



Expert Perspectives on AI

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From the Editor

In this column, interviews were conducted to gather perspectives from academia and industry about important focus areas for artificial intelligence (AI), how AI will affect the way people work and live, misconceptions/big win opportunities, and hopes for the AI field in the future.

Experts From Academia

- Dr. Yolanda Gil, president of the Association for the Advancement of Artificial Intelligence and lead of the *20-Year Community Roadmap for AI Research in the US*
- Dr. Daniel Gillblad, head of AI research at RISE and codirector of the European Data Science Academy
- Dr. Martial Hebert, dean of the School of Computer Science at Carnegie Mellon University.

Experts From Industry

- Ulrika Jägare, head of AI/machine learning strategy execution, Ericsson North America
- Dr. Kai-Fu Lee, chair and chief executive officer of Sinovation Ventures and president of Sinovation Venture's Artificial Intelligence Institute
- Dr. Shuang Yang, senior director and head of machine learning at Ant Financial Services
- Dr. Dongmei Zhang, assistant managing director, Microsoft Research Asia.

IEEE SOFTWARE: WITH the rapid changes occurring in the fields of

artificial intelligence (AI) and machine learning (ML), what areas do you think are the most important to focus on right now, especially in relation to software engineering?

Martial Hebert: The most powerful developments will occur when we can combine or reach out across a wide range of areas. At Carnegie Mellon University (CMU), we have been

Digital Object Identifier 10.1109/MS.2020.2987673
Date of current version: 18 June 2020

trying to look at AI very broadly, from the physical layers (sensors), to software, to the ML algorithms, to human interactions and the social sciences. So, I think it's a mistake to try to narrow down the field to any one essential component. Software engineering, however, has helped provide a key benefit for AI: the ability to democratize it; that is, making intelligence accessible for every organization, perhaps even for every person within the organization. The future of AI is using hardware and software to see and hear patterns, make predictions, learn and improve, and take action with this intelligence. We now have high school students who can create fully functional apps due to advances in software engineering and AI.

Some other areas I think we need to focus on are resource-limited AI and AI engineering. Much of ML depends on large amounts of training data. Now, we need to step back from that and learn how we can do ML with limited amounts of data and limited amounts of power. We need to get ML to a point where it requires fewer and fewer resources, which is the natural progression of most fields. In relation to AI engineering, we need to be able to go beyond the development of individual techniques and put them together in a systematic fashion with predictable and quantifiable performance. The problem is, we don't know how to do this very well. This is a high-level concern that cuts across all disciplines of AI.

Yolanda Gil: There are many areas of AI where software engineering can play a big role, such as helping us understand how to build systems with integrated intelligence and, also, ensuring that AI systems can provide

interactions that matter. For integrated intelligence, we have to build systems in a modular way to integrate higher functions, and we don't know how to do this very well with AI capabilities. How do we build intelligence? Do we build it piecemeal or as an integrated architecture from the start?

We simply don't know these things yet, and software engineers will play a role in figuring them out. For interactions that matter, we need to be able to create AI systems that can take on tasks for us and communicate with humans more fluidly. Software engineering is very important here because we have learned over the years that you can't just design a capable system and stick a user interface on at the end. You must incorporate user-centered design into AI systems.

Kai-Fu Lee: Although current deep learning has done a remarkable job in learning new representations from data, that is not enough to guide us to the next level. I think many smart researchers are now further focusing on enhancing AI models so that they have the ability to reason. New tools must be created to achieve that goal, and I'll be excited to see breakthroughs here.

Shuang Yang: One thing to focus on is eliminating barriers to adoption. One of the key barriers—and the cause of today's relatively low penetration of AI—is the increasing gap between the supply of AI skills and the demand there is for applying AI in the real world. Another issue is that, while AI opportunities exist in almost every area and discipline, the areas are too vast and diverse for any AI generalist to grasp. To accelerate AI adoption and fully

unleash its power, more AI practitioners should shift their attention away from standard, generalist types of approaches and focus on solving problems in fine-grained specialized areas. Only through these two groups working together (those who are experts in AI and those who are experts in their particular disciplines) will we be able to understand how to integrate the two domains to build highly optimized technologies that can revolutionize industries. To that end, it is equally important for AI practitioners to deep dive into specialized disciplines and for experts in those disciplines to learn and acquire AI skills.

