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In memoriam

Marvin Lee Minsky (1927–2016)

Marvin Minsky
photo credit: Marie Cosindas

Almost a year ago now, on 24th January 2016, Marvin Lee Minsky passed away. Half a century earlier he was one of the founders of the new research field Artificial Intelligence; he also devised the first artificial neural network already in the 1950s and one of the first programmable robots. Even though the era of digital computers had just begun, Minsky didn't use them at this time for these projects. "On the one hand, I was afraid of the complexity of these machines. On the other hand, I thought that they weren't big enough to do anything interesting in the way of learning", he recalled in a long conservation with scientist and essayist Jeremy Bernstein, who published an article on Minsky in *The New Yorker* in December 1981 [1].

Shortly afterward he was fascinated by digital computers. He combined this fascination with his passion to understand how the brain works and to explore what is called "learning". From then on, these new machines had a significant impact on his life. Consequently, the journal *Wired* published an obituary that was written by a news-writing machine named *Wordsmith*, which "isn't exactly an AI. It takes structured data–stuff that fits into a spreadsheet–and fits it into templates of increasing complexity", as Adam Rogers, Articles Editor at *Wired*, wrote in that journal on January 26 [2]. This machine's obituary was very short and was written in a short time; in contrast, my human-written text spans more pages and required a long period of deliberation.

Born on 9th August 1927 in New York City into a Jewish family with the older sister Charlotte and the younger sister Ruth, Marvin Lee Minsky was a son of the physician, musician and painter Dr. Henry Minsky and his wife Fannie Reiser. His father was director of Mount Sinai Hospital's ophthalmology department in Manhattan, and there were lenses, prisms, diaphragms and other instruments at the family's home. Henry and Fannie's inquisitive son, Marvin, would take these instruments apart and his father would "quietly put them together again" [3].

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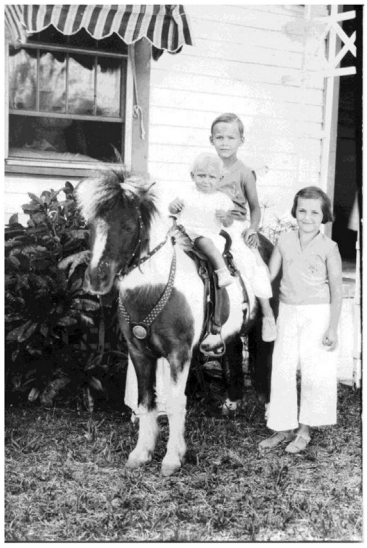


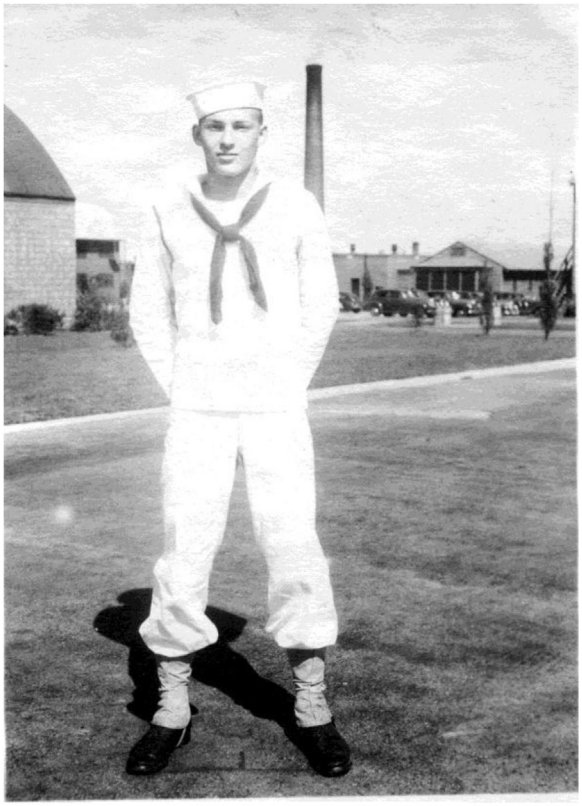
Left: Marvin as Young Boy c. 1937 to 1940, right: with younger and older sisters on Pony - Florida - 1932
photo by courtesy of Minsky family

