AlphaCurrents

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Artificial Intelligence and Automation: Fourth Industrial Revolution

- Artificial intelligence is an exciting high growth area, but separating reality from hype is difficult
- Combination of data availability and improved processing power are driving commercialization
- Consider investing in the broader ecosystem set to benefit from the technology shift instead of just the largest players

Since the 1950s, scientists and researchers have forecasted the coming of intelligent machines capable of executing complex tasks. One needs look no further than popular entertainment like *2001: A Space Odyssey*, *The Terminator* and *The Matrix* to see people's infatuation with thinking machines. The notion of machines with advanced reasoning power evokes curiosity, wonder and concern.

Most predictions have fallen far short of reality. A machine that replicates human reasoning and abstraction likely remains some distance off. Still, advances in computational capabilities and sensing technology facilitate automation that is attractive for many companies. Away from the science fiction and doomsday headlines, the latest innovations in artificial intelligence and robotics could generate a meaningful economic impact.

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Original concepts like neural networks and Bayesian statistics have progressed to new technologies like "deep reinforcement learning," "generative adversarial networks" and "computational revealed algorithms." Each of these represents different ways that experts believe machines can learn. No single technology seems to dominate, but rather a range of methods that are best when paired with appropriate tasks.

Understanding artificial intelligence (AI) and the evolving technology is a challenge, but investors stand to benefit from rapid growth in an industry that is likely to improve business efficiency across sectors. We believe the industry could reach almost $1 trillion in revenues by 2050, a compounded annual growth rate of 15.4%, well above global economic growth forecasts. Despite the early stages of development, gaining exposure to the technology seems a prudent course.

At the center of the industrial transformation is automation, which serves as the ultimate goal. What makes the current stage of automation different from earlier ones? Since the 1960s and on to modern use of advanced robotics on assembly lines, much of the automation was physical substitution for human labor. Robots augment human capabilities on manual activities. The next evolution of automation, courtesy of AI, is in cognition. Machines will no longer be limited to mimicking human physical activities, but will also aid in cognitive actions like decision-making. In fact, AI is increasingly referred to as cognitive technology.

This shift from the automation of physical to the cognitive lies at the heart of the "fourth industrial revolution." The idea of the fourth revolution is somewhat controversial. The first revolution is widely acknowledged to be centered on technologies like the steam engine and steel furnace in the late 1700s to the mid-1800s. This was followed by the modern production process typified by the assembly line in the early 1900s. Many argue the third arose out of advances in microprocessing or digitization that made computing widespread.

To some, the AI advances on the horizon are simply the logical extension and conclusion of the third revolution. Alternatively, those additional advances in computing could be viewed as one step in automating physical activities as spreadsheets made the physical counting more efficient and email reduced the need for physical delivery. We see the fourth revolution blending cognitive and physical automation in a truly unique fashion that will change the nature of business, work and productivity.

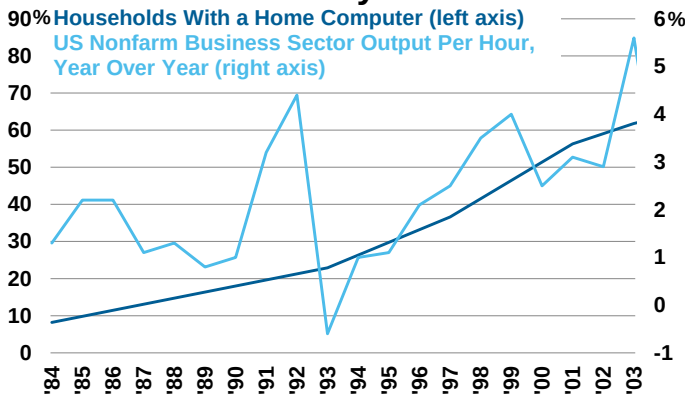
This report aims at arming investors with three critical elements to inform financial decision-making. First, it explores the impact that AI, robotics, and automation might have on the global economy in the coming years. There is also an assessment of the industry and size of the market. The next section explores the technology to help investors understand the range of approaches employed by engineers. Finally, we offer a framework for thinking about investment in these technologies and how they can be paired against specific business challenges.

