Toward Human Level Machine Intelligence—Is It Achievable?

The Need for a Paradigm Shift

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Extended Abstract

In the fifties of last century, the question "Can machines think?" was an object of many spirited discussions and debates. Exaggerated expectations were the norm, with no exceptions. In an article "Thinking machines—a new field in electrical engineering," published in January l950, I began with a sample of headlines of articles which appeared in the popular press in the late forties. One of them read "Electric brain capable of translating foreign languages is being built." Today, half a century later, we have translation software, but nothing that approaches the level of human translation. In l948, on the occasion of inauguration of IBM's Mark l relay computer, Howard Aiken, Director of Harvard's Computation Laboratory, said "There is no problem in applied mathematics that this computer cannot solve." Today, there is no dearth of problems which cannot be solved by any supercomputer. Exaggerated expectations should be forgiven. As Jules Verne said at the turn of last century, "Scientific progress is driven by exaggerated expectations."

Where do we stand today? What can we expect in the future? AI was born in l956. Today, half a century later, there is much that AI can be proud of—but not in the realm of human level machine intelligence. A telling benchmark is summarization. We have software that can passably summarize a class of documents but nothing that can summarize miscellaneous articles, much less books. We have humanoid robots but nothing that can compare in agility with that of a four year old child. We can automate driving a car in very light city traffic but there is nothing on the horizon that could automate driving in Istanbul. Far too often, we have to struggle with a dumb automated customer service system which we are forced to use. Such experiences make us keenly aware that human level machine intelligence is an objective rather than reality.

In an article "A new direction in AI—toward a computational theory of perceptions," AI Magazine, 200l, I argued that, in large measure, the lack of significant progress in many realms of human level machine intelligence is attributable to AI's failure to develop a machinery for dealing with perceptions. Underlying human level machine intelligence are two remarkable human capabilities. First, the capability to perform a wide variety of physical and mental tasks, such as driving a car in heavy city traffic, without any measurements and any computations. And second, the capability to

reason, converse and make rational decisions in an environment of imprecision, uncertainty, incompleteness of information, partiality of truth and partiality of possibility. A principal objective of human level intelligence is mechanization of these remarkable human capabilities.

What is widely unrecognized is that mechanization of these capabilities is beyond the reach of classical, Aristotelian, bivalent logic. What is needed for this purpose is fuzzy logic. AI's deep commitment to bivalent logic has impeded its acceptance of fuzzy logic. In my view, achievement of human level machine intelligence is infeasible without the use of fuzzy logic. What is fuzzy logic? What does it have to offer? There are many misconceptions about fuzzy logic. The following précis of fuzzy logic is intended to correct the misconceptions. Fuzzy logic is not fuzzy. Basically, fuzzy logic is a precise logic of imprecision and approximate reasoning. In fact, fuzzy logic is much more than a logical system. It has many facets. The principal facets are logical, fuzzy-set-theoretic, epistemic and relational. Most of the applications of fuzzy logic involve the concept of a linguistic variable and the machinery of fuzzy if-then rules. The formalism of linguistic variables and fuzzy if-then rules is associated with the relational facet. The cornerstones of fuzzy logic are graduation, granulation, precisiation and the concept of a generalized constraint. Graduation should be understood as an association of a concept with grades or degrees.

In fuzzy logic, everything is or is allowed to be a matter of degree or, equivalently, fuzzy. Furthermore, in fuzzy logic everything is or is allowed to be granulated, with a granule being a clump of attribute values drawn together by indistinguishability, equivalence, proximity or functionality. Graduated granulation or, equivalently, fuzzy granulation is inspired by what humans employ to deal with complexity, imprecision and uncertainty. Graduated granulation underlies the concept of a linguistic variable. When Age, for example, is treated as a linguistic variable, its granular values may be young, middle-aged and old. The granular values of Age are labels of fuzzy sets.

