the institute

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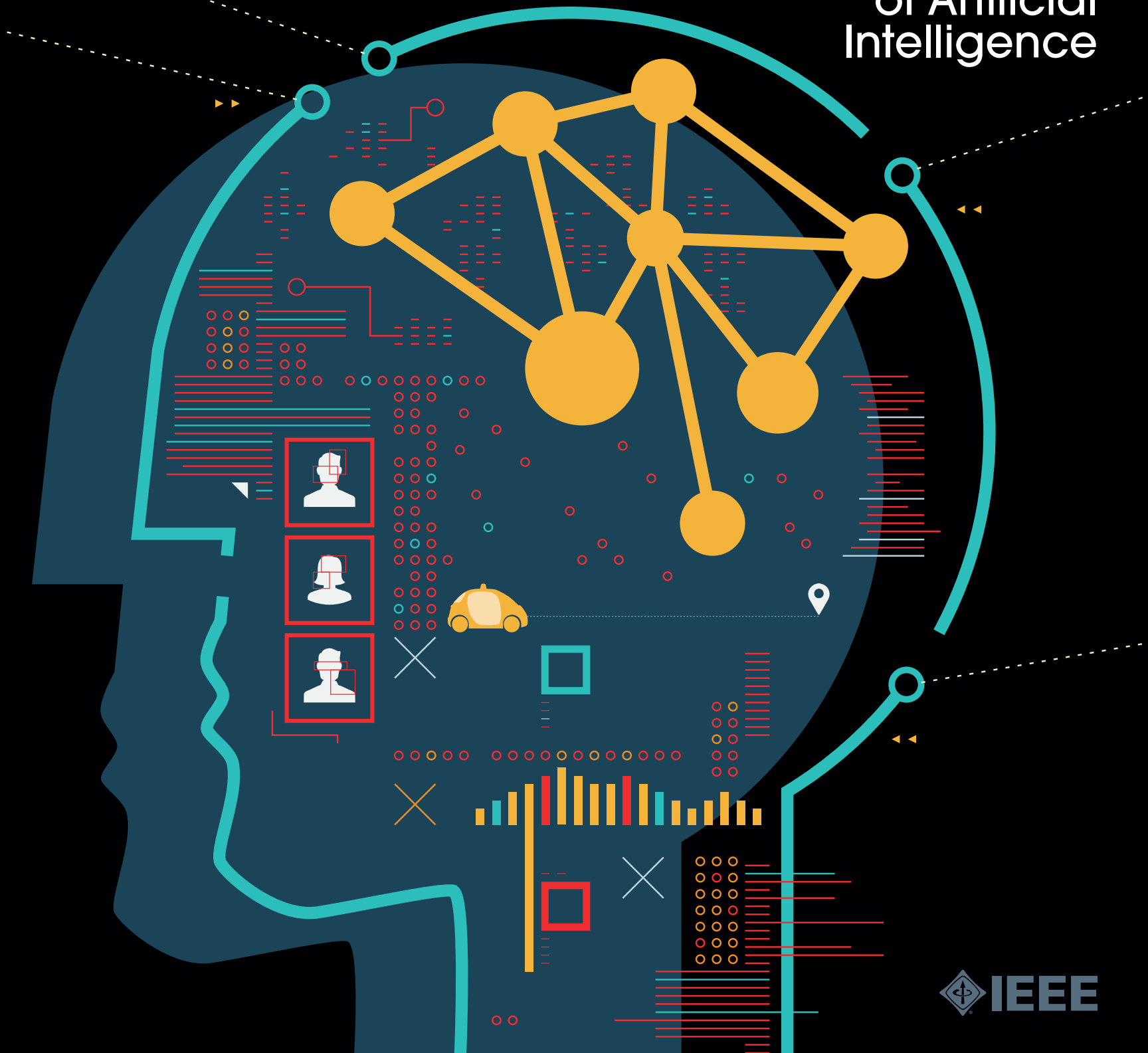
SPECIAL REPORT

The Promise of Artificial Intelligence



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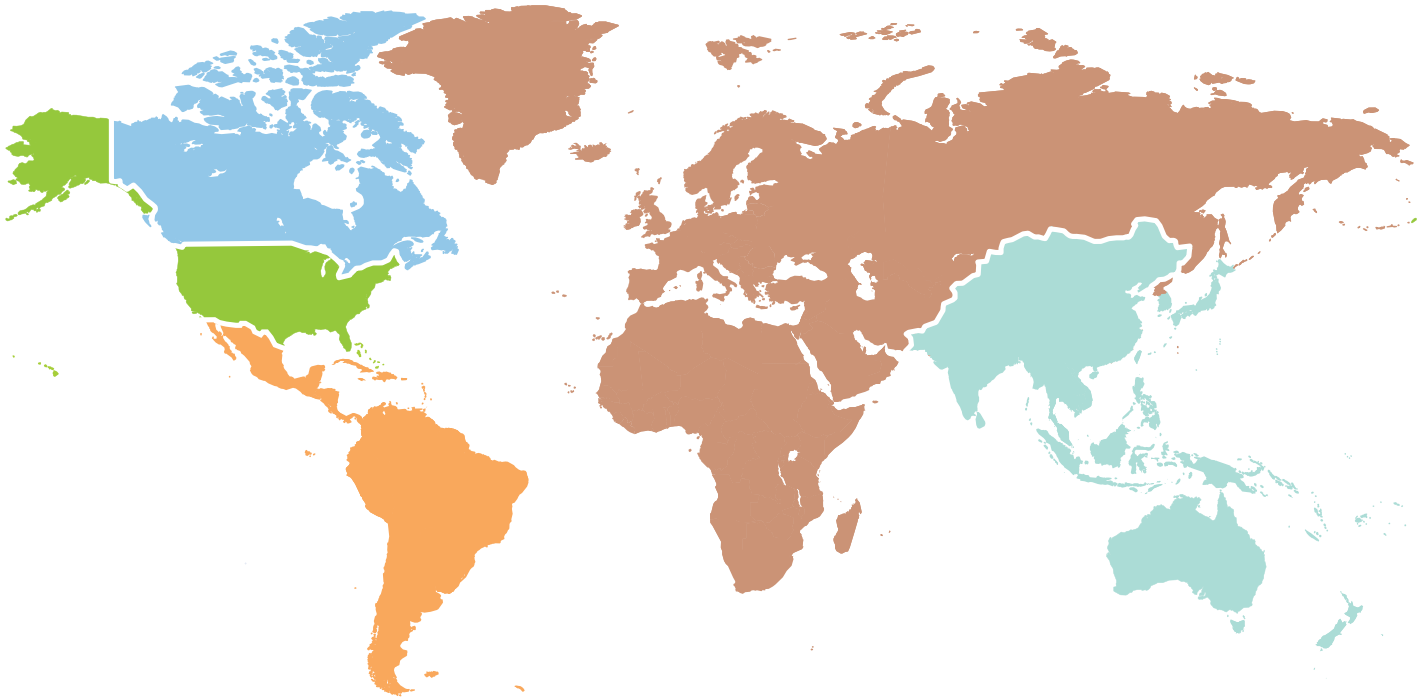

REGION NEWS

REGION 1

NORTHEASTERN UNITED STATES

■ **Connecticut Section** forms IEEE Women in Engineering (WIE) affinity group.

REGION 2

EASTERN UNITED STATES

■ Student branch at **Rowan University, Glassboro, N.J.,** forms IEEE WIE affinity group.

■ Student branch at the **University of Akron, Ohio,** forms IEEE Industry Applications Society chapter.

REGION 3

SOUTHEASTERN UNITED STATES

■ **Miami Section** forms IEEE WIE affinity group.

■ **Richmond (Va.) Section** forms joint chapter of IEEE Engineering in Medicine and Biology and IEEE Magnetics societies.

REGION 4

CENTRAL UNITED STATES

■ Student branch at **Concordia University Chicago, River Forest, Ill.,** forms IEEE WIE affinity group.

REGION 6

WESTERN UNITED STATES

■ **San Diego Section** forms IEEE Young Professionals (YP) affinity group.

■ An IEEE-Eta Kappa Nu (HKN) chapter is installed at **Western Washington University, Bellingham.**

■ An IEEE-HKN chapter is installed at **Eastern Washington University, Cheney.**

REGION 7

CANADA

■ **Montreal Section** forms chapters of IEEE Antennas and Propagation and IEEE Photonics societies.

■ **New Brunswick Section** forms joint chapter of IEEE Engineering in Medicine and Biology and IEEE Signal Processing societies.

REGION 8

EUROPE, MIDDLE EAST, AND AFRICA

■ Student branch formed at **Benha University, Egypt**.

■ Student branch at **Tallinn University of Technology, Estonia,** forms IEEE WIE affinity group.

■ **Finland Section** forms IEEE Computer Society chapter.

■ Student branch formed at **Technical University of Berlin.**

■ Student branch at **Yarmouk University, Irbid, Jordan,** forms IEEE Computer Society chapter.

■ Student branch formed at **Arts, Sciences, and Technology University, Beirut.**

■ **Lithuania Section** forms IEEE Computer Society chapter.

■ **Oman Section** forms IEEE Power & Energy Society chapter.

■ **Poland Section** forms IEEE Systems, Man, and Cybernetics Society chapter.

■ **Qatar Section** forms IEEE WIE affinity group.

■ **Western Saudi Arabia Section** forms IEEE Electron Devices Society chapter.

■ Student branches formed in **Saudi Arabia** at **Alfaisal University, Riyadh,** and **Effat University, Jeddah.**

■ Student branch formed at **Université Gaston Berger, Saint-Louis, Senegal.**

■ **South Africa Section** forms IEEE Engineering in Medicine and Biology Society chapter.

■ Student branches formed in **Turkey** at **Balikesir** and **Izmir** universities.

■ Student branch at **Bogaziçi University, Istanbul,** forms IEEE WIE affinity group.

■ Student branch at **American University of Sharjah, United Arab Emirates,** forms IEEE Solid-State Circuits Society chapter.

■ **United Kingdom and Ireland Section** forms IEEE Systems, Man, and Cybernetics Society chapter.

REGION 9

LATIN AMERICA

■ Student branch at **Universidad Privada Boliviana, Cochabamba, Bolivia,** forms chapters of IEEE Computer and IEEE Robotics and Automation societies.

■ Student branch at **Universidade Federal de Juiz de Fora, Brazil,** forms IEEE Circuits and Systems Society chapter.