How Will Automation Impact The Global Economy?

Integration of AI and automation could have a meaningful impact on the global economy, especially when the technology is targeted against specific tasks, problems or inefficiencies. The science fiction general-purpose supercomputer remains more fiction than science, but the applications of decision-support tools and algorithms to repetitive activities that carry high labor costs could be transformative.

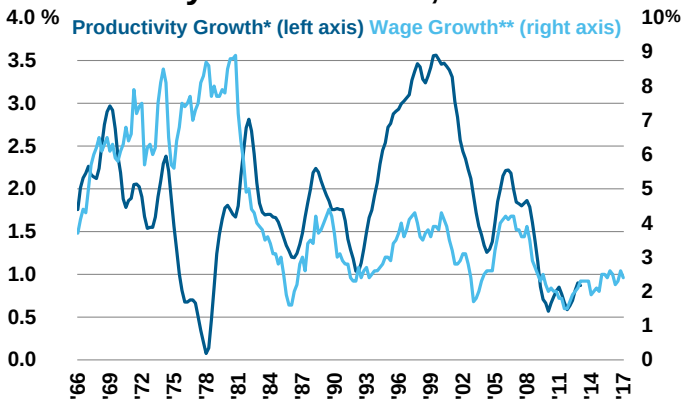
The introduction of microchips and the diffusion of the personal computer (PC) are instructive. While much of the technology used in the modern PC originated from designs in the 1970s, the 1980s marked a period of widespread expansion as technology moved out of large server rooms and onto the desktop. During the peak of PC adoption, there were strong gains in both productivity and the equity markets. Productivity improved with the widespread use of PCs (see Exhibit 1), and US GDP growth during that period averaged 5.7%, well above readings of the previous decade. US equities increased five times in the 1985-2003 period. PwC

Exhibit 1: PC Adoption Led to Strong Growth in Productivity



Source: Morgan Stanley Wealth Management, Bloomberg, US Census Bureau, Current Population Survey, Select Internet Release date: January 2014

Exhibit 2: When Wage Growth Increases, Productivity Growth Does, Too



*Year-over-over US nonfarm business sector output, four-year moving average lagged four years **Year-over-year US average hours earnings, nonfarm payrolls
Source: Morgan Stanley Wealth Management, Bloomberg as of Dec. 31, 2017

estimates that AI could generate $15 trillion in efficiencies by 2030, which in today's global economy would mean 20.8% cost savings annually.

Successful applications of AI and automation in this phase focus on narrowly defined tasks. Customer support is one area that has drawn significant investment. Most customer requests are relatively mundane; a few queries represent a disproportionately high level of requests and there is a finite solution set to choose from.

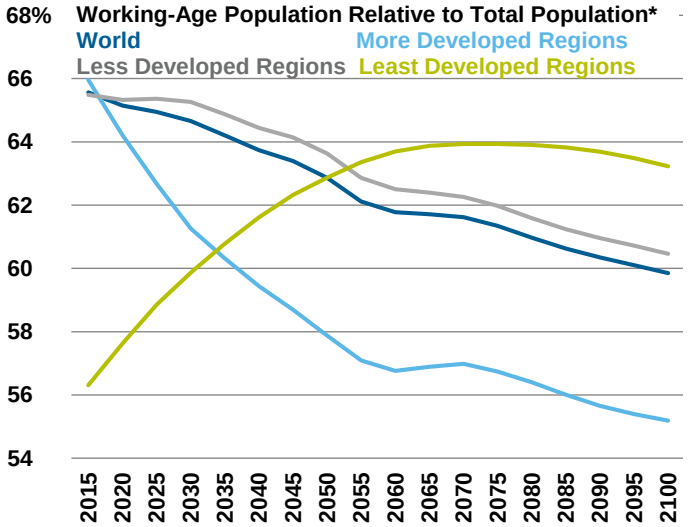
An automated customer service assistant for airlines or hotels is one such example. Most people contact customer support to book new reservations, modify existing plans, seek refunds or require help with delayed or canceled flights. The first three are often relatively straightforward situations that could be ideal for an AI with modest natural-language capabilities. Instances where requests get more complicated can then be routed to people who can handle the most complicated situations. Other areas could be automated include fast-food restaurants, benefit management, auditors and processing functions.