A concept which plays a pivotal role in fuzzy logic is that of a generalized constraint, represented as X isr R, where X is the constrained variable, R is the constraining relation and r is an indexical variable which defines the modality of the constraint, that is, its semantics. The principal generalized constraints are possibilistic, probabilistic and veristic. The fundamental thesis of fuzzy logic is that information may be represented as a generalized constraint. A consequence of the fundamental thesis is that the meaning of a proposition, p, may likewise be represented as a generalized constraint. The concept of a generalized constraint serves as a basis for representation of and computation with propositions drawn from a natural language. This is the province of NL-Computation—computation with information described in natural language.

NL-Computation opens the gate to achievement of human level machine intelligence. The validity of this assertion rests on two basic facts. First, much of human knowledge, and especially world knowledge, is described in natural language. And second, a natural language is basically a system for describing perceptions. What this implies is that NL-Computation serves two major functions: (a) providing a conceptual framework and techniques for precisiation of natural language in the context of human level machine intelligence; and (b) providing a capability to compute with natural language descriptions of perceptions. These capabilities play essential roles in progression toward human level machine intelligence.

In summary, achievement of human level machine intelligence is beyond the reach of bivalent-logic-based tools which AI has in its possession. What is needed for this purpose is addition of concepts and techniques drawn from fuzzy logic to AI's armamentarium. However, what should be stressed is that fuzzy logic is merely one of many tools which are needed to achieve human level machine intelligence. What is obvious is that achievement of human level machine intelligence is a major challenge which will be very hard to meet.

Biography

Lotfi A. Zadeh joined the Department of Electrical Engineering at the University of California, Berkeley, in 1959, and served as its chairman from 1963 to 1968. Earlier, he was a member of the electrical engineering faculty at Columbia University. In 1956, he was a visiting member of the Institute for Advanced Study in Princeton, New Jersey. In addition, he held a number of other visiting appointments, among them a visiting professorship in Electrical Engineering at MIT in 1962 and 1968; a visiting scientist appointment at IBM Research Laboratory, San Jose, CA, in 1968, 1973, and 1977; and visiting scholar appointments at the AI Center, SRI International, in 1981, and at the Center for the Study of Language and Information, Stanford University, in 1987-1988. Currently he is a Professor in the Graduate School, and is serving as the Director of BISC (Berkeley Initiative in Soft Computing).

Until 1965, Dr. Zadeh's work had been centered on system theory and decision analysis. Since then, his research interests have shifted to the theory of fuzzy sets and its applications to artificial intelligence, linguistics, logic, decision analysis, control theory, expert systems and neural networks. Currently, his research is focused on fuzzy logic, soft computing, computing with words, and the newly developed computational theory of perceptions and precisiated natural language.

An alumnus of the University of Tehran, MIT, and Columbia University, Dr. Zadeh is a fellow of the IEEE, AAAS, ACM, AAAI and IFSA, and a member of the National Academy of Engineering. He held NSF Senior Postdoctoral Fellowships in 1956-57 and 1962-63, and was a Guggenheim Foundation Fellow in 1968. Dr. Zadeh was the recipient of the IEEE Education Medal in 1973 and a recipient of the IEEE Centennial Medal in 1984. In 1989, Dr. Zadeh was awarded the Honda Prize by the Honda Foundation, and in 1991 received the Berkeley Citation, University of California.

In 1992, Dr. Zadeh was awarded the IEEE Richard W. Hamming Medal "For seminal contributions to information science and systems, including the conceptualization of fuzzy sets." He became a Foreign Member of the Russian Academy of Natural Sciences (Computer Sciences and Cybernetics Section) in 1992, and received the Certificate of Commendation for AI Special Contributions Award from the International Foundation for Artificial Intelligence. Also in 1992, he was awarded the Kampe de Feriet Prize and became an Honorary Member of the Austrian Society of Cybernetic Studies.