■ Student branch at **Universidade Federal do Vale do São Francisco, Petrolina, Brazil,** forms IEEE WIE affinity group.

■ **Chile Section** forms joint chapter of IEEE Circuits and Systems and IEEE Solid-State Circuits societies.

■ Student branch formed at **Universidad de Córdoba, Colombia.**

■ **Ecuador Section** forms joint chapter of IEEE Control Systems and IEEE Industrial Electronics societies.

■ Student branch at **Universidad Nacional Autónoma de Honduras, Tegucigalpa,** forms joint chapter of IEEE Communications and IEEE Computer societies.

■ Student branches formed in **Mexico** at **Universidad Tecnológica de Campeche** and **Universidad de Quintana Roo, Chetumal.**

■ Student branch at **Benemérita Universidad Autónoma de Puebla, Mexico,** forms IEEE WIE affinity group.

■ Student branch at **Pontifical Catholic University of Peru, Lima,** forms IEEE Consumer Electronics Society chapter.

■ **Puerto Rico and Caribbean Section** forms IEEE Power & Energy Society chapter.

REGION 10

ASIA AND PACIFIC

■ **New South Wales (Australia) Section** forms IEEE Electromagnetic Compatibility Society chapter.

■ Student branches in **Bangladesh** at **Rajshahi University of Engineering and Technology** and **United International University, Dhaka,** form IEEE WIE affinity groups.

■ **Beijing Section** forms joint chapter of IEEE Communications and IEEE Signal Processing societies.

■ **Harbin (China) Section** forms IEEE Geoscience and Remote Sensing Society chapter.

COVER: ERIC FROMMELT; THIS PAGE: ISTOCKPHOTO

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■ Student branch at **South China University of Technology, Guangzhou,** forms IEEE Instrumentation and Measurement Society chapter.

■ Student branch at **Xi'an Jiaotong University, China,** forms IEEE Ultrasonics, Ferroelectrics, and Frequency Control Society chapter.

■ Student branches formed in **India** at **Aditya Institute of Technology and Management, Aryanet Institute of Technology, CMR College of Engineering and Technology, Heera College of Engineering and Technology, KPR Institute of Engineering and Technology, Malla Reddy Engineering College, Marian Engineering College, Sahyadri Valley College of Engineering and Technology,** and **Vishwakarma Government Engineering College.**

■ Student branch at **Christ University, Bangalore, India,** forms IEEE Antennas and Propagation Society chapter.

■ Student branch at **Reva Institute of Technology and Management, Bangalore, India,** forms IEEE Power & Energy Society chapter.

■ Student branch at **Northern India Engineering College, New Delhi,** forms IEEE WIE affinity group.

■ Student branch at **Rajalakshmi Engineering College, Chennai, India,** forms IEEE Engineering in Medicine and Biology Society chapter.

■ Student branch at **Telkom University, Bandung, Indonesia,** forms IEEE Industry Applications Society chapter.

■ **Nagoya (Japan) Section** forms IEEE YP affinity group.

■ Student branch formed at **Universiti Malaysia Perlis, Arau.**

■ **Lahore (Pakistan) Section** forms IEEE Computational Intelligence Society chapter.

■ Student branch at **Bahria University, Islamabad,** forms IEEE Computer Society chapter.

■ **Singapore Section** forms IEEE RFID Council chapter.

■ An IEEE-HKN chapter is installed at the **Singapore University of Technology**.

■ **Thailand Section** forms IEEE Computational Intelligence Society chapter.

■ An IEEE-HKN chapter is installed at **Chulalongkorn University, Bangkok.**

■ **Vietnam Section** forms IEEE WIE affinity group.

SEND US YOUR NEWS

We announce the formation of new groups once they've been approved by IEEE Member and Geographic Activities. To send us news of student branch events and competitions, WIE or preuniversity outreach efforts, or other IEEE group activities, use the form on the Region News page: http://theinstitute.ieee.org/region-news.

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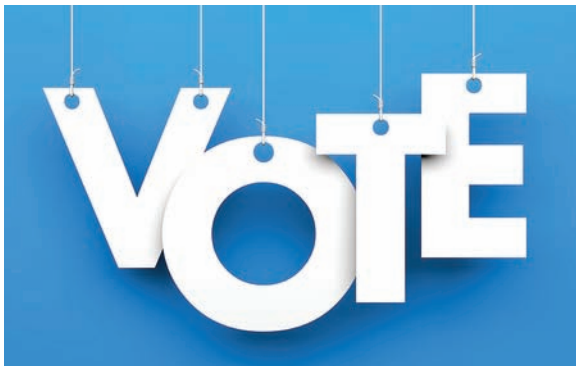
BRIEFINGS



Annual Election Begins in August

LOOK FOR YOUR ANNUAL election ballot package to arrive in August via first-class mail with a postage-paid reply envelope. You'll also receive instructions by email explaining how you may access and return your ballot electronically.

In addition to the election of officers, this year members will be asked to vote on an amendment to the IEEE Constitution. For more information on the amendment, visit http://www.ieee.org/about/corporate/election/2016_constitutional_amendment.html.

Those eligible to vote include new members as of 30 June and students elevated to member or graduate student member grades on or before that date. Associate members are not eligible to vote.

To be eligible to vote, student members graduating this year between 1 January and 30 June must update their education information online to be elevated to member or graduate student member grade.

You must be regularly employed in an IEEE-designated field and have a combination of education and work experience totaling at least six years in order to become an IEEE member. To apply for transfer to member grade, complete the form at http://www.ieee.org/membership_services/membership/grade_elevation.html.

Log in to your IEEE account at https://www.ieee.org/profile by 30 June and confirm or update your contact information, member preferences, and education information. That will help guarantee you receive your ballot package.

ELECTION DEADLINES

15 AUGUST
IEEE annual election ballots are mailed to voting members, and electronic ballots are accessible.

3 OCTOBER
Last day that members' marked ballots can be accepted by IEEE, by noon CDT USA/17:00 UTC.

17 OCTOBER
Election results are announced by the IEEE Tellers Committee.

20–21 NOVEMBER
IEEE Board of Directors acts to accept the report of the Tellers Committee. Election results are made official.

INSIDE

ONLINE

at theinstitute.ieee.org

TECH HISTORY In 1770 an Austrian inventor unveiled a mechanical man that could play chess—or so he claimed. Read about the earliest AI hoax in history.

IN MEMORIAM IEEE mourns the loss of three of its members.

Calendar *of Events*

JUNE

6–7
IEEE Tech Industry Summit in Santa Clara, Calif.

15–20
IEEE Meeting Series in New Brunswick, N.J.

18
IEEE Honors Ceremony in New York City.

18–19
U.S. National Maker Faire in Washington, D.C.

JULY

16
IEEE Milestone dedication ceremony honoring Germany's first radio transmission, broadcast on 22 December 1920. A commemorative plaque will be unveiled at the Wireless Technology Museum in Königs Wusterhausen.

18–21
IEEE International Conference on Cloud and Big Data Computing in Toulouse, France.

AUGUST

15
IEEE annual election ballots are mailed to voting members, and electronic ballots are made accessible.

22–25
IEEE International Conference on Nanotechnology in Sendai, Japan.

SPECIAL REPORT

ARTIFICIAL INTELLIGENCE

POPULARIZED IN science fiction, AI is no longer merely a figment of our imaginations. In the past few years, the technology has moved from research labs into our everyday lives. It's being used in medical devices, smart-home systems, and video games—to say nothing of robots and autonomous cars. And AI has started to do what many people have feared: outsmart humans.

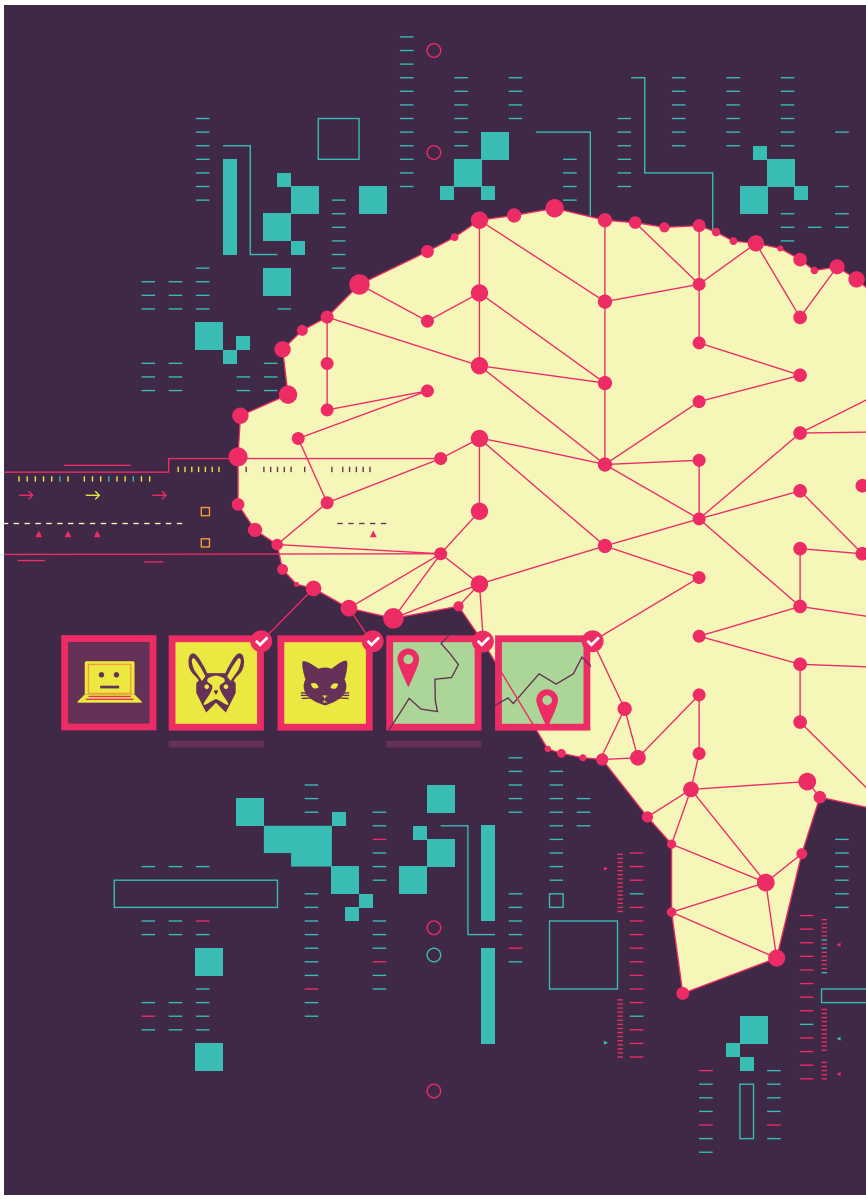
In this special report, *The Institute* describes one of the latest AI developments: deep learning, in which neural networks teach themselves and make decisions on their own. Google, Microsoft, and other tech companies are racing to improve deep learning and apply it to new applications. Noteworthy AI applications already in place include computer systems writing news articles and preventing credit card fraud [p. 6].

