Cognizant

Digital Business

The AI Path: Past, Present and Future

Just as computing and the World-Wide Web progressed through stages of maturity on the way to full acceptance, artificial intelligence is destined to do the same. By understanding the comparable challenges that were overcome and benefits achieved with earlier technologies, organizations can better see today where AI is heading and ensure that they are properly positioned to reap its full value.

October 2019

Executive Summary

Computing power is something that we now take for granted — if we even think about it at all. In fact, this computing capacity came about following decades of astounding leaps of ingenious engineering that provided a fertile ground for business and social innovations to follow. Our most basic tasks in ordering goods, using smartphones and switching TV channels with our voice now rely on computing power scarcely imaginable even a few decades ago. The lessons of how this took hold and became foundational are relevant in the context of today's coming-of-age megatrend — AI.

Another example is the internet and the web, which allowed social and network connections to grow atop this prior breakthrough in computing power. The earlier rise of distributed and personal computing power, by itself, did not change society or business; such change required connections, networking, and a shift to a more collaborative and sharing mindset. The web's protocols reached a critical mass of acceptance and created the nucleus that attracted new joiners and made today's internet-based and web services possible. Similarly, there are lessons in how barriers to adoption were overcome in the web's march to success that are relevant to AI.

In our view, AI is meant to augment and enhance the human experience. AI can bring the best thinking of the best teachers to distant schools;[1] it can automate routine medical tasks[2] to allow clinicians to focus on complex diagnoses and patient care; it can provide consistency and explainability to business decisions around hiring[3] and credit decisions that will help bring opportunity to billions of people who may otherwise be overlooked using traditional systems and guesswork.

The development, deployment and management of a virtuous and helpful AI may seem daunting at first. However, a crucial observation is that while AI is relatively new and somewhat complex, it is not that different from other recent technologies that started as limited research projects and ended up as a foundational element of modern digital infrastructure, such as computing and the web.[4] By identifying what succeeded and what didn't, we can identify obstacles to AI's development and consider ways to overcome them.

To do this, we have identified four main phases that describe how technology breakthroughs reach their end goal: standardization, usability, consumerization and foundationalization. The same four phases are then mapped to AI's journey, and recommendations are offered based on lessons learned from the development of computing and the web.

If AI is developed in the guided manner we propose, the technology will assume a foundational and beneficial position — similar to the way computing and the web play an integrated role in our personal and professional lives today.

Four phases: AI's historical analogies

Writer and futurist Arthur C. Clarke coined the sentence "Any sufficiently advanced technology is indistinguishable from magic,"[5] but we believe there is a corollary: any widely deployed technology completes its journey by becoming unremarkable. The phases that lead from the first tentative steps out of the laboratory, into Clarke's "magic" moment, and then to full deployment and foundational integration into our lives are worth studying and understanding (see Figure 1). In the case of AI, we are unique observers who are in the middle of this transition, but can also look to history for examples of technologies that have completed all phases.

Let's first consider the explosion of computing power. Until the early 1970s, computing technology was accessible to only a handful of individuals working in research institutions or deep inside corporate finance departments managing taxes and balance sheets. In the late 1970s, the first personal computers emerged.[6] Initially, these machines ran on different architectures and operating systems, such as Altair 8800,

The four phases

	PHASE 1: Standardization	PHASE 2: Usability	PHASE 3: Consumerization	PHASE 4: Foundationalization
Definition	Development of common protocols and interfaces between stakeholders in a growing industry segment.	Standards are encapsulated in higher order functions and interfaces, enabling the technology to be hidden from direct user awareness.	Markets hit a critical mass of potential customers, encouraging investment in rollout of features and technologies at scale.	The innovations are widely deployed and the basis of much social and commercial interaction.
Policy actions that encourage growth	Industry and government standards provide a degree of trust to aid in adoption. Standards compliance clauses in business create an environment to attract investment.	Establishment of open and competitive markets encourage investment and innovation.	Watch and learn to ensure regulation is supportive of consumer adoption, and mitigate unintended consequences.	Turn attention to the human impact, to guide positive personal and economic outcomes.