In 1993, Dr. Zadeh received the Rufus Oldenburger Medal from the American Society of Mechanical Engineers "For seminal contributions in system theory, decision analysis, and theory of fuzzy sets and its applications to AI, linguistics, logic, expert systems and neural networks." He was also awarded the Grigore Moisil Prize for Fundamental Researches, and the Premier Best Paper

Award by the Second International Conference on Fuzzy Theory and Technology. In 1995, Dr. Zadeh was awarded the IEEE Medal of Honor "For pioneering development of fuzzy logic and its many diverse applications." In 1996, Dr. Zadeh was awarded the Okawa Prize "For outstanding contribution to information science through the development of fuzzy logic and its applications."

In 1997, Dr. Zadeh was awarded the B. Bolzano Medal by the Academy of Sciences of the Czech Republic "For outstanding achievements in fuzzy mathematics." He also received the J.P. Wohl Career Achievement Award of the IEEE Systems, Science and Cybernetics Society. He served as a Lee Kuan Yew Distinguished Visitor, lecturing at the National University of Singapore and the Nanyang Technological University in Singapore, and as the Gulbenkian Foundation Visiting Professor at the New University of Lisbon in Portugal. In 1998, Dr. Zadeh was awarded the Edward Feigenbaum Medal by the International Society for Intelligent Systems, and the Richard E. Bellman Control Heritage Award by the American Council on Automatic Control. In addition, he received the Information Science Award from the Association for Intelligent Machinery and the SOFT Scientific Contribution Memorial Award from the Society for Fuzzy Theory in Japan. In 1999, he was elected to membership in Berkeley Fellows and received the Certificate of Merit from IFSA (International Fuzzy Systems Association). In 2000, he received the IEEE Millennium Medal; the IEEE Pioneer Award in Fuzzy Systems; the ASPIH 2000 Lifetime Distinguished Achievement Award; and the ACIDCA 2000 Award for the paper, "From Computing with Numbers to Computing with Words—From Manipulation of Measurements to Manipulation of Perceptions." In addition, he received the Chaos Award from the Center of Hyperincursion and Anticipation in Ordered Systems for his outstanding scientific work on foundations of fuzzy logic, soft computing, computing with words and the computational theory of perceptions. In 2001, Dr. Zadeh received the ACM 2000 Allen Newell Award for seminal contributions to AI through his development of fuzzy logic. In addition, he received a Special Award from the Committee for Automation and Robotics of the Polish Academy of Sciences for his significant contributions to systems and information science, development of fuzzy sets theory, fuzzy logic control, possibility theory, soft computing, computing with words and computational theory of perceptions. In 2003, Dr. Zadeh was elected as a foreign member of the Finnish Academy of Sciences, and received the Norbert Wiener Award of the IEEE Society of Systems, Man and Cybernetics “For pioneering contributions to the development of system theory, fuzzy logic and soft computing.” In 2004, Dr. Zadeh was awarded Civitate Honoris Causa by Budapest Tech (BT) Polytechnical Institution, Budapest, Hungary. Also in 2004, he was awarded the V. Kaufmann Prize by the International Association for Fuzzy-Set Management and Economy (SIGEF). In 2005, Dr. Zadeh was elected as a foreign member of Polish Academy of Sciences, Korea Academy of Science & Technology and Bulgarian Academy of Sciences. He was also awarded the Nicolaus Copernicus Medal of the Polish Academy of Sciences and the J. Keith Brimacombe IPMM Award.

