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GLOBAL ROBOTICS

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Contents

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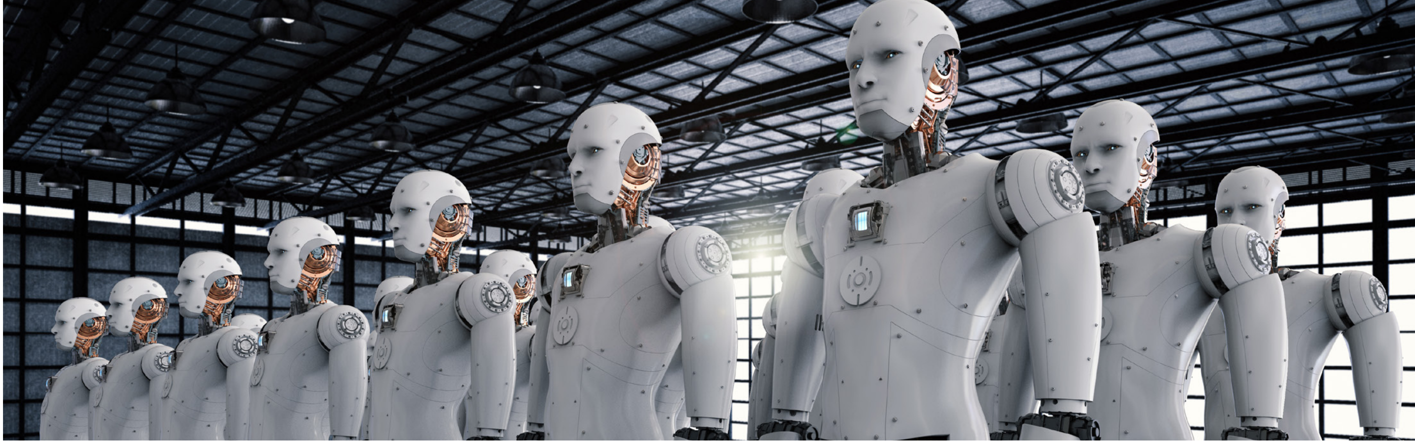
“We spend a great deal of time studying history, which, let’s face it, is mostly the history of stupidity. So it’s a welcome change that people are studying instead the future of intelligence.”