Source: Cognizant
Figure 1

Commodore PET, the Apple II and TRS-80. Personal computing remained a relatively rare occurrence until IBM PCs were introduced in 1981.[7]

Second, let's consider the emergence of the World-Wide Web (WWW). The smartphone and web browser interactions we now take for granted have followed an amazing 50-year path from the basic networking transport protocols of 1969[8] to highly advanced experiences made possible with the synthesis of software, data, computing power and network speeds that support today's 22 billion devices connected to the internet (growing to 50 billion by 2030).[9]

Phase 1: Standardization

We've long understood the distinction between knowledge and implementation, between raw science and applied technology. Implementation at scale takes decades to become foundational to daily life. Greek philosophers used the word "techne" (τέχνη)[10] to describe the moments when something becomes real and practical.

Thus, while the earliest moments in the laboratory layer one scientific discovery atop another to produce breakthroughs, the societal payoff comes when these discoveries are available in standard forms. For example, the first working transistor in 1947 was a new invention and conformed to no standard. It was not until 1954 that commercially available transistors could be purchased from a catalog, and the integrated circuit (the heart of modern computing) was not commercially available until 1964,[11] with another seven years needed to bring a functioning computer in a chip to the market at scale.[12]

So how does standardization set up the journey for success?

It represents the first step in commercialization. Companies rush to monetize years of research and development by fielding initial offerings. These offerings generally do not work with other companies' products. They can only be used by experts. They are fragile when applied to business, requiring significant support and tuning, and significant barriers against mistakes and unintended consequences. Companies adopt *de facto* and government standards to resolve these issues and grow the value of their initial offerings.

In the world of computing, open architectures emerged that allowed the mixing and matching of components and the development of economy of scale production. The memory (chips and rotating disks) from one manufacturer would now work with another company's PCs; monitors from one computer would work with another; software could be written that ported across other computers using the same standards.

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In the web world, standardization came about in 1993 with the WWW's lingua franca, the HTML protocol.[13] This made it possible to build content in a common format, and access it worldwide using HTML readers (i.e., browsers).

Phase 2: Usability

In Phase 2, the pioneers and early adopters have been reached, but commercial scale requires a wider audience. Usability, in our use of the term, means that higher order functions are offered to designers that hide the details of the underlying technology.

For example, a designer of a personal computer no longer needed to know whether the underlying circuits used silicon or germanium, and a designer of internet software no longer needed to know TCP/IP packet sizes and protocols — these core technologies were hidden beneath a layer of usability enhancements.

Phase 2 illustrates a need to transcend early adopters and experts to achieve wider business use. In this phase, companies focus heavily on the usability of their products. In some cases, substantial copying ensues of usability innovations, often without any interoperability between companies and platforms. User growth grows dramatically but with challenges.

With computing, usability came to the end user in the form of graphical interfaces, a mouse and touch screens (light pens in the early days), where knowledge of operating system details was not needed for most functions.

The development of the web followed a remarkably similar trajectory. HTML authoring went from being a skilled programming exercise using text editors, to a graphical drag-and-drop experience where design happened visually and the creation of standards-conforming HTML was hidden by the design software. Standards for separating content from presentation and the use of file transfer protocols allowed the initial tiny world of text-oriented Usenet in 1980[14] to grow to the billions of web users today.

Standards also evolve with usability. For example, HTML was complemented in 1996 by the invention of style sheets,[15] which made the web vastly more flexible and usable. Separating presentation and content, it was possible to present information in a visual manner that made the content accessible to a wider audience. It therefore was possible to develop web interfaces for businesses, and information in general became accessible through the web as an extension of traditional media, setting up the next phase of adoption.

Phase 3: Consumerization

Consumerization is when investments begin to pay off, at scale. Ironically, many technical pioneers fall aside as the market size draws the attention of other entrants.[16]

Phase 3 reveals the technology's massive expansion to consumers and individual innovators to create value. Smartphones are sold in vending machines, tablets are handed out as freebies to attendees at conferences and the Android App store offers nearly 2.5 million app choices.[17]

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With computing, the introduction of the IBM Personal Computer and its licensed architecture, in concert with Microsoft's DOS (and later Windows), came a proliferation of competing vendors and price points, but within a common software framework. An estimated 1.5 billion PCs are in use today.[18]

The real breakthrough in computing power comes with the expansion of touch points where technology can fit into our lives — and thus the three billion smartphones and 1.3 billion tablets[19] greatly exceed the number of PCs. These figures don't include the 22 billion internet-connected devices mentioned above that have basic computing power as part of their edge computing requirements.

A similar path has led to an explosion of touch points for the web. The web's consumerization phase was aided by the 1999 introduction of Web 2.0.[20] Rather than maintaining passive consumers of information, Web 2.0 ushered in the era of anyone contributing to and participating in the web. Much of personal use (and later our professional lives) now passed through the web via social media platforms such as Facebook. User-generated content such as blogs flourished and videos could now find an audience through YouTube and other similar sites.

