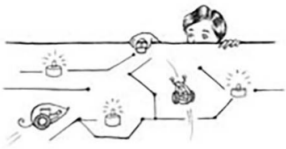
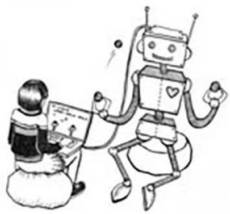


Inventive Minds

Marvin Minsky on Education



Marvin Minsky
edited by Cynthia Solomon and Xiao Xiao
illustrated by Xiao Xiao

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Inventive Minds

Marvin Minsky on Education

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The MIT Press
Cambridge, Massachusetts
London, England

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This book was set in ITC Stone Serif Std by Toppan Best-set Premedia Limited. Printed and bound in the United States of America.

Library of Congress Cataloging-in-Publication Data

Names: Minsky, Marvin, 1927-2016, author. | Solomon, Cynthia, editor. | Xiao, Xiao, editor.
Title: Inventive minds : Marvin Minsky on education / Marvin Minsky ; edited by Cynthia Solomon and Xiao Xiao ; illustrated by Xiao Xiao.
Description: Cambridge, MA : MIT Press, [2018] | Includes bibliographical references and index.
Identifiers: LCCN 2018011627 | ISBN 9780262039093 (hardcover : alk. paper)
Subjects: LCSH: Critical thinking--Study and teaching. | Thought and thinking--Study and teaching. | Learning, Psychology of. | Minsky, Marvin, 1927-2016
Classification: LCC LB1590.3 .M555 2018 | DDC 370.15/2--dc23 LC record available at https://lccn.loc.gov/2018011627

10 9 8 7 6 5 4 3 2 1

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Acknowledgments

We are immensely grateful to Marvin Minsky for writing his thoughts on children and education. We are also grateful for Seymour Papert and his collaboration with Marvin.

This book would not have happened without the input and support of Gloria Rudisch and Margaret Minsky. Gloria, a pediatrician and public health practitioner, was also Marvin's wife. She was extraordinarily helpful as the book slowly came together. She graciously allowed us to work from the Minsky home in Brookline, Massachusetts, and was always ready to read and offer feedback on our drafts. Margaret, our close colleague and friend, is also Marvin's elder daughter. Deeply familiar with her father's work and life, Margaret has been an invaluable resource and sounding board throughout this project.

We are greatly indebted to all our contributors: Mike Travers, Alan Kay, Hal Abelson, Gary Stager, Brian Silverman, Walter Bender, Patrick Winston, and Margaret Minsky. Thanks to their understanding and appreciation of Marvin, each of their essays brought out new facets of Marvin's words.

Cynthia thanks several people who played major roles in this project. Artemis Papert and Brian Silverman were critics, editors, and cheerleaders, as were Derek Breen, Allison Druin, and Dylan

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Holmes. Anna Cullen-Voyatzakis, Belinda Berman-Real, Sandra Avola, and Sherry Thompson were also extremely supportive and encouraging.

Xiao gives special thanks to Idit Harel for her advice, encouragement, and anecdotes. Many of Xiao's own views on the art of learning came from interactions and conversations with Donal Fox and the late Edith Ackermann. Insights from Donal on music learning inspired several illustrations in essay 5. Xiao is grateful to her former advisor, Hiroshi Ishii, for the freedom to explore her interest in learning in her doctoral thesis, and for the appointment of Research Affiliate at the MIT Media Lab while working on this book. Xiao also thanks Danbee Kim, DonDerek Haddad, and Briana Eden for their suggestions, motivation, and loving support.

We thank our families—for Cynthia: Erric Solomon, Jon Solomon, Eva Hopf, Sandi Slone, Bruce Ehrmann, and Luwen Solomon, and for Xiao: Xiaocheng Wu, Ke Xiao, Yongji Li, Xianda Wu, Xiaomei Wu, Jianghai Han, and Andy Han.

We also thank the Minsky extended family—Richard Amster, who was an invaluable resource in helping us review our book contract; the Minsky grandchildren, Miles Steele, Charlotte Minsky, Gigi Minsky, and Harry Minsky, each an inventive mind and all an inspiration; and other Minsky family members including Oliver Steele, Julie Minsky, Lance Rushing, Henry Minsky, Milan Minsky, Richard Amster, and Ruth Amster for their support.

