SHEPHERDING EXPONENTIAL TECHNOLOGIES AND AI IN THE BOARDROOM: PART I OF II

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Exponential technologies are the next phase in the evolution of modern technology. These innovations achieve adoption at unprecedented rates with highly disruptive effects. They normally begin slowly and then accelerate rapidly because the innovations are built on foundations provided by previous technologies much like smartphones provided the foundations for Uber and Airbnb. As exponential technologies emerge, integrate, and converge, the pace accelerates, the effects of compounding become steadily more unpredictable, and the risks mount even as perceived value escalates. These vectors have significant implications for board members, executives, and almost all organizations.

Martin Rees writes in "A Win-Win Roadmap to the Future" that the smartphone, web, and their ancillaries, which are ubiquitous today, all seemed rather mystical only a few decades ago. In reimagining the future, board members and executives need to keep their minds open to transformative advances which sometimes appear more like science fiction than reality.[1]

George Westerman, Didier Bonnet, and Andrew McAfee write in *Leading Digital: Turning Technology into Business Transformation* that today's innovations are both powerful and compelling. Their pace and impact have been sensational, yet only a prelude for what is to come. They predict that soon technology will be 10 times as powerful as today. Within the next 10 years, the increase will be more than one hundredfold. If those in the boardroom have struggled to keep pace with the changes over the past few years, they need to prepare for the headwinds and extraordinary opportunities ahead.[2]

Deloitte notes that planning for the future requires an understanding and sense of tomorrow's possibilities. It requires an appreciation of new technologies and the market forces driving change. There is a growing interest in the boardroom to look beyond "What

"Any sufficiently advanced technology is indistinguishable from magic."

— Sir Arthur C. Clarke, an English futurist, writer, and inventor (1917-2008) is new?" to "What is next?" Board members and executives know that recognizing what is on the horizon informs strategy and enables decisions that make reaping the rewards of the future distinctly possible.[3]

Boards and management of forward-leaning organizations are initiating programs to align innovation with their strategy and the technology landscape. Their innovation agendas could be to invest in the creation and incubation of disruptive technologies, in the early identification and co-investments in disruptive technologies, or in the adoption of emerging technologies. These companies take a programmatic and pragmatic approach to sensing, experimenting, and incubating trends until the market, the technologies, and the applications are ready on an organization-wide scale. Other organizations apply the same approach by using the knowledge and experience gained to transform before they are disrupted. In a world of limitless unknowns and unimaginable possibilities, Deloitte recommends that board members and executives need to focus on a collection of advanced and exponential technologies that, taken together, can chart the path to a better and much different tomorrow.[4]

Farabi Shayor writes in *Exponential Progress* that technology is progressing to shape and control everything from banking and business to education, medicine, and the very basis of the human genome. Businesses and the entirety of humanity are moving toward a future that is becoming dominated by the outcomes of inventions and innovations which are evolving. Shayor emphasizes that technological progress was slow and buggy at the beginning but the rate of advancement is now exponential, affecting businesses and lives in ways that are virtually incomprehensible.[5]

An illustration of the art of the possible is the mRNA-based vaccine that was developed in record time by Moderna in the U.S. and BioNTech in Europe. Both of these drugs are examples of the use of large-scale computational harnesses to quickly understand a specific disease pathogen and develop an antidote to combat the COVID-19 virus. This represents a triumph of 60 years of progress, stemming from and leading to innovations in nanotechnologies, synthetic and computational biology, and high-speed sequencing. It is the convergence and integration of several exponential technologies, each progressing along separate paths and coming together to create one of the most significant disruptions in the modern era.

Hans J. Ornig writes in *Leading into the Future: The 'So What?' on Exponential Technology and Leadership* that Gordon Moore, the co-founder of Intel Corporation, observed that the number of transistors per square inch on integrated circuits had doubled every year since the integrated circuit was invented. More than five decades later, that observed trend continues today and is referred to as "Moore's Law." Moore's extrapolation meant significant increases in the capacity and speed of computers with decreasing costs. That this would occur at an ever-increasing rate appears to be the primary definition of an exponential technology. Ornig maintains that Silicon Valley has led the defining of exponential growth and applies the term to a ubiquitous set of discoveries. There remains, however, mixed interpretations of what specifically constitutes an "exponential technology." Ornig indicates that although

