John McCarthy – Father of Artificial Intelligence

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In this article we summarise the contributions of John McCarthy to Computer Science. Among his contributions are: suggesting that the best method of using computers is in an interactive mode, a mode in which computers become partners of users enabling them to solve problems. This logically led to the idea of time sharing of large computers by many users and computing becoming a utility – much like a power utility. The major contributions for which he is known is coining the term Artificial Intelligence to describe computer programs which seemingly exhibit intelligence, that is, computers perform tasks which when performed by humans require them to be intelligent. He was a life-long believer in using mathematical logic to describe knowledge, including commonsense knowledge, which led to the development of the subject of knowledge representation. He invented LISP (a programming language which has lived for over fifty years) to solve problems in Artificial Intelligence. Besides his technical contributions he was a great teacher and was instrumental in creating two famous schools in Artificial Intelligence: one at MIT and the other at Stanford.

Introduction

I first met John McCarthy when he visited IIT, Kanpur, in 1968. During his visit he saw that our computer centre, which I was heading, had two batch processing second generation computers – an IBM 7044/1401 and an IBM 1620, both of them were being used for 'production jobs'. IBM 1620 was used primarily to teach programming to all students of IIT and IBM 7044/1401 was used by research students and faculty besides a large number of guest users from several neighbouring universities and research laboratories. There was no interactive computer available for computer science and electrical engineering students to do hardware and

software research. McCarthy was a great believer in the power of time sharing computers. In fact one of his first important contributions was a memo he wrote in 1957 urging the Director of the MIT Computer Centre to modify the IBM 704 into a time sharing machine [1]. He later persuaded Digital Equipment Corporation (who made the first mini computers and the PDP series of computers) to design a mini computer with a time sharing operating system.

The first commercial time-sharing computer, PDP-1, was manufactured by DEC in 1959 [2] and one of the early computers was bought by McCarthy for Stanford's Artificial Intelligence Laboratory. McCarthy offered to donate this machine to the computer centre at Kanpur as Stanford was buying a better computer. I readily accepted the offer, even though I knew that maintaining an old machine solely with student power was not easy. The period 1968–75 was also a very difficult time in India as foreign exchange was scarce and there were many restrictions on buying computers. With assistance from the Kanpur Indo–American Progamme the PDP-1 arrived in 1969 and was installed in the computer centre at IIT Kanpur. It was the first time-shared computer to be installed in India. It was used for software development and many hardware enhancements were made by students. A unique feature of the PDP-1 was a program to play one of the first computer games called 'space war'. A large

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Figure 1. The console of PDP-1 computer. See the large CRT display and an IBM Selectric typewriter for interactive use of the computer. Courtesy: Image reproduced with permission from http:/edthelen.org/comp-hist/vs-dec-pdp-1.jpg

Cathode Ray Display along with a joystick was used to play the game. Many students got addicted to it. Interactive computing with a small number of electric typewriter based terminals was also a novel feature. McCarthy's visit and lectures inspired students to study computer science, one of them being N R Narayana Murthy who after attending his talks decided to specialize in computer science for his master's degree [3] at IIT Kanpur.

McCarthy's Journey Towards Artificial Intelligence

John McCarthy was born on September 4, 1927 in Boston, USA to John Patrick McCarthy, who had emigrated to USA from Ireland, and Ida Glatt McCarthy, who had emigrated from Lithuania. When the Great Depression started in the United States of America at the beginning of 1930 his parents were jobless for some time and after brief stints in New York and Cleveland settled in Los Angeles where the senior John McCarthy was employed as a labour organizer for the Amalgamated Clothing Workers and Ida was an activist in the women's suffrage movement. Both of them were active members of the Communist Party of USA [4].