Companies can't find enough engineers qualified in machine learning and other AI applications, so we provide tips for breaking into the growing field [p. 8]. And you'll find IEEE products and services [p. 15] as well as conferences and books [p. 16] on AI and related topics.

We profile IEEE Fellow Fatih Porikli about his work in computer vision and deep learning [p. 17]. We also feature an IEEE member who helped found Clearpath Robotics, a leader in self-driving vehicles for warehouses [p. 18]. And don't miss our Q&A with 2017 IEEE president-elect candidates IEEE Life Senior Member Jim Jefferies and IEEE Fellow Wanda Reder [p. 10].

To let us know about your work in AI or to comment on what you've read in this special report, email the editors: institute@ieee.org.

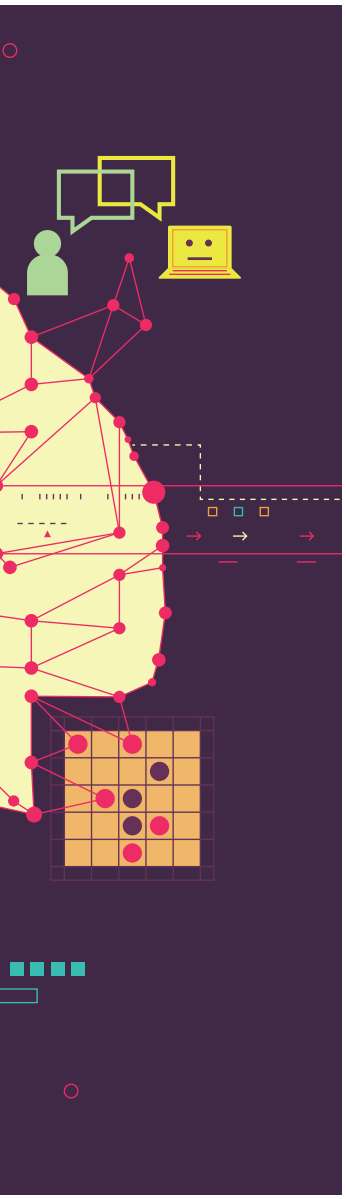
—Monica Rozenfeld, associate editor



ERIC FROMMELT

Mastering Deep Learning

The next step for AI is machines that get smarter on their own BY MONICA ROZENFELD



HAVE YOU EVER USED a voice-activated service such as Apple's Siri only to find it completely missed what you were saying? Or played a game against a computer and felt it didn't even put up a fight? That's about to change with advances in deep learning, which improves computers' ability to process information and make decisions—like people do, and oftentimes even better.

Deep-learning techniques allow a computer system to connect the dots from many different areas of knowledge, similar to how the human brain works, to make the best decision possible. Facebook, Google, Microsoft, and other tech companies are in a race to apply deep learning to make machines intelligent without much help from the programmers.

Take that voice-activation service, for example. Say a user with an accent is dictating a message amid background noise. A deep-learning machine could detect and process those factors to interpret what the person is saying. And this is just a starting point. Applications for deep learning are endless.

"Deep learning can be applied horizontally across many fields and applications," says IEEE Member Rajan Goyal, a distinguished engineer at Cavium, in San Jose, Calif., who works on next-generation accelerators. He is exploring silicon designs for deep learning. "The power of deep learning is that it can solve many problems that have been impossible to solve to date."

THE MIND OF A MACHINE

Deep learning is a relatively new form of artificial intelligence that gives an old technology—a neural network—a twist made possible by big data, supercomputing, and advanced algorithms. Data lines possessed by each neuron of the network communicate with one another.

It would be impossible to write code for an unlimited number of situations. And without correct code, a machine would not know what to do. With deep learning, however, the system is able to figure things out on its own. The technique lets the network form neural relationships most relevant to each new situation. First, however, the machine needs to learn how to learn.

One of the first deep-learning exercises was carried out by Yann LeCun, director of AI research at Facebook. LeCun taught a computer system how to recognize the differences between images of dogs and cats. When the system chose incorrectly, he would correct it until the program figured out the reason it was wrong, such as not, for example, having considered the shape of a nose or an ear. Eventually, the machine started to distinguish a cat from a dog nearly every time.

"Just like human beings grow up learning about the environment around them and reacting to it, machines can also learn complex tasks this way," Goyal says. Basically, the machines learn from their own mistakes.

Now add millions of inputs beyond those for cats and dogs, and you start to have a highly intelligent system. Because tomorrow's intelligent systems will have so much knowledge, they aren't likely to make the mistake of reading a word incorrectly just because the handwriting is poor or a letter is missing. Instead, the machine would, for example, consider the context of the word, such as how it is written, and on what medium—on a billboard, say, or in a newspaper—as well as what words or images surround it.

"Instead of teaching the machine everything, let it teach itself," Goyal says. "By creating a system that can learn on its own, the time to develop it is drastically reduced."

The more an intelligent machine knows, the faster it can pick up new information. Eventually, humans might not be able to teach it much at all. One of the latest examples is the AlphaGo program, which defeated Go champion Lee Sedol. Go, an ancient board game renowned for its intuitive strategy, has more possible combinations than the number of atoms in the universe.

In response to the victory, Demis Hassabis, cofounder of DeepMind, the company that developed AlphaGo and has since been acquired by Google, said it demonstrates that AI could be used to solve problems that confound humans.

And then there's Google Brain. For each image of a location collected for Google Maps, a team of employees had the tedious task of clicking yes or no for whether a photo was of an actual address and not, for example, of an empty stretch of street or unoccupied woods. Then the company's engineers trained its computer system to handle the task. And using deep-learning image recognition, Google's machines were able to identify with street addresses all the homes and buildings in France in less than an hour.

IEEE Fellow Li Deng, chief scientist of AI at Microsoft Applications and Services Group and research manager at Microsoft Research, pioneered research and applications in deep learning speech recognition. With colleagues at Microsoft Research, he explored multimodal intelligence involving images and natural language for computers to communicate like humans. Deng received the IEEE Signal Processing Society's 2015 Technical Achievement Award for contributions to deep learning and to automatic speech recognition.

When a deep-learning system views an image or video, it can describe what it sees. The system identifies visual cues—such as woman, camera, flowers, and purple—then uses natural-language models to generate many possible sentences describing the scene. The system can then quickly determine what it understands to be the most sensible description: A woman is taking photos of purple flowers.

The opposite is also true. If you type in a descriptive sentence, the machine can bring up the most relevant media it finds on the Web.

That ability to understand an image's content and express it in natural language, Deng says, will be useful for a wide variety of applications. At a Microsoft conference on 30 March, a blind software developer showcased how he was able to "see" using a deep learning–enabled headset. The user tapped a button on the headset to take a snapshot of the scene in front of him, and the system explained what was in the photo. The system could even describe facial expressions and detect if a person in the image looked happy or confused, for example.

THE FUTURE OF AI

More precise than humans, intelligent machines will be able to pick up subtle cues, such as differentiating fake smiles from real ones—which is often difficult for a person to discern—Goyal says. Deep learning also will enable machines to predict a person's needs, Deng adds. For example, in the future when you text a friend that you plan to see a movie, Uber or a similar car service could be automatically programmed to pick you up if you do not have your own car. Intelligent systems, he says, will be able to make decisions far more accurately and faster than humans can, and we're already starting to see that happen. ◆

AI Is All Aro

Machines are writing news articles, composing music, and protecting our money BY AMANDA DAVIS

ARTIFICIAL intelligence has crept into our everyday lives, even though we're not always aware of it. Here are some examples of AI's many applications.

MAKING HEADLINES

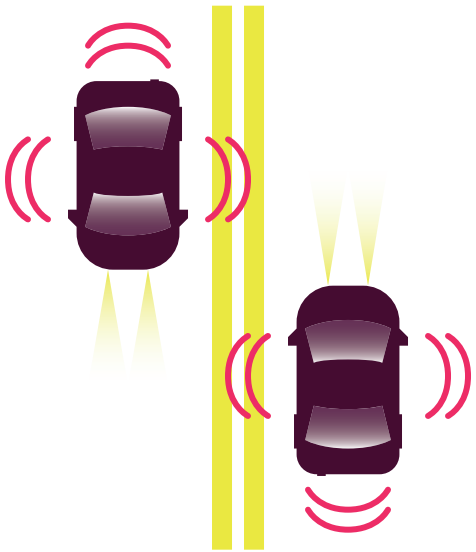
Journalists might not care for this, but AI programs are becoming smart enough to compile bits of information and turn them into articles. Although long-form features and investigative pieces are still being left to reporters, the Associated Press, Fox News, Yahoo, and other outlets are using AI to fill in the blanks of simple, data-driven stories, like financial summaries and sports score recaps.

Last year Automated Insights, a software company in Durham, N.C., launched the news-writing bot Wordsmith, which fills in the blanks of an article template with simple words and information such as stock market figures or baseball stats.

Wired magazine really put Wordsmith to the test by using it to write an obituary for IEEE Life Fellow Marvin Minsky, the AI pioneer who died in January. The bot produced a 150-word "just the facts" obituary with such information as Minsky's name and age, the cause of death, and names of family members—which could be useful if a news outlet wants to be the first to publish the story.

There's also an AI program to write clickbait headlines—the kind designed to drive online readers to an article. The program uses recurrent neural networks (RNNs), which form connections based on the data they receive.

After uploading and practicing on several million articles from BuzzFeed, Gawker, The Huffington Post, and other sites, the software has produced a number of grammatically correct—yet offbeat—headlines such as "How to Get Your Kids to See the Light" and "This Guy Thinks His Cat Was Drunk for Five Years."



As its creator, Lars Eidnes, explained in a blog post, "We can show an RNN a bunch of sentences and get it to predict the next word, given the previous words. So, given a string of words like *Which Disney Character Are*, we want the program to produce a reasonable guess, like *You*, rather than, say, *Spreadsheet*."