The Legend of Exponential Growth

The emperor was a chess enthusiast who had the habit of challenging visitors to a game of chess. Many years ago, a traveling sage was challenged by the emperor. To motivate his opponent, the emperor offered any reward. The sage modestly asked just for a few grains of rice in the following manner: The emperor was to put a single grain of rice on the first chess square and double it on every consequent one on the chessboard with 64 squares. Having lost the game and being a man of his word, the emperor ordered a bag of rice to be brought to the chessboard. He then started placing rice grains according to the arrangement: One grain on the first square, two on the second, four on the third, eight on the fourth, and so on. Following the exponential growth of the rice payment, the emperor soon realized that he was unable to fulfill his promise because, on the twentieth square, the emperor would have had to put 1 million grains of rice. On the fortieth square, the emperor would have had to put 1 billion grains of rice. And, on the last and sixty-fourth square, the emperor would have had to put more than 18,000,000,000,000,000,000 grains of rice, equal to 210 billion tons and allegedly sufficient to cover the entire territory of India with a meter thick layer of rice. At ten grains of rice per square inch, the amount would require rice fields covering twice the surface area of the Earth, oceans included. It was at that point the sage told the emperor that he does not need to pay the debt immediately but can do so over time. Visiting pilgrims to this day continue to feast on the rice and the emperor's debt to the sage is still being repaid.

Source: "Exponential Growth and the Legend of Paal Payasam," Singularity Symposium, 2021.

the term may not be universally accepted, when thought leaders create labels, they tend to stick. No matter what adjectives are used to describe the current technological development frenzy, one thing is certain: Technology is developing at an astounding rate.[6]

When they start their relentless march, exponential technologies operate below the radar screen. However, at some point during their voyage, they hit the proverbial "knee in the curve" and become highly visible and take off. Ornig points to computers as an example but there are others like artificial intelligence, which has been around for some time with many doubling periods. Another attribute of exponential technologies is that they are at the point in their cycle where their price-performance makes it possible to be incorporated into solving today's most vexing problems in ways that were not previously possible. For instance, it used to be that only the outsized budgets of the military could afford to spend significant amounts on each drone. Today, consumer-level drones can be conveniently acquired for only a few hundred dollars. Put simply, Ornig writes, exponential technologies are on short doubling periods and have entered the cycle of their exponential growth curve where they can facilitate extraordinary outcomes at acceptable costs.[7]

The renowned futurist Ray Kurzweil describes a point in time when computer intelligence will surpass that of its human counterpart. Kurzweil calls this point the "singularity." He posits that once the singularity is reached, machine intelligence will be more powerful than all human intelligence combined. Given the number of today's exponential verticals, Ornig writes, it is unlikely that there will be this single point. Within the next 20 years, however, it is forecasted that the convergence of exponential technologies will threaten to disrupt most jobs, including those previously considered safe from automation.[8]

"Organizations that are able to leverage exponential technologies can realize disruptive outcomes. Directors and management are faced with a critical strategic choice. They can either invest and position their businesses to disrupt or allow the organization to stand still and be targeted for disruption," commented Richard Munro, a board member of UST, LLC.

Peter H. Diamandis and Steven Kotler write in *The Future Is Faster Than You Think* that today's technology is accelerating far more quickly than anyone could have expected. During the next decade, there will be more upheaval and wealth created than in the past one hundred years. Wave after wave of exponentially accelerating technologies will impact economies, businesses, societies, and daily lives. Computers are being used today to design even faster new computers, creating a feedback loop that will further fuel the acceleration.[9]

Convergence is having a significant impact and dramatically changing the nature of forecasting. It occurs as formerly independent waves of exponentially technologies integrate with other independent waves of technology. The speed of drug development, as an example, is accelerating not only because biotechnology is progressing at an exponential rate, but as a result of artificial intelligence and other exponentials converging on the field. In other words, these waves are overlapping, stacking atop one another, producing tsunami-sized behemoths that wash away everything in their sight. As exponential technologies converge and integrate, their potential for disruption increases dramatically. Diamandis and Kotler write that solitary exponentials disrupt products, services, and markets. Convergent exponentials wash away products, services, and markets, as well as the multiple layers and foundations that support them.[10]

If board members and executives have struggled to track the growth of singular innovations, they are helpless in the face of converging technologies. Diamandis and Kotler suggest that paradigm-shifting, game-changing, nothing-is-ever-the-same-again breakthroughs are no longer an occasional occurrence. They are happening regularly as a result of convergence of these technologies.[11]

"The potential of exponential technologies is manifested by integration. Applying them in different combinations to other innovations in both processes and products can push organizations to strategic advantage over their competitors," commented Marios C. Papaefthymiou, Dean of the School of Information and Computer Science, University of California Irvine.