Marvin first attended the Ethical Culture School in Manhattan and then the Fieldston School in Riverdale, where he finished the eighth grade in 1941. Even as a young boy he was interested in science, especially in electronics. In the autumn of 1941, he became an excellent student at the Bronx High School of Science, and in 1944 his parents sent him for his senior year to the private Phillips Academy in Andover, Massachusetts to prepare for college entry. In June of 1945, he finished school; he was 17 years old and World War II was still in progress. Minsky served for the U. S. Navy (1944/45) in the Great Lakes Naval Training Center because he was told that he would be sent to an electronics school. He was there for only two months, and, as he recalls, "there really wasn't anything to do, so we spent a couple of months chatting. I finished up my term of enlistment at a naval base in Jacksonville, Florida, and then I was discharged—in time for me to go to Harvard as a freshman" [1].

He started studies in 1946 in physics as well as biology, neurophysiology and neuroanatomy. He was astonished that he already knew the Harvard coursework in physics from his High School years, and he used the spare time to take courses in sociology, psychology and neurology.

Professor John Henry Welsh (1901–2002), who served as chairman of the Department of Biological Sciences from 1947 to 1950, let him do some laboratory work investigating how nerves in a crayfish claw worked. "At one point," Minsky recalls, "I had a crayfish claw mounted on an apparatus in such a way that I could operate the individual nerves. I could get the several-jointed claw to reach down and pick up a pencil and wave it around. I'm not sure that what I was doing had much scientific value, but I did learn which nerve fibres had to be excited to inhibit the effects of another fibre so that the claw would open. And it got me interested in robotic instrumentation—something that I have now returned to" [1].

Minsky was fascinated by questions surrounding the workings of the nervous system, the interconnections of the nerve cells, and the learning process. His wife, the paediatrician Gloria Rudisch,–they married in 1952–recalled many years later: "He said he wanted to know about how the brain worked. I thought he is either very wise or very dumb. Fortunately, it turned out to be the former" [4].



Marvin Minsky Sailor First Class - 1945
photo by courtesy of Minsky family

Minsky made the acquaintance of George Armitage Miller (1920–2012), who was then assistant professor of psychology with special interest in how language affects human cognition, and the mathematician Andrew M. Gleason (1921–2008), who was a Junior Fellow working on his PhD and, although only six years Minsky's senior, was already well recognized as a mathematician, particularly for his work on Hilbert's fifth problem concerning topological groups.

Minsky wanted to earn an undergraduate degree; however, this was not possible in the physics department so he switched to the mathematics department in order to write an undergraduate thesis. Inspired by Gleason, Minsky started working on a fixed-point problem and read about the Japanese-US-American Yale-mathematician Shizuo Kakutani (1911–2004), who had proved a generalization of the fixed-point theorem of Luitzen E. J. Brouwer (1881–1966), which was later called the *Kakutani fixed-point theorem*. "He recalled later: 'I became convinced that Kakutani had not got the most general result out of his logic'" [1]. Gleason was impressed by Minsky's work, which culminated in his B.A. thesis at Harvard in 1950 [5], and said "you are a mathematician ... therefore you should go to Princeton" [1].

In the next year, Minsky switched to Princeton for graduate studies, and he earned a PhD in mathematics in 1954 [6]. At Princeton, Solomon Lefschetz (1884–1972) was director of a project on ordinary nonlinear differential equations funded by the Office of Naval Research. However, Lefschetz afforded all graduate students the freedom they needed to do their own research.

Already as an undergraduate, Minsky dreamt of creating electronic machines that could learn by providing them with memory "neurons" connected to "synapses", and he had read the now famous article "A Logical Calculus of Ideas Immanent in Nervous Activity" written by Warren Sturgis McCulloch (1898–1969) and Walter Harry Pitts Jr. (1923–1969) [7], who proposed the first logical model of interconnected neurons building a network.

Minsky was intent on building such an artificial neural network machine, using tubes and motors that mimic in simplified form the synaptic wiring of the cells in a brain and simulate a learning system "like rats or something" finding their way through a maze.

