The Rise of Artificial Intelligence

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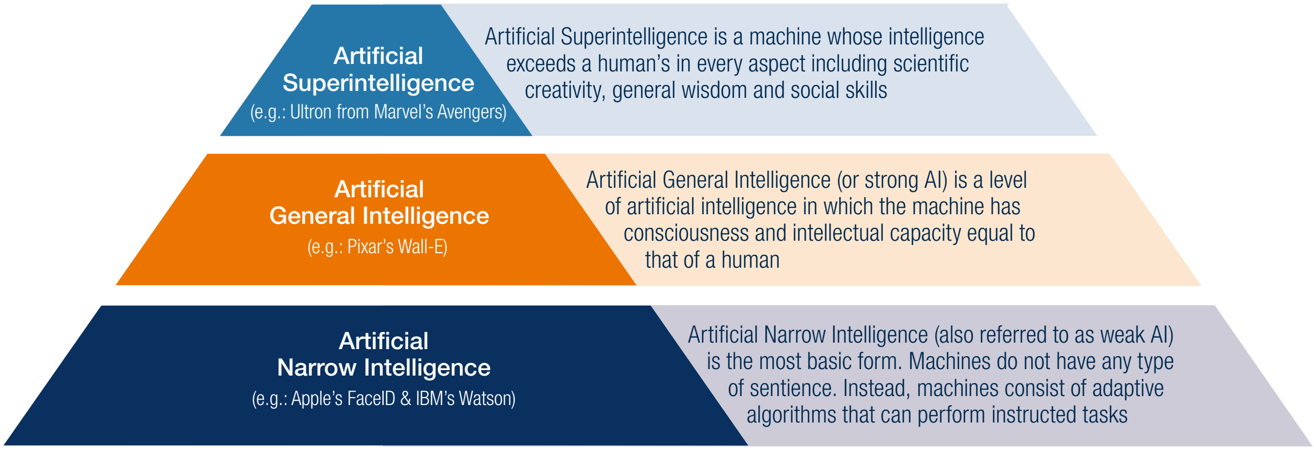
Artificial intelligence (AI) is one of the hottest buzzwords in the tech world today and for good reason — it is a revolutionary breakthrough in technology that will ultimately affect most, if not all, industries. That said, it is still in the early innings right now.

So what is AI? Merriam-Webster defines it as "the capability of a machine to imitate intelligent human behavior" while the Cambridge dictionary describes it as "the use of computer programs that have some of the qualities of the human mind, such as the ability to understand language, recognize pictures, and learn from experience." Broadly speaking, AI is the ability of computers to think like humans. AI can be placed into three tiers: Artificial Narrow Intelligence, Artificial General Intelligence and Artificial Superintelligence (summarized below).

Only weak AI has been achieved to date and experts believe that strong AI is decades, if not centuries, away from reality, let alone Artificial Superintelligence.

The concept of artificial intelligence has been around since the 1950s but a confluence of technological advancements has recently led to major breakthroughs in AI, revitalizing society's interest in it. On the hardware side, computing power continues to improve led by GPUs (graphic processor units) which can process data in parallel and thus operate at speeds that dwarf those of traditional CPUs (central processing units). Memory technology (specifically dynamic random-access memory) continues to improve, also boosting processing performance.

Three Tiers of Artificial Intelligence



In addition to hardware improvements, data availability continues to grow exponentially driven by the technological adaptation of formerly "dumb" things, ranging from phones to refrigerators to factory equipment. Data is critical to the development of artificial intelligence as machines need data to "learn". The expanding coverage and accelerating speeds of Internet and cellular traffic enable more seamless data transfers from endpoints to centralized data centers where the data can be stored and mined. Meanwhile, the costs for computation and storage continue to decline, making all of this economically feasible, in addition to being technologically possible.