Eidnes has launched an auto-generated news site, Click-o-Tron, which adds headlines to short articles—all assembled by the RNN program.

LETTING GO OF THE WHEEL

Self-driving cars might be a few years from the showroom floor, but several manufacturers have already incorporated AI in their cars.

This year BMW introduced its 750i xDrive model, the first car that can park itself with no one behind the wheel. Simply press a button on the car's remote and the full-size sedan backs out of a driveway or maneuvers itself into a tight parking space.

The 2015 Infiniti Q50S and the 2015 Mercedes-Benz S65 AMG have systems of sensors that engage the brakes when the car comes too close to the vehicle in front, an object on the road, or a pedestrian. Such models also have a lane assist feature, which adjusts the car's course when it begins to drift.

In January, Toyota hired IEEE Member Gill Pratt, a robotics expert, as CEO of its research institute, and it plans to spend US $50 million to support collaborative AI research at Stanford and MIT. The company is working on a camera that can read road signs and determine the colors of traffic signals—which could help vehicles get through intersections safely.

INTELLIGENT PLAY

AI programs can keep gamers on their toes as their computer-based opponents become less predictable. First-person shooter games, like *Call of Duty*, make significant use of AI to enable the background characters to analyze their surroundings to find objects or take actions that might be crucial to their survival. The characters take cover, investigate sounds, and communicate with other AI characters to increase their chances of victory.

Another game, *Left 4 Dead*, features an AI "director." The director isn't an onscreen character but an invisible force that increases the number of opponents to beat as the game progresses based on each player's situation, status, skill level, and location.

In fact, AI has been part of video games for more than 60 years. An early example was Nimrod, a computer designed for the 1951 Festival of Britain exhibition by IEEE Life Member John Bennett and built by engineer Raymond Stuart-Williams. Exhibition attendees could play Nim, a mathematical game of strategy, against the computer. The player would make moves by pressing buttons on a panel, with each button corresponding to a light on the machine; the computer would run through calculations to make its next move based on the player's actions.

The 1978 game *Space Invaders* introduced AI into computer-generated opponents, whose movements depended on the player's input. *The Sims*, one of the best-selling computer games of all time and still on the market,

ERIC FROMMELT (5)

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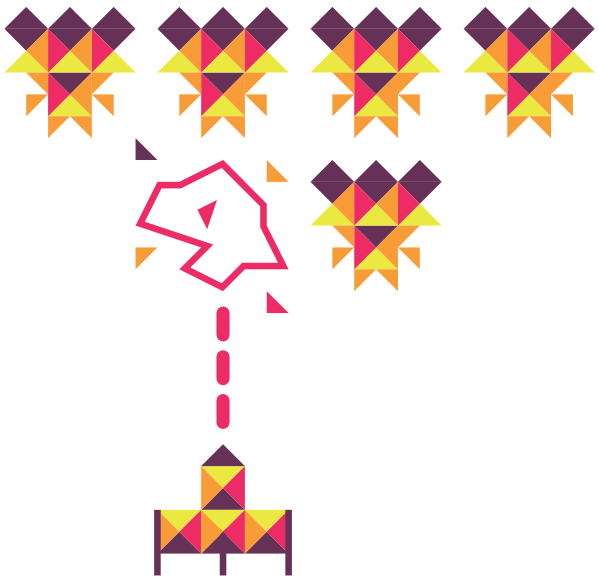


premiered in 2000 and took AI a step further. Players create characters, build houses for them, and assign them careers, but the characters exhibit a certain degree of free will, reacting to situations (such as meeting new neighbors or dealing with kitchen fires) in somewhat unpredictable ways.

FOR YOUR ENTERTAINMENT

Are you bored with your current music playlist or can't decide which TV show to watch? AI might be able to help. Netflix, Pandora, Spotify, and other streaming services use the technology to recommend movies and music based on their customers' past selections. By applying deep-learning algorithms, the services make recommendations that their subscribers are likely to enjoy.

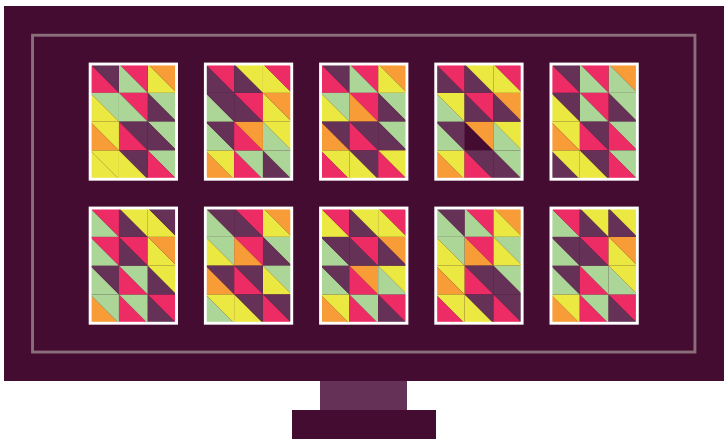
To make accurate choices, the companies' programmers manually tag songs, movies, and TV shows with certain traits. A song on Pandora, for example, might have deep bass and dynamic vocals listed as traits. If you listen to such a song all the way through, AI selects another one with similar attributes.

Not only are computers now selecting music, but they're also composing it. Researchers at the Sony Computer Science Lab, in Paris, are working on algorithms to let computers produce original symphonies and other music.

A symphony could be in the style of composer Johann Sebastian Bach, for example, or the AI could produce riffs that sound like, say, jazz musician John Coltrane's, or original melodies that conjure up a particular pop star. The jazz bot can even come up with songs that combine the attributes of two musicians, such as a tune that sounds like it was written by composer and conductor Pierre Boulez and played by saxophonist Charlie Parker.

"The commercial applications of such efforts may include endless streams of original music in shopping malls that can respond to crying babies with soothing harmonies, as well as time-saving tools for busy composers," says William Hochberg, who wrote about the technology in *The Atlantic*.

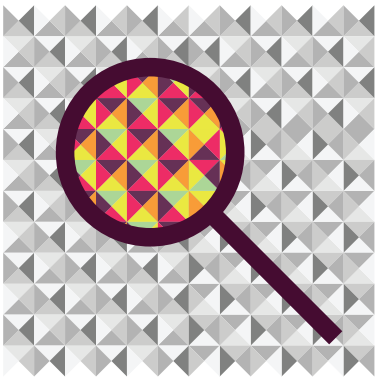
But can computer-composed music move an audience the way live music can? Is it able to replicate nuances, like a singer's imperfect vibrato or a blues musician's soulful strum of a bass guitar? AI has a ways to go, according to Hochberg. Oftentimes "ham-fisted dynamics and pointless melodies" make it clear, he says, that the song wasn't composed or performed by a human.



FRAUD PREVENTION

It's a scenario becoming familiar to more and more people: You go to a café to grab a cup of coffee, only to have your credit card declined. Minutes later, you receive notice that your card has been suspended because a large purchase was made by someone at a store on the other side of the globe. Your account is frozen, and a new card arrives in the mail several days later.

AI and data-analysis programs work together to stop thieves. AI systems are fed a large sample of normal and fraudulent transactions so they can learn what each type looks like. If, for example, a client typically makes most of her credit card purchases locally, and then buys a high-priced item in another state or country, the system flags the transaction.



Similar technology has been in place since the late 1990s, but as IEEE Member Jungwoo Ryoo says in an article on *The Conversation*, an online research publication, the process has now become almost instantaneous.

The algorithms in use today can handle more data and do it faster, making the job of fraud detection not only less labor-intensive but also more accurate, says Ryoo, associate professor of information sciences and technology at Pennsylvania State University, in State College. That is important for companies such as PayPal, which processes some 1.1 petabytes of data at any given moment. Because AI improves through practice, every new piece of information makes the system that much smarter and more efficient. ◆

Landing a Job in Artificial Intelligence

Companies can't hire skilled professionals fast enough BY JOHN R. PLATT

THOUSANDS OF openings in artificial intelligence and machine learning posted on job boards are going unfilled. In fact, though AI is one of the fastest-growing areas for high-tech professionals, according to a recent *Kiplinger* report, there are too few qualified engineers.

"Supply is far lower than demand," says Boris Babenko, a machine vision engineer at Orbital Insight, a company in Palo Alto, Calif., that uses AI to make sense of data gathered from satellite images. "That's true of all software engineering, but AI is a niche on top of that."

The need for AI specialists exists in just about every field as companies seek to give computers the ability to think, learn, and adapt.

"If you look hard enough, any industry you can think of has a need for AI and machine learning," says Geoff Gordon, acting head of the Machine Learning Department at Carnegie Mellon University, in Pittsburgh.

Many open positions exist in Silicon Valley, of course, but AI jobs can be found in Boston, New York, Pittsburgh, London, Hong Kong, and just about any city, Gordon says.

A recent report from Shivon Zilis, a founding partner at the investment fund Bloomberg Beta, points to Apple, Google, and IBM as AI's three top hiring companies. But those three firms are far from alone. Zilis's report shows that AI is used in many fields including advertising, agriculture, health care, and transportation.

GETTING IN

How do you get a job in AI? According to Gordon, some workers start in software engineering or a data-heavy field such as physics.

"Others might come from a field like biology," he says. "Machine learning becomes an important part of what they do, and they end up loving it." He says a lot of his Ph.D. students have returned to school to study AI after a few years in industry.

A background in software engineering, experts agree, is a must-have.

"We assume that when people first come in they have not only formal thinking ability but also the know-how to code and work with computers," Gordon says. The exact programming language doesn't matter; most students know several.

"We love seeing candidates who have had some open-source projects," Babenko says, "so we can look at the code they've written."

Beyond technical skills, AI requires an innate sense of curiosity and a drive for problem solving.

"We're trying to train people who can take on the impossible problems and solve them," Gordon says. "Someone once described our students as elite machine-learning ninjas who would get dropped in by black helicopters to solve all your problems."

A combination of analytical ability and creativity also matters, according to Matthew Michelson, chief scientist at InferLink, an AI firm in El Segundo, Calif.

"This is a difficult combination to find, but you need to be analytical to understand the data and to craft algorithms," Michelson says. Creativity is important, he adds, because "the problems are often new and require new solutions." He looks at candidates' hobbies—he's partial to those who developed games—when considering how they might handle problems.