Diamandis and Kotler emphasize that organizational structures are evolving and changing. Rather than utilizing armies of employees or large physical plants, organizations today have smaller structures focusing on technologies, dematerializing the once physical and creating new products and revenue streams in months, sometimes weeks, or even days. It no longer takes a large organization to cause an outsized disruption. In many cases, the driving force is an exponential technology. These technologies do not just put linear organizations out of business, they threaten entire industries. Businesses and industry structures which were built on and embrace top-down command and control structures, processes, and practices are in peril of fading away. Diamandis and Kotler suggest that exponential technologies are shifting the landscape and forcing organizations to rethink core processes, move faster, and constantly explore and experiment.[12]

Diamandis created a framework to help navigate the voyage that an exponential technology takes, known as the Six Ds, which is a course of what happens when an exponential technology is created and matures. The Six Ds are framed as digitalization, deception, disruption, demonetization, dematerialization, and democratization.[13]

Ornig describes *digitization* or digitizing as the representation of an object, image, sound, document, or a signal by a discrete set of points or samples. Strictly speaking, digitizing means capturing an analog signal in digital form. Once a technology is digitized, the space becomes much more informative and computer-manageable. *Deception* refers to a phase of disappointment and disillusionment because the expectation or anticipatory hype to enjoy the benefits of the technology are deferred for a period of time. Exponential growth is difficult to identify because the early stages of development are almost imperceptible. *Disruption* occurs as a result of the gap between the step-by-step linear progression of events and the fast-paced exponential growth of the technology. The gap between competing and diverging factors causes the disruption. *Demonetization* takes money out of consideration. Whether this is brought about by a new technology replacing what used to cost money, or the new products and services available on the internet, there is little doubt that exponentials have eliminated or minimized the costs for things that used to be purchased at premium pricing. *Dematerialization* refers to the effect technologies can have on the savings of materials and even negating the requirement for physical goods (i.e., the paper saved by electronic correspondence). The sixth phase is *democratization*. As products or services are democratized, they become more accessible and universally affordable and accepted. Products, services, and information that were once available to only wealthy nations, research labs, or large organizations become available to many.[14]

The exact course that technologies of the exponential future will follow in the 6D cycle is highly unpredictable. Ornig writes that what is clear is that these phases have been chronicled as the technologies spread across an increasingly wide range of industries and organizations.[15]

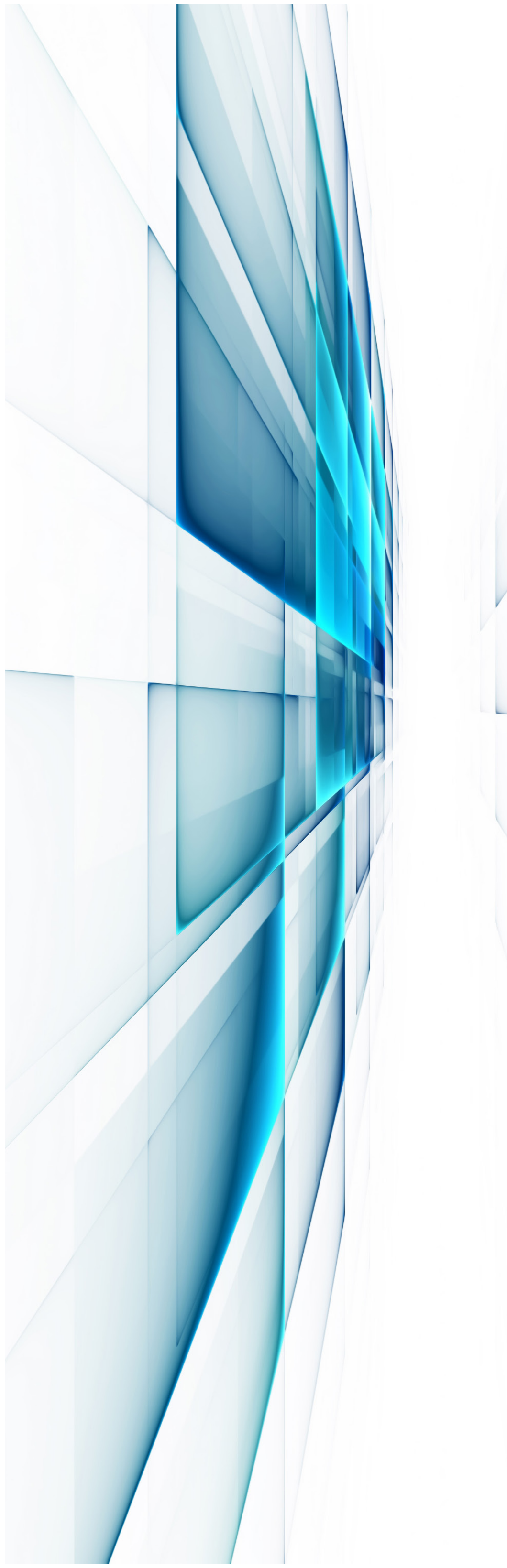
"Many organizations today that consider themselves immune to the disruption caused by exponential technologies are likely candidates for disruption tomorrow. Boards and management should not be complacent about what lies ahead," commented Stephen Roberts, chief information security officer with American Honda Motor Co., Inc.