There are also a number of topics in AI that have remained open technological challenges that require attention and joint effort from the entire community. My personal interests here include the following:

- a deep understanding of ML, especially deep learning, and its underlying mechanisms and potential pitfalls
- algorithms that can cowork with human operators, including those that can be comprehended, trusted, controlled, and regulated by humans, and those that can effectively incorporate human knowledge and apply wisdom that's missing from data or not captured by automated algorithms
- algorithms that can start acquiring intelligence from scratch (or from a small amount of data) and learn to improve themselves continuously as the data grow to eventually replicate or even surpass human ability.

Daniel Gillblad: There is a need for collaboration among industry,

government, society, and research. Having good data is one aspect of AI and ML, but you also need real applications, which means real data and real domain experts to reach fully enabled solutions.

Dongmei Zhang: Research breakthroughs do not happen overnight. They often require persistence and long-term investment, which means only going after the hot topics may not bring big success. I think the question is about understanding what problems we want to study and solve in our own research areas (e.g., in software engineering) and how AI would impact our methodologies and approaches. My research group in Microsoft Research Asia, the Data, Knowledge, Intelligence group, focuses on the areas of data intelligence and knowledge computing. Our vision is to democratize data intelligence and empower people and organizations to derive insights, learn and share knowledge, and build intelligence that can turn data into action.

We focus on three research themes around data: understanding, generation, and interaction. For understanding, we mainly research the representation learning of different forms of data. The data generation theme is about helping people become more productive and creative when they create data. For example, how can we help developers write code or test cases more efficiently? How can we help users discover errors in their spreadsheets? How can we help information workers create more engaging presentations? The data interaction theme is about making the interaction between people and data more natural and efficient. With the significant progress in natural language processing in recent years, we would

like to explore how to leverage natural language to bring the multimodality interaction to the next level.

IEEE Software: Almost everyone agrees that AI will affect the way people work and live. How do you think it will affect the lives of people who work in software engineering? What about the human experience as a whole—do you think it's getting better or worse as this technology matures?

augment, in workloads in the cloud, or even at the device level.

Yang: I believe, as is the case with all technologies, that AI is neutral. Using it for good or evil depends entirely on who uses it and how it's used. That being said, special attention should be paid to studies on the deep understanding of AI, especially on its underlying mechanisms and potential pitfalls as well as technologies that enable us to better

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Ulrika Jägare: AI will change how we work and what we do greatly, and we will see the role of humans become much more specialized. AI solutions will manage many of the basics. For example, in telecommunications, we will have AI and automation capabilities running the network for us, while humans take a step back and manage the data pipeline and the AI models instead. In the services area, we can see this fundamental change already, but in the development and product areas, this is just getting started. AI will also enable us to manage tasks that have previously been too complex. Through the combination of AI, automation, and the computational power that is now available, we will be able to execute tasks very quickly, regardless of whether it happens inside a product that we want to

comprehend, trust, control, and regulate AI algorithms. The community should also work together to set up rules and policies and collaborate to build shared tools and platforms to ensure that, as much as is possible, AI is used for its intended purposes and that we retain the ability to intervene when needed.

I believe, as AI matures, there will be a number of profound impacts to our society. For example, the economy will be more productive (e.g., growing GDPs) as AI improves production efficiency. Workers will likely have more free time as productivity improves or some of the work gets automated. Life expectancy will grow as AI helps to discover drugs or cure diseases. Everyday life experiences will be more efficient. However, that does not necessarily mean life would be better than today. Guidance,

regulations, and policies are needed to make sure these changes are in favor of the welfare of the whole society. For example, we need to make sure productivity improvement does not lead to worsened economic inequality or job displacements of vulnerable groups.

Zhang: In general, I think AI will help tremendously in the field of computing for different roles, such as programmers, software engineers, architects, and designers. One example in programming is the progress in code search, code completion, and program autorepair. Such progress has high potential to help increase the productivity of programmers in writing code. Another example is log analysis, which greatly helps developers systematically and efficiently debug their systems and is especially helpful when they work on large-scale distributed systems. There is a rich set of research conducted on log analysis, such as the work from Prof. Michael Lyu's group at the Chinese University of Hong Kong.

In my group, we have related research that focuses on AI operations and AI for systems. Some of our research results have already been transferred into production at Microsoft to increase developer productivity and make service systems more reliable, performant, and efficient. One important factor to consider in creating better experiences is that AI needs to work with human intelligence because, quite often, AI is an enabling technology component, not an end-to-end solution.

Also, to design AI to be trustworthy, we need work in the field of responsible AI. As software engineering researchers, we might have an advantage here since human

factors have always been an important part of software engineering research.