STAYING CURRENT

As for education, jobs exist for those with a master's degree, and there are plenty of lower-level positions as well. Employers hiring in AI value Ph.D. candidates for their depth of education and the work they produce during their doctoral program.

Attending conferences [like those on p. 15] is a good way to keep your AI knowledge up to date—vital with the field evolving so rapidly—and to find job leads.

"My advice to those interested in working in AI is to network, attend events, and follow industry news closely—become part of the industry conversation," says Jana Eggers, CEO of Nara Logics, a synaptic intelligence company in Cambridge, Mass., that combines neuroscience and computer science. "It is the best way for you to assess your fit with a company, as well as to learn of professional opportunities."

> *Just about every industry needs employees with AI skills*

Babenko praises competitions such as those run by Kaggle, which styles itself as "the world's largest community of data scientists." The competitions can be great for networking, he points out.

WHERE TO LOOK

The big tech companies are all hiring, and paying top dollar for talent. Those deep-pocket companies might, in fact, be pricing some of the smaller ones out of the market.

"I don't think Orbital Insight can compete with the larger companies," Babenko says of his employer.

But well-equipped candidates should consider their own personalities, he adds: "Google has a lot of cool projects, but you're a drop in the bucket there," whereas a smaller company, like Orbital, provides him with a feeling that he's doing more.

The job boom, for the most part, has been in industry. Gordon has not seen a corresponding increase in academic jobs, although he expects that to change.

And the number of AI jobs will only keep increasing. "The field will continue to be hot," Gordon says. ◆

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Get to Know the Candidates for 2017 President-Elect

Jim Jefferies and Wanda Reder talk about their visions for IEEE

BY MONICA ROZENFELD

STEPHEN SIMPSON

THE ANNUAL IEEE election process begins in August—be sure to check your mailbox then for your ballot. To help you choose the 2017 IEEE president-elect, we interviewed the two candidates: IEEE Life Senior Member Jim Jefferies and IEEE Fellow Wanda Reder. In addition to speaking about increasing the visibility of IEEE and supporting members who work in industry, they lay out their strategic plans for the organization.

Jefferies is a retired AT&T and Lucent Technologies executive who in 33 years rose from manufacturing engineer to vice president. He was responsible for teams that transferred glass technology from Bell Telephone Laboratories and developed fiber-optic cables at AT&T. He also served as logistics vice president, responsible for international distribution, quality assurance, and export planning.

After retiring in 2000, he teamed with fellow Stanford graduates and served as chief operating officer of USBuild, a company that developed supply-chain solutions for homebuilders.

Jefferies has been an IEEE volunteer for years. As 2015 IEEE-USA president, he helped the organization expand its focus on young professionals, public policy, and visibility.

On the IEEE-USA board of directors from 2009 to 2015, he served as vice president of government relations and of professional activities. He has provided valuable expertise to the IEEE Audit and Employee Benefits committees, and is currently chair of the IEEE-USA Entrepreneurship and Innovation Policy Committee. He served as 2012–2013 director of Region 5 and was 2008 chair of the IEEE Denver Section. He is a registered professional engineer and a member of IEEE–Eta Kappa Nu, the organization's honor society.

Reder is the chief strategy officer at S&C Electric Co., a provider of switching, protection, and control systems for electric power, headquartered in Chicago.

Prior to S&C, she served as vice president at Exelon, overseeing asset management, engineering, and standards for electric utility operations in Philadelphia and Chicago.

Throughout her 29-year career, Reder has led efforts in the development and deployment of smart-grid technologies. She also serves on the U.S. Department of Energy's Electricity Advisory Committee, chairing the smart grid subcommittee. In February, she was elected to the National Academy of Engineering for her leadership in electric power delivery and workforce development.

She was a member of the IEEE Board of Directors in 2014 and 2015, serving as director of Division VII. She also led the IEEE Ad Hoc Committee on Industry Engagement and served on the IEEE Public Visibility Committee and the IEEE Ad Hoc Committee on Holistic IT Development. She now serves on the IEEE Foundation board and leads its Audit Committee.

Reder was the first female president of the IEEE Power & Energy Society (PES), in 2008 and 2009, and has served on its governing board since 2002. As president, she initiated strategies to rebrand the society, effectively attracting a more diversified membership worldwide and improving overall financial results.

She helped launch the IEEE PES Scholarship Plus Initiative in 2011, a program in partnership with the IEEE Foundation that encourages electrical engineering undergrads to pursue careers in power engineering.

In 2010 she helped launch the IEEE Smart Grid initiative and was involved in the global development of several other smart-grid resources including the *IEEE Transactions on Smart Grid* and the Innovative Smart Grid Technologies conference series.

She was elevated to IEEE Fellow in 2012 "for leadership in power engineering implementation and workforce development." She also received the 2014 IEEE Richard M. Emberson Award "for leadership in the IEEE Smart Grid program and in the continued growth of the PES, including the creation of its scholarship fund."

If elected, what would be your top two priorities?

JEFFERIES IEEE has organizational breadth, a powerful brand, an enviable

mission, and a clear direction in its strategic plan. Starting from this strong base, my priority would be to assure IEEE is prepared for the future.

Membership organizations like IEEE must adapt to change in order to stay relevant. Our strategic plan is only as good as its implementation. That means setting priorities, improving accountability, and creating a collaborative environment with a commitment to innovation. The result will be more engaged members who will lead the way in developing emerging technologies, and become a growing voice for technical professionals worldwide.

My second priority will be to renew IEEE's focus on the value of membership. I will respect all points of view and take care to honestly represent the voice of all our members. We are a professional membership organization with a broad scientific and humanitarian purpose whose members create much of the value of IEEE. Our membership includes those studying, teaching, practicing, inventing, and advocating for the advancement of technology.

We need to develop membership value propositions and be open to alternative membership models tailored to differing needs. We should ask: Why did you join, and why would you stay a member?

REDER Making IEEE the leader in new technology development and fostering innovation is a key priority. Achieving this requires participation in the convergence of technical disciplines and collaborating globally using contemporary tools to access, search, and analyze information.

Another priority is bolstering competency-based education [a personalized learning approach] to help members advance through their careers. As engineering careers require us to become increasingly collaborative, multidisciplinary, entrepreneurial, and global, IEEE can be essential to members' development and professional success.

What skills would make you a strong leader for IEEE?

REDER Leadership, technical vision, and strategic planning are some important skills of mine. These skills, plus my broad range of IEEE and executive industry experience and a proven record of execution, will enable me to successfully fulfill the responsibilities of IEEE president-elect.

My experience includes taking a leadership role from 2010 to 2014 in launching the IEEE Smart Grid initiative, which now has more than 90,000 followers through social media and involves 14 groups within IEEE. It's a success story because we were able to collaborate, build a trusted voice, form partnerships with industry, adopt social media best practices, and establish a model for other multidisciplinary initiatives to follow.

As president of the IEEE Power & Energy Society in 2008 and 2009, I rebranded the society to increase global membership and diversity by changing its name and creating a new website. With its leadership, I developed a line of new products, services, and marketing materials that increased membership and diversity. Since then, PES membership has consistently grown, making it IEEE's second largest technical society.

The IEEE PES Scholarship Plus Initiative was launched under my direction and has attracted US $6.5 million in philanthropic contributions, awarding more than 900 scholarships and nearly doubling the pipeline of power engineering graduates. Enthusiasm of young professionals in the society continues to build.

Serving as a director on the IEEE board, the IEEE Foundation board, and the IEEE Technical Activities board has provided me with a sound operational knowledge of the organization. I have gained an in-depth understanding of global membership needs by giving keynote addresses, tutorials, and training in all IEEE regions.

I also have industry experience as chief strategy officer at S&C Electric Co. I am responsible for leading strategic planning, acquisitions, and mergers and coordinating the company's future direction with our board of directors. These skills, coupled with my experience launching, managing, and directing engineering organizations, have established a great foundation for becoming IEEE president.

JEFFERIES I have a management science degree from the Stanford Graduate School of Business, which I earned midcareer as a Sloan Fellow studying with business leaders from around the globe. I have worked and volunteered as an engineering manager, director, and corporate vice president at AT&T and Lucent Technologies, all of which required in-depth technical and business know-how. Later in my career, I teamed up with fellow business school graduates at USBuild.

My perspectives on leadership and organizational development formed by this experience give me confidence and insight and the ability to provide well-measured responses. I have a creative approach to management that challenges people to think harder but also inspires them to enjoy and celebrate the process and their successes.

I have served multiple terms on the IEEE board and effectively represented IEEE as a public policy spokesperson. I am a respected leader who listens well, communicates articulately, and supports the innovations of those around me.

As president, what would you do to increase the public visibility of IEEE?

JEFFERIES IEEE has a powerful brand. When I will try to meet with industry or government leaders, our name alone will open doors. But many of those who know our name may not know everything we do.

Therefore, we must build on our public visibility campaigns to describe how we help in advancing technology for humanity. We have powerful stories that can be shared in many public forums to better represent what we stand for. I would drive the organization to take that next step in delivering these stories, especially to outside organizations that share our interests.

REDER I plan to create a strategic focus on science, technology, engineering, and mathematics (STEM) government initiatives in all global regions and emphasize the important role of IEEE in STEM. This includes through collaboration with the IEEE Foundation promoting and publicizing more IEEE technology competitions and scholarships for students and young professionals.

I'd also convey the importance of IEEE to the advancement of technology and innovation through stories that highlight its

benefits to humanity, and provide greater support to sections and chapters to increase public awareness of IEEE's role in each region.

What products and services can IEEE offer to help its members working in industry?

REDER As a senior executive in industry and active in my career, I relate with executives and am uniquely qualified to engage them. Such engagement is important to establish a meaningful basis for providing what they value. Having chaired the IEEE Ad Hoc Committee on Industry Engagement in 2014, my initial focus will apply recent findings of that committee to position IEEE as a partner with industry in developing its employees' careers, and collecting and disseminating examples for others to emulate best practices of IEEE serving industry. This would be aided with online tools to more readily access, share, and distribute information.

The focus will be on moving from theory to practice throughout IEEE. An example is creating guides and webinars aimed at applied technology, increased productivity, life-cycle extension, and safety. This would include search tools that scan all of IEEE's assets to form custom information packages that address individual interests.

JEFFERIES The answer is important because we have lost valuable links to industry. Industry leaders visited last year by outreach teams from the IEEE board asked for new or unique industry and technology trend information. IEEE members in industry expressed a need for practical education and career support that could stand in for what their employers today are less likely to offer.