Phase 4: Foundationalization

Foundationalization represents the process of technology reaching an advanced state of such consumerization and acceptance that the very foundations of our society and commerce become dependent on it. This is the moment when we take the technology for granted — if we even think about it at all.

This is consumerization's inflection point, where businesses built natively for the new technologies begin to dominate the market — or at least challenge the incumbents. In this phase, companies that did not embrace new technologies fail, while newer or more adaptive businesses capture the bulk of the available market.

Technology phases for computing

	PHASE 1: Standardization	PHASE 2: Usability	PHASE 3: Consumerization	PHASE 4: Foundationalization
Best action to encourage growth in each phase	Definition of standards for interoperability	Establish open and competitive markets	Watch and learn to ensure regulation is supportive of consumer adoption	Establish human-centered objectives to ensure positive social and business impact
Computing	Open architectures	GUI (graphical) interfaces	Explosion of PCs, smartphones, tablets and IoT devices	Cloud computing

Source: Cognizant
Figure 2

Foundationalization is the moment when we take the technology for granted — if we even think about it at all.

For computing power, the proliferation of computing touchpoints (i.e., PCs, tablets and smartphones) and tens of billions of intelligent internet-connected devices has already been discussed.

Perhaps the ultimate expression of computing power, foundationalization is the seamless merging of local and centralized computing power in ways that are not even visible to users. In cases where centralized computing power is needed to illuminate the larger situation by aggregating insights across millions or billions of touchpoints, cloud computing (growing at 18% per year)[21] offers access to massive technology stacks to anyone with a credit card or a contract, thereby eliminating the need for companies to build their own rigid infrastructure before participating in the technology-driven economy. Computing power, with the cloud, is now as foundational as the electrical power grid. You don't care which generator produces your electricity, much like you are unfazed by which chip in a server rack produces the computing power needed.

Technology phases for the web

	PHASE 1: Standardization	PHASE 2: Usability	PHASE 3: Consumerization	PHASE 4: Foundationalization
Best action to encourage growth in each phase	Definition of standards for interoperability	Establish open and competitive markets	Watch and learn to ensure regulation is supportive of consumer adoption	Establish human-centered objectives to ensure positive social and business impact
Web	HTML	Style sheets and separation of content from presentation	Web 2.0 and social networks	Digital economy

Source: Cognizant
Figure 3

For the web, the fourth phase is ongoing, and its implications are huge. The web has become a standard infrastructure for commerce and creativity. It is possible for small businesses to reach consumers across the globe. Brick-and-mortar stores have taken a back seat in many areas of retail such as books, apparel and groceries. Travel, entertainment and everyday life in general is now organized through the web.

As a result, the web is the foundation of most digitized human activity in the modern world, enriching our lives and making our daily routine much more efficient than ever before.

On the other hand, this ecosystem allows bad actors to quickly reach their victims: for example, fake news is now easily propagated via social media, fake profiles can damage real reputations, and social computing and gaming have emerged as addictions. In fact, any outage of social media service often causes outrage,[22] demonstrating that our relationship with the web is addictive,[23] complex and still evolving.

Quick Take

When the Phases Come Together

These four phases represent how breakthrough technology moves from the incubator to mass adoption. Individual companies that benefit from selling or embracing a breakthrough technology may join in late phases, or leave after exhausting their funding during early phases.

For example, Xerox's famous Palo Alto Research Center (PARC) invented many of the concepts that we now take for granted: the mouse, the graphical user interface and (arguably) the self-contained personal computer system like the Xerox Alto[24] with 2,000 units built — an insignificant number by today's standards, with around 1.5 billion personal computers still in use. But these breakthroughs served to propel other companies to success when PARC's innovations failed to bring significant returns to Xerox. Today, computing power is so commonplace most users are barely aware that they are in the Phase 4 of this breakthrough.

Similarly, the inventor of HTML, Tim Berners-Lee, in 1991 built a primitive but functional web browser, Nexus, to go with his protocol.[25] In 1994, Netscape began to commercialize the browser at consumer scale. With Microsoft's release of Windows Explorer in 1995, Netscape faced a determined rival. And when Google Chrome entered the space in 2012, Netscape's dominance came to an end. Google, in fact, has taken and held top browser honors since then.[26] But the real Phase 4 value is that browsers have reached the point where HTML and the web are so widely deployed, most consumers see no significant difference in value regardless of the browser used. This is the definition of breakthrough maturity — ubiquitous to the point of being almost unnoticed.