Hebert: Saying “better or worse” is a little tricky. I'm not saying it can't have bad effects, but I'll talk about the benefits. I think the key benefit can be summarized in one word: democratization. We are lowering the barrier to entry for using these technologies, and almost anyone with any computing experience will be able to put together very complex systems. For example, AI/ML could be used in medical robotic projects that could potentially enable people to do major medical procedures with limited medical resources—democratizing access to state-of-the-art health care. It's not just the idea of cheaper devices, it's the idea of making it possible, with limited skills, to put together these robots using simple components and program them.

Lee: People working in computing will benefit a great deal from AI because workloads will get lighter. There have been tremendous efforts developing AI software that helps programmers write better code and automatically detect bugs. Engineers will have more time to work on building creative and challenging solutions, too, instead of doing repetitive coding. Machines perform best in computational and repetitive tasks, whereas human qualities of creativity, collaboration, and compassion can be rediscovered as our time and energy are relieved by AI. I believe AI is here to liberate us and to allow us to reset and refocus on where we as humans can further excel. My ideal blueprint for AI-human coexistence is this: let machines be machines, and let humans be human.

IEEE Software: Which software engineering or AI project that you worked on or led did you find the most interesting?

Lee: I led an R&D team at Apple a few years ago to develop a speech recognition and synthesis program called *Casper*, and I demonstrated it on the *Good Morning America* show with John Sculley, the Apple chief executive officer then. Apple was my first job out of academia after my Ph.D. program and a few years after teaching at CMU. *Casper* was my first real product launch. It was a breakthrough in AI as well as a tremendous learning experience for me personally on bringing technology from the lab to market. On one hand, *Casper* became one of the primary areas where Apple boasted technology leadership at that time; on the other, it was a foundation for my career in building, developing, and investing in AI in the decades after.

Hebert: In my time at the CMU School of Computer Science, I was fortunate enough to be exposed to many fascinating projects. When I first joined in 1984, it was the year that the first federally funded program started for autonomous and semiautonomous vehicles. The idea was to have a driverless truck drive down the road. It's very primitive compared to what we have now, but this project demonstrates a few key points, such as the role of long-term research—it took 30 years to build up the basic research, pipeline of knowledge, and people trained in that kind of work to get where we are today. For example, in the DARPA Urban Challenge, teams were able to build autonomous vehicles capable of driving in traffic,

performing complex maneuvers, such as merging, passing, parking, and negotiating intersections. Second, when research such as that starts, it's hard to imagine where the idea will go and what form it will take in the future.

In general, the projects that I find most interesting are the ones that reach out far from the initial obvious circle of application. In CMU's School of Computer Science, the ML lab is looking at massive amounts of data from signals and systems and using it for things like predictive maintenance of aircraft. But there are connections to other fields, and another way they've applied it is to fighting human trafficking. ML is used to process data and information on the Web to identify human trafficking rings and victims, and that program is now being used by hundreds of law enforcement agencies. This project takes the original technology—which was technical and high level—very far and uses it to really affect human life.

Yang: Financial services are designed specifically for the top of the economic pyramid. As of today, more than 2 billion adults, or roughly 50% of the work age population, are completely unbanked, without access to any financial services, which is believed to be one of the root causes of poverty and economic inequality. My team at Ant Financial has been dedicated to making financial services more inclusive, especially to those who have been previously excluded by the financial industry. We achieve this goal using AI.

One of my favorite projects is a risk perception and management system that we built on top of graph neural networks. Graphs are abundant in the financial industry, not

only because the data we deal with everyday often possess complex structures that are naturally described by graphs, but, also, because there are strong networked effects in the interactions among our users, merchants, and various services on our platform. Traditional approaches rely heavily on human experts to design features that stitch signals scattered in fragmented log tables, and, then, shallow models are trained and updated every few months. This process is slow, labor heavy, error prone, easy to saturate (quality-wise), and, most importantly, it doesn't scale. Over the past few years, we have rearchitected the system entirely.

This is based on using graph data as first citizens and graph neural networks as the backbone for all risk-related tasks, ranging from profiling, monitoring, and assessment to decision making and intervention. The system has been deployed to production, making multiple services at Ant accessible to billions of users while remaining at a minimum risk level. For example, in our credit and loan business, we are able to provide loans to billion-scale users with an unprecedented user experience known as 3-1-0 (that is, 3 min to apply, 1 s to get funded, zero human intervention).