Other identified opportunities involve new publications specific to those in industry and hosting workshops that appeal to engineers working in industry. Classes on emerging technology can be taught on job sites to reinforce our commitment to working with industry. In my case, certain IEEE publications and networking opportunities, such as study groups for professional licensure, helped solidify my own commitment to IEEE membership.

What was your most memorable IEEE event, and why?

JEFFERIES I have attended many IEEE events and always found them to exceed expectations for content and quality. Events are a major IEEE strength, whether a symposium or conference for technical leaders or the Sections Congress for regional leaders. An annual event that never ceases to amaze me is the IEEE Honors Ceremony. The achievements pioneered by the award recipients highlight the lasting contributions made by our incredible community of technology leaders. They demonstrate to me the best in IEEE.

REDER Receiving the IEEE Richard M. Emberson Award in Amsterdam at the IEEE Honors Ceremony in 2014 was memorable, especially knowing that my accomplishments, attributable to collaboration and teamwork, were recognized. Recognizing the work of volunteers is very important.

Another memorable event was in 2009 when I was copresenting an overview of women in engineering, sharing my personal experiences, at an all-female student seminar in Abu Dhabi, United Arab Emirates. I was humbled to be admired by attendees, who had met few professional female role models. The demonstration of their strength and determination to follow their dreams and pursue engineering careers, certainly a nontraditional path for women there, left a lasting impression.

What is the best career advice you ever received?

REDER Be true to yourself, work hard, follow your passion, and know that it's your unique attributes that set you apart from others. Also, who you know usually has a bigger impact on your next career opportunity than what you know. It has been true for me!

JEFFERIES Keep focused on doing your assignment well, but also express what your long-term perspectives are, and be willing to take on additional responsibility. Any career path depends on many unpredictable events and changes. Of the many promotions I received, all had some element of surprise. Career paths in today's job market, with its likelihood of multiple employers (one of which might be yourself), require an understanding of where your skills fit, a look over the fence at opportunities, and a constant check of the landscape.

What must IEEE do to stay relevant for the next generation of engineers?

JEFFERIES It is interesting that there are more millennials than the baby boomers they will replace. They have a different perspective regarding the value of membership and how they want to participate in a membership organization. IEEE must engage them on new terms and give them freedom to take on roles and responsibilities that matter to them. Given the right support, they provide energy and new perspectives, and there is a place for them in IEEE's top leadership.

Overall, maintaining relevance with the next generation will require listening to their needs and connecting with them in whatever method of communication has their attention.

REDER Incorporating the perspective of young professionals by inviting them to participate actively throughout IEEE is critically important. I will provide leadership to better engage them and focus on becoming more nimble in providing products and services that meet rapidly evolving expectations. This is an important matter that I take very seriously, and I can point to a record of success as a proponent of investing in young engineers for our future. An example of this is my creation of the IEEE PES Scholarship Plus Initiative.

To learn more about the candidates, visit jamesajefferies.com and wandareder.com.

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OPINIONS

Sparking Conversation

In March, *The Institute* posted a blog entry about efforts to attract and retain women in STEM (science, technology, engineering, and math) careers. Another post explored the idea that humans might form romantic relationships with robots. Here are a few of the comments from our readers.

WOMEN IN STEM

"A Large Paycheck Isn't Enough to Keep Women in Engineering" explored some of the reasons why women leave the field and what might entice them to stay.

I am a woman who spent the last 13 years as an engineer. Even after working considerably harder and smarter than my male counterparts, I was overlooked for several promotions. After finally getting a promotion and making personal sacrifices, including both to my health and family, I was not given the resources I needed to succeed. Engineering consulting firms are old boys' clubs. The women I know who say they left their engineering careers to be "closer to their families" were using that reason as an excuse to get away from the misogyny.

—Stella

Women must create an environment that fosters success, and it might not be at your present company. Moving to a different organization that appreciates talent is only one way to achieve that goal. When I was unhappy with the direction the consulting firm I worked for was taking, I left to start my own. Or you can stay and fight incompetent management, no matter what the outcome. Companies will soon realize they are making a mistake when they don't protect and nourish their talent.

—Margaret Stambach

My company let me take six months off after having each of my two children; I worked part time until they were teenagers. There's no reason not to allow women in the engineering field to work part time. I usually did the work of a full-time employee but did it in only 25 to 30 hours a week. I knew my time at work was limited, so I worked extra hard.

—Chick Engineer

ROBOT ROMANCE

IEEE Senior Member Kevin Curran argued in a blog post, "In the Future, Humans Will Form Romantic Relationships With Robots," that people one day will "inevitably" fall in love with robots. He warns, though, that robots are incapable of loving us back.

The impact of robots on society will be significant. The idea of robotic spouses raises strong emotions, and I presume many would consider this sinful. One thing is sure: A company that sells good-looking "male" and "female" robots complete with humanlike anatomy will make more money than Apple, Google, and Microsoft combined. The idea may seem shocking, but in the future people will see it as normal, just as normal as smartphones are now.

—Goju

Without having free will, robots are unable to truly love. That's also why it would look crazy for a robot to bow down and worship you—it has no free will to do so. Another problem is that people might become so enamored with their robot mates that they abandon human relationships. And if nothing else, we'll all be entertained by "robomance" films from Hollywood that will come out within the next few decades.

—Colin

I disagree with Curran's comments on love. Since we don't know how human consciousness really works, we can't comment on whether consciousness could be simulated acceptably. If we believe that when humans fall in love, the brain is just implementing some algorithm, why shouldn't a machine be able to implement it too?

—Richard Whitehead

Is It Ethical to Kick a Robot?

When robotics company Boston Dynamics wanted to show off how its doglike robot Spot [above] could keep its balance, it filmed its employees kicking it, then posted the footage on YouTube. The video, which went viral, enraged many people, who called the behavior cruel and immoral. In another video, a Boston Dynamics employee used a long cardboard tube to shove the company's humanoid robot Atlas to the floor to show off Atlas's ability to stand back up.

As robots begin to look and act more like living things, violence against them makes people feel uncomfortable, according to a report by CNN. But hitting a robot touches no rule of ethics. As Noel Sharkey, professor of artificial intelligence and robotics at the University of Sheffield, in England, told CNN, "The only way it's unethical is if the robot could feel pain."

CHIME IN *Tell us what you think by commenting online at http://theinstitute.ieee.org/opinions/question.*

LEFT: JAVIER PIERINI/GETTY IMAGES; RIGHT: BOSTON DYNAMICS

Honoring the Giants Who Make a Difference

IEEE members continue to change the very fabric of our world

BARRY L. SHOOP IEEE PRESIDENT AND CEO

IN A LETTER to Robert Hooke in 1676, Isaac Newton wrote, "If I have seen further [than others], it is by standing upon the shoulders of giants." Newton's words remain as relevant today as when he first composed them. By succinctly capturing both the cumulative nature of scientific advancement and technology's central role in shaping the future, Newton's quotation is both instructive and illuminating.

IEEE's history is replete with giants on whose shoulders we stand today. We count among them our past presidents Alexander Graham Bell, William R. Hewlett (Hewlett Packard), and Edward Weston (Westinghouse). Our member roll of Nobel laureates includes such names as Marconi (1909 for wireless telegraphy), Shockley (1956 for the transistor), Kilby (2000 for the integrated circuit), Boyle (2009 for the charge-coupled device), and Akasaki, Amano, and Nakamura (2014 for blue LEDs).

Whether it yields paradigm-shifting breakthroughs or furthers the continuum of technological progress, our work has a direct positive impact on the quality of human life.

In 1971, computing giant Alan Kay coined the oft-quoted phrase "The best way to predict the future is to invent it." For more than six generations, that is precisely what IEEE and its members have done. Together, we have connected the power of technology to the betterment of human well-being and quality of life. Essentially, IEEE and its predecessor societies have made the future brighter and the world a better place for 132 years; and that tradition continues.

PHILANTHROPIC PROJECTS

Naturally, when I speak of IEEE's positive global impact, the important work of the IEEE Foundation comes to mind. The foundation is a full partner in our mission of advancing technology to benefit humanity. In 2015, it gave more than US $4 million to worthy IEEE humanitarian, educational, and opportunity-building initiatives throughout the world.

For example, the EPICS (Engineering Projects in Community Service) in IEEE initiative, a signature program of the IEEE Foundation, engages students in community projects in 17 countries. The foundation raises and provides funds for programs chosen to yield immediate and broad impact and that are sustainable over the long term.

Some 200 IEEE volunteers, together with more than 1,200 university and preuniversity students, have created and implemented systems that have bettered the lives of more than 90,000 people in underserved communities on five continents.

Another IEEE Foundation effort is IEEE SIGHT (Special Interest Groups in Humanitarian Technology). SIGHT helps sponsor and promote humanitarian projects by connecting IEEE members so they can work together to help communities in need. There are 76 SIGHT groups around the world.

In Africa, SIGHT and the IEEE Society on Social Implications of Technology are targeting an international health care crisis in several impoverished areas. They are providing analytic groundwork for a three-year health care "intervention" campaign in rural areas of Ethiopia, Kenya, Malawi, and South Africa. The project aims to provide critical yet otherwise unavailable services to save lives and provide people and communities the opportunity to thrive.

Another IEEE Foundation signature program, IEEE Smart Village, provided nearly 20,000 people living in eight of the world's most energy-deprived communities with access to power.

The foundation also provided financial support to six IEEE sections and two societies in 2015, enabling impactive IEEE projects in the areas of robotics, cybernetics, information theory, imaging technology, geothermal energy, and power grid technology. And looking to the future, the foundation awarded 300 scholarships and grants, empowering students and young professionals to pursue their dreams of being among tomorrow's technology giants.

TODAY'S GIANTS

On 18 June at Gotham Hall in New York City, IEEE will celebrate the achievements of some of today's IEEE giants at the IEEE Honors Ceremony. Among those honored will be Life Fellow G. David Forney Jr., recipient of this year's IEEE Medal of Honor, sponsored by the IEEE Foundation; and Fellow Roberto Padovani, who will receive the IEEE Alexander Graham Bell Award, sponsored by Nokia Bell Labs.

Forney's contributions to realizing reliable high-speed data communications and Padovani's innovations in wireless wideband Internet access are of monumental importance. The collective impact of these two giants has served to enlighten, empower, and connect people and communities throughout the world. What a towering vantage point their shoulders will provide to future generations.