Lessons for the future of AI

By understanding the evolution of computing and the web, we can better understand how AI is likely to develop over time. Strictly speaking, AI as a concept and as a set of computing technologies dates back to 1950, when pioneer Alan Turing described ways in which a computer could simulate the dialogue of a human (the Turing Test,[27] as it became known). The term "artificial intelligence" itself was first used in 1956, and described research into formal logic for human reasoning.[28]

Setting aside these moments of foreshadowing, AI is still in its early days or just past that opening phase, similar to computing in the late 1970s or the Web in the mid-1990s. While many examples of AI successes exist, they are somewhat disjointed and opaque. Moreover, they are accessible and understandable to experts only. The following lays out how we believe AI will progress moving forward.

Phase 1: Standardization

Like the open architecture of PCs and the HTML of the web, open standards for AI systems are a necessary requirement. Such standards will make it possible to build interoperable AI systems (i.e., those which build on the successes of others). For instance, it will be possible to connect a language generation system to a vision system, and then a translation system to generate in another language and a speech generation system to output the result.

Through standards, it should be possible to transport AI functionality from one task to another — for example, to learn to recognize a different category of objects. It should be possible to swap modules of a system in and out, such as replacing one language with another or one speech recognition tool with another. Such standardization will leverage the success of current AI and make many more applications possible.

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An important aspect of standardization is the ability to know when something such as an AI decision or the data feeding AI is trustworthy. That is, what standards define whether AI is performing intelligently? Consider the home-buying process. There are standard forms and disclosures that allow a consumer to compare multiple loan options. There are standard systems that allow a seller or a real estate agent to identify the viability of a consumer (the credit score, for example).

In this example, the buyer demonstrates transparency by having a preapproved mortgage commitment in hand; to the agent, this means the buyer is qualified. Trust, in contrast, is when the buyer believes the agent understands and represents their best interests and the agent believes the buyer is serious and committed. This includes tangible evidence, such as dual agent disclosures, and intangible evidence, such as soft skills in listening. Personalization of the experience, through a combination of human insight and technology-driven real estate aids, allows the agent to choose a meaningful path to shopping and closing on a deal.[29]

Currently, AI is lacking in similar markers of transparency and trust. There is no AI equivalent of the U.S. Consumer Credit Protection Act of 1968 or similar legislation in other countries. In the absence of such standards, we should not halt AI's development or deployment. Rather, we should seek to collectively establish standards of trust and transparency and find ways to certify to a common standard that the behavior of AI is fair and unbiased, that it knows its limits, and is safe and explainable.

Phase 2: Usability

Just as the web made computing and information accessible to nonexperts, with style sheets and website authoring tools, so AI needs interfaces that make it possible for everyone to use them. An important lesson comes from the browser wars of the late 1990s. Rapid development and innovation among web browsers characterized the initial phase of development. However, in the late 1990s, Microsoft gained a dominant position by bundling its Explorer into Windows, in essence eliminating the need for most consumers to seek alternatives. As a result, innovation slowed for several years, until an antitrust lawsuit against Microsoft was resolved, the browser wars reignited, and mobile computing provided new impetus for progress and new channels for user interfaces.

For AI to grow and prosper in a larger market context, open competition and innovation must be ensured. It should not be possible for one player to force adoption of its AI technology simply because the organization dominates a portion of the IT space. Note that standards help in this regard as well, making it possible for emerging technological approaches to interoperate with existing ones, instead of making various forms of AI incompatible. The result will be open innovation in creating AI that will be useful to the general population.

Phase 3: Consumerization

We believe that AI has a broad spectrum, with the majority of work now in the usability phase, but some clear and growing successes in consumerization (and still some lagging unsolved issues with standardization).

Just like iPhone and Android smartphones made computing nearly ubiquitous, and Web 2.0 made it possible for anyone to contribute to the web, AI consumerization will make it possible for anyone to build AI applications to their specific needs and for general consumption. This means mass production of AI-based systems by the general public: people can routinely produce, configure, teach and engage such systems for different purposes and domains. They may include intelligent assistants that manage an individual's everyday activities, finances and health, but also AI systems that design interiors, gardens and clothing, maintain buildings, appliances and vehicles, and interact with other people and their AIs.

