Technology Predictions: Art, Science, and Fashion

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Making accurate predictions isn't easy. However, many people have enjoyed making predictions throughout history, and even more individuals have taken part in learning about predictions.

Predicting the future is never easy; it always entails a degree of uncertainty, if not luck. Predicting technology trends is even harder, as it requires both technical and business acumen, that is, whether the technology will be developed, productised, and ultimately adopted on the market. It is almost an art to distill between a fashion and a true technology trend. At the same time, the public likes to read predictions, and many individuals and organizations regularly write technology predictions, such as Gartner,[1] the Massachusetts Institute of Technology,[2] Forbes,[3] and many others.[4–6]

The IEEE Computer Society (IEEE CS) started its technology predictions informally in early 2010 and formally via annual press releases in 2014, followed by their respective scorecards in 2016.[7] We realized that our audience appreciates self-evaluation; hence, we introduced scorecards at the end of the period of prediction. Our predictions reached a substantial audience; for example, in 2018, our predictions were picked up by 300 media outlets

(with a combined audience of 84.6 million people), which is entirely different from classical publishing. We considered predictions as a new type of publication, a lightweight, short publication (approximately a paragraph per prediction). These predictions also triggered other media outreach, such as blogs,[8] interviews,[9] panel sessions,[10] and this special issue of *Computer* magazine.

Over the years, we became better at using press releases and social media to announce our report to the extent that it became visible at the IEEE Board of Directors and found its way to the report of the IEEE executive director. One notable side product that grew out of our predictions was the 2022 report[11,12] that comprehensively predicted 23 technologies seven years ahead. This report had a sister study,[13] written by the Industrial Technology Research Institute, Taiwan, on technology predictions specific to Asia. These technology predictions surpassed all our expectations in terms of impact, and we plan to continue for as long as an audience has interest.

HISTORY

We started predicting technology trends in 2010 as part of the IEEE CS Industry Advisory Board (IAB) meetings, where industry experiences were informally collected to help align the editorial calendar of *Computer* with relevant industry trends. Since then, the process has become more formal, with IAB members ranking feedback and casting their votes to create an approximate list of the top 10 technologies predicted for the coming years. The first such prediction was published on the IEEE CS Press Room webpage in 2013 for 2014,[14] and in 2016,[15] we created the first scorecard. These scorecards are published annually in November, and predictions for the following year are published in December.[16] See Table 1 for the 2019 scorecard. This November, we will be working on our predictions for 2020, to be published in December. We do this close to the publishing date to be able to allow as much time for technology adoption.

Over time, we expanded the team and separated it from its IAB origins. The team has grown from four to five at its inception to 11 members today. The process consists of each member proposing one or more technology predictions for the following year by writing a paragraph-long description, followed by online voting. Voting is used primarily to separate clear outliers (rejects and top candidates) and then, through discussion, the final selection is decided on. The profile of the typical team member is deeply technical, with an understanding of business and spanning multiple broad technology areas. This is generally called *T-shaped*, deep in one area and broad across multiple areas, and some are even π-shaped people, those deep in two areas and broad across multiple others. The team environment fostered a productive and efficient discussion and relatively quick selection of the list. Voting was never considered the final outcome but only a facilitator for easier selection. Nothing would replace discussion as the final decision-making tool. This December, we will reveal our technology predictions that we anticipate for the year 2020.

IMPACT

The primary goal of the predictions is to reach a wide audience, well beyond publications such as *Computer* or even *IEEE Spectrum*. For example, the 2018 Tech Trends press release was picked up by 294 media outlets with an audience of 84.6 million people, the highest ever for an IEEE CS news release. The press release was also highly promoted via social media and achieved top placement on Twitter, with more than 10,000 views and hundreds of retweets. An extensive reach also meant lighter and shorter content. We did not explore deep technical details, and the length of every prediction was roughly one paragraph.

It has been reported that the predictions were used by several universities to formulate their research program around certain subjects. The IEEE CS 2022 Report (published in 2015)[11,12] also had its impact on the IEEE CS and was used as a technical underpinning for two strategic plans; two student competitions; and many distinguished lectures given in different regions. Our predictions undoubtedly helped the visibility of the IEEE CS within the IEEE and in general. Since beginning our top 10 list of predictions, others have making annual predictions.

LESSONS LEARNED

Nothing can replace good judgment and human conversation. Although we ranked, voted, and narrowed down the choices, only through discussion by experts were we able to come up with quality predictions.