John McCarthy was a child prodigy and even though he joined school late due to a childhood illness, he made up and finished school early. While in school he developed a deep interest in mathematics and applied to the California Institute of Technology for the BS programme. In his statement of intent he wrote one sentence, "I intend to be a Professor of Mathematics". He was admitted in 1943 and graduated in 1947 and continued his postgraduate studies in mathematics there. He attended Hixon symposium on 'Cerebral Mechanisms in Behavior' at CalTech in September 1948 [5] in which there were talks, among others, by famous mathematicians John Von Neumann, Alan Turing, Claude Shannon, psychologist Karl Lashley and brain scientist Warren McCulloch. Computers were just then being made and the discussions inevitably led to the comparison of computers with the brain. The discussions kindled McCarthy's interest in computers and the possibility of making them think like people.

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In 1949 he moved to Princeton University to pursue doctoral studies in mathematics. His thesis was related to the solution of partial differential equations. He was awarded a PhD degree in 1951 and stayed on there as an instructor. During the summer of 1952 McCarthy worked at The Bell Telephone Laboratories and requested Claude Shannon to collaborate with him to edit a collection of papers on machine intelligence. Shannon was well known for his work on switching theory and information theory [6]. He had also published one of the first papers on how computers can be taught to play chess. Shannon was conservative and was not keen on using the term intelligence and suggested that the collection be called *Automata Studies*. The collection was a potpourri of papers on diverse topics such as mathematical logic, neural nets and game playing. It was published in 1956 by the Princeton University Press [7] and is probably the first publication in the fledgling field of artificial intelligence (the term was coined later). McCarthy was not satisfied with this effort and wanted a better focus on the topic of building machines which could reason intelligently. He coined the term Artificial Intelligence and wrote a proposal on August 31, 1955, along with Marvin Minsky, Nathaniel Rochester, and Claude Shannon, to the Rockefeller Foundation titled, 'A proposal for the Dartmouth summer research project on Artificial Intelligence' [8]. It stated: "We propose that a 2 month, 10 man study of artificial intelligence be carried out during the summer of 1956 at Dartmouth College in Hanover, New Hampshire. The study is to proceed on the basis of the conjecture that every aspect of learning and any other feature of intelligence can in principle be so precisely described that a machine can be made to simulate it. An attempt will be made to find how to make machines use language, form abstractions and concepts, solve kinds of problems now reserved for humans, and improve themselves. We think that a significant advance can be made in one or more of these problems if a carefully selected group of scientists work on it together for a summer".

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computational complexity, self improvement, and randomness and creativity. The project was approved and brought together a group of researchers which included pioneers such as Newell, Simon, McCarthy, Solomonoff, Shannon, Minsky, and Selfridge, all of whom made seminal contributions to the field of Artificial Intelligence in later years.

Box 1. John McCarthy's Biography – Timeline

1927	Born in Boston, USA.
1943	Joins BS programme in mathematics at Caltech–graduates 1947.
1948	Attends Hixon Symposium on 'Cerebral Mechanisms in Behavior', at Cal Tech. It was attended among others by Turing, Von Neumann, and Shannon. Interest in how humans think and solve problems and the possibility of mechanizing this is kindled in him.
1949	Joins Princeton University graduate school in mathematics.
1951	Obtains PhD in mathematics – Princeton University.
1951–52	Instructor in mathematics at Princeton University
1952	Spends summer in Bell Telephone Laboratories. Collaborates with Claude Shannon and edits Automata Studies.
1952–55	Acting Assistant Professor of mathematics at Stanford University.
1955–56	Assistant Professor of mathematics at Dartmouth College.
1956	Dartmouth summer school in Artificial Intelligence – the term Artificial Intelligence coined along with Marvin Minskly (MIT), Claude Shannon (Bell Labs) and Nathaniel Rochester (IBM). Start of organized research in AI by Newell, Simon, McCarthy, and Minsky.
1956–57	Obtained Sloan fellowship to spend a year at MIT.
1957–62	Appointed Assistant Professor at MIT. Productive years. Designs LISP language, proposes time sharing of computers, and computer utility. Establishes AI laboratory at MIT along with Minsky. Starts work on commonsense reasoning and points out its importance in AI research.
1962	Moves to Stanford University as Professor of Mathematics.
1963	Moves to newly established department of Computer Science.
1963–2011	Associated with Artificial Intelligence Laboratory at Stanford. Contributions include extension of first order logic to accommodate non-monotonic reasoning, formal methods to represent knowledge, circumscription – ability to retract after jumping to conclusions, situation calculus – a language that facilitates action and change.
2011	Passes away at Stanford.