- Stephen Hawking 1942 - 2018



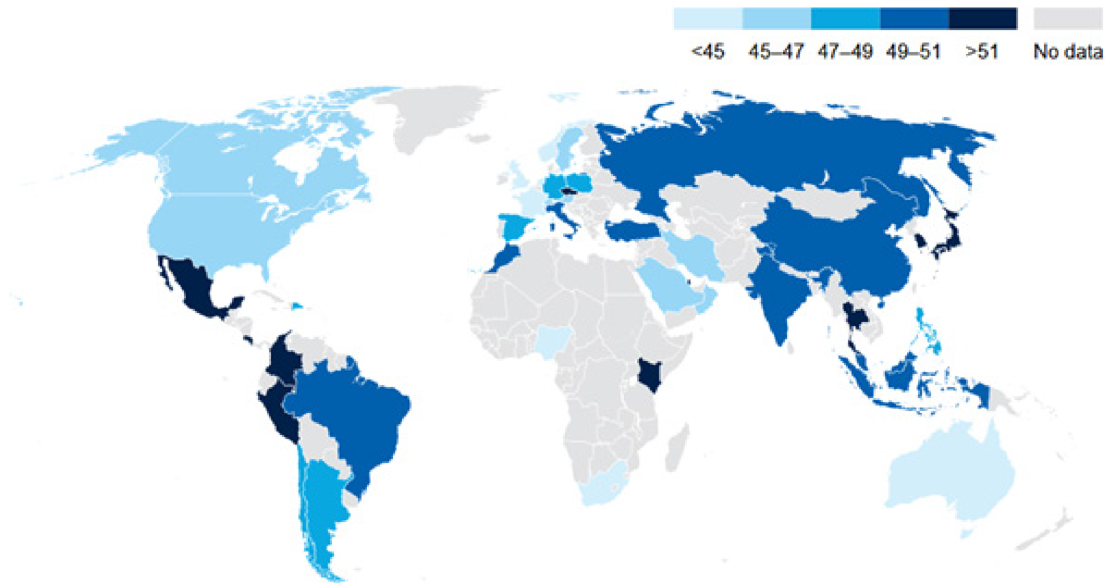
Introduction

The word ‘Robot’ was coined by the Czech science-fiction writer Karel Capek in the 1920’s: since then, they have captured the imagination of mankind for almost 100 years. Today, we are on the verge of intersecting science fiction and reality, as advances in robotics, artificial intelligence, cloud, automation and machine learning look to significantly alter the current economic landscape.

The developments in robotics and automation are facilitating rapid change to traditional business models, capital flows and the role of labour in the new ‘4.0’ economy. Historically, robots and automation were relegated to repetitive and menial tasks with limited flexibility and high cost implications. Indeed, in the 20th century machines have mainly alleviated dull simplistic activities, relieving humans of routine and mundane chores. In the 21st century however, we expect them to significantly substitute low skilled job functions and replace cognitive processes, making tacit judgements that could soon outperform human performance.

McKinsey sees robotic automation raising global productivity growth by 0.8 to 1.4 percent annually. They approximate 60% of all occupations have at least 30% of constituent activities which can be fully automated. According to them, more than half of the work activities performed by today’s labour force could be automated by 2055. The way in which this manifests is of course an important consideration for global economic growth and consumption patterns but it is our base case that the implementation of robotics will be net positive in terms of macro-economic development.

Employee weighted overall % of activities that can be automated by adapting currently demonstrated technologies



Source: McKinsey

The drivers behind this automation push will be contingent on a variety of factors:

Cost of Deployment: The installation of robotic infrastructure will be largely dependent on the cost of the systems. This includes both the CAPEX and software which is required to support organizational systems. The unit costs of robotics have been driven down in recent times, and this, coupled with higher flexibility, will drive higher adoption rates in small and medium sized enterprises. However, one must consider the key difference between CAPEX and OPEX. Robotics may generate cost savings in the longer term, but opportunity costs against cheap labour which can easily be adjusted in a recession cycle must be clearly understood. The pace of technological development may also shorten the lifespan on these investments, as becoming obsolete is a significant risk.

Labour Market: The adoption of robotics will also be contingent on the demand and supply dynamics of manual labour. Certain sectors and professions could be easily automated, but labour market dynamics may not facilitate the shift. We see a higher potential level of adoption of robotics in nations which exhibit ageing populations and a higher per capita wage. As participation rates decline in the developed world, the retiring workforce could be replaced by higher degrees of automation. On top of this, improvement in workplace safety with regards to robots will certainly play a critical role in terms of the pace of adoption.

Regulatory, Ethical and Social Acceptance: One of the largest impediments to a faster pace of adoption evolves around regulatory and ethical considerations. Concerns surrounding massive unemployment and increases in income inequality may delay rapid adoption of new technologies. The reconfiguration of complex supply chains and business models may also exhibit high degrees of organizational inertia. Ethical questions such as what it constitutes to be human, and whether we should truly significantly replace human interaction, may be key contingencies impacting a rapid rollout.

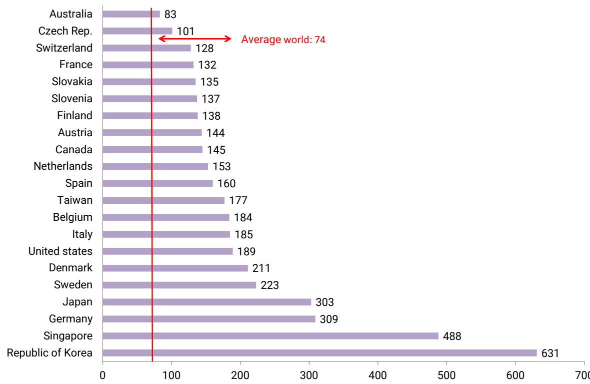
Despite all this, we see the shift to a higher degree of automation as somewhat inevitable in the medium term as positives outweigh the negatives.