Tailoring programs for machines to handle ordinary tasks could produce significant productivity gains. Exhibit 2 shows that when wage growth increases, there is eventually a pick-up in productivity. Why? Businesses facing higher labor costs make technology investments that reduce those expenses. Wage growth has been relatively subdued since the end of the recession, struggling to reach and remain above 2% year over year. The tight labor market and recent fiscal stimulus that push wages higher could unleash a new spending push to improve productivity.

The dark side, which is common in discussions of AI and automation, is that investments disrupt the labor markets. This concern has survived through the ages going back to the Luddites' fear that the loom would take everyone's jobs. There is no doubt that modern automation will have an impact on the job market, but demographic conditions set an ideal backdrop to absorb this new technology. The world is aging, and as a result, the working-age population relative to the total population is declining (see Exhibit 3). If those at the top of the age pyramid continue consuming goods and services, there could actually be a labor shortage ahead. AI and autonomous technologies could alleviate that problem.

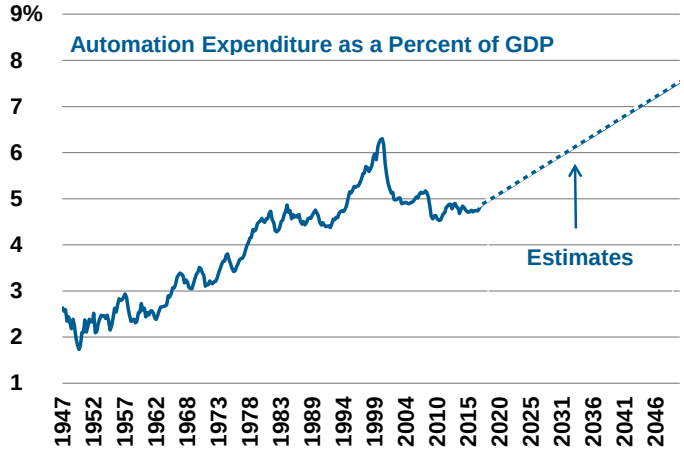
Forecasting the size of the AI/automation market is difficult. A survey of market research firms put the near-term growth through 2022 or 2025 at 30% to 50% year-over-year. Our estimate stems from the potential labor shortage discussed above. The total population is expected to grow by 22% by 2050, but the working-age population will only expand by 14%. That will generate a shortfall of 18 million workers in the US alone. Given the median income of $60,000 per year and 2% income growth, the median income will be $115,000 in 2050. If companies invest to overcome this shortfall, the labor parity replacement cost is $978 billion by 2050. Further, the combination of information technology

Exhibit 3: Workforce to Population Ratio Appears Set to Decline



*Forecast
Source: Morgan Stanley Wealth Management, UN Population Division, World Population Prospects: The 2017 Revision

Exhibit 4: Spending on Automation Is Forecast to Accelerate in Decades Ahead



Source: Morgan Stanley Wealth Management, Bloomberg, Fundstrat Global Advisors, UN Population Division, World Population Prospects: The 2017 revision. Automation expenditure is the sum of information process equipment, industrials equipment and software components of GDP.

equipment, industrial equipment and software grow at 7.9% per year. By 2050, that would translate to $12 trillion and approximately 7.5% of total GDP. Exhibit 4 shows the potential growth.

How Is the Technology Evolving?