After he spent the summer of 1952 in Bell Labs, McCarthy worked for three years as an Assistant Professor of Mathematics at Stanford and was not given tenure (see *Box* 1). He shifted to Dartmouth College in 1955 as an Assistant Professor. He received a Sloan Fellowship to spend the period 1956–57 doing independent research. He chose to spend the year at MIT as it had one of the largest computers then (a first generation IBM 704). The frustration of using a batch processing machine to write programs for artificial intelligence research led him to write to the Director of the Computer Centre to modify 704 as a time-shared computer [1]. He was given a choice between directing the buiding of a time-shared machine or continuing his work in artificial intelligence. His passion was in the latter and he teamed up with Marvin Minsky who had also joined MIT in 1957 to set up an Artificial Intelligence Laboratory at MIT. He spent the period 1956 to 1962 at MIT which was one of the most productive periods in his career.

In 1956 all programming was done in assembly language. The first high level programming language appeared in 1957, namely, FORTRAN which was developed by John Backus at IBM. FORTRAN was primarily intended to perform numerical calculations. Artificial Intelligence (AI) programming required manipulating non numerical data and writing algorithms which were radically different from numerical algorithms. McCarthy set out to design a language suitable for AI and developed a language called LISP (LISt Processing) during 1957–59. The major characteristics of LISP are that it is based on lambda calculus of Alonzo Church and computes with symbolic expressions rather than numbers. LISP, along with FORTRAN, is a language which has survived for over 50 years which shows the soundness of its design. LISP, unlike FORTRAN, was not supported by any computer manufacturer. LISP pioneered many new ideas in computer science including list data structure, tree data structure, a common or same structure for program and data, higher order functions, dynamic typing, idea of recursion, automatic storage managements (which included the idea of garbage collection), and the idea that an

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interpreter for a language can be written using the language itself. LISP programs may be used as data by other LISP programs. A detailed discussion of LISP appears in an article by Karnik in this issue of *Resonance*.

While at MIT he also started work – which he continued lifelong – on applying formal logic to perform 'commonsense reasoning' which humans do all the time, seemingly effortlessly. To endow computers with this ability is a great challenge and McCarthy set out to solve this problem. Most other researchers were concentrating on endowing computers with the ability to play games and prove theorems which were easier to formalize. In a seminal paper titled 'Programs with Common Sense' [9], McCarthy argued about the need for computers to perform commonsense reasoning if they were to be considered intelligent. He also wrote on the need to represent formally using mathematical logic, commonsense knowledge along with an inference method to reason with this knowledge. When this paper was published it was controversial as critics pointed out that McCarthy's ideas were simplistic as reasoning with commonsense knowledge is not very easy as too many exceptions will arise in real life. (This criticism is valid as the general problem is still not fully solved.)

Commonsense Reasoning

Deductive reasoning in mathematical logic has a property called monotonicity. This property implies that if one starts with some assumptions and reaches a conclusion and later adds new assumptions there may be some new conclusions due to the new assumptions but the original conclusions do not change, that is, they remain valid. Many situations which we encounter every day, where reasoning is applied for solving problems, or producing answers, do not necessarily have this monotonicity property. For example, if you know that I go to office every day by car, you may conclude that you can request me for a ride. On a particular day my car may have a flat tire (which is new information that does not contradict the original assumption that I have a car), then you would conclude that you cannot ask me for a ride. However,

if I tell you that the flat tire will be changed in ten minutes you may change your conclusion back to the original conclusion. This is what is meant by non-monotonic property of reasoning in everyday activity of humans. Many critics of logical approach to AI pointed out this problem and concluded that formal logic was not an appropriate tool to be used in AI. McCarthy strongly disagreed and proceeded by supplementing formal logic with additional modes of non-monotonic reasoning. This formalization gives certain rules of conjecture rather than rules of inference. The conjectures will be correct until more facts are obtained which may force the system to withdraw these. The method was called *circumscription* [10] and is an important contribution of McCarthy.