Era of Artificial Intelligence

Of all the technologies that are driving exponential growth, none is more impactful and far-reaching than artificial intelligence. Jeff Brown describes in "Growth in Artificial Intelligence Is Beyond Exponential" that in the summer of 1956, John McCarthy was an assistant professor at Dartmouth College. He met with colleagues to discuss a topic that most considered at the time to be bordering on the surreal. The subject was the potential of thinking machines, which he coined "artificial intelligence." Within a few years, scientists were teaching computers to play checkers, solve word problems, and speak English. One of McCarthy's fellow scientists, Herbert Simon, predicted at the time that, "Machines will be capable within two decades of doing any work a man or woman can do."[16]

Simon's timeline has proven to be overly exuberant, although AI is becoming the preeminent technology of the modern age. AI perceives the environment and acts to facilitate achieving its goals. Most importantly, it also learns. Brown writes that there is now no area of society or business untouched by the influence of artificial intelligence.[17]

Until about 10 years ago, computing power doubled every few years, roughly following Moore's Law of exponential growth. Since that time, Brown emphasizes that computational capacity has made significant advances. AI computing power is now doubling every three or four months and solving problems that, in the past, were believed to be unthinkable.[18]



"The researcher building the software writes code that can read images, text, video, or audio, and learn. Once the machine has learned, that knowledge is put to use elsewhere."

Lasse Rouhiainen describes in *Artificial Intelligence: 101 Things You Must Know Today About Our Future* that artificial intelligence learns and uses its knowledge to make a decision, much as humans do. The researcher building the software writes code that can read images, text, video, or audio, and learn. Once the machine has learned, that knowledge is put to use elsewhere. In other words, AI is the ability of machines to use algorithms[19] to learn from data and use what has been learned to make decisions like a human. Unlike humans, however, AI-powered machines do not need to take breaks or rest. They can analyze massive volumes of information all at once, limited only by the physical limitations of bandwidth, bound by the laws of physics. Most of all, the rate of machine error is drastically reduced.[20]

AI can be programmed to be self-referential. Rouhiainen writes that AI enablement has machines assessing their own work to identify and correct mistakes, learning the nature of mistake-making in the process. If the same or similar process is iterated, mistakes are not ever repeated. This feature enables exponentiation and leads to formidable error-spotting-and-correction mechanisms.[21]

Rouhiainen emphasizes that the notion that computers or software programs can both learn and make decisions is particularly significant as their processes grow exponentially over time. Because of these two characteristics, AI is able to accomplish tasks that were once reserved for humans. Artificial intelligence holds the potential for reinventing operating models and transforming customer experiences. It is changing the way people live and work. AI is not just one technology but a set of innovations that can be combined in a variety of ways to sense, comprehend, and act. It has become the foundational technology in areas as diverse as self-driving cars and financial trading. Self-learning algorithms are now embedded in mobile and online services. Researchers are leveraging advances in processing power and the data streaming from digital devices and connected sensors to improve performance. And, machines have essentially cracked speech and vision specifically and human communication generally.[22]

Angus Loten and Kevin Hand write in "Making Senses" that even the smartest computers cannot fully understand the world without the ability to see, hear, smell, taste, or touch. But in the decades-long race to make computers or software programs think like humans, the idea of endowing a machine with human-like senses no longer seems far-fetched. Capabilities powered by artificial intelligence, like image or voice recognition, are commonplace features of smartphones and virtual assistants. Now, customized sensors, machine learning, and neural networks[23] are pushing digital senses to the next level, creating robots that can tell when a package is fragile, sniff out an overheated radiator, and identify phony Chardonnay.[24]

"Use Cases" of AI

Processes	Marketing	Sales	Research and Development
Automate shared service centers	Ad targeting	Accurate forecasting	Research literature and periodicals
Fraud management	Content generation	Sales rep. advising systems	Idea testing and validation
Personalized customer service	Customer segmentation	Intelligent routing	Neural networks for structural design
Strong service reliability	Customer insights and offerings	Optimal shelving and merchandising	AI for imaging
Optimize talent	Best pricing	Trade funds ROI	Targeting candidates for testing

Source: *Why Digital Transformations Fail: The Surprising Disciplines of How to Take Off and Stay Ahead*, by Tony Saldanha, Barrett-Koehler Publishers, Inc., 2019.