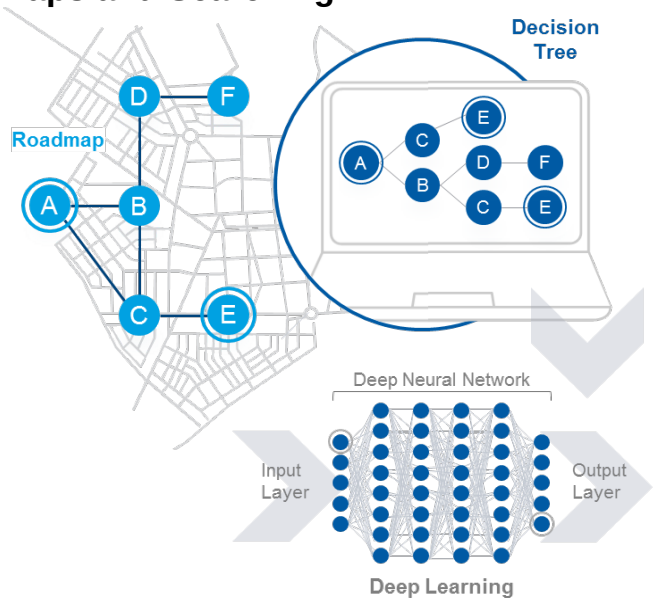
Artificial intelligence as both a technology and concept has ebbed and flowed since the idea was first introduced in the 1950s when renowned mathematician Alan Turing questioned whether a computer could communicate as well as a human. Since then, experts have debated the definitions of AI and intelligence itself. Significant support for AI research continued into the 1970s when interest subsequently declined. Interest was rekindled in the 1980s, but efforts fell short.

Experts have shown a tendency to overestimate AI capabilities over time. In 1955, Nobel laureate Herbert Simon believed that a computer would be a chess champion within a decade. It was not until 1997 that a computer defeated chess champion Gary Kasparov. A survey of computer scientists in 1972 showed that more than half of the respondents believed that a computer displaying behavior at an adult human level was less than 50 years away. A more recent poll pushes that out further out, with 50% of respondents indicating a mean year of 2072. Given the nonlinear or discontinuous trajectory of AI and automation technology it is important to understand why projections and excitement are building now.

Two changes have driven the interest this time: significant improvements in processing power and an explosion in available data. These elements are the raw materials, the necessary but not sufficient conditions, for successful deployment of AI. There is also a more tempered or cautious approach forming around AI. In prior cycles, AI was thought of as mimicking human adult intelligence. However, humans have visual and audio intuitions that are extremely hard to replicate with machines, in part because scientists do not know how they work. This latest round of research has distinguished between artificial general intelligence (AGI), the typical conception of the machine that reasons like a person, and intelligence applied to narrow purposes.

At the core, artificial intelligence is the process drawing relationships between objects, paths and goals. Most learning algorithms have some mapping feature that instructs the computer to draw relationships such as roads connecting places on a map, website pages that contain common hyperlinks or phrases that contain common words. Machine learning is the processes by which the computer generates these relationship maps and searches through them for a desired end state. What makes the machine intelligent is the ability to refine the program's mathematical or statistical parameters to engage in more efficient mapping and search. This seems complicated, and AI decision trees can get strikingly large (see Exhibit 5, page 4), and algorithms can get exceedingly complicated, but the concept of

Exhibit 5: AI as a Generator of Maps and Searching



Source: Morgan Stanley Wealth Management

drawing associations between objects and searching for answers is relatively simple.

There is no single technology or rule system that defines modern AI research or products, but there is an array of methods that might be optimal for different purposes. The common element is the algorithm, which is logical or mathematical rules often intended to be iterated over multiple cycles. Beyond the use of rule-based logic to instruct the machine, the means of drawing associations can vary greatly.

What Are the Investment Opportunities?

There are a number of interesting ways that investors can use for exposure to AI, robotics and automation, which should offer meaningful returns for investors as the technology gains wider adoption across the commercial and industrial landscape. We offer a framework to help investors understand the opportunities across the different facets of the industry (see Exhibit 6).