To paraphrase poet Ralph Waldo Emerson, making contributions that allow you to leave the world a better place is the true measure of success. A similar assessment can be made of a company, institution, or association: Is the world a better place for having your organization in it? In IEEE's case, the answer is a resounding yes. Standing on the shoulders of yesterday's giants, we create a better tomorrow for people all over the world. It is at once an immensely consequential duty and an extraordinary opportunity.

I am inspired daily by the contributions of IEEE and our members. Contact me at president@ieee.org and share your "giants of IEEE" stories. More information about the IEEE Foundation can be found at http://www.ieeefoundation.org. ◆

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BENEFITS

Smarten Up on Machine Learning

IEEE offerings can help engineers improve their understanding BY KATHY PRETZ

THESE RESOURCES can get you up to speed on various aspects of AI.

PUBLICATIONS

The quarterly *IEEE Technology and Society Magazine* publishes articles concerned with how artificial intelligence and other technologies affect the world. The magazine is from the IEEE Society on Social Implications of Technology.

IEEE (2)

The quarterly *IEEE Transactions on Computational Intelligence and AI in Games* discusses video and mathematical games, and other amusements, as well as human-computer interactions. It explores using games as platforms for building embedded intelligent agents for the real world.

The publication is sponsored by the IEEE Computer, Computational Intelligence, and Consumer Electronics societies, as well as the IEEE Sensors Council.

The scope of the monthly *IEEE Transactions on Cybernetics* from the IEEE Systems, Man, and Cybernetics Society includes computational approaches to the field. It covers such areas as computer vision, neural networks, genetic algorithms, machine learning, fuzzy systems, cognitive systems, decision-making, and robotics.

Also from the society is the *IEEE Transactions on Human-Machine Systems*. Published six times a year, it covers human organizational interactions including cognitive ergonomics and system testing and evaluation.

The monthly *IEEE Transactions on Pattern Analysis and Machine Intelligence* investigates statistical and structural pattern recognition, image analysis, computational models of vision, computer vision systems, shape and texture analysis, restoration, segmentation, and feature extraction.

Published by the IEEE Computer Society, the journal also includes articles on artificial intelligence, logical and probabilistic inference, speech recognition, and understanding natural language.

The *IEEE Transactions on Robotics*, published six times a year, and the quarterly *IEEE Robotics & Automation Magazine* are produced by the IEEE Robotics and Automation Society. Both publications cover advances in theory and experiments that underpin the science of robotics and automation.

GROUPS

An IEEE Standards Association Industry Connections Activity—the Global Initiative for Ethical Considerations in the Design of Autonomous Systems—was formed in March to help provide recommendations for the ethical implementation of standardized intelligent technologies. An executive committee composed of experts within the realms of artificial intelligence, autonomous technologies, and ethics is providing guidance for the initiative.

The IEEE Computer Society Technical Committee on Pattern Analysis and Machine Intelligence is concerned with pattern recognition, AI, expert systems, natural language understanding, image processing, and computer vision. ◆

Conferences Focus on Artificial Intelligence

Upcoming events cover machine learning, cognitive systems, and gaming

International Conference on Artificial Intelligence and Pattern Recognition

LODZ, POLAND; 19–21 SEPTEMBER

TOPICS: AI modeling and simulation, social impact of AI, speech recognition, machine learning, evolutionary algorithms, brain-machine interfaces, cognitive systems, computer vision, game theory, intelligent networks and databases, data mining, quantum computing, and fuzzy systems.

SPONSOR: IEEE Poland Section
VISIT: http://sdiwc.net/conferences/aipr2016

International Conference on Computer Science and Information Technology

AMMAN, JORDAN; 13–14 JULY

TOPICS: Machine learning, AI, human-computer interaction, data mining, big data, cloud computing, multimedia processing, business analytics, enterprise systems, supply-chain management, software testing and verification, and the Internet of Things.
SPONSOR: IEEE Computer Society
VISIT: http://csit.asu.edu.jo/csit2016

IEEE International Conference on Autonomic Computing

WÜRZBURG, GERMANY; 19–22 JULY

TOPICS: Software engineering for autonomic computing, machine learning, control theory, rule-based systems, organic computing systems, cloud computing, cognitive computing, the Internet of Things, and resource management for data centers.
SPONSOR: IEEE Computer Society
VISIT: http://icac2016.uni-wuerzburg.de

IEEE International Conference on Software Engineering and Service Science

BEIJING; 26–28 AUGUST

TOPICS: AI systems, cloud computing, data mining and analysis, evolutionary computation, machine learning, neural networks, decision support systems, e-commerce, the Internet of Things, robotics and automation, multimedia and communications systems, and parallel computing.
SPONSOR: IEEE Beijing Section
VISIT: http://www.icsess.org

IEEE International Conference on Intelligent Systems

SOFIA, BULGARIA; 4–6 SEPTEMBER

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IEEE Computational Intelligence and Games Conference

FIRA, GREECE; 20–23 SEPTEMBER

TOPICS: AI in video games, AI-based game generation and monitoring, augmented reality, learning in games, intelligent interactive narratives, realistic games for simulation and training, and virtual cinematography.
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Three E-books on AI

Explore bioinformatics, neural networks, and visual attention

BY **KATHY PRETZ**

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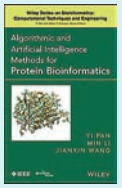
Algorithmic and Artificial Intelligence Methods for Protein Bioinformatics

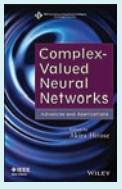
BY YI PAN, MIN LI, AND JIANXIN WANG (2014)



This is an essential reference for bioinformatics specialists or for anyone who wants to better understand the field. The book covers recent developments and includes methods for the analysis of protein data, with a focus on the analysis of sequences, structures, and interaction networks. Data preparation, simulation, evaluation methods, and applications are also examined. Case studies and visuals illustrate how to apply the methods.

Complex-Valued Neural Networks: Advances and Applications

BY AKIRA HIROSE (2013)



Complex-valued neural networks use complicated arithmetic, exhibiting specific characteristics in their learning, self-organizing, and processing dynamics. This guide is for advanced computational intelligence and electromagnetism theorists and mathematicians interested in artificial intelligence, machine-learning theories, and algorithms.

The networks are suitable for processing complex amplitudes—involving amplitude and phase—which is a core concept in physical systems to deal with electromagnetic, light, sonic, and ultrasonic waves, as well as electron and superconducting waves.

This resource deals with advanced theories in a wide variety of applications including brain-computer interfaces and communications and image-processing systems. Topics also include conventional complex-valued, quaternionic, and Clifford-algebraic neural networks.

Selective Visual Attention: Computational Models and Applications

BY LIMING ZHANG AND WEISI LIN (2013)

Visual attention combines a number of disciplines: artificial neural networks, artificial intelligence, vision science, and psychology. The aim of the technology is to build computational models similar to human vision to solve problems in applications including object recognition, unmanned vehicle navigation, and image coding and processing. The book covers the significance of vision research, psychology, and computer vision; existing computational visual attention models; and applications in image-processing tasks.

LEFT: ISTOCKPHOTO; RIGHT: IEEE (3)

Fatih Porikli Sets the Bar for Computer Vision

The IEEE Fellow helps AI applications move forward BY **PRACHI PATEL**

COMPUTER VISION, a field concerned with processing, understanding, and analyzing data from still images and video, gives artificial-intelligence systems a better means of understanding and interacting with the physical world.

"Any time we can squeeze a camera on, say, an unmanned aerial vehicle, computer vision has the potential to provide intelligence and automation," IEEE Fellow Fatih Porikli says.

Porikli, a professor of engineering at the Australian National University, in Canberra, is the computer vision group leader at NICTA, Australia's Information and Communications Technology Research Centre of Excellence, also in Canberra. NICTA's role is to pursue ICT-related research to benefit the Australian economy.

Porikli has made significant contributions to object and motion detection, object tracking, and video analytics. His pioneering region covariance descriptor, which assigns statistical attributes to an image, has become the standard for computer-vision algorithms.

He moved to NICTA in 2013, after 13 years at the Mitsubishi Electric Research Laboratories, in Cambridge, Mass. Before that he worked at HRL Laboratories, in Malibu, Calif., and AT&T Research Laboratories, in Middletown, N.J.

In 2014, he helped launch the annual IEEE DeepVision workshop, which brainstorms theories and processes for deep-learning architectures, a relatively new form of machine learning in which machines teach themselves [p. 4]. *The Institute* interviewed Porikli about the future of computer vision and the role of deep learning in AI.

WHAT INTERESTED YOU IN COMPUTER VISION?

Human eyesight has always fascinated me. We sense, perceive, and understand the world with our eyes. These small, magical organs are so precious. But how do we see and process visual information so effortlessly? That question has always reverberated in my mind.

WHAT ARE THE BEST EXAMPLES IN USE TODAY?

Many are found in our daily lives. These include the fingerprint-recognition and face-detection features in our smartphones, and driver-assistance and collision-avoidance systems in cars. These systems save lives. With depth-sensing cameras, which capture objects in 3-D, computer vision also enables marvelous gaming experiences. Industrial vision systems used in farming can now literally separate grain from chaff.

HOW COULD DEEP LEARNING BOOST COMPUTER VISION? WHAT DOES IT DO THAT OTHER MACHINE-LEARNING SYSTEMS CAN'T?

Two recent developments made deep-learning applications possible for computer vision. One is the availability of very large annotated image data sets. Such sets contain millions of images, with labels that describe their features. The other development is the ever-increasing computational capability of machines.

Before deep learning, humans had to make lots of assumptions on what was important in the data and what could be ignored.

Deep-learning networks, on the other hand, learn by themselves what is important about the data. They learn which are the discriminative and informative parts of, say, a human face, such as the eyes, nose, and so on. Thus, the networks themselves eliminate any dependency on user-defined models, which are often suboptimal.

Another significant advantage of such networks is their capacity to incorporate complex models in their architectures. This is critical in complicated classification tasks where data cannot be split up simply into different classes. Another advantage is that deep-learning networks are applicable to modern computational architecture because they can be implemented to run parallel tasks—which makes them very fast.

YOU'VE ORGANIZED TWO IEEE DEEPVISION WORKSHOPS. WHAT WERE THE TAKEAWAYS?