This book is part of a broader effort led by Margaret Minsky to archive Marvin's life and work. Others who have been involved in that effort include Yoshiki Ohshima, Brian Bradley, Richard Amster, Teresa Marrin Nakra, Paula Aguilera, Jonathan Williams, Ruben Marques, and Rodrigo Santos. Their work has been an invaluable resource for us. Heikke Ruuska has also been very helpful.

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Many thanks to Mel King and Susan Klimczak at the South End Technology Center for hosting several of our work sessions. In particular, we thank David Cavallo for his reminders of Seymour, Ed Baffi for his input on titles, and Harlem Cruz for equipping us with a workspace.

Last but not least, we thank Susan Buckley and Noah Springer at the MIT Press and Chris Bourg at the MIT Libraries for their belief in the value of Marvin's ideas on learning and education. We are deeply grateful for their support in bringing this book to life.

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In 1985, Minsky published *The Society of Mind,* a book in which 270 interconnected one-page ideas reflect the structure of the theory itself. In 2006, he published a sequel, *The Emotion Machine,* which proposes theories that could account for human higher-level feelings, goals, emotions, and conscious thoughts in terms of multiple levels of processes, some of which can reflect on the others. By providing us with multiple different "ways to think," these processes might account for much of our uniquely human resourcefulness.

In addition to his technical achievements, Marvin was an accomplished classical pianist. He taught himself to improvise in the style of Bach and Beethoven, and continued to play until his death on January 24, 2016.

Marvin's own formal schooling played an important role throughout his life, and so we list it here.

The Fieldston School, New York

Bronx High School of Science, New York

Phillips Academy, Andover, Massachusetts

United States Navy, 1944–1945

B.A. Mathematics, Harvard University, 1946–1950

Ph.D. Mathematics, Princeton University, 1951–1954

Junior Fellow, Harvard Society of Fellows, 1954–1957

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Preface

Cynthia Solomon

> Computer Science is not only about computers themselves; more generally, it provides us with a whole new world of ways to understand complex processes—including the ones that go on in our own mind. For until those new techniques arrived (such as programming languages for describing processes, and data structures for representing knowledge), we had no expressions that people could use to articulate—and then communicate—good new ideas about such things.
>
> —Marvin Minsky[1]

Marvin Minsky is known worldwide as a cofounder of the field of artificial intelligence (AI). For Marvin, AI was not about creating machines with only the surface appearance of intelligent behavior. He was interested in making machines that mimic how humans think. At heart, Marvin's vision for AI was always a quest to unravel and understand the mysterious mechanisms behind the human mind. His books *The Society of Mind* and *The Emotion Machine* proposed elegant theories explaining the diverse dimensions of human thinking including common sense, emotions, perception, action, and how thinking evolves in an individual over time.[2]

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Marvin's insights about the mind are relevant not only for creating intelligent machines, but also for providing new perspectives on children's learning and thinking, as well as on the role of computers, both in education and in schools. These are the topics explored by the essays in this book.

Marvin Minsky and Seymour Papert

When I think about children I cannot help but think about Seymour Papert and his statement that "you can't think about thinking without thinking about thinking about something."[3] Known for his pioneering work in bringing computers to children and rethinking school, Seymour was a close colleague of Marvin's for many years. They codirected the Artificial Intelligence Laboratory at MIT, collaborated on countless projects, and co-advised many students in both the MIT AI Lab and the MIT Media Lab.

In reading the essays in this book I am reminded of how much Marvin and Seymour thought alike. A kind of proof is in the story of how they met at a conference in England in the summer of 1960. Without prior knowledge they gave almost identical papers—on learning in random nets. Their shared outlooks resonated throughout their work both together and individually over the next forty years.

This similarity in thinking may not be obvious for those who did not know the two personally. They both thought about using computers to make artificial intelligence and also to enhance people's learning and ways of thinking. Even though both of them were fascinated by the mind and by learning, their priorities differed. Marvin's goal was to create machines that could think like people while Seymour focused on machines as a

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Marvin Minsky (left) and Seymour Papert (right)

means to empower children to think about their own thinking. This collection of essays illustrates their overlapping interests in learning and education.