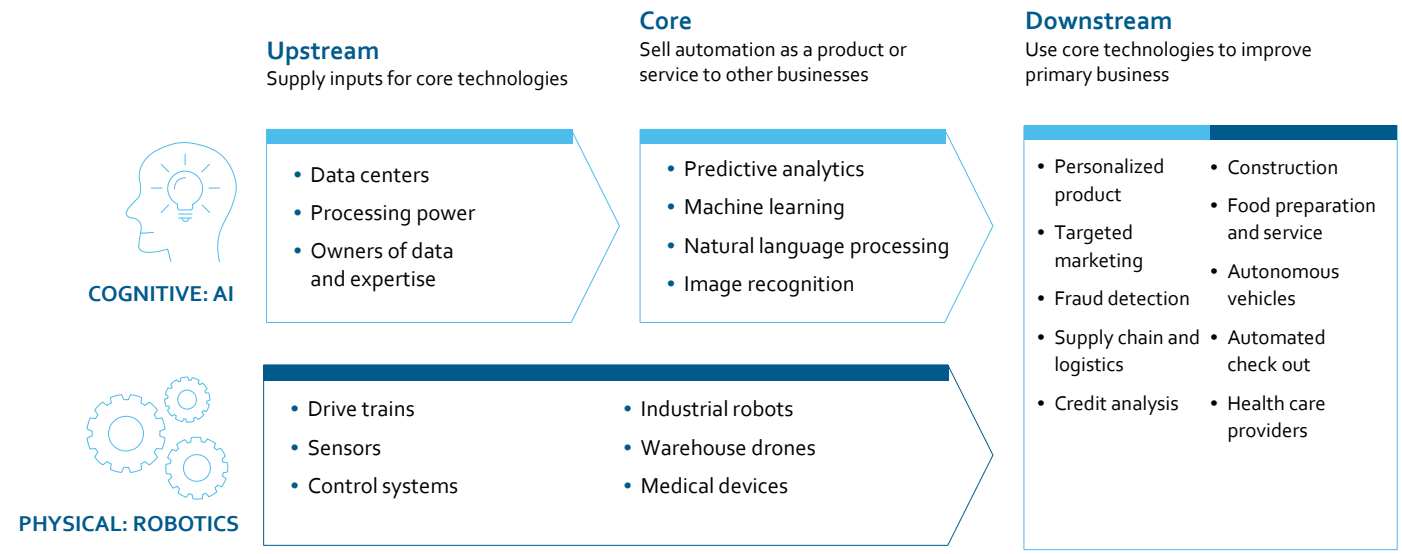
The ultimate end-state is automation. AI helps automate cognitive functions just as robotics automates physical activities. The first question is what each of these technologies need as the primary inputs. We consider these inputs the upstream opportunities and identify some of the businesses well-positioned to support the growing industries. Next, upstream capabilities feed into the core businesses of AI and robotics, which are the companies that own the technology and deliver products to market. The AI industry, being relatively new, has more clearly defined barriers between upstream and core. The robotics industry, which is more mature, has greater vertical integration up the supply chain. Many of the robotics manufacturers also make the components. Finally, companies in the core sell to those downstream, which are the firms that embrace automation and integrate AI or robotics to achieve greater business efficiency.

Upstream

Recent advances in processing power, data and expertise have driven the improvements and now early commercialization of AI technologies. While many might begin their investment search among the companies that provide the actual services, there may be greater opportunities for investors in those that create AI's upstream inputs than there is among the algorithm owners themselves. This is not to ignore those on the forefront of AI, but companies providing the necessary inputs are positioned to benefit. Companies in the Philadelphia Semiconductor Index, critical for processing, saw sales grow at 21% last year. Data structuring firms, companies that do organize information, saw topline growth well above the S&P 500 in 2017.