Dr. Zadeh is a recipient of twenty-five honorary doctorates from: Paul-Sabatier University, Toulouse, France; State University of New York, Binghamton, NY; University of Dortmund, Dortmund, Germany; University of Oviedo, Oviedo, Spain; University of Granada, Granada, Spain; Lakehead University, Canada; University of Louisville, KY; Baku State University, Azerbaijan; the Silesian Technical University, Gliwice, Poland; the University of Toronto, Toronto, Canada; the University of Ostrava, the Czech Republic; the University of Central Florida, Orlando, FL; the University of Hamburg, Hamburg, Germany; the University of Paris(6), Paris, France; Jahannes Kepler University, Linz, Austria; University of Waterloo, Canada; the University of Aurel Vlaicu, Arad, Romania; Lappeenranta University of Technology, Lappeenranta, Finland; Muroran Institute of Technology, Muroran, Japan; Hong Kong Baptist University, Hong Kong, China; Indian Statistical Institute, Kolkata, India; and the University of Saskatchewan, Saskatoon, Canada. Dr. Zadeh has single-authored over two hundred papers and serves on the editorial boards of over fifty journals. He is a member of the Advisory Committee, Center for Education and Research in Fuzzy Systems and Artificial Intelligence, Iasi, Romania; Senior Advisory Board, International Institute for General Systems Studies; the Board of Governors, International Neural Networks Society; and is the Honorary President of the Biomedical Fuzzy Systems Association of Japan and the Spanish Association for Fuzzy Logic and Technologies. In addition, he is a member of the Advisory Board of the National Institute of Informatics, Tokyo; a member of the Governing Board, Knowledge Systems Institute, Skokie, IL; and an honorary member of the Academic Council of NAISO-IAAC.

Machine Learning in Cryptanalysis

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Extended Abstract

Cryptanalysis, the science and art of breaking secret codes, is both a mathematically intensive and a computational intelligence intensive subject. Code-breaking used to be purely a military or government task, and in fact, the main task of the US National Security Agency NSA) is \to collect, process and disseminate foreign signal intelligence". The term \signal intelligence" here is interpreted as \encrypted messages". Surprisingly, with the advent of Internet, cryptanalysis is no more just a military or government task, but also an important task in e.g., secure e-commerce, since all the sensitive and encrypted business communications over the Internet must be unbreakable.

Let us take the most famous and widely used cryptographic system RSA (for which its three inventors, Rivest, Shamir and Adleman received the Year 2002 Turing Award) as an example to see how computational intelligence can play an important role in the cryptanalysis of RSA. Given a plaintext M and the public-key $(e; n)$, where $n = pq$ with $p; q$ prime, and ed = 1 (mod $\phi(n)$)*:*

To get the RSA encoded ciphertext C, we perform the encryption process $C = M^e$ (mod n)*:* It is easy to decrypt the message if one has the decryption exponent d, since $M = C^d$(mod n)*:* However, it is extremely difficult to break the code if d is not known. The most straightforward way to recover M from C is to factor $n = pq$, since once p and q are known, we can compute $d = 1/e$ (mod $(p - 1)(q - 1)$)*;* and hence break the RSA code.

The problem here is that how to efficiently factor n is? It is well-known that there are many methods to factor n, but none of them can be performed in polynomial-time. At present, the most general and powerful factoring algorithms are all based one way or another on finding the suitable x and y in the following congruence $x^2 = y^2$ (mod n), since if so, we can successfully factor n by computing gcd(x+ *or* - $y; n$) = $(p; q)$ with probability at least 1/2. So, the new problem now is how to find the suitable x and y, which can lead to a successful factorization of n? We argue that this is exactly the place where advanced techniques from both mathematics and artificial intelligence or even physics can play a role.

In this talk, we shall first discuss the most powerful (so far the fastest) factoring algorithm, the Number Field Sieve (NFS) to factor n and to break the RSA code C. Although NFS employs some very complicated mathematical tools from algebraic number theory, it does not reduce the complexity of the computation, and in fact, it is of sub-exponential complexity $O(\exp(c(\log n)^{1/3}(\log \log n)^{2/3}))$, so it is hopeless to break RSA in polynomial-time. There should be at least two research directions to produce a faster factoring algorithm than NFS, one obviously is to develop some more powerful mathematical tools for factoring, the other would be use some techniques from artificial intelligence to find a quick and clever way for factoring (or even develop a new clever way to break RSA without factoring). In this talk, however, we should concentrate on the development of a new practical learning algorithm, based on Valiant's learning theory, which can be used to beak the RSA code.