We advocate the creation of AI guidelines, and believe that a lack of standards in conveying trust will be a drag on AI's adoption in business and personal applications. In our view, industry and government should jointly engage consumers in building guidelines that companies can use to signal their compliance with reasonable and customary behavior. Just as investors can receive financial news presented in a Safe Harbor[30] provision or its equivalent, those companies seeking to employ AI should be able to describe its process and purpose in a recognized format.

Phase 4: Foundationalization

As computing has become invisible and the web has emerged as our primary means of interaction, the amount of data and the complexity of our digital lives and business interactions are exceeding our ability to make sense of it in an economical and timely way. AI can and, we believe, will fill this gap by bringing the interpretation and experience layer to the foundational status of computing and the web. This means that AI will be routinely running or augmenting business operations and optimizing government policies, transportation, agriculture and healthcare. This does not mean that human decision-making will be replaced by machines — it means that human decision-making is augmented and empowered by machines.

More specifically, AI will not be limited to prediction, but will include prescription of what decisions need to be made to achieve given objectives.[31]

Foundationalization is important — and implies a deep integration into daily business and personal life. For example, early mobile users were pleased simply to discover facts about where they were; modern users expect their smartphone to tell them how to drive there based on current traffic, and what to eat on the way.

Similarly, AI will begin prescribing courses of action to achieve a given outcome, by combining historical examples, cognitive reasoning, and real-time and near-real-time assessment of the current environment. For instance, we may decide to maximize productivity and growth, but at the same time to minimize cost and environmental impact, and promote equal access and diversity. AI can then be directed to discover ways in which those conflicting objectives can be simultaneously maximized and attained.

As an important part of the prescription process, the identification of a desired outcome and the weight placed on different components (price vs. quality, for example) should be made directly by business and society leaders. AI can then bring its computing and understanding power to the solution in a way that would be impossible or not cost-effective to do without AI. AI broadens our ability to solve problems and make recommendations with complex multiple objectives — that is, to work in the real world.

Historically, decision-making is often obscured by special interests, historical inertia and personal agendas, and consequently it has been difficult to prevent conflicts and promote opportunity despite best efforts. In contrast, AI in this fourth phase — when transparency and trust are standardized — can provide the tools to identify such factors and allow an open debate on the kind of society we want.

Technology phases for AI

	PHASE 1: Standardization	PHASE 2: Usability	PHASE 3: Consumerization	PHASE 4: Foundationalization
Best action to encourage growth in each phase	Definition of standards for interoperability	Establish open and competitive markets	Watch and learn to ensure regulation is supportive of consumer adoption	Establish human-centered objectives to ensure positive social and business impact
AI	Standards for interoperability	Interfaces for non-programmers	Training and deployment by consumers	Intelligence-based economy

Source: Cognizant
Figure 4

> We may decide to maximize productivity and growth, but at the same time to minimize cost and environmental impact, and promote equal access and diversity. AI can then be directed to discover ways in which those conflicting objectives can be simultaneously maximized and attained.

Quick Take

Looking Ahead: Potential Challenges to AI

AI is the technology that can make a better future possible. A common misconception is that AI is something uncontrollable that leads to disasters or human beings being subjugated by intelligent machines. This misconception is based on several factors — a steady stream of Hollywood style plot extensions, a recognition that much new technology we personally encounter comes with its hiccups, and the well-meaning and justifiable concern from industry thought leaders that AI — if badly handled — can do awful things before we stop it, similar to the way automated stock trading leads to flash crashes[32] that can take place too quickly for humans to intervene.

AI can and will be designed and constrained to deal with these concerns, and must take its place as a vital technology that will be part of the foundation of modern life. Specifically:

- **AI can and should be required to "explain itself"[33] in ways that comply with current legislation.** For example, in the U.S., the 50-year-old Fair Credit Report Act (FCRA) of 1970 still has relevance for AI-driven credit decisions. The act requires that any loan rejection includes a rationale. Thus, credit issuers are required to use only AI or data science techniques that have a clear path to explanation and stand up to regulatory supervision.
- **AI can and should be used as an augmentation and aid to human decisioning, and not be allowed to directly interfere in less frequent high-value decisions.** Thus, AI should complement a doctor's diagnosis, not replace it; AI should gather research for a community investment decision, not undertake the investment directly. The exceptions would be cases where AI's objectives are vetted and governed by humans but require faster response time than humans can handle. In cases like this, AI controls the brake pedals as a last resort during an emergency.