Zhang: There are many interesting projects I've worked on. If I must pick, then I'd say In4, which stands for interactive, intuitive, instant insights. I pick In4 because it demonstrates thought leadership in research, it is an excellent collaboration project involving all of our 12 team members, and its outcomes include publications at top-tier conferences and successful technology transfers to Microsoft products.

It started in November 2014, when we wanted to expand our research into new areas. Business intelligence (BI) was a natural candidate because of its focus on data, its interdisciplinary nature involving database, system, data mining/ML, and information visualization, and its obvious business value as a mature market for several decades. After studying the popular systems in the BI market, I made an interesting observation. When users analyzed data using BI systems, the users would always play the active role, telling the system what to do—for example, return a query result or create a chart. The system would always passively respond to users' requests.

However, the interaction should not work that way. Why couldn't the BI system proactively analyze the data and recommend the relevant analyses? As I envisioned it, there was an opportunity to create a truly bidirectional interaction paradigm between users and BI systems. This means that, based on the user's analysis context, BI systems would be able to automatically understand data, perform analyses, and recommend insightful results to users. With In4, we aimed to achieve this goal with algorithm research, interaction design, and end-to-end system building.

Gil: I have, at the moment, a project I'm very interested in—using AI to understand causality at a regional level. For example, in California, how do we manage natural resources, like water, with human activities, such as agriculture and so forth, and understand how they connect with and influence one another? If we can understand these complicated interactions, we can then work together to improve the state of the world. This work could have

applications all over—for example, in Texas and also in sub-Saharan Africa. Understanding and modeling the effects of different interventions require significant software engineering to integrate concepts and implementations across disciplines with very diverse designs and assumptions.

IEEE Software: What’s the biggest misconception that you think software practitioners and engineers have about AI?

Zhang: I’d say it is “AI can solve anything.” AI beats the human in memory and computing, it has made huge progress in vision and speech perception, and it starts to demonstrate potential in cognition, such as reading comprehension and insight recommendation. However, there is a long way to go for AI to achieve full cognition capabilities, such as reasoning and decision making, and to reach the even higher levels of human creativity and wisdom. For now, AI is a component technology, and, again, I think AI plus human intelligence is the way to go.

Gil: The biggest misconception I see when I talk to people who are not long-term AI researchers is that they tend to equate AI only with ML. They have a tendency to assume it is a set of ML algorithms you throw data at, and it automates tasks. This neglects a lot of other aspects of intelligence we are pursuing. I would encourage anyone who is a software engineer to go beyond what is being talked about right now to look at other interesting and important aspects of AI, such as intelligent architectures and systems that have the ability to assess their own performance and set their own goals for learning.

Lee: For software engineers, it’s tempting to think about AI as a magical black box that can be plug and play, but, actually, programming AI is still in its formative stages. As such, it doesn’t yet have the many safeguards that mature software technologies have. For example, AI bias (such as discriminating against gender or race) is often the result of not having either a large enough or balanced data set. AI will come across security risks that are different from what engineers have tackled with PCs and phones.

For example, malicious hackers can modify AI model parameters to cause catastrophic failures or camouflage objects to trick computer vision algorithms driving autonomous vehicles. Also, AI’s power in optimizing a single objective function (such as user time spent on Facebook) may make it vulnerable to externalities that could be inadvertently introduced or exacerbated. These inadequacies require better tools that can capture the potential dangers and provide a warning about systems before they are deployed. We also need to include ethics, privacy, and security in education for engineers so that they are aware of these pitfalls and their responsibilities for developing safe and trustworthy AI software.

Jägare: I think there are mainly two misconceptions. One is that you can treat AI like any other software, which means people underestimate how different the model development approach needs to be (much more exploratory, for example). But there is also misunderstanding in how AI models need to be managed once they are in live operations. Since AI models are not static, they will continue to train

on data in the live setting and dynamically change. The model performance and evolution need to be closely monitored over time because the model performance will eventually degrade, and the models will need to be refactored, retrained, or even replaced.

The other misconception I have encountered is that people believe that AI/ML will not work in their environment. They dismiss this technology early on, and, as a consequence, they don’t learn the new AI methods, and their entry into the AI space is delayed.

Gillblad: Digitalization, more automation, and more software-reliant ways of working are the drivers that enable almost all industry experiments with AI/ML learning systems. Currently, we claim there is no limit to what we can do if we are able to think much more cross functionally and outside of the box to solve problems, but this is not entirely true. There are many limitations as to what could be expected from this technology. Some of this now may be hype, but when we talk about what will be done 10 years from now, there are many exciting aspects of this technology.