The possibilities and potential of AI are profound, according to The Boston Consulting Group. AI can identify objects and recognize optical patterns, allowing machines to leave the virtual space and enter the real world. AI knows how to read text and absorb encyclopedic knowledge. It also has the ability to correspond with others based on its findings and conclusions. Machines can interact with people intuitively and naturally on a wide range of topics at considerable depth, which was a fundamental challenge posed by Alan Turing, formulated as the *Turing Test*.[25] BCG notes that machines solve problems and accomplish tasks in their own unique way. While humans are fast at parallel processing (e.g., pattern recognition) and slow at sequential processing (e.g., logical reasoning), computers have mastered the former and are superfast in the latter.[26]

McKinsey emphasizes four factors propelling the use of AI today: (1) unlimited access to computing power, (2) the explosion of data, (3) the development of the internet and cloud computing, and (4) new and sophisticated algorithms. Despite periods of rapid advances, AI has often failed to live up to its hype. Decades were spent trying to describe human intelligence precisely, although its sluggish progress failed to deliver on the earlier excitement. Since the late 1990s, however, McKinsey suggests that technological progress has quickened. Machine learning algorithms have progressed, especially through the development of deep learning and reinforcement learning techniques. Exponentially more computing capacity has become available to train large, complex models. This capacity is aggregated in hyperscale clusters, increasingly made accessible to users through the cloud. Bandwidth is abundant and cheap. Another factor is the massive amounts of data being generated and now available to train AI algorithms.[27]

Marco Iansiti and Karim Lakhani write in *Competing in the Age of AI: Strategy and Leadership When Algorithms and Networks Run the World* that artificial intelligence is transforming the core of organizations, enabling digital scale, scope, and learning, and erasing limits that have often constrained growth. Assets deployed are substantially different in organizations embracing and employing AI. In the process, many time-honored assumptions about strategy no longer apply. AI-enabled "what if" capabilities enable organizations to hypothesize and test endlessly, at near-zero marginal cost. AI-driven processes are vastly more scalable than traditional processes, allow massive increases in scope, enable organizations to straddle industry boundaries, and create opportunities for learning. AI is not only displacing human activity but changing the nature of organizations, how they operate, and how they compete.[28]

"In imagining the possibilities with artificial intelligence, board members and management need to focus on both the operational and exploratory opportunities. The operational relate to productivity improvements that can be achieved by applying AI to existing processes. The exploratory focus on developing new operating models or processes in areas like achieving greater customer satisfaction and retention through the insights derived from data," commented Bruce Edwards, a board member of Semtech Corporation.

Espindola and Wright write in *The Exponential Era: Strategies to Stay Ahead of the Curve in An Era of Chaotic Changes and Disruptive Forces* that in the last decade there has been an emergence of a new kind of organization, one that is architected from the beginning to operate in a digital operating model, leveraging networks, large amounts of data, and algorithms. This new operating model spurred by AI is adept at functioning in much greater scales, scopes, and capabilities that can overwhelm traditional businesses, resulting in a level of disruption which challenges the legacy methods. In order to compete in the new world, traditional organizations need to transition to a different kind of company, rearchitecting how they access and use data, react to information, and make decisions.[29]

Tony Saldanha writes in the *Why Digital Transformations Fail: The Surprising Disciplines of How to Take Off and Stay Ahead* that the key to unlocking the vast potential of exponential technologies lies in the use cases, which are applications of specific tools to given problems. The reason why AI is so popular is that the number of its use cases has hit a tipping point driven by affordable computing power. Saldanha emphasizes that this phenomenon is true of all exponential technologies but AI now happens to be at the peak of the cycle.[30]

The internet was one such exponential technology 20 years ago that spawned an explosion of use cases. Saldanha writes that much of the dot-com boom was about innovators creating new use cases on top of the internet. Most of the early use cases were about access such as buying products online, monitoring bank account information, and executing transactions with the Bureau of Motor Vehicles. As the dot-com era died, it spun off a second generation of use cases that were, in themselves, further platforms to build even more use cases. Cloud computing is one example. It essentially made computing server capacity available online to anyone with an internet connection, which in turn is spinning off a new generation of cloud-based software applications that are dramatically better. AI today is experiencing a similar explosive growth of use cases.[31]

Rouhiainen writes that board members and executives should consider the following:

- *Speed of implementation* – AI innovations are being introduced at an incredibly fast pace. Only a handful of experts understand all the implications of these quickly evolving technologies.
- *Impact on society* – It is hard to comprehend the sheer number of things that AI will be able to improve, transform, and create.
- *Shifting focus* – Even Google, a company that stated that mobile was its first priority, has shifted focus toward AI. Nearly every technology company is heavily investing in AI research and development and demonstrating the importance that it holds for the future.
- *Shortage of talent* – Because AI is growing so rapidly, there is a tremendous gap in talent with algorithm skills, data scientists, machine learning experts, and other experts who can build AI solutions.
- *Competitive advantages for first movers* – Both large and small companies can apply AI, and those who do it first will create measurable and sustained competitive advantages.
- *Legal implications* – In almost every country, laws and regulations are being developed to incorporate the new trends of the AI era.
- *Communication of the opportunities* – Sharing information and describing the benefits offered by AI is an important ingredient to become comfortable with adopting these new technologies. AI can be as simple as the junk mail sorter or as helpful as bad-actor screening in airports.
- *Collaboration between the private and public sectors* – Research and development should not be confined to large organizations. There needs to be open collaboration internationally, as well as between and among companies of all sizes, and between the public and private sectors.[32]

"It is critical that the board and management agree on how artificial intelligence can he used to create the most value and durable advantage. AI is ideal in areas that require large amounts of data and operations that have webs of routine tasks. This does not limit the possibilities because it describes almost all activities in most organizations," said Jim Bemowski, a board member of Hyster-Yale Materials Handling, Inc.

Absorb Data and Generate Action

AI is not a plug-and-play technology. Organizations cannot simply buy intelligence and apply it to their problems. Although elements of AI are available in the market, the work of managing the interplay of data, processes, and technologies occurs in-house. BCG notes that the conceptual framework for putting AI to work is fairly intuitive. AI algorithms absorb data, process it, and then generate action, relying on the integration and convergence of several layers of technology.[33]

BCG points out that the data processing requirements of AI differ from those of big data and traditional data analytics in two important ways:

First: data, training, and processing – Algorithms are not natively intelligent. They require sensory input and feedback to develop intelligence. AI training requires company-specific data and focused effort. Data scientists must feed volumes of data into machines to weight countless correlations and connections, ultimately creating an algorithm whose intelligence is limited to that specific realm of data. This inductive approach to learning explains why AI is described as data-hungry.

Second: action and self-improvement – An algorithm accepts live data and delivers actions, like a credit score decision and its automated delivery to a customer, a cancer diagnosis based on a medical image, or a left-hand turn into oncoming traffic by a driverless car. Although this data-to-action process differs little from the workings of a standard computer program, AI continues to learn and transform itself. The data is a source of both action and self-improvement, similar to an executive who makes decisions based on facts and uses the information to polish future decisions.[34]

Setting up a data-to-action process is often challenging. BCG emphasizes that organizations cannot buy it in the marketplace, and those that try to avoid the laborious work by taking shortcuts are mostly disappointed. Organizations need to rely on their own scientists to find, collect, collate, and create data sources and develop and train company-specific AI systems. Organizations can, of course, outsource the process or activity, such as an HR task, together with all the data. But by outsourcing the tasks to third-party

Field of AI Research

- Machine learning[37] refers to the ability of computer systems to improve their performance by exposure to data without the need to follow explicitly programmed instructions. At its core, machine learning is the process of discovering patterns in data. Once discovered, the patterns are used to provide insights and make predictions.
- Deep learning is part of a broader family of machine learning methods based on artificial neural networks. Deep learning models are inspired by information processing and communication patterns in biological nervous systems. In deep learning, machines re-ingest their output iteratively, seeking second- and third-order patterns, and smoothing for variables in the process.
- Computer vision deals with how computers can gain high-level understanding from digital images or videos. From an engineering perspective, it seeks to understand and automate tasks that the human visual system can do.
- Natural language processing is concerned with the interactions between computers and human language, in particular how to program computers to process and analyze large amounts of natural language data. The goal is a computer capable of understanding the contents of documents, including the contextual nuances of the language within them.
- Speech recognition develops methodologies and technologies that enable the recognition and translation of spoken language into text by computers.
- Robotics integrates computer science and engineering. It involves design, construction, operations, and the use of robots. The goal of robotics is to design machines that can substitute for humans and replicate human actions. Certain robots require use input to operate while other robots function autonomously.