Low Density & Growth Potential

The analysis of current Robot densities shows that a large proportion of companies have yet to adjust their business models to better encompass robotics in a more holistic sustainable manner.

But clearly, the automation of production is accelerating around the world: 74 robot units per 10,000 employees is the new average in manufacturing industries (2015: 66 units). Regionally the average robot density in Europe is 99 units, in the Americas 84 and in Asia 63 units (According to the International Federation of Robotics IFR). The presence of a developed Automotive or Electronics industry in a specific country tends to inflate its density number, which is why out of the 22 countries above world average, 14 are in Europe or why South Korea reaches a very high 631 figure. But overall, the highest growth in robotics and automation came from Asia, as ageing populations in China and Japan coupled with higher per capita wages have encouraged robot installations. The development of robot density is very dynamic in China (currently only 23rd in the world, but catching up fast): the government intends to be within the top 10 most automated nations by 2020. In 2019 the IFR expects 40% of the worldwide market volume of industrial robots to be sold in China. The "Made in China 2025" policy may push Beijing to install 600,000-650,000 industrial robots, in order to reach a robot density of 150 units by 2020.

Number of installed robots per 10,000 employees in the manufacturing industry 2016



Source: IFR

With countries like India or Indonesia still showing densities of 3 and 4 respectively in 2016, it is easy to understand the tremendous potential for Robotics growth in the years to come.

Economic Implications

The seismic shift that will be the product of robotics and automation is likely to redefine the global growth trajectory and our economic prospects. In today's economic climate, we are faced with shorter product life cycles, lower inventory and short production lead times with higher customization: further developments in this field will rely on a heavy presence of robotics and automation, ushering in a new technological revolution. The very nature and structure of economies will be redefined as labour is progressively substituted for robotic capital. The implications will be far reaching and the way machines are integrated to our world will eventually determine the success of their implementation and sustainability of their growth. Below we analyse the various narratives:

Utopia: when forming a view for the future, some find it useful to analyse periods in history with similar rapid technological shifts. In the 1950's and 1960's, agents were concerned for jobs because of the then nascent computerization push. However it did not manifest in massive job losses, but rather led to rapid productivity growth in subsequent years and a rise in the standard of living. According to David Autor (MIT, 2014), the average American worker today works roughly 17 weeks to live at the annual income in 1915 (inflation adjusted). This is why the optimists see a new era of increased productivity driving rapid growth in real incomes and living standards. The rhetoric is that technology, robotics and automation will not displace workers but will allow for more efficient production. Algorithms in use in companies such as Uber, WeWork and AirBnB will allow for a more efficient allocation of resources, contributing to greater economic benefit. Advocates of this utopian vision argue, somewhat naively, that robotics and automation will drive a long period of strong and stable economic growth.

Dystopia: according to an economic model considered by Andrew Berg of the IMF, we should define intelligent robots as a different type of capital to conventional capital in order to demonstrate its substitutability to the human workforce. The conventional macroeconomic models define production as a result of physical capital stock (machines and structures, both private and public) and labour. In this context, if we assume robotics exhibit a high degree of flexibility and productivity, we can consider perfect substitutability for labour. This would effectively increase the stock of labour available, driving output per person up, driving down wages and subsequently creating wage deflation in a market-driven economy. This could be further amplified as investments in traditional capital (buildings and infrastructure) are diverted towards robotic capital, which would cause further unemployment. In the long run, as robotic stock increases, return on traditional capital is driven up and causes growth in both forms of capital, dominating the entire economy. The role of labour is slowly diminished within the economy, as output continues to climb and wages fall in relative and absolute terms. A paradoxical scenario emerges as output climbs but wages fall. Assuming robots do not consume, the additional output is bought by the owners of capital. Consumption is driven by the growth of capital owners' income and wealth, contributing to higher levels of income inequality (Piketty). Higher levels of income inequality then drive populism, and eventually fuel civil unrest, heavy taxation and a big shift in the current paradigms of geopolitics – a rather dark scenario that is hardly supportive of long term Robotics development.