Consistency in annual predictions is critical for developing an audience that expects predictions. As mentioned previously, we wrote our November scorecard for predictions in October and published it in November. Being early with predictions and publishing them in December (rather than January) also helped increase visibility.

TABLE 1. The 2019 technology trends scorecard.

2019: B (in November 2019)	2018: B	2017: A−	2016: B+
Deep-learning accelerators: A	Deep learning: A−	Industrial Internet of Things: B+	5G: B
Assisted transportation: A/B	Digital currencies: C−	Self-driving cars: B−	Augmented reality and virtual reality: B+
The Internet of Bodies: B/C	Blockchain: A	AI, machine learning, and cognitive computing: A+	Nonvolatile memory: B−
Social credit algorithms: B-	Industrial Internet of Things: A+	5G: B	Cyberphysical systems: B+
Advanced (smart) materials and devices: B/C	Robotics: B+	Accelerators: A	Data science: A
Active security protection: B-	Assisted transportation: A−	Disaggregated memory/fabric-attached nonvolatile memory: C+	Capability-based security: C
Augmented reality and virtual reality: B+	Augmented reality and virtual reality: B−	Sensors everywhere and edge computing: A−	Advanced machine learning: A
Chatbots: B	Ethics, laws, and policies for privacy, security, and liability: C+	Blockchain (beyond Bitcoin): A	Network function virtualization: B
Automated voice spam (robocall) prevention: C	Accelerators and 3D: A	Hyperconverged systems: B	Containers: A
Technology for humanity (specifically machine learning): B/C	Cybersecurity and AI: C	—	—

Continuous innovation and experimentation helped us to always be aware of current social media interests and attract broader audiences. Every year we introduced something new, be it a new approach, a new product, or a fresh perspective. Although we could always use more analysis and publish our predictions sooner, only lengthy reports, for example, the 2022 Report, warrant deeper analysis.

While content quality is absolutely required, an important component of content promotion is quality social media management. The careful, planned release of predictions via the IEEE CS's social media platforms maximized our exposure and helped us ascend to the top of both Google's and Bing's search listings. Argument persuasiveness is critical, and several of the predicted technologies actually fared better (or worse) than we argued; however, we just didn't make a good enough case to justify our ranking.

CHALLENGES TO PREDICTIONS

The team observed various challenges to our predictions, and we are providing the following rationale behind our extensive analysis:

❯ We want to maintain a high standard of predictions; however, occasionally, we made risky bets.
❯ We are cognizant of the difference between near- versus long-term horizons. Many times, one year is too brief for a certain technology to be adopted. As of late, we have also begun to list a few technologies that we feel could be adopted in the near future, but more than one year out.
❯ Separating fashion from economically backed technologies (that is, separating fluff from substance) is never easy. Marketing is tempting, but, thus far, we have resisted. This challenge is also about balancing what everyone else thinks will happen (and, therefore, is somewhat uninteresting to readers) with bold, surprising predictions, which may have a lower probability of success. Note that this challenge dovetails with the first challenge on this list. Going forward, we may include indications of "likelihood,"

"confidence," or "risk/reward balance," so that people who are looking for thought-provoking, unconventional ideas can find what they are looking for, and people looking for sound, policy making predictions can find something else.

❯ Heterogeneity in opinions makes the overall predictions better or at least more interesting (that is, akin to a diversified portfolio of perspectives). Previously, there were predictions that a few of us would not endorse (either because of a lack of expertise or faith in the technology); however, they were received from another team member. This helps us "cover more bases." It is therefore vital that we continue to strive to diversify the team, both in terms of expertise and demographics.

❯ "Beauty is in the eye of the beholder." Some technologies, for example, digital twins, were continually brought up but did not make it into the rankings until recently because not everyone was as passionate about it.

TECHNOLOGY TRENDS SCORECARD

In November 2016, the IEEE CS released its first scorecard, grading its 2016 predictions (which were published in December 2015) with the score based on the advancements of each trend and analysis forward. The score was a B+. Every year thereafter, we have continued the process of grading the predictions and publishing the scorecards, which have become nearly as popular as the predictions.