When Minsky told George Miller, at Harvard, about this planned project, he managed to support it with some thousand dollars from the Office of Naval Research. In the summer of 1951 with the help of Dean Edmonds then a graduate student in physics, he designed such an abstract model of interconnected nerve cells. As Minsky recalled, they "worked out some circuits so that–in principle, at least–we could realize each of the neurons with just six vacuum tubes and a motor." The actual system "had three hundred tubes and a lot of motors. It needed some automatic electric clutches, which we machined ourselves. The memory of the machine was stored in the positions of its control knobs–forty of them–and when the machine was learning it used the clutches to adjust its own knobs. We used a surplus gyropilot from a B-24 bomber to move the clutches" [1]. When he brought this to mind a quarter century later he remarked "I didn't think that it would be very intelligent. I thought it would work pretty well with about forty neurons" [1].

This system became famous as the first neural network simulator: SNARC (Stochastic Neural-Analogue Reinforcement Computer). He finished his 564-page-PhD thesis "Theory of Neural-Analog Reinforcement Systems and Its Application to the Brain Model Problem" [8] under the supervision of Lefschetz's successor to chair of the mathematics department, the US-American mathematician Albert William Tucker (1905–1995) in Princeton. The mathematicians John Wilder Tukey (1915–2000) and John von Neumann (1903–1957) completed his thesis advisory committee.

In 1955 and as Harvard student, he could work in the Lyman laboratory of Physics. Here he developed a symmetrical microscope with an objective lens and a pinhole at either side of the specimen which eliminate the scattered and out-of-focus light. His reasons for developing the microscope were twofold and related: on the one hand, not much was known about neural networks; on the other, it was not possible to distinguish the neural networks due to the scattering of light using the imaging systems of that time.

In 1980 Minsky remembered: "To be sure, a good deal was known about the shapes of certain types of nerve cells, because of the miraculous way in which the Golgi treatment tends to pick out a few neurons and then stain all the fibres that extend from them. But this permits you to visualize only one cell at a time, whereas to obtain the required wiring diagram you need to make visible all the cells in a three dimensional region. And here was a critical obstacle: the tissue of the central nervous system is solidly packed with interwoven parts of cells. Consequently, if you succeed in staining all of them, you simply can't see anything. This is not merely a problem of opacity because, if you put enough light in, some will come out. The serious problem is scattering. Unless you can confine each view to a thin enough plane, nothing comes out but a meaningless blur. Too little signal compared to the noise: the problem kept frustrating me" [9].

For the invention and construction of the first Confocal Scanning Microscope, with better resolution and image quality than any microscopy apparatus before, Minsky applied for a patent in 1955 and was granted US Patent Number 3,013,467 in 1961.

During that time, Minsky was approached by some scientists who were planning to start a new department on systems analysis at Tufts University. Minsky was ready to join them; however, "Senator Joseph McCarthy made a vicious attack on several members of the group, and its funding vanished. But then Gleason came to me and said that I should be a junior fellow at Harvard" [1].

Gleason's nomination of Minsky to the select group of Junior Fellows at Harvard was supported by IAS-professor von Neumann; MIT-professors Norbert Wiener (1894–1964), the founder of the new interdisciplinary research field and author of *Cybernetics* [10]; and Claude E. Shannon (1916–2001), the author of "A Mathematical Theory of Communication" and with it the inventor of information theory [11].

During the three postdoctoral years at Harvard, Minsky's interest in the learning process of natural brains met the idea of reproducing human intelligence in a machine. This idea was originally proposed some years earlier by the British mathematician Alan M. Turing (1912–1954). The physicist Julius Robert Oppenheimer (1904–1976), who was then director of the Institute for Advanced Study (IAS) in Princeton, invited Minsky to lunch with Kurt Friedrich Gödel (1906–1978) and Albert Einstein (1879–1955), both members of the IAS, and, as Minsky reminisced many years later, "after that lunch I spent a year learning about Turing machines" [1].

In 1956 he published the paper "Some Universal Elements for Finite Automata" [12] in the volume "Automata Studies" that was edited by Shannon and a young professor at Dartmouth, John McCarthy (1927–2011). Minsky already knew McCarthy, whom he had met in Princeton as a fellow graduate student, and they had become friends.