Source: Wikipedia

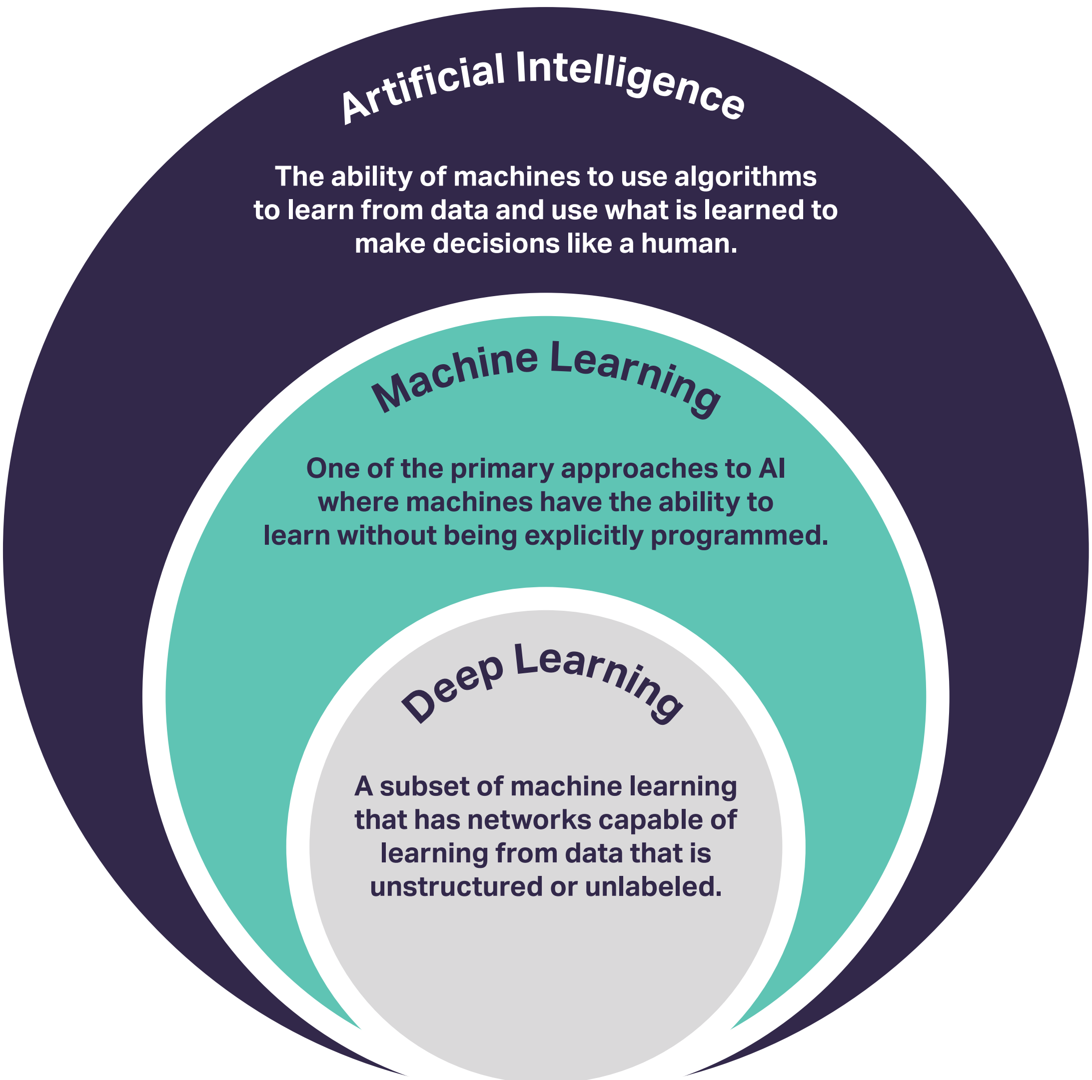
service providers that handle multiple clients, organizations can forfeit the opportunity to gain a distinctive, competitive advantage.[35]

Cognitive Technologies

Cognitive technologies emanate from the field of AI research. Deloitte notes that these technologies have coalesced into systems that "do, think, learn, and continuously adapt." Cognitive technologies perform tasks that only humans used to be able to perform, such as machine learning, deep learning, computer vision, natural language processing, speech recognition, and robotics.[36]

Shayor writes that in using machine learning, the computer learns and adapts according to past experiences. The system learns from its mistakes and adapts according to its needs. Because of algorithms, simulations are run multiple times and the system adapts and learns to perform. The algorithm can correct itself if it faces errors and does not rely on human commands to correct it. Machine learning is software-based learning so that all the algorithms are written using programming languages. Simulations are used to perform "trial and error" corrections. Shayor points out that machine learning is frequently compared with the actual learning process, where people perform their day-to-day tasks

AI, Machine Learning, and Deep Learning



based on individual experiences and knowledge.[38]