Finally, software algorithms continue to evolve. Deep learning was a key breakthrough on the software side and arguably the most important recent development in AI. Before delving into deep learning however, it is necessary to understand what machine learning is. Machine learning refers to algorithms that are capable of making informed decisions based on data that the algorithms have processed and analyzed. In traditional computing, machines don't "learn" anything from data. The programming is static and does not change – the model takes input and converts it to output. However, machine learning "trains" a computer using data and algorithms. Once the machine processes and analyzes the data, it makes decisions based on what it has "learned". Machine learning has been around since the 1980s and has been a major driver in the development of many current applications like voice recognition (Siri, Cortana, et al.) and personalization/recommendation (Amazon, Netflix, Pandora, et al.).

Deep learning is the next level of machine learning. Deep learning requires Artificial Neural Networks, which simulate human brains. The primary difference between deep learning and machine learning is that in a machine learning model, the machine must be instructed on how it should make a decision whereas a deep learning model learns how to make decisions without programming direction. Google's AlphaGo is a good example of deep learning.

Companies are looking to harness deep learning to create more value for their businesses by cutting costs, generating incremental revenue or both. Deep learning can help in multiple ways, such as supplementation/replacement of human labor in factories and warehouses, acceleration of new product/service roadmaps, supply chain management, customer support and a whole host of other possibilities.

The Role of AI in Automation

Today, the most common use of artificial intelligence is in industrial automation. Historically, industrial automation has been concentrated in the automotive industry but it is proliferating to other fields such as electronics assembly and medical equipment as the technological advances of AI are expanding the functionalities of automation and lowering its costs.

Automation has been prevalent in factories for years now, especially in manufacturing. Robots generally handle tasks that are repetitive, dangerous, and/or labor-intensive. However, while these robots are efficient and tireless, they are not very "smart" as they cannot adapt to any changes in the manufacturing process. They can only operate exactly as programmed and instructions must be very specific. Any changes in the product, process or environment can render robots inefficient or useless. However, the advances in artificial intelligence and deep learning have expanded the capabilities of robots with new abilities like image recognition and path planning. Factory automation represents a large market opportunity, estimated at $300 billion in annual revenues with annual growth rates in the mid- to high-single digits.[1]

AI in Automation

	Object Identification	Object Classification	Dynamic Control	Path Planning	Scene Understanding	Multi-agent Coordination	Expert System
INDUSTRIAL ROBOT							
Welding	⚙		⚙	⚙	⚙	⚙	
Material Building	⚙	⚙		⚙	⚙		
Assembly	⚙	⚙	⚙	⚙			
MACHINE VISION							
Inspection	⚙	⚙					⚙
Guiding	⚙	⚙					
INDUSTRIAL INTERNET OF THINGS (IIOT)							
Predictive Maintenance							⚙
Operation Optimization						⚙	⚙
COMPUTER-AIDED DESIGN (CAD)							
Product Design	⚙	⚙					⚙

Source: Alliance Bernstein, "Artificial Intelligence in Automation: You say disruptor, I say multiplier" (December 2017).

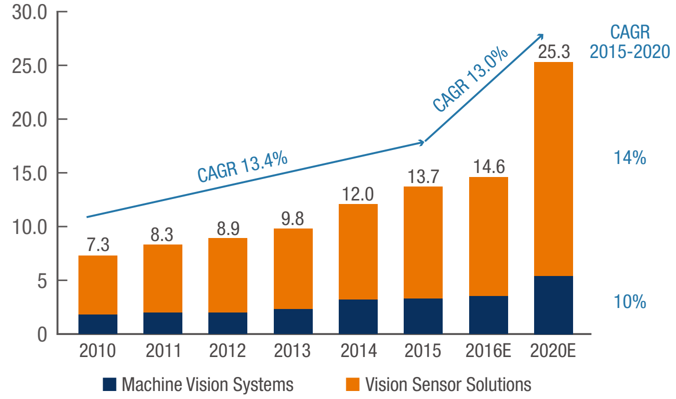
[1]Bernstein Research (2017), Accessed in 2018.

The global vision market is roughly $15 billion today and growing in the mid-teens, making it one of the fastest growing sub-markets within automation.