Quick Take

AI's Coming Success

Given the progression described herein, we believe:

- **AI is something that can and will be developed by humans in service of humans.** AI will eventually become powerful enough to power much of the society's infrastructure, but it will only get there through the phases outlined above.
- **No winning idea came to fruition instantly and completely without social and business support.** AI will be no different. The breakthroughs that came with personal and distributed computing and the web share common attributes, and AI is following the same path. We recommend an embrace of AI in our personal and business decisions, recognizing that only AI can bring the computing power and insight needed to the nearly limitless opportunities available. More specifically, we suggest:
  - **Encourage and embrace both voluntary and regulatory guidelines to ensure that AI is explainable**, constrained in its ability to harm and turned to those opportunities that will enhance our quality of human life.
  - **Build plans with the lessons of history as a guide.** Don't give up prematurely, and don't miss the moment when emerging technologies like AI shift into a different phase. Work tirelessly to engage stakeholders who are both funding and interacting with new technology like AI so they understand its purposes and benefits.
  - **AI's benefits are coming** — and like other breakthroughs before it, will move through phases to become a foundation of society and business.

Endnotes

1 Joe McKendrick, "Now, AI Makes Online Courses Even Smarter," *Forbes*, Dec. 4, 2018, www.forbes.com/sites/joemckendrick/2018/12/04/now-ai-makes-online-courses-even-smarter/#305833eb10b1.

2 Mike Miliard, "As AI, virtual care reshape the healthcare workforce, remember the difference between 'tasks and jobs,'" *HealthcareITNews*, July 10, 2019, www.healthcareitnews.com/news/ai-virtual-care-reshape-healthcare-workforce-remember-difference-between-tasks-and-jobs.

3 "How Employers Are Using AI to Stop Bias in Hiring," *HR Technologist*, Feb. 4, 2019, www.hrtechnologist.com/articles/digital-transformation/how-employers-are-using-ai-to-stop-bias-in-hiring/.

4 For simplicity, the combination of TCP/IP as an internet network protocol and the World-Wide Web's uses of HTML are combined here and simplified as WWW or simply the web. We recognize that these are distinct technologies, and that many applications benefit from TCP/IP without using HTML.

5 Clarke, A. C., *Profiles of the Future* (revised edition, 1973).

6 For a good summary of this era, consider Ceruzzi, P. E. (2003). *A History of Modern Computing*. Cambridge, MA: MIT Press. and Freiberger, P., and Swaine, M. (2000). *Fire in the Valley: The Making of the Personal Computer*. New York: McGraw-Hill.

7 www.retrocomputing.net/info/siti/total_share.html.

8 "45 years ago: First message sent over the Internet," CBS News, Oct. 29, 2014, www.cbsnews.com/news/first-message-sent-over-the-internet-45-years-ago/.

9 "Number of connected devices reached 22 billion, where is the revenue?" HelpNetSecurity, May 23, 2019, www.helpnetsecurity.com/2019/05/23/connected-devices-growth/.

10 https://en.wikipedia.org/wiki/Techne.

11 www.computerhistory.org/siliconengine/first-commercial-mos-ic-introduced/.

12 https://en.wikipedia.org/wiki/Intel_4004; the Intel 4004 changed the commercial model for embedded electronics by allowing product engineers to focus more on logic and features and less on hardware, setting Intel on the path to multidecade dominance in the chip computing market.

13 Berners-Lee, T., and Connolly, D. (1993). Hypertext markup language (html): A representation of textual information and metainformation for retrieval and interchange. ww.w3.org/MarkUp/draft-ietf-iiir-html-01.txt.

14 https://en.wikipedia.org/wiki/Usenet. Just before the advent of the WWW, FidoNet, a bulletin board system, reached a peak of 40,000 nodes in 1994.

15 Lie, H. W., and Bos, B. (1999). *Cascading Style Sheets, designing for the Web*. New York: Addison-Wesley.

16 www.businessinsider.com/10-first-to-market-companies-that-lost-out-to-latecomers-2009-11#atari-8. These examples are not exhaustive but provide some guidance for both pioneers seeking to maintain an advantage and newcomers seeking to break into a nascent market.

[17] www.statista.com/statistics/276623/number-of-apps-available-in-leading-app-stores/.

[18] www.statista.com/statistics/610271/worldwide-personal-computers-installed-base/.

[19] https://newzoo.com/insights/trend-reports/newzoo-global-mobile-market-report-2018-light-version/.