At the fore of these upstream businesses are the firms that enable advances in processing power. Supercomputers and advanced graphics chips are critical in AI. Many of these technologies require vast computing power to map and search through terabytes (1,000 gigabytes) rapidly. The semiconductor sector currently sells at a discount to the broader market, with a forward price/earnings ratio of 15.3 versus the S&P 500's 17.5. The price/book ratio for the semiconductor index is 3.4 times compared with the broad market's 4.9. Of course, not all semiconductor companies will

Exhibit 6: How the Artificial Intelligence Pieces Fit Together



Source: Morgan Stanley Wealth Management

benefit equally. The technology that could make one a leader in smart phones or compact devices might not necessarily provide AI's high-capacity processing needs.

While still exploratory, quantum computing could also be a game-changing technology for AI and industrial-scale applications. Quantum computing is based on qubits, which allow the byte going through the processing chip to be a 0 or 1, the basic language for all computing, simultaneously. By allowing the microchip to process data as 0 or 1 simultaneously, the time to run complex calculations is drastically reduced. This could disrupt industry leaders or vault an existing firm into sector leadership.

The next input investors should consider are firms that own vast amounts of data and those that provide data structuring support. Machines require vast amounts of data to simulate intelligence, and until recently, there were few data repositories large enough for the tasks. With current technology, sources like call center logs, customer email inquiries, internet history and traffic patterns make data more readily available. Those that own data and can provide others access to train AIs stand to monetize a resource that was up until recently less valuable.

Alongside the data owners, firms that can structure data should continue to grow. While firms are collecting more data than ever, much of the content remains unstructured, such as plain text or recorded discussions that lack labels and classifications. Google Trends shows that web searches for unstructured data have increased by 50% in five years, and interest in an open source tool named Hadoop used for data structuring remains high. Firms that leverage technologies like Hadoop to unlock the value of a company's proprietary data could play a critical role in the coming transformation.

The final upstream area that stands to benefit disproportionately are those with expertise in AI, the coordination or integration across AI technologies, and functional expertise to assist in training the machines. Consulting, advisory, and technology services firms could be well-positioned, but largely those that have a dedicated practice in AI integration and support.

Core

What we label the core consists of the companies developing the actual AIs. The AI industry at present consists of a few large and well-resourced players and many small start-ups exploring new technologies. There are some mid-sized firms focused on decision support as well. The larger companies within the core have the upper hand. Most of them invested in extensive processing capabilities through existing cloud services, and also use the cloud to service clients that might be interested in incorporating AI into their business processes. In addition, the large firms also have significant data repositories from core businesses that can be used to train and test the machines. If processing, data, and expertise are critical inputs, some of the larger tech firms look to be more integrated with the upstream than smaller players. That said, smaller players are more likely to experience rapid growth should their approaches to respective technologies to AI prove successful. The larger companies, in turn, have and will likely continue to buy those smaller players with interesting capabilities.

A few firms in the core have actively moved to advertise AI capabilities and have offerings in the market, but others are still experimenting with technologies and proper application. As is typical in technology, the first to market with new technology does not always become the dominant player. The technology around AI and the potential uses are sufficiently differentiated that the market could accommodate a number of players in the future. While some companies are investing in artificial general intelligence, there is no one with an offering in that segment yet.

Robotics

The robotics sector is more mature than the cognitive counterpart, and companies are more vertically integrated up the supply chain as a result. Firms that produce industrial robots for auto assembly, for example, also design and sell the specialized sensors that are critical for functioning. Upstream technologies in robotics consist of components like drive trains, sensors and control systems. Many of these firms are industrial specialists or conglomerates that have been making robots and associated technologies for decades.

The final products consist of machines used by those companies or in the industrial, logistics and medical sectors. Most likely, these current cases are just scratching the surface. That said, the more mature industry of robotics is not expected to grow at the same pace as AI. Robotics industry revenue growth is expected to range from 15% to 20% for the next five years, according to the International Federation of Robotics. We believe that growth rate could pick up as robots are empowered by improved cognitive technologies, but that will take some time.