Welding is a good example that illustrates the differences in efficiency and functionality of automation models (conventional robot automation vs. machine learning-enabled robots vs. deep learning models). Welding is a very complex process with a number of variables like temperature, geometry, pool size and depth, to name a few. Conventional robots can handle spot welding but require human engineers to program positioning and paths. Any kind of change, even if minor in nature, requires recalibration, which can be time-consuming and costly. Machine learning improves the efficiency, speed and accuracy of robots. More importantly, machine learning-enabled robots are more adaptable as they are able to adjust to certain changes in variables based on their programming. With deep learning, these robots have become even smarter and require even less human handling. Deep learning-enabled robots are able to determine the appropriate welding process in response to all of the different associated variables with minimal human direction.

Outside of manufacturing, deep learning has also affected automation in other areas, like logistics. According to Alliance Bernstein research, automation can improve package retrieval efficiency and total turnaround time by 3-4x while significantly reducing floor space and workforce (by up to 75%). Within a warehouse, automation is helpful for tasks such as storage/retrieval, picking and packing, and sortation. The development of advanced vision systems has played a key role in driving this evolution.

Market Size of Vision Systems (USD Billion)



Source: IHS, company reports, and Bernstein estimates and analysis. E=estimate. Compound annual growth rate (CAGR) is the mean annual growth rate over a specified period of time longer than one year.

[2]Alliance Bernstein, "Global Automation: And There Was Light — A Summary of Our Blackbook on Vision and Laser" (July 2017).
[3]Ibid.

Vision is one of the most important trends within artificial intelligence and one of the most impactful for automation. Vision products (e.g. sensors and cameras) allow robots to find, measure, position and inspect components and products. Vision improves production efficiency, while reducing error rates, making it highly critical to automation. The global vision market is roughly $15 billion today and growing in the mid-teens, making it one of the fastest growing sub-markets within automation.

Vision technology is particularly helpful for semi-automation solutions, which involve less human oversight. In particular, 3D vision has been a breakthrough development. Non-3D vision technology struggles with inconsistent surfaces and low contrast. Robots without any type of vision today can only locate objects that are placed according to specific parameters set by humans. Robots with vision can "see" the objects themselves and don't need as much human presorting but will struggle in less than ideal situations (irregularly shaped items, low color contrast, distorted background etc.). Robots with 3D vision can distinguish between different objects easily, regardless of conditions, and require minimal human involvement. The 3D vision market is roughly $750 million today, which is 5% of the overall vision market, and growing quickly.[2]

Historically, vision was primarily utilized in component inspection. However, as the technology improves, it is being utilized in more and more applications like "picking and placing" tasks in warehouses. These are tasks that legacy automation solutions could not have handled given that things in a warehouse are not always neat and orderly. The "holy grail" of logistics robots is bin picking — being able to differentiate and find random objects from containers — and picking them up. Imagine a customer orders several items via Amazon like a pair of shoes, a book and a computer. These all might be stored in the same warehouse but in different locations within that warehouse. Robots capable of bin picking would be able to track these items, go to the appropriate containers and then pick out the needed items from mixed inventory containers. They could then bring those items back to sorting and packaging, another process that might someday be fully automated. All of this could be done with minimal human aid. Logistics workers spend the majority of their time picking and packing, so automating this function would free up a lot of human capital, in addition to making the process more efficient. Logistics only accounts for 8% of the vision market today but it is one of the fastest growing segments, increasing 30% annually.[3]