Neutropia - our base case: we assume a more realistic scenario whereby robotics are not a perfect substitute for labour, but rather amplify the efficiency of the labour force. Robotics are considered to be a close substitute to labour, especially within the lower skilled segment. However creativity, empathy and lateral thinking are considered core human qualities and complement the operation of robots. As in the dystopian scenario, we have an initial fall in wages, followed by labour becoming increasingly specialized, valuable and productive as it combines with traditional capital and robotic capital. The overall increase in labour productivity through robotics can eventually lead to higher output, wage growth and improving living standards. Andrew Berg expects this productivity effect to outweigh the substitution effect over a period of 20 years. Capital will become a larger proportion of the economy and subsequently, the owners of capital will benefit. If we define labour as a combination of skilled and unskilled workers, the unskilled part will largely be substituted, whilst the skilled labour gets more productive and real wages increase, widening income inequality. Berg postulates that the real wages of the low skilled labour segment will decrease by 40%, and the group's share of national income drop from 35% to 11%. However there is scope for reclassification of workers through training and skills enhancement (with an emphasis on STEM, i.e. Science, Technology, Engineering and Maths), which we believe may dampen some of the negative impacts of the income inequality scenario. Labour redeployment will be a critical question in terms of sociological changes – government awareness and immediate emphasis on training and education should bring a smoother transition.

Robotics: A Long Term Call?

When discussing robotics and its potential impact on our everyday lives, it's easy to fall into the trap of Science-Fiction and rewrite the scenario for the next instalment of Star Wars rather than prepare a full blown investment thesis. For most of us, a world full of intelligent machines doesn't seem very far, but doesn't look very close either. And for that reason, investing in the sector might be regarded as a long term strategy, where benefits can only be reaped in a rather distant future…But modern Robotics actually offer very real and very immediate applications, both in the Industrial and Service worlds with clear potential to improve productivity, product quality and enhance our direct environment at home, or in the workplace.

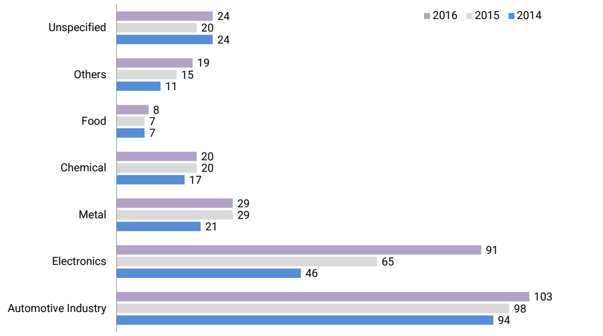
INDUSTRIAL APPLICATIONS

The first use of an industrial robot is generally attributed to General Motors in 1961 – it was called the Unimate, was hydraulically driven and was used to transport die castings from an assembly line and weld the parts together on auto bodies (a dangerous task for human workers who were at risk of being poisoned by toxic fumes or losing limbs…). Several generations of machines later, the automotive industry still is the biggest user of Robots (accounting for 35% of the total world supply in 2016 according to the International Federation of Robotics) and even if "adoption" is somewhat more mature in this sector (in particular for welding, assembling or painting), the constant need for upgrades and unit replacements will support a steady growth of 10-12% per annum.