Downstream

Downstream companies could see the biggest cost efficiencies or business model transformations through automation. This is perhaps the hardest group to identify, because individual firms have to commit to these new technologies and then execute strategies effectively. Companies with high labor costs devoted to

simples tasks are probably the most obvious beneficiaries. Fast food is one area where companies are using robotics to experiment with food preparation, but integrating new routines in larger companies could more challenging than for smaller players. Autonomous logistics and delivery systems is another area that stands to benefit from improved cost efficiency. Retail and consumer goods may look to adopt technologies to help alleviate the pressure from ailing brick-and-mortar retail and improve margins. The hospitality industry could benefit from labor-saving automation, and industries with high customer-service demands will also benefit as natural language processing and machine learning improve.

Conclusion

Artificial intelligence and automation promise to be one of the most exciting industrial technologies and growth areas in the market. We believe that investors will benefit from investing across the automation ecosystem upstream, core and downstream.

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Appendix

One technology called k-means clustering divides observations in associated groups based on similar characteristics. Search trees use ordering principles and rules to determine whether decision node pathways should look right or left. This was central to the technology that helped a machine beat a human player at the game of Go. Another technology called generative adversarial networks (GAN) uses two neural networks simultaneously whereby one network creates data and the other judges the efficacy. The system learns by rewarding points to the respective network in competitive fashion.

Much of the corporate investment, according to McKinsey, has flowed to a technology called deep learning. This is a deviation from prior approaches to generate intelligence through rules or expert decisions. Instead, machines are fed massive amounts of data on prior cases or examples and determine which actions led to the best outcomes. This process is referred to as training the AI, and training can be supervised or unsupervised by people with expertise on the task. At present, supervised learning generates better outcomes than unsupervised across a range of technologies. The process is called deep learning because the algorithm generates maps and searches that occur in a hidden layer. The machine then adjusts weights on the parameters as new data is integrated.

As physical and cognitive technologies integrate, data inputs like sensors become increasingly important. This is one area that has received significant attention in robotics. Machines can only learn and respond if there is new and accurate information available. Whether machines are asked to identify images in recognition software, navigate the 3D world by moving boxes to the most efficient positions in a warehouse or transport people in self-driving cars, the technology needed to identify images, phrases, objects or impediments is critical. Since we do not understand exactly how the human sensing system works in conjunction with the brain, sensors have been built to approximate capabilities. Sensor technology is not new; it has been used in factories and on military satellites for years, but leveraging this improved technology for AI is an advancement.

There is an array of interesting new technologies feeding information into systems. They include mini lasers leveraging light beams to judge distance and audio beaming or radar using sounds waves to identify position. The growth in sensor technology is partially driven by the increased need for information in systems, but a number of innovations have also helped. Miniaturization, minimal power use, enhanced capacity to communicate directly with networks and application-ready output now facilitates widespread deployment.

The nature of robotics continues to evolve as interfaces change, sensors allow greater control, and machine learning powers the robots. Robots have been in widespread industrial use for decades, but these productivity enhancing tools are moving off the assembly lines and factory floors. Advanced sensors and the explosion of shared data among machines now allow robots to interact dynamically with their environment and even coordinate production with each other. Autonomous robots can work collaboratively to 3D print portions of cars, ships, or fuselages, dividing the work area into boxes and coordinating so that no box is missed. They can recharge themselves when their batteries are low and transmit their data to other bots that can pick up where they left off. Modern logistics operations rely on robots to organize and move packages. Robots may soon be stocking shelves at grocery and drug stores. As the dexterity of machines improves and cognitive technology matures, the number of fully automated activities will increase.

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Index Definitions

PHILADELPHIA SEMICONDUCTOR INDEX This is a modified capitalization-weighted index comprised of companies that are involved in the design, distribution, manufacturing and sale of semiconductors. The index was developed with a base value of 100 as of Dec. 1, 1993.

For other index, indicator and survey definitions referenced in this report please visit the following:
http://www.morganstanleyfa.com/public/projectfiles/id.pdf

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