather than from the cloud – as any network problem or excessive latency could leave the robot unable to perform safely

- Factory-wide management systems that include, say, optimizing how robots are to be used within the factory and higher-level route planning for mobile robots within the factory, can be carried out in the cloud.

Because of the latency requirements of robotics processes, a mobile edge computing (MEC) approach may be appropriate here: if latency can be reduced to below 100ms, then some robot guidance applications become possible from the cloud; reducing latency below 10ms frees other control applications from having to be processed locally. As industrial robots become more intelligent, and make more use of cameras, laser scanning and image recognition, then fast, low-latency mobile broadband networks could enable event flexible, untethered robots to benefit from cloud computing.



8 - http://www.ros.org/
9 - http://rosindustrial.org/

DRONES EXTEND ROBOTICS SYSTEMS IDEAS TO THE SKIES

The last few years has seen great advances in unmanned aerial vehicles (UAVs) – popularly known as drones. Early drones were either extremely expensive military hardware – sometimes based on existing conventionally piloted aircraft, or scaled down versions of manned aircraft, or unstable and difficult-to-fly model aircraft.

More powerful processors and smaller, integrated sensors have brought better stability; battery advances have enabled longer flights; and fast mobile communications networks have resulted in drones becoming part of the Internet of Things, and allowed smartphone apps to be used to program flights and control drones in real time. Software for control of drones either individually, in fleets or on a geographical basis (as in Air Traffic Control for conventional aircraft) has developed alongside the mechanical improvements in drones.

As the capability of commercial drones has increased, they have developed into flying robots with the potential, subject to air traffic control legislation, to become part of logistics operations delivering parcels, medical supplies or samples; carrying cameras and other equipment for surveying; and even acting as nodes in communications networks, as AT&T is exploring in the US[10]. Some drones – for instance those used for military reconnaissance or communications – can be solar powered and remain in the sky for weeks or months at a time.

While many communication technologies are used to connect drones, including encrypted military radio, commercial WiFi, residential WiFi and even Bluetooth (for short range), unlicensed spectrum, licensed cellular networks are also used – both for drone control[11] and to stream video from the drone (very many drones carry cameras). Cellular network reliability, freedom from interference problems, data security and connection into the cloud are of benefit to drone operations, and improvements in latency performance and throughput of 5G networks will further increase its applicability.

10 - http://about.att.com/innovationblog/drones_new_heights
11 - http://www.theverge.com/2016/2/22/11091566/att-intel-drone-test-lte-miles-away

ADVANCED MOBILE COMMUNICATIONS NETWORKS FREE ROBOTS FROM PREVIOUS LIMITATIONS

Traditionally, most robot arms in factories do not move, except for infrequent production line replanning, or within factory cells where some robot arms will move on rails.

This fact – together with the need to provide electrical power to robots – has meant that almost all industrial robot arms have used wired connections for control, and to link to factory automation and ERP systems. However, smart manufacturing in the Industry 4.0 concept envisages much more frequent replanning of production lines – even for production of one-off items. The increasing use of co-bots to act as mobile parts-delivery machines to manufacturing cells within a factory means that robot mobility is required. This is much more easily achieved with wireless communication for robot control. Tesla's Gigafactory is an example of a site making extensive use of AGVs[12]. As noted earlier, once wireless connections match the reliability of a cable, there will be a profound change in the ways factories are designed and operated.

Outside factories, in robotics applications such as logistics, particularly in shared spaces like hospitals and airports, wireless connectivity (and autonomous power) are essential.

Wireless communications for factory robots has not traditionally involved cellular networks; rather, proprietary radio networks have been used, for reasons of perceived security, cost of ownership over the long term, and because many solutions were built on a bespoke basis to suit an individual factory. Of course, in wide area applications for robots – such as in agriculture or across large sites including mines, quarries, ports and airports – cellular networks have played a role.

Advanced cellular networks can now deliver all the benefits of proprietary network technologies, at lower cost and with performance benefits. Narrowband IoT (NB-IoT) and LTE Cat-M1, standardised as part of LTE, can address many machine-to-machine applications, though not those requiring very low latency, and standardised modules mean low cost and an expanded supply ecosystem for products.

Use of mobile edge computing will cut latency and increase suitability of LTE for robotics. Future 5G networks, with ultra-low-latency (targets of <1ms), will support all existing robotics requirements, and new ones that until now have been very difficult to achieve – such as remote surgery requiring very fast visual and haptic feedback.

Where untethered robots and low latency is required, private cellular networks can be used, to provide benefits of security, standardised technology and a large supply ecosystem, along with local deployment to deliver low latency and a choice of business models (build/own or network service subscription).

Huawei's OneAir@Smart X solution offers three network technologies: LTE@Licensed (deployed in licensed spectrum); LTE@Unlicensed (deployed in 2.4GHz or 5GHz unlicensed bands); and Enterprise Wireless-IoT (eW-IoT; deployed in unlicensed sub-GHz spectrum). The network solution supports multiple services for enterprise campuses including robot control, voice, general industrial SCADA (supervisory control and data acquisition), smart sensors, meters and actuation, video surveillance and broadband access. Huawei launched the solution to industrial customers at CeBIT in Hannover in March 2016, and has an agreement in place with leading robot maker ABB to integrate OneAir solutions within ABB's industrial robot and industrial automation systems.

By providing true mobility and secure, reliable, low latency, high-throughput communications, 5G networks will allow robots to work more efficiently, benefit from advanced AI and image recognition applications delivered from the cloud, and support more applications inside and outside the traditional factory environment. Analysts expect the market for 5G-connected robots to grow to USD14.6 billion by 2030[13].

"Reliable industrial wireless networks are an important component during the automatic, digital, and intelligent transformation of industries. We are positive about the prospect of incorporating LTE wireless communication technology into the industrial sector. Huawei ... and ABB [will] develop E2E wireless products and solutions tailored to industrial characteristics and requirements. In the future, Huawei and ABB will fully leverage their respective strengths and extend cooperation and influence to multiple vertical industries."

- Edward Deng, President of Wireless Solution, Huawei

12 - https://electrek.co/2016/07/31/tesla-gigafactory-robots-machines-battery-factory/
13- http://www.mindcommerce.com/5g_and_robotics_emerging_technologies_solutions_market_outlook_and_forecasts.php

KEY TAKEAWAYS

01 The robotics market is on the cusp of huge growth with 2.6 million industrial machines expected to be in service by 2019.

02 AI, machine and deep learning has developed to the point where robot vision and ability to respond to less predictable environments mean that the scope of what a robot can achieve is growing.

03 Factories are becoming smarter, with connected and flexible robots at the heart of the Industry 4.0 concept.

04 The cost of advanced robotics is being brought down using open source software and cloud computing

05 Existing wireless technologies can already set robots free from their tethers – and expand the concept of the robot to the sky in the shape of commercial drones for logistics and other applications.

06 Huawei's OneAir solution enables remote configuration, monitoring and management capabilities for industrial robot users that need a private wireless network; in the future, 5G networks' improved latency performance and throughput will support robotic applications in the wide area – not just in factories.

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