However, the fastest growth for robotics implementation currently lies with the Electronics Industry. According to the IFR, this sector accounted for 31% of the total robot supply in 2016, but exhibited a +41% progression of robot purchases that year…Speed, accuracy and precision are increasingly needed to produce quality components in sufficient quantity to service the largest global customers like Samsung, Apple etc. A form of Artificial intelligence is necessary to adapt to the increasingly complex production processes: Robots pick up and place components into electronic assemblies where the position is not always precisely known or parts cannot be reliably placed without finessing. Adaptive tools such as vision or force control allow the robot to 'feel' its way into an assembly. In doing so, particular attention must be placed on avoiding interference from dust displacement that could damage the end product. Similarly, in handling semiconductors, the robot must not only be fast but must gently handle wafers to avoid introducing micro-cracks or physically damaging the very thin products. Indeed, as semiconductor wafers become thinner and thinner to fit into smaller and lighter smartphones or high-end devices, there is clearly potential for increased damage caused by direct human labour – and therefore a need for smart machinery to takeover.

Metals (cutting, melting, welding and arc-welding…), **Chemicals** (handling of toxic substances / waste but also research and testing automation for specialty chemicals…) and Food industries (packaging, clean handling) represent another 20% of the world robot supply.

Estimated annual supply of industrial robot at-year-end by industries worldwide in thousands of units



Source: IFR

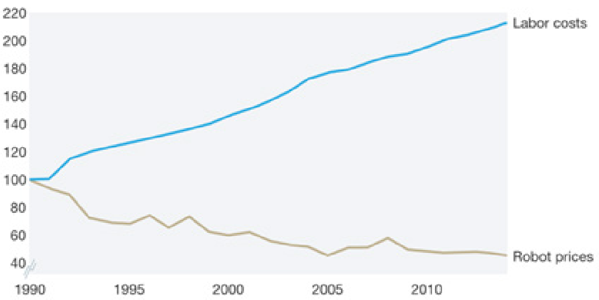
Typically, every industry involved in mass production with highly repetitive and labour intensive tasks has already entered the realm of robotics in some form or another and managed to increase productivity as a result. This trend will continue as evidenced by the still relatively low density of robots outside of the Automotive and Electronics segments. But it won't stop here: as the population of robots increases, so is worldwide demand for Robotics solutions to optimise usage, maintenance and energy consumption.

One interesting example of this is what FANUC Corp, the Japanese robotics expert, calls the Zero Down-Time (ZDT) solution. In today's complex assembly lines, the breakdown of a single Robot component somewhere in the chain can lead to hours of factory shutdowns, which always translates into heavy costs for manufacturers. According to the Robotics Industries Association, in the automobile industry, where a new car body comes down the assembly line every 60 or 90 seconds, downtime can cost over $20,000 a minute and when lines screech to a halt, those backups can impact the entire supply chain, further compounding the losses. The delays also trickle down to customers, the automotive dealers, fleet users, and the car-buying public. This is why ZDT is using Fog Computing and AI to assess the live state of all robot units across multiple sites to try and predict when a component is likely to breakdown before it actually does. ZDT also allows performing maintenance when it actually matters and avoids unnecessary and costly interventions. It's easy to see why companies like General Motors have been hooked to the product from the start and why similar AI solutions have such a huge commercial potential.

Energy efficiency is another hot topic when discussing Robotics: some manufacturers are already operating "Lights Out" plants, where production is fully automated and takes place in the dark, without the need for food, air-conditioning or heating. As for the optimisation of the energy needed to run a factory's autonomous unit, Deepmind is a striking example of how AI can help achieve greater results: Google saved 15% on its Energy bill at its data centres, immediately improving the company's ROIs (and contributing to a cleaner environment at the same time!).

But perhaps the most compelling reason why Robots are about to change the face of industrial manufacturing is that, traditionally, only the largest companies operating in the most predictable environments were able to afford and implement a fully automated production line (Autos). This isn't true anymore.