Biography

Song Y Yan is currently Visiting Professor in the Department of Mathematics at Harvard University and MIT on a Global Research Award from the Royal Academy of Engineering London.

He is Professor of Computer Science and Mathematics, and Director of the Institute for Research in Applicable Computing at the University of Bedfordshire, England. His research interests include number theory, cryptography, and information security. In addition to more than 40 research papers, he published three well-received research monographs in number theory and cryptography by Springer-Verlag, which have a great impact on the field.

Agent-Based Virtual Organization

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Abstract

Recently we observe a surge in new technologies that are expected to change the way we process information and support workers in an organization. Two of them that are very often mentioned as "disruptive technologies" are: ontologies and software agents. In our recent project we attempt at conceptualizing the way in which these two technologies can be combined and utilized in information management within an organization. In the proposed approach a virtual organization is conceptualized in terms of roles to be played by agents, organization structure and information flow are represented in terms of agent-agent and agent-human interactions, while all resources (e.g. workers, brake pads, books, software artifacts, etc.) are ontologically demarcated. Finally, all information processing is semantically-driven. In the presentation current state of our work will be summarized.

Biography

Marcin Paprzycki is a Senior Member of the IEEE and Senior Fulbright Lecturer. He has received his M.S. Degree in 1986 from Adam Mickiewicz University in Poznań, Poland and his Ph.D. in 1990 from Southern Methodist University in Dallas, Texas. His initial research interests were in high performance computing and parallel computing, high performance linear algebra in particular. Over time they evolved toward distributed systems and Internet-based computing; in particular, agent systems. He has delivered more than 100 invited presentations at conferences and seminars and has published more than 250 research papers. He was also invited to Program Committees of over 300 international conferences and is a member of editorial boards of 15 journals and a book series.

Artificial Intelligence Techniques in Software Engineering

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Extended Abstract

Artificial Intelligence (AI) techniques have been applied in many areas of software engineering. However due to the complexity of software systems these techniques are usually considered in research laboratories and their use in industry is very limited. This talk provides an insight into applications of AI techniques in software engineering and how AI can assist in achieving ever competitive and firm schedules for software development projects. The pros and cons of using AI techniques are investigated and specifically the application of AI in software application development and software security is considered.

Organisations that build software applications do so in an environment characterised by increased pressure to reduce cost, reduce development schedules with every limit resources and tight deadlines. Organisations need to build software adequately and quickly. One approach to achieve this is to use automated software development tools from the very initial stage of software design up to the software testing and installation. Considering software testing as an example, automated software systems can assist in most software testing phases.

AI can also assist in software security and reliability. Data security, availability, privacy and integrity are very important issues in the success of a business operation. Data security and privacy policies in business are governed by business requirements and government regulations. Business requirements demand not only data security but also data accessibility and integrity. Implementing data security using data encryption solutions remain at the forefront for data security. Many solutions to data encryption at this level are expensive, disruptive and demand intensive resource. Using AI for data classification in organizations can assist in identifying and encrypting only the relevant data thereby saving time and processing power. Without data classification organizations using encryption process would simply encrypt everything and consequently impact users more than necessary. Data classification is essential and can assist organizations with their data security, privacy and accessibility needs. This talk explores the use of AI techniques (such as fuzzy logic) for data classification and suggests a method that can determine requirements for classification of organizations' data for security and privacy based on organizational needs and government policies.

Biography

Masoud Mohammadian research interests lie in adaptive self-learning systems, fuzzy logic, genetic algorithms, neural networks and their applications in industrial, financial and business problems. His current research concentrates on the application of computational intelligence techniques in software development and automation.

He has chaired over twelve international conferences on computational intelligence, intelligent agents and software engineering. He has published over ninety research papers in conferences, journal and books as well as editing and co-authoring twenty books and conference proceedings. Masoud has seventeen years of academic experience and he has served as program committee member and/or co-chair of a large number of national and international conferences. He was the chair of IEEE ACT Section and he was the recipient of many Awards from IEEE from USA and Ministry of Commerce from Austria.