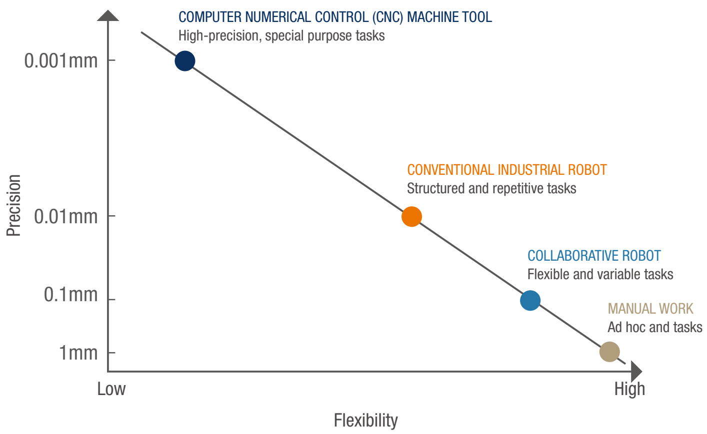
Estimates and forecasts are only projections and not guarantees.

There are many cases where it makes sense to use robots to supplement and integrate with human labor — tasks that require human dexterity and creativity combined with the strength, precision and consistency of robots.

Collaborative Robots — Expanding the Use of AI

The use of collaborative robots ("cobots") is growing steadily, and we see expanded use cases for these machines over time. Currently, conventional robots replace human labor where it makes sense — usually labor-intensive, static, repetitive and/or potentially dangerous tasks. Humans handle tasks that might have unexpected variability. However, some tasks require both human flexibility and the repetitive precision of robots. This is where cobots can shine. There are many cases where it makes sense to use robots to supplement and integrate with human labor — tasks that require human dexterity and creativity combined with the strength, precision and consistency of robots.

Collaborative Robots



Source: Alliance Bernstein, "The Long View: Collaborative robots, driving automation at the granular level" (January 2018).

In addition, today's industrial robots are isolated from humans for safety reasons but cobots are designed to work side by side with humans. The chart below shows some applications where cobots would be viable.

Cobots differ from conventional robots in several ways. Engineers have implemented certain measures in cobots to ensure the safety of human co-workers. For example, some cobots might have sensors that alert them to the proximity of humans while others have limited weight load bearing capabilities. Cobots usually weigh less and are more mobile, allowing them to move around to different tasks as needed. Lastly, cobots are simpler than traditional robots which means they are easier to program and cheaper to buy, operate and maintain. Thus cobots are typically more affordable, adaptable, and easier to use than conventional robots which increases their appeal to smaller businesses who can "plug and play" cobots where they are needed as opposed to bigger, more complex and expensive robots. However, instead of replacing robots, cobots will likely expand the addressable market for robotic automation as certain tasks still make more sense for conventional robots while others might be more suited for cobots. Various research estimates put the current cobot market at $200-250 million with the potential to grow to $7-10 billion by 2025.

Machine Shop

	What Cobots Do	What Humans Do
Machine Tending	Machine tending	Setting computer numerical control parameters
Quality Inspection	Tending testing machine	Setting testing machine parameters, checking quality
Assembly	Palletizing materials/ finished parts Putting finished parts into packages	Inserting and fixing parts Attaching labels, sealing packages

Source: Alliance Bernstein, "The Long View: Collaborative robots, driving automation at the granular level" (January 2018).

AI as an Investable Theme

AI is still in its infancy and is a long way from being a mature market; therefore, it is difficult to say with certainty which companies will be the "big winners" from an investment perspective. Indeed, it is likely that different companies will benefit at different points throughout the AI evolution. That said, we have some thoughts on the types of companies that could potentially be long-term winners in the AI race. We believe that there will be two buckets of winners — those that leverage AI as a tool to improve their own operations (through cost cutting, demand creation, better customer service etc.) and those that sell products/tools/services to enable AI for others. The first bucket encompasses many companies and it is difficult, at this point, to calculate the savings companies can generate from AI given the limited publicly disclosed information (though we expect the savings to be meaningful). The second bucket is likely what investors refer to when they say they want to invest in AI as a theme. At this time, we believe that semiconductor companies are one way to invest in AI as these companies sell chips that enable the high speed processing, data storage and connectivity necessary for AI. Ultimately, we believe that in the long run, consumers will be the biggest winners from the AI revolution as it should help improve their overall quality of life.

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