Deep learning is a set of techniques to implement machine learning based on an artificial neural network. McKinsey emphasizes that these AI systems loosely model the way that neurons interact in the human brain. Neural networks have many layers of simulated interconnected neurons, hence the term "deep learning." Whereas earlier neural networks had only a few layers and dozens of neurons,[39] deep learning networks today can have many more layers with simulated neurons numbering in the millions.[40]

Part II of the article, in the February edition of The RMA Journal, *will cover creating value with AI, opportunities in banks, and risks and challenges.*

Notes

1. *After Shock*, edited by John Schroeter, Abundant World Institute, 2020.
2. *Leading Digital: Turning Technology Into Business Transformation*, by George Westerman, Dudier Bonnet, and Andrew McAfee, Harvard Business Review Press, 2014.
3. "Tech Trends 2020," Deloitte, 2020.
4. Ibid.
5. *Exponential Progress*, by Farabi Shayor, Independent Publishing Network, 2019-2020.
6. *Leading Into the Future: The 'So What?' On Exponential Technology and Leadership*, by Hans J. Ornig, Balboa Press, 2016.
7. Ibid.
8. Ibid.
9. *The Future Is Faster Than You Think*, by Peter H. Diamandis and Steven Kotler, Simon & Schuster, 2020.
10. Ibid.
11. Ibid.
12. Ibid.
13. Ibid.
14. *Leading Into the Future: The 'So What?' On Exponential Technology and Leadership*, 2016.
15. Ibid.
16. "Growth in Artificial Intelligence Is Beyond Exponential," by Jeff Brown, Legacy Research Group, October 22, 2020.
17. Ibid.
18. Ibid.
19. Algorithms are routine processes of sequences of actions for solving a problem or performing tasks. They represent mathematical instructions. Algorithms can perform calculations, data processing, and automated reasoning tasks. Algorithms represent the basic logic of a computer program. To make a computer perform a task, a computer program is required. The program tells the computer exactly what it needs to do step-by-step. Algorithms drive the connectedness between people, things, businesses, and information, as well as dramatically improving the performance of AI and machine learning.
20. *Artificial Intelligence: 101 Things You Must Know Today About Our Future,* by Lasse Rouhiainen, 2020.
21. Ibid.
22. Ibid.
23. Neural networks are sets of algorithms, modeled after the human brain, that are designed to recognize patterns. They interpret sensory data through a kind of machine perception by labeling or clustering raw data input.
24. "Making Senses," by Angus Loten and Kevin Hand, *The Wall Street Journal*, July 9, 2021
25. The *Turing Test* refers to a machine's ability to exhibit intelligent behavior equivalent to, or indistinguishable from, that of a human. The test results do not depend on the machine's ability to give correct answers to questions, only how closely its answers resemble those a human would provide.
26. "Competing in the Age of Artificial Intelligence," by Philipp Gerbert, Jan Justus, and Martin Hecker, The Boston Consulting Group, January 16, 2017.
27. "The Promise and Challenge of the Age of Artificial Intelligence," by James Manyika and Jacques Bughin, McKinsey & Company, October 30, 2018.
28. *Competing in the Age of AI: Strategy and Leadership When Algorithms and Networks Run the World*, by Marco Iansiti and Karim Lakhani, Harvard Business Review Press, 2020.
29. *The Exponential Era: Strategies to Stay Ahead of the Curve in An Era of Chaotic Changes and Disruptive Forces*, by David Espindola and Michael W. Wright, John Wiley & Sons, 2021.
30. *Why Digital Transformations Fail: The Surprising Disciplines of How to Take Off and Stay Ahead*, by Tony Saldanha, Barrett-Koehler Publishers, Inc., 2019.
31. Ibid.
32. *Artificial Intelligence: 101 Things You Must Know Today About Our Future*, 2020.
33. "*Putting Artificial Intelligence to Work,*" by Philipp Gerbert, Martin Hecker, Sebastian Steinhäuser, and Patrick Ruwolt, The Boston Consulting Group, September 2017.
34. Ibid.
35. Ibid.
36. "Demystifying Artificial Intelligence: What Leaders Need to Know About Cognitive Technologies," Deloitte, 2014.
37. Machine learning is based on algorithms that can learn from data without relying on rules-based programming. It came into its own as a scientific discipline in the late 1990s as advances in digital and inexpensive computing power enabled data scientists to stop building finished models but rather train computers to do so. The volume and complexity of the data that is now being generated increases the potential of machine learning and drives the need for it.
38. *Exponential Progress*, 2019-2020.
39. Neurons are electrically excitable cells that communicate with each other. They are the main component of the nervous tissue in virtually all animals.
40. "The Promise and Challenge of the Age of Artificial Intelligence," October 30, 2018.

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