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Second Innings at Stanford

In 1962 Stanford University invited him to return to the Mathematics Department. He agreed to come provided he was offered a full Professorship which the department did. A year later, a new Department of Computer Science was started at Stanford and he shifted there. He initiated AI activity and consequently established a full-fledged AI laboratory. A world famous school in AI started at Stanford with activities in robotics, speech processing, and knowledge representation. Over thirty students obtained PhDs working with McCarthy; many among them went on to win the Turing Award. Much of McCarthy's research in commonsense reasoning was done at Stanford.

Awards and Honours

John McCarthy was awarded the Turing Prize in 1971 by the Association for Computing Machinery, USA (considered equivalent to the Nobel Prize by computer scientists) for his pioneering work on Artificial Intelligence. Besides this, he obtained the Kyoto Prize in 1988, the National Medal of Science (USA) in 1990, and the Benjamin Franklin Medal given by the Franklin Institute in 2003. He was inducted into the AI Hall of Fame in 2011, and named as one of Stanford's Engineering Heroes. He

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was a member of the American Academy of Arts and Sciences (1984), the National Academy of Engineering (USA), (1987), and the National Academy of Sciences (USA) (1988).

Personality Traits

McCarthy was generous in sharing his ideas and articulating them effectively. He had a personal website [11], where in later years he published many interesting articles. One of them 'What is Artificial Intelligence' is in a question answer mode posing a number of questions which persons new to AI ask and McCarthy's answers. For example the first question is: "What is Artificial Intelligence?" He gives the answer: "It is the science and engineering of making intelligent machines, especially intelligent computer programs. It is related to the similar task of using computers to understand human intelligence, but AI does not have to confine itself to methods that are biologically observable". To "What is Intelligence?" he answers, "Intelligence is the computational part of the ability to achieve goals in the world. Varying kinds and degrees of intelligence occur in people, many animals and some machines". An interested student may like to read the answers to about 30 questions he has posed and answered.

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There are also a collection of many pithy sayings [11] of McCarthy in his website a few of which are given below:

• There is nothing so powerful whose idea has come – Victor Hugo. Yes, even if it is a bad idea – McCarthy.
• Personal dishonesty is not needed to produce a dishonest business plan or research proposal. Wishful thinking suffices.
• People prefer dealing with machinery to dealing with bureaucracies.
• There is only one thing more harmful to society than an elected official forgetting the promises he made to get elected; that's when he doesn't forget them.
• Writing a "future work" section of a paper is like a dog pissing on the trees at the boundary of its territory.
• When architects get prizes people suffer.

• He who refuses to do arithmetic is doomed to talk nonsense.

Last Days

John McCarthy officially retired from Stanford University on January 1, 2001. McCarthy however continued to be an active researcher. His last two doctoral students defended their theses in 2002 and 2003. He passed away on 24 October 2011 at his home in Stanford. He is survived by his first wife Martha Coyote and two daughters, Susan and Sarah, and his third wife Carolyn Talcott and their son Timothy. His second wife Vera Watson died in 1978 in an accident while climbing Annapurna in Nepal.

Acknowledgements

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Suggested Reading

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[2]   PDP-1 from Wikipedia, See also Computer History Museum PDP-1 Restoration Project for pictures of PDP-1.

[3]   N R Narayana Murthy, *A Better India: A Better World,* Penguin Books, India, pp.3, 4, 2009 (Personal Communication confirming that the Professor mentioned in the book is John McCarthy.)

[4]   John McCarthy (Computer Scientist) –Wikipedia.

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