The following authors contributed to technology predictions and scorecards in recent years:

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❯ Mary Baker, Hewlett Packard (2019)
❯ Tom Coughlin, Coughlin Associates (2020)
❯ Erik DeBenedictis, colead, Quantum Initiative (2019)
❯ Zoran Dimitrijevic, principal engineer, Airbnb Lab (2019)
❯ Fred Douglis, chief scientist, Perspecta Labs (2019)
❯ Paolo Faraboschi, Hewlett Packard enterprise fellow (2017–2020)

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› Danny Lange, Unity (2020)
› Phil Laplante, Penn State University (2014–2020)
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› Avi Mendelson, professor, Technion (2019–2020)
› Cecilia Metra, professor, University of Bologna (2019)
› Dejan Milojicic, Hewlett Packard enterprise distinguished technologist (2014) and 2014 IEEE CS president (2011–2020)
› Roberto Saracco, chair of the Symbiotic Autonomous Systems Initiative of the IEEE-Future Directions Committee (2019–2020).

Predicting is never easy, but it is a very popular and natural activity. At the IEEE CS, a team of volunteers and staff have made predictions since 2010. These predictions were largely published using social media. But lately, we have begun using traditional media, such as this issue of *Computer*, panels at conferences, and technical reports. These overall predictions served their purpose of provoking thought about the future and achieved substantial visibility, as evidenced by how often they were picked up by the press. C

REFERENCES

1. D. Cearley and B. Burke, "Top 10 strategic technology trends for 2019," *Gartner*, 2019. [Online]. Available: https://www.gartner.com/en/doc/3891569-top-10-strategic-technology-trends-for-2019

2. "Ten breakthrough technologies," *MIT Technology Review*, 2019. [Online]. Available: https://www.technologyreview.com/lists/technologies/2019/

3. D. Blomstrom, "10 tech and industry 2019 predictions that you will read everywhere," *Forbes*, 2018. [Online]. Available: https://www.forbes.com/sites/duenablomstrom1/2018/12/17/10-tech-and-industry-2019-predictions-that-you-will-read-everywhere/#428f4c6a1996

4. J. Burt, P. Heltzel, N. Henderson, and K. D. Schwartz, "10 future technology predictions to watch in 2019," *ITPro Today*, 2018. [Online]. Available: https://www.itprotoday.com/data-security-and-encryption/10-future-technology-predictions-watch-2019

5. C. DesMarais, "31 tech predictions for 2019," *Inc.com*. Accessed on: June 2019. [Online]. Available: https://www.inc.com/christina-desmarais/31-tech-predictions-for-2019.html

6. T. Briseno, "10 futurist predictions in the world of technology," *HowStuffWorks*, 2012. [Online]. Available: https://electronics.howstuffworks.com/future-tech/10-futurist-predictions-in-the-world-of-technology.htm

7. IEEE Computer Society, "IEEE Computer Society Press Room." Accessed on: June 2019. [Online]. Available: https://www.computer.org/press-room

8. N. T. Bajju, "Interview with Dejan S. Milojicic on top technology trends and predictions for 2019," *Big Data Blog*, 2019. [Online]. Available: https://bigdata-madesimple.com/interview-with-dejan-s-milojicic-on-top-technology-trends-and-predictions-for-2019/

9. M. Martinez, "China Global Television Network interviews IEEE Computer Society leader about our top 10 tech trends for 2019," Jan. 14, 2019. [Online]. Available: https://publications.computer.org/computer-magazine/2019/01/14/computer-society-2019-top-10-tech-trends-cgtn-interview/

10. "2020 Tech Predictions: A preview of the end of the year Computer Society report," July 12, 2019. [Online]. Available: https://conferences.computer.org/services/2019/plenary/2020-Tech-Predictions.html

11. H. Alkhatib et al., "2022 report," IEEE Computer Society Document, IEEE Computer Society Board, Washington, D.C., Feb. 2014.

12. H. Alkhatib et al., "What will 2022 look like? The IEEE CS 2022 report," *Computer*, vol. 48, no. 3, pp. 68–76, 2015.

13. "2030 Advanced technology from an Asian perspective," *ITRI*. Accessed on: June 2019. [Online]. Available: https://www.computer.org/publications/tech-news/trends/2030-asia-advanced-technology-itri

14. IEEE Computer Society, "Top technology trends for 2014." Accessed on: June 30, 2016. [Online]. Available: https://www.computer.org/publications/tech-news/trends/2014-top-10-tech-trends

15. IEEE Computer Society, "IEEE Computer Society grades its 2016 technology predictions: Gets a B+: Capability-based security lags behind 2016 predictions." Accessed on: June 30, 2016. [Online]. Available: https://www.computer.org/press-room/2016-news/2016-tech-grades

16. IEEE Computer Society, "Computer Society Press Room." Accessed on: June 30, 2016. [Online]. Available: https://www.computer.org/press-room