The three researchers together with IBM's electrical engineer Nathaniel Rochester (1919–2001) worked out a plan for a conference and submitted a proposal to the Rockefeller Foundation:

"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 or 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

Marvin Minsky maybe with John McCarthy, maybe at British Museum
photo by courtesy of Minsky family

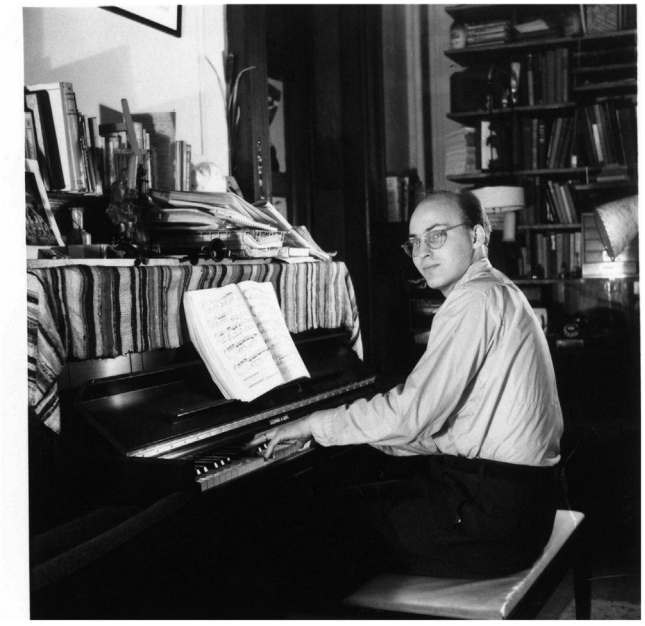
Marvin Minsky - Claude Shannon - Ray Solomonoff - Plus 2 - Dartmouth 1956 Conference
photo by courtesy of Minsky family

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" [13].

The application was successful and they were granted US $ 7500 funding, which included expenses and travelling costs for participants coming from a distance. The Dartmouth workshop took place in summer 1956 and among the organizing applicants seven further scientists took part: Raymond J. Solomonoff, Oliver Selfridge, Trenchard More, Arthur Samuel, Herbert A. Simon and Allen Newell. The latter two presented their computer program *Logical Theorist* too that could prove 38 of the first 52 theorems in the *Principia Mathematica* by Russell and Whitehead [14].

Today, the Dartmouth-workshop symbolizes the starting point of a new field of research, and it was McCarthy who coined the expression *Artificial Intelligence* for this research field.

After 1957 Minsky moved to the Massachusetts Institute of Technology (MIT), where he was to remain. First, he became a member of the staff in the Lincoln Laboratory, a centre for research operated by the MIT with the joint support of the U. S. Army, Navy, and Air Force. He pursued his interest in using computers to model and to understand human thought. In addition, John McCarthy had moved to MIT as a professor of electrical engineering. He had already invented and developed the LISP computer programming language and contributed to the development of time-sharing computer systems. In 1959 the two cofounded the Artificial Intelligence Laboratory (AI Lab), which was then emerged with the Laboratory for Computer Science to form the MIT Computer Science and Artificial Intelligence Laboratory (MIT CSAIL) in 2003.



Marvin playing the Piano in the late 50s or 60s
photo by courtesy of Minsky family

For the first issue of the journal *Proceedings of the IRE* in 1960, Minsky had been requested to write a summary on the state of the art of what is called "artificial intelligence". The result was his long article "Steps Toward Artificial Intelligence" [15], in which he outlined five essential skills for A.I.–search, pattern-recognition, learning, planning, and and how they could be construed to be processable by a computing machine. The last section of this 23 pages article is entitled "Models of Oneself", and it started as follows: "If a creature can answer a question about a hypothetical experiment, without actually performing that experiment, then the answer must have been obtained from some submachine inside the creature. The output of that submachine (representing a correct answer) as well as the input (representing the question) must be coded descriptions of the corresponding external events or event classes. Seen through this pair of encoding and decoding channels, the internal submachine acts like the environment, and so it has the character of a "model." The inductive inference problem may then be regarded as the problem of constructing such a model" [15]. No later than at this point, he started thinking about philosophical issues in Artificial Intelligence.

Minsky's change of direction from more mathematical and pure scientific to more philosophical analysis was initiated around the second half of the 1960s. In his book *Computation: Finite and Infinite Machines* [16], published in 1967, he gave a good introduction for undergraduate students into the subject of computability whereas in his paper "Matter, Mind, and Models", published in 1965, he addressed "questions about the relation between mind and brain", and, according to him, "some of the necessary technical and conceptual tools are becoming available as a result of work on the problems of making computer programs behave intelligently" [17]. In this paper, he gave a philosophical analysis on models and self-models, he analyzed the problem of making self-aware machines, and he commented on free will.