Cost of Automation: Index average robot prices & labor compensation in manufacturing in the US, 1990 = 100%



Source: Economist Intelligence Unit; IMB; Institut für Arbeitsmarkt- und Berufsforschung; International Robot Federation; US Social Security data; McKinsey analysis

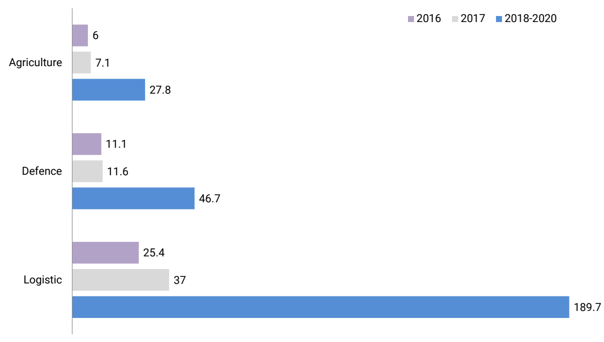
Robots are becoming cheaper: as showed by McKinsey, over the past 30 years, the average robot price has fallen by half in real terms. They are also smaller, smarter and able to multitask. They can learn to operate in any environment, and adapt to the exact specifics of any manufacturer. Emerging technologies are making them easier to integrate and control directly through voice recognition systems… In one word: they are more flexible. And as they become more affordable and easier to program through more sophisticated and user-friendly interfaces, they allow smaller, just-in-time productions to become more profitable, reducing inventory levels and increasing responsiveness at the same time… This will render Robotics extremely appealing to those smaller industries previously unable to justify the costs of implementation given the less scalable nature of their businesses. The Adidas "Storefactory" concept is the perfect illustration of this: at this experimental shop, customers were able to design their own sportswear and get them fabricated and delivered in a matter of hours. The company also developed a "SpeedFactory" in Anbach making full use of Robots and bringing its production facilities closer to the end customer for greater product flexibility and exponentially improved delivery speed…In fact, for these smaller companies, Robotics is often seen as a very powerful marketing tool, and a way to completely redefine the way they interact with their customers: in the very near future, firms like Adidas could design and produce specifically adapted and customised shoes (climate, terrain…) for any marathon in the world just a few days before the race, sell them online and extract significant financial value out of such process.

For all these reasons, the current trend in Industrial Robotics sales is unlikely to break down… From 2018 to 2020, according to the IFR, global robot installations will increase by at least 15% on average per year (CAGR). Total global sales will reach about 521,000 units in 2020. Between 2017 and 2020, it is estimated that more than 1.7 million new industrial robots will be installed in factories around the world bringing the total worldwide stock of operational industrial robots to around 3.1 million units at the end of 2020…According to the same source, In 2016, on average, each unit was worth around 45,000 USD. Assuming that the trend for cheaper robots continues and brings the average price per unit down to 40,000 USD by 2020, the size of the industrial robots market can conservatively be estimated to be around 21bn USD in 2 years. IFR explains that these figures do not include the cost of software, peripherals and systems engineering. Including these elements would result in the actual robotics market value being three times as high, i.e. around 60bn USD in 2020.

SERVICE APPLICATIONS

In the past 10 years, Robots have also entered the Professional Service arena even if these activities currently represent less than 20% of the world robot stocks. Common applications range from **Agriculture** (fruit collection, harvesting etc.) to **Logistics** (mail sorting, warehouse management, prehension systems etc.) and **Defence** (unmanned planes, weaponry, spybots etc.).Robotics growth in these sectors is looking promising even if the current market / sales value is somewhat lower than for Industrial applications at this stage (circa 5bn USD in 2016):

Service Robots for Professional Use in main applications. Unit Sales & Forecasts in thousand units



Source: IFR

However, 10 to 15 years down the line, we see very exciting developments in the robotics space that should translate into fast accelerating sales in the long term. In particular, we find applications in the Mobility, Medical and Domestic fields very interesting.