The workshops crystallized the notion that deep-learning networks provide a significant boost in performance to a variety of applications compared with previous machine-learning methods. And by combining different types of processing layers, functions, and topologies, it's possible to create a vast number of deep-learning systems for different tasks, demonstrating nearly endless possibilities. Our intuition has also been confirmed that deep learning is not a momentary trend but a permanent revolution reshaping computer vision research on all fronts.

WHAT IS THE FUTURE OF COMPUTER VISION? WHAT ARE THE BIGGEST CHALLENGES STILL TO BE OVERCOME?

The past several years have seen significant progress, particularly in object recognition. However, our journey is far from complete. How will computer vision facilitate augmented reality and telepresence applications, providing 360-degree images? What will be possible with intelligent cameras connected to the Internet of Things? We have amazingly capable robots, yet painfully cumbersome ways of programming them. How can computer vision change the way we program, interact with, and teach robots what they must do? Imagine robots that learn simply by observing humans. Over 1,000 hours of video data is being uploaded to social media platforms every minute. How will computer vision respond to the enormous amount of visual data so that we don't drown in it?

Soon, I believe, we will see something like a computer vision app store. This will allow any app developer to access and incorporate advanced computer-vision tools into various applications. This will open opportunities for many more people to contribute and benefit from the technology. I think the biggest challenge is to learn to leverage computer-vision components easily into high-level applications.

ANY WORDS OF WISDOM FOR YOUNG ENGINEERS WHO WANT TO WORK IN THE FIELD?

Most outstanding computer-vision achievements come from collaborative interdisciplinary environments. Take retail marketing, which provides image-based product searches that can also be applied to security for contraband screening. Keep this in mind and think outside the box.

To get a snapshot of the latest developments in the field, consider attending a computer-vision conference. An internship, in particular for young engineers and data scientists, would be another avenue for entering the field. Pursuing a postgraduate degree in computer vision is a great way to dive in even deeper. It's not unusual to be self-taught through courses and other online resources, however, or to learn from a mentor. ◆

COURTESY OF FATIH PORIKLI

Blazing a Trail With Self-Driving Warehouse Vehicles

An IEEE member helped found a startup as an undergrad BY **MONICA ROZENFELD**

Clearpath's Otto 1500 self-driving transporter [above] is designed to move materials around a warehouse, avoiding obstacles while taking the fastest possible route to its destination. IEEE Member Ryan Gariepy [below] cofounded Clearpath while pursuing a bachelor's degree.

WHILE IEEE MEMBER Ryan Gariepy was pursuing a bachelor's degree in mechatronics engineering at the University of Waterloo, in Ontario, Canada, he and three of his classmates entered a robotics competition—which led them to launch their own venture. The four students, each possessing his own set of engineering and business skills, founded Clearpath Robotics in 2009 in nearby Kitchener. The privately held company's revenues are now in the millions.

Clearpath, which started out by customizing outdoor vehicles for academic researchers, branched out last year to make self-driving vehicles for industrial warehouses. Between its research and industrial divisions, the company offers nine types of robotic vehicles including a catamaran and two aerial models.

Clearpath formed a strategic partnership with General Electric Ventures in 2013, and last year the company secured US $11.2 million in venture capital. The money is being used for product development and manufacturing.

Marc Tarpenning, a cofounder of Tesla Motors, joined Clearpath's advisory board in March. The robotics company now has more than 500 customers in 40-plus countries, including General Electric and John Deere. It serves e-commerce, mining, and other industries, as well as the military.

THE BEGINNING

Initial funding from angel investors helped the startup get off the ground. Clearpath used the money to manufacture parts and store inventory. The company broke even after 18 months.

"By the time we started raising capital for our self-driving vehicles, we were five years into a successful business," says Gariepy, the company's CTO. "Investors were looking to get into robotics, and because of our proven track record, Clearpath was an intriguing opportunity with relatively low risk."

Artificial intelligence has been incorporated into the vehicles to make them more efficient. For example, they can avoid obstacles and determine the fastest route to take without human guidance.

The self-driving approach shares the same underlying technology used in Google's driverless car. SLAM (simultaneous localization and mapping) technology uses lidar sensors to scan the environment and create two-dimensional maps, then stores the maps so the vehicles know where they are and how to get to their destination.

Gariepy says he expects more AI capabilities to be added. Meanwhile, he says, what makes Clearpath stand out from its competitors is how easy its robotic vehicles are to deploy.

"The question for us right now," he says, is "How do we get as many of our robots out in the world as possible?"

READY TO ROLL

The Otto line of self-driving vehicles is designed to move materials around a warehouse. The Otto 100 transporter can carry up to 100 kilograms; the Otto 1500 up to 1,500 kg. SLAM and other AI software allows the Otto to travel the fastest route to its destination while avoiding obstacles. Each vehicle has front and rear lidar sensors, which provide vision for the route and identify things in its path.

"A customer would start by driving Otto around the facility to give it a tour," Gariepy says. "As it moves around, the vehicle makes a map. Then the Clearpath system is configured to set up the rules of the road for that facility by setting speed restrictions and guidelines on where Otto can and can't go."

Whether you have five Otto vehicles or a fleet of 50, the centrally controlled system needs to be set up with only one vehicle, which can then communicate with the others. Otto transporters can be configured with an accessory such as a conveyor or a lift to make it easier to reach and pack items. With accessories, different vehicles serve different purposes.

The vehicles enable warehouse operators to reduce the time it takes to get merchandise to the loading docks. They also lower labor costs.

On the research side of the business, Clearpath has a number of vehicles for rugged mining, military, and agricultural environments. The flagship product in this area is the battery-powered Husky UGV (unmanned ground vehicle), which can be customized to fit a variety of applications. It can carry 75 kg. The smaller Jackal, which was designed with the U.S. Army Research Laboratory, has a built-in GPS and onboard computer. The electric Grizzly RUV (robotics utility vehicle) can carry up to 600 kg.

One of the startup's earliest research platforms was the Heron USV (unmanned surface vessel). Among the 28-kg catamaran's uses are collecting water samples, monitoring harbor conditions, and measuring sludge in storm-water management ponds.

LOOKING AHEAD

Clearpath, which started with four students, now has 130 employees. The team expects to add 100 hires this year across all departments including engineering, marketing, and sales. Last month, for example, the company was looking for an electrical engineer with experience in circuit design and debugging, as well as a robotics systems engineer with experience in industrial automation and software development. Job listings are at http://www.clearpathrobotics.com/careers.

More than 6,000 people have applied for positions in the past year, Gariepy says. "Finding the right hire is one of the most challenging parts of my job," he says, "because we want team members to be a strong fit in terms of skill level and culture.

"We have a good understanding of what our deficiencies are and our short- and long-term goals. We know what roles we need to fill today so that we can build the company we envision for the future."

Gariepy's advice for entrepreneurs is to get a lot of input before starting a venture—particularly from potential customers. "Don't be afraid of talking to people about your idea," he says. "They're not going to steal it."

The biggest challenge he faces at Clearpath, he says, is deciding what's best for the company. "There's always a question of risk versus reward," he notes. "What is the thing I can work on now that can make the biggest difference for the company? It's difficult to make such calls." ◆

This article is part of a series introduced this year featuring IEEE members who have launched their own ventures.

CLEARPATH ROBOTICS

OF NOTE

Nominations Needed for Technical Field Awards

Nominate candidates by 15 January 2017

IEEE Biomedical Engineering Award
For outstanding contributions to the field of biomedical engineering.
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IEEE Cledo Brunetti Award
For outstanding contributions to miniaturization and nanotechnology in the electronics arts.
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IEEE Components, Packaging, and Manufacturing Technology Award
For meritorious contributions to the advancement of components, electronic packaging, or manufacturing technologies.
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IEEE Control Systems Award
For outstanding contributions to control systems engineering, science, or technology.
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IEEE Electromagnetics Award
For outstanding contributions to electromagnetics in theory, application, or education.
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IEEE James L. Flanagan Speech and Audio Processing Award
For an outstanding contribution to the advancement of speech and/or audio signal processing.
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IEEE Fourier Award for Signal Processing
For an outstanding contribution to the advancement of signal processing, other than in the areas of speech and audio processing.
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IEEE Andrew S. Grove Award
For outstanding contributions to solid-state devices and technology.
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IEEE Herman Halperin Electric Transmission and Distribution Award
For outstanding contributions to electric transmission and distribution.
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IEEE Masaru Ibuka Consumer Electronics Award
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IEEE Internet Award
For exceptional contributions to the advancement of Internet technology for network architecture, mobility, and/or end-use applications.
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IEEE Richard Harold Kaufmann Award
For outstanding contributions in industrial systems engineering.
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IEEE Joseph F. Keithley Award in Instrumentation and Measurement
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IEEE Gustav Robert Kirchhoff Award
For an outstanding contribution to the fundamentals of any aspect of electronic circuits and systems that has a long-term significance or impact.
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IEEE Koji Kobayashi Computers and Communications Award
For outstanding contributions to the integration of computers and communications.
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For outstanding contribution(s) to the advancement of power electronics.
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IEEE Daniel E. Noble Award for Emerging Technologies
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IEEE Donald O. Pederson Award in Solid-State Circuits
For outstanding contributions to solid-state circuits.
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IEEE Frederik Philips Award
For outstanding accomplishments in the management of research and development resulting in effective innovation in the electrical and electronics industry.
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IEEE Photonics Award
For outstanding achievements in photonics.
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IEEE Robotics and Automation Award
For contributions in the field of robotics and automation.
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IEEE Frank Rosenblatt Award
For outstanding contribution(s) to the advancement of the design, practice, techniques, or theory in biologically and linguistically motivated computational paradigms, including but not limited to neural networks, connectionist systems, evolutionary computation, fuzzy systems, and hybrid intelligent systems in which the paradigms are contained.
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IEEE Marie Sklodowska-Curie Award
For outstanding contributions to the field of nuclear and plasma sciences and engineering.
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IEEE Innovation in Societal Infrastructure Award
For significant technological achievements and contributions to the establishment, development, and proliferation of innovative societal infrastructure systems through the application of information technology with an emphasis on distributed computing systems.
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IEEE Charles Proteus Steinmetz Award
For exceptional contributions to the development and/or advancement of standards in electrical and electronics engineering.
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IEEE Eric E. Sumner Award
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IEEE Nikola Tesla Award
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IEEE Kiyo Tomiyasu Award
For outstanding early to mid-career contributions to technologies holding the promise of innovative applications.
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IEEE Transportation Technologies Award
For advances in technologies within the fields of interest to the IEEE as applied in transportation systems.
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