[20] O'Reilly, T. (2005). "What is Web 2.0." O'Reilly Network; Retrieved 3/17/2019 at www.oreilly.com/pub/a/web2/archive/what-is-web-20.html.

[21] www.gartner.com/en/newsroom/press-releases/2019-04-02-gartner-forecasts-worldwide-public-cloud-revenue-to-g.

[22] A news search on outage and outrage brings up many examples, such as this article: www.techtimes.com/articles/235652/20181120/facebook-instagram-are-down-and-the-internet-goes-crazy.htm.

[23] www.aihc-assn.org/Blog/tabid/1676/ArticleID/379/Internet-Addiction-A-Digital-Problem-in-the-Real-World.aspx. ICD-10 codes do not specifically recognize internet addictions, but the foundation for addictive behavior descriptions is present in existing classification schemes.

[24] https://en.wikipedia.org/wiki/Xerox_Alto.

[25] www.boutell.com/newfaq/history/fbrowser.html.

[26] https://thehistoryoftheweb.com/browser-wars.

[27] https://searchenterpriseai.techtarget.com/definition/Turing-test.

[28] https://plato.stanford.edu/entries/artificial-intelligence/.

[29] AI: Ready for Business, Cognizant, July 2018, www.cognizant.com/whitepapers/ai-ready-for-business-codex3752.pdf.

[30] https://en.wikipedia.org/wiki/Safe_harbor_(law).

[31] Miikkulainen, R. (2019). "Creative AI through evolutionary computation." *CoRR*, abs/1901.03775.

[32] www.investopedia.com/articles/markets/012716/four-big-risks-algorithmic-highfrequency-trading.asp.

[33] www.darpa.mil/program/explainable-artificial-intelligence.

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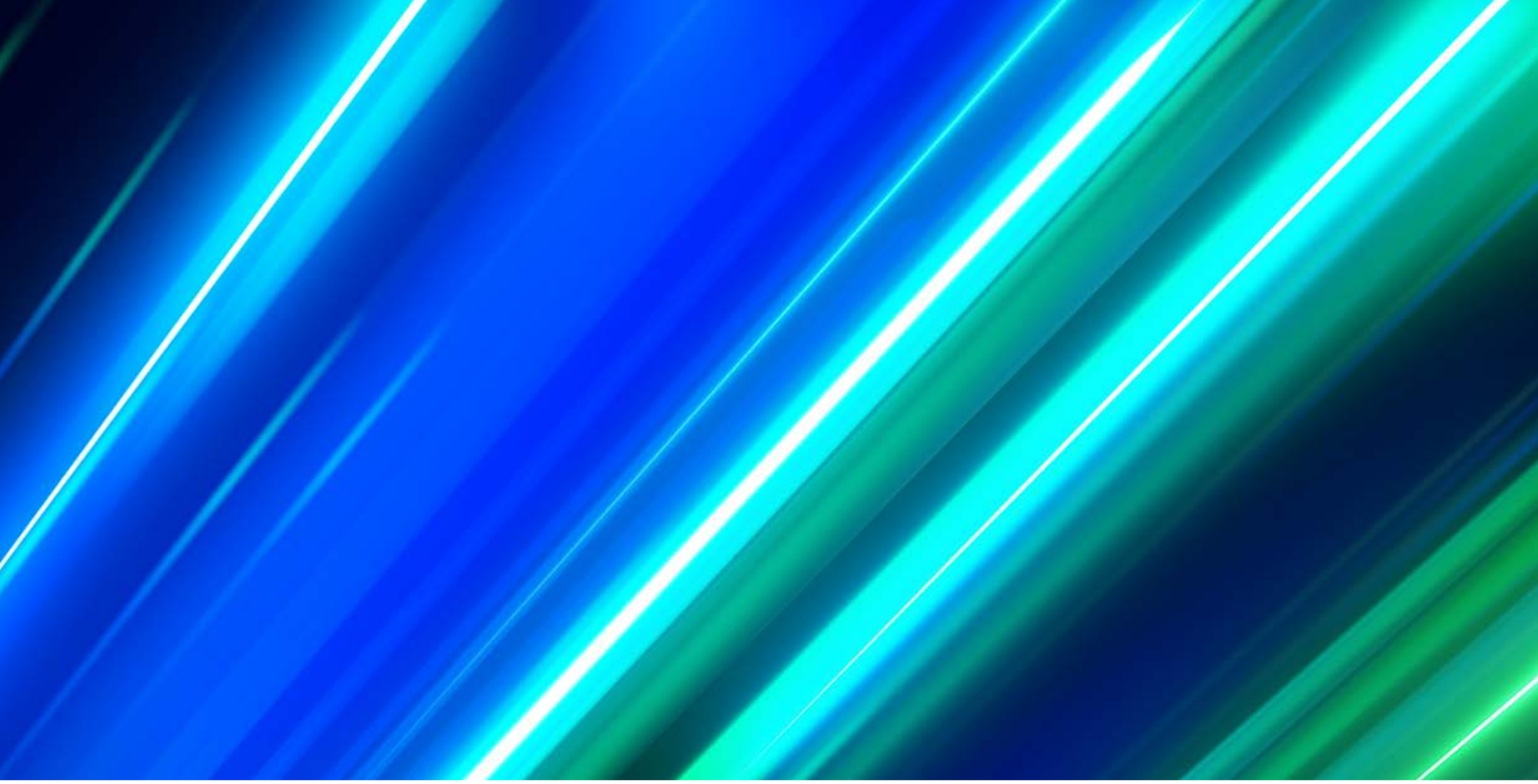
Risto Miikkulainen is Associate VP of Evolutionary AI at Cognizant and a Professor of Computer Science at the University of Texas at Austin. His current research focuses on methods and applications of neuroevolution, as well as neural network models of natural language processing and vision. At Cognizant, Risto is scaling up these approaches to real-world problems. Prior to that, he was the CTO of Sentient Technologies. Risto received an MS degree in engineering from the Helsinki University of Technology (now Aalto University) and a doctorate in computer science from UCLA. He has authored over 400 articles in these research areas. Risto is an IEEE Fellow and was honored with the 2020 IEEE CIS Evolutionary Computation Pioneer Award. His work on neuroevolution has recently been recognized with the Gabor Award of the International Neural Network Society and Outstanding Paper of the Decade Award of the International Society for Artificial Life. Risto can be reached at risto@cognizant.com | www.linkedin.com/in/risto-miikkulainen-ab43b9b8.