Around this time, in 1963, the South African mathematician Seymour Aubrey Papert (1928–2016) became a research assistant at MIT. He came from the University of Geneva, where he had assisted the Swiss clinical psychologist Jean Piaget (1896–1980). At MIT Papert continued to work on theories of constructivist learning. He started collaborating on new research in human perception, child psychology, experimental robots, and the theory of computation with neurophysiologist and cybernetician McCulloch, who had worked with Wiener at the MIT Research Laboratory of Electronics since 1952. In 1967 he became professor of applied mathematics and co-director of the MIT Artificial Intelligence Laboratory. Minsky and Papert collaborated for many years. Together they developed a computer language for children, LOGO, and they founded a company to sell LOGO and a hardware "turtle" to schools; however, they were not successful for long: "Seymour and I weren't very good at getting people to part with their money," Minsky recalled [1].

Three years after Minsky's publication of the first neural network simulator (SNARC), a new electronic device emerged that could solve a classical problem that any artificial neuronal network was supposed to solve, the classification of patterns. Psychologist Frank Rosenblatt (1928–1971) had invented this machine named "Mark I Perceptron", which was funded by the United States Office of Naval Research in 1957 at the Cornell Aeronautical Laboratory in Ithaca, New York.

Marvin Minsky and John McCarthy
photo credit: Lotfi A.Zadeh

He described this early artificial neuronal network in an essay for the *Psychological Review* as the first model of a neuronal network that was capable of learning and in which it could be shown that the proposed learning algorithm was always successful when the problem had a solution at all. [18]

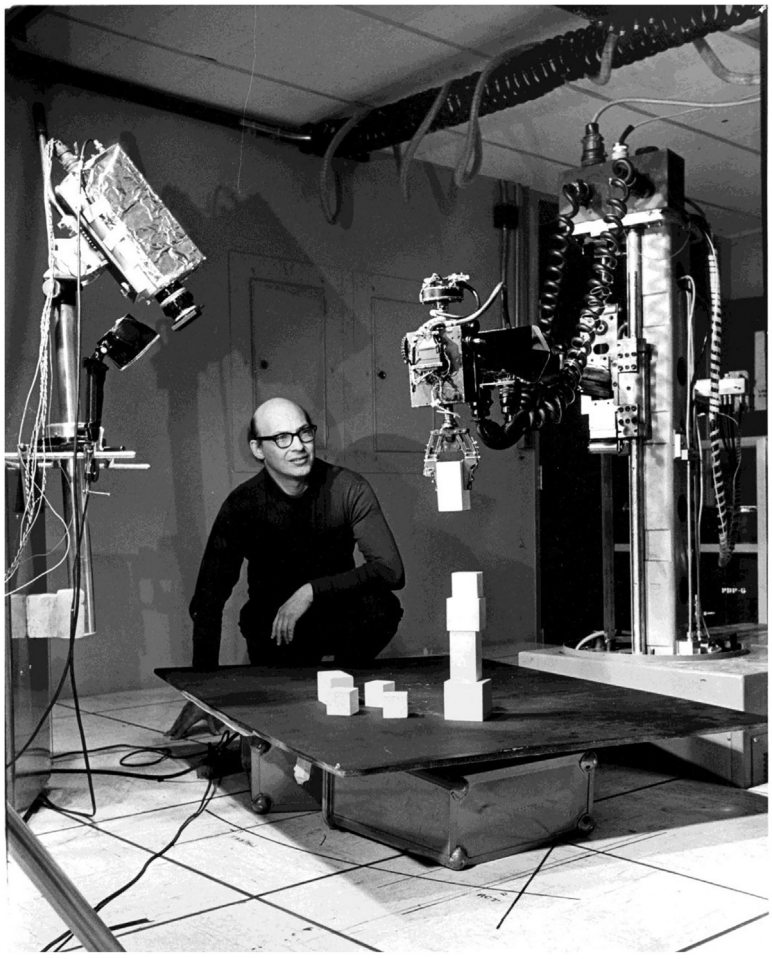
The Perceptron had appeared to be a universal machine and Rosenblatt had also heralded it as such in an essay for *The New Scientist* in 1958: "For the first time, we have a machine which is capable of having original ideas. ... As an analog of the biological brain, the perceptron ... seems to come closer to meeting the requirements of a functional explanation of the nervous system than any system previously proposed" [19].