In a previous piece, we discussed how **driverless vehicles** are likely to transform our immediate environment. Improvements of computing power and sensors technology have allowed robotics to shift from assembling vehicles to navigation and driving. Without making any assumption here in terms of who will be the actual winners and losers of that revolution, the potential size of the market is very significant… The driverless car market is expected to be worth $77 billion by 2035, according to data from Boston Consulting Group. Chipmaker NVIDIA believes that its total addressable market in artificial intelligence computing for driverless cars will be worth $4 billion by 2025. Intel released a report in 2017 that showed that driverless cars will eventually create a $7 trillion "passenger economy" with nearly half of that amount coming from business-to-business services and the rest from new consumer services… Mass adoption of fully autonomous cars by the general public is probably a decade away, as explained in mid-2017 by Mitch Bainwol, the CEO of the Alliance of Automobile Manufacturers (which represents General Motors, Toyota, Volkswagen, BMW, Ford, Fiat Chrysler, and other automakers): "Level 4 geo-fenced self-driving vehicles that can only be operated by an Automated Driving System will probably begin around 2021. But, retail sales to consumers of so-called Level 5 vehicles that can operate anywhere a person can drive a conventional vehicle today is unlikely to happen until around 2025 or after. ... Ubiquity is not projected to occur for at least four decades largely due to the fact that over 260 million light duty vehicles are registered in the U.S." Nevertheless, companies like Volkswagen are already investing 40bn EUR a year in CAPEX and R&D to prepare for that new era and there will be a strong advantage to early movers. Companies like Rio Tinto are already experimenting with driverless vehicles for their mining operations and are realising safety, efficiency and productivity gains…Finally, mobility isn't just about cars, and for example, sales of powered human exoskeletons were up from 4,970 units in 2015 to 6,018 units in 2016 (still according to the IFR). These robots are successfully used for rehabilitation and ergonomic support for reducing loads and have a high growth potential. As they are getting lighter, have longer battery autonomy and allow for increasing movement speed, about 41,000 units are estimated to be sold between 2018 and 2020 despite a fairly elevated unit cost (currently anywhere between 40,000 and 85,000 USD). As the cost of these devices finally becomes more affordable, wider adoption is likely and sales growth should accelerate.

Medical robotics is another high potential market: the IFR is telling us that in 2016, sales of medical robots increased by 23% to 1,600 units. The total value of sales that year was around US$ 1.6bn meaning each unit is worth US$ 1.0m on average, making them, by far, the most expensive robots out there (excluding defence systems). An understandable characteristic given the fact that human lives are directly at stake here…The main applications evolve around Telepresence (allowing physicians to examine and treat patients in rural or remote locations), Surgical Assistance (for complex high precision operations), Rehabilitation, Sanitation, Disinfection (to stop viruses like EBOLA spreading) and Prescription Dispensing systems…Nascent technologies like nanoparticles and nanomaterials will allow for new types of treatments and we expect growth in that segment to remain very robust.

Finally, in the longer term, domestic applications probably constitute the biggest growth opportunity for robotics. At the present stage, these are limited to autonomous cleaning machines or vacuum cleaners, some of which sell for 200 EUR only on Amazon…Although these nice little gadgets are popular and work reasonably well already, we see developments in "Personal Robots" as much more interesting going forward: thanks to fast improving artificial intelligence algorithms, these would be able to care for the elderly, help with the education of children, provide highly engaging modes of entertainment or personal advisory and quite simply put, provide an almost human presence at home when an increasing number of people from all ages and all walks of life suffer from loneliness and depression…The work of professor Cynthia Breazeal at the MIT is quite enlightening in that respect: for her, "Robots are all about people". It's still very early stage, but the display of realistic human body language or facial expressions by some of these machines alongside the quality of their verbal communications is quite staggering at times. And when they finally become able to understand human emotions and socialise with human beings, they will be up for mass consumption.

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