Bret Greenstein

Global Senior Vice President & Head of Digital Business AI Practice, Cognizant

Bret Greenstein is Global Senior Vice President and Head of Cognizant's Digital Business AI Practice, focusing on technology and business strategy, go-to-market and innovation, helping clients realize their potential through digital transformation. Prior to Cognizant, Bret led IBM Watson's Internet of Things offerings, establishing new IoT products and services for the industrial Internet of Things (IIoT). He built his career in technology and business leadership across a range of roles throughout IBM, in software, services, consulting, strategy and marketing, and served as IBM's CIO for the Asia-Pacific region. Bret has worked globally in these roles, including living in China for five years, working with clients and transforming IBM's IT environment. Bret holds patents in the area of collaboration systems. He holds a bachelor's degree in electrical engineering and a master's degree in manufacturing systems engineering from Rensselaer Polytechnic Institute. He can be reached at Bret.Greenstein@cognizant.com | www.linkedin.com/in/bretgreenstein/.



About Cognizant Artificial Intelligence Practice

As part of Cognizant Digital Business, Cognizant's Artificial Intelligence Practice provides advanced data collection and management expertise, as well as artificial intelligence and analytics capabilities that help clients create highly-personalized digital experiences, products and services at every touchpoint of the customer journey. Our AI solutions glean insights from data to inform decision-making, improve operations efficiencies and reduce costs. We apply Evolutionary AI, Conversational AI and decision support solutions built on evolutionary computation, deep learning and advanced analytics techniques to help our clients optimize their business/IT strategy, identify new growth areas and outperform the competition. To learn more, visit us at ai.cognizant.com.

About Cognizant Digital Business

Cognizant Digital Business helps our clients imagine and build the Digital Economy. We do this by bringing together human insight, digital strategy, industry knowledge, design, and new technologies to create new experiences and launch new business models. For more information, please visit www.cognizant.com/cognizant-digital-business or join the conversation on LinkedIn.

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Cognizant (Nasdaq-100: CTSH) is one of the world's leading professional services companies, transforming clients' business, operating and technology models for the digital era. Our unique industry-based, consultative approach helps clients envision, build and run more innovative and efficient businesses. Headquartered in the U.S., Cognizant is ranked 193 on the Fortune 500 and is consistently listed among the most admired companies in the world. Learn how Cognizant helps clients lead with digital at www.cognizant.com or follow us @Cognizant.

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