Yang: There are a few interesting viewpoints. One I personally disagree with is the analogy of AI to electricity. Electricity can be standardized, but, for AI, that is hard (if not impossible) to do. By AI here, I don’t mean AI tools or infrastructure (which can be standardized), but AI solutions that have to be heavily customized and continuously optimized to a specific application. A standard AI solution rarely provides the quality that’s adequate to be practically useful; this becomes

even more true over time as the quality bar progresses (e.g., the demand for further improvement), while the model quality turns to decay and becomes increasingly unusable. Standard plug-and-play solutions are less useful. There is no escape from the no-free-lunch theorem.

IEEE Software: What would you most like to see happen in this field in your lifetime?

Gil: Many things—I have a very long wish list! But what I'd really like to see is an AI system nominated for or even win a Nobel Prize. My research is on AI for scientific discovery, and I think it is a fascinating vision for AI systems to be able to perform scientific discovery to that level. Thinking that someday, in AI, we will be able to capture the genius and subtlety of Nobel-worthy discoveries is very exciting. Scientific discovery involves many different aspects: insight, creativity, an aha moment—seeing an AI system capable of doing these things would be fascinating.

Lee: I would most like to see great enhancements in health care with the aid of AI. I can envision AI programs and tools that work with doctors and caretakers side by side, enhancing their workflow efficiency and accuracy so they can spend more time interacting with their patients with compassion. I could foresee more medical industry disruptions, such as AI-assisted diagnostics, computation-aided drug discovery, precision medication, and more. AI presents humans with great potential to reduce suffering and to extend and expand our healthy lifestyles.

Jägare: The entire AI industry is very much driven by open source—which

makes AI easily accessible to a lot of people and pushes the evolution forward fast. However, as AI matures, so far, we have seen very little standardization taking place, and I would like to see that.

Some de facto standardization is happening, mostly related to model development methods and not so much to the aspect of running models in their target environments. So far, most AI models in the industry are part of a stand-alone solution. But this is slowly starting to change, and we are seeing AI models in the same product or different products working alongside each other, maybe with overlapping scope. This means we will soon need to manage cooperating or nested models, and

field: deep learning research, AI applications, and the future capability of AI. Regarding deep learning research, I would really like to see a breakthrough made on the theory of deep learning. Nowadays, deep neural networks have achieved excellent results on a rich set of tasks in different domains, such as computer vision, speech, and natural language processing. However, from the theoretical aspect, we also need to understand why it works and how it works, which is very important. Regarding AI applications, although there are many AI practitioners working on digital transformation today, it is far from being done. I would like to see it become pervasive in our society.

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there is an urgent need for standardization. Examples of the documentation I'd like to see for AI models include the data used, process used, decision scope, model type, accuracy at release, and its interfaces. All of these are needed to prepare models for cooperation and even hierarchical setups (AI models managing other AI models). From a trustworthy-AI perspective, this is especially important.

Zhang: There are different aspects of what I would like to see in the AI

Regarding the future of AI, I would like to see whether we can go one or multiple levels higher in the intelligence hierarchy. A lot of research is conducted at the perception level. We also touch upon the cognition level, like natural language understanding, but there is so much to do to achieve true human cognition capabilities. Can we go one level up to achieve human creativity? For example, can AI conduct scientific discovery by itself? Such huge and exciting progress is definitely what I would like to see in the future.



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Gillblad: I see the importance of not just competing among ourselves but, instead, joining forces to provide AI technology that is climate sustainable, fair, inclusive, and beneficial for all of society. Software engineering is successful in Sweden due to close cooperation with industry. The direction is to be as open as possible for the benefit of humanity—in opposition to more closed countries, who see data as a control mechanism of the society or for private business benefit. This is also a concern of the European Union—keeping privacy

and security for the individual is a key objective. We should use AI technology to create more democratic solutions for society. What we learn about methods, tools, languages, and specific subdomains must be shared.

Yang: What I'd mostly like to see is that software would become truly soft. Over the past half century or so, we've achieved huge success in making lots of things digital, processed, and conveniently controlled by software. However, this revolution has,

thus far, been physically soft but still logically hard, meaning that software is hard coded based on human designs or heuristics and only programmable to a limited extent. With the advances in AI, especially things like probabilistic reasoning and differential programming, there's an opportunity to redefine software to be truly soft, both physically and logically. No more hard-coded control flows, no more deterministic correctness, but, instead, they can be probabilistically correct, self-programmable, and truly adaptive to data and experiences. 🤖