The euphoria came to an abrupt halt in 1969, however, when Minsky and Papert completed their four-year study of Perceptron networks. They "set out to kill the Perceptron, or, at least, to establish its limitations–a task that Minsky felt was a sort of social service they could perform for the artificial-intelligence community" [1]. The results of the mathematical analysis to which they subjected Rosenblatt's Perceptron were devastating: artificial neuronal networks like those in Rosenblatt's Perceptron are not able to overcome many different problems! In 1969 they published their findings in the book *Perceptrons* [20].

In 1963 John McCarthy left MIT and started the Stanford University Artificial Intelligence Laboratory. In the same year, Stanford acquired the first artificial and computer-controlled arm robot, which was developed at Rancho Los Amigos Hospital in Downey, California, as a tool for handicapped people. It was the first robot arm of a long series, including Stanford's "Orm robot" (1965), built by mechanical engineering students Larry Leifer and Victor Scheinman. Later Scheinman construed another Stanford Arm robot (1974) and in 1968, Minsky also created a robotic arm that was part of a machine equipped with a video camera and a computer, which was designed to build with children's blocks. This tentacle arm can be seen in a video recorded in this year [21].

This work gave rise to a model of diverse simple mechanisms, called *agents*, which are themselves mindless but show intelligence in their interaction. Based on this idea, Minsky proposed that the human mind is composed of a multitude of little processes called "agents."

Again in collaboration with Papert, he elaborated on this idea. He argued that the agents' interactions constitute a "society of mind", an expression that was to form the title of his book *The Society of Mind*, which was published in 1986 [21]. In this book, he expresses his idea as follows: "Each mental agent by itself can only do some simple thing that needs no mind or thought at all. Yet when we join these agents in societies–in certain very special ways–this leads to true intelligence" [22]. 20 years later he finalized his last book, *The Emotion Machine*, which presented an elaborated and expanded view of how this society of minds works [23].



Marvin Minsky - Block Blocks Vision Robot MIT
photo by courtesy of Minsky family

Before pursuing this line of inquiry, Minsky had written another book *A Framework for Representing Knowledge*, published in 1974 [24]. He took the word "framework" in the title literally. In this new approach to AI, a new model of knowledge representation was set out. *Frames* are data structures which represent phenomena in cognition, language understanding, and visual perception; they divide knowledge into substructures by representing "stereotyped situations". With this new approach he again opened up new avenues of investigation for AI.

Minsky co-directed the AI Lab until 1974, the year when he became Donner Professor of Science (until 1989), and in 1990 he became Toshiba Professor of Media Arts and Sciences at the MIT Media Laboratory.

Minsky left behind his wife Gloria and three children, Margret, Julie und Henry Minsky, a sister and four grandchildren. Their house was a meeting point for a large and active circle of friends. Among them were the physicist Richard Feynman (1918–1988) and science fiction writers Robert Anson Heinlein (1907–1988), Isaac Asimov (1919–1992), and Sir Arthur Charles Clarke (1917–2008). The latter can easily be linked to the filmmaker Stanley Kubrick (1928–1999), who finished his movie "2001: A Space Odyssey" in 1968. The film was partially inspired by Clarke's short story "The Sentinel", and Clarke and Kubrick wrote the screenplay for the movie while Minsky acted as an advisor on AI-matters. In the movie, the character Victor Ka[*M*]*insky* was named in honour of Minsky, and he was mentioned in both Clarke's novel as well as in the movie. He was certainly in the frame!

Marvin Lee Minsky won the A. M. Turing Award (1969), the Japan Prize (1990), MIT's James R. Killian Jr. Faculty Achievement Award (1989–1990), the Royal Society of Medicine's Rank Prize (for Optoelectronics) (1995), the Computer Pioneer Award from IEEE Computer Society (1995), the Optical Society of America's R.W. Wood Prize (2001), and the Benjamin Franklin Medal (2001). In 2006, he was inducted as a Fellow of the Computer History Museum in Mountain View, CA, US; and, in 2011, he was inducted into IEEE Intelligent Systems, AI's Hall of Fame. In 2013 he received the BBVA Foundation Frontiers of Knowledge Award in the Information and Communication Technologies category. In the following year, he won the Dan David Prize for "Artificial Intelligence, the Digital Mind".

Marvin at Organ with his wife Gloria
photo by courtesy of Minsky family

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