In a nutshell, Seymour's writings concentrated on the "outside" (e.g., schools, social situations, environments) while Marvin's centered on the "inside" mechanisms of the mind. This difference can be traced in part to their imprimers. For Marvin it was Freud, whom Marvin saw as the first person in history to have theories of mind that one could work with, whether they were right or wrong: there are different parts of the mind and executive systems for managing them. For Seymour it was Piaget, who showed that children are not empty vessels. For Piaget, children have theories that are different from those of adults but, with age

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Seymour Papert and Cynthia Solomon

respectively. Marvin was involved in the creation of the first floor turtle and built the music box controlled through Logo.

In 1970–1971, Seymour and I taught fifth graders. We had a new version of Logo that talked to a "display turtle," a "floor turtle," and Marvin's music box. Kids could compute, write, make line drawings, animate, and make music. By 1972, the lab built a completely new Logo environment on a time-shared Digital

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Cynthia Solomon teaches Logo

Equipment Corporation (DEC) PDP-11 with turtle-graphics terminal stations.

We ran into trouble with the cost of the hardware and its scarcity, so in 1972, we started a company called General Turtle to make our own turtles and music boxes. Marvin got the idea of making a Logo turtle-graphics computer. The 2500, as it was called, used vector graphics and provided a new extension to

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turtle graphics. By this time it was the mid-70s, when the Altair and a new generation of standalone desktop computers were coming into being.

The next time Marvin, Seymour, and I (along with a couple of other people) formed a company was in 1980. Logo Computer Systems' first job was to make a Logo for the Apple II Computer. I directed the group, most of whom had been part of the Logo Group at MIT. I also wrote an introductory book for turtle graphics.

Marvin and Me

My next step was to start the Atari Cambridge Research Lab under the aegis of Alan Kay. The Boston office of Logo Computer Systems closed and most of those folks joined me at Atari where we were building the *PlayStation of the future*. This core contingent of Logo employees had been part of the push to make Apple Logo commercially available. That job done, we were now free to rethink the language and its environment. Marvin was our major advisor.

Most of this group had a shared history of collaborating with each other, and with both Marvin and Seymour. We had a vision of building a new object-oriented Logo with modules for color vector-graphics, animation, and music construction. We experimented with peripherals such as a force-feedback joystick and created one of the earliest force-sensing screens.

Logo Computer Systems in Montreal made a commercial version of Logo for the Atari computer. Margaret Minsky and I decided to publish a growing collection of interesting Atari Logo programming projects created by our friends, and Marvin wrote a preface.[5] It is essay 1 in this book.

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The Atari Lab, as glorious and productive as it was, only lasted about two years, and closed just as the MIT Media Lab opened. Marvin and Seymour were two of the founding faculty of the Media Lab.

I followed a different path, finishing up my doctorate and teaching children. Several years later, Marvin and I rejoined our efforts with children and computing through One Laptop per Child (OLPC), which was an ambitious project founded by Nicholas Negroponte, Seymour, and partners. Its mission was to empower children in developing countries to learn by providing laptops to every school-age child. One of Marvin's contributions to OLPC was a series of essays on education. They are essays 2 through 6 in this book.

How This Book Came About

Marvin had posted his writing on his website. Most were published elsewhere, but these essays on education were released in now-defunct media. The book containing essay 1 is now out of print. Essays 2 through 6, written for One Laptop per Child, were not widely publicized. Given the new wave of interest in computer science education, these essays are more relevant than ever. I invited a group of leading thinkers in their fields to comment on Marvin's essays. Some are educators, others are pioneering researchers in computing and AI, and all knew Marvin well. Here are the people I chose to comment on each of the essays:

Alan Kay met Marvin in 1968 and was captivated by Seymour and Marvin's thoughts on children's learning. That year he also visited the seventh grade Logo math class Seymour and I taught. In 1970 as he began work on Smalltalk, the Alto, and the Dynabook at Xerox PARC, he visited us again observing fifth graders

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programming floor and display turtles and making music. His Smalltalk world would include graphics, animation, music, debugging aids, and editors for children.

As Chief Scientist at Atari, Inc., Alan asked me to set up the Atari Cambridge Research Lab near MIT in 1982. When the Atari Lab closed in 1984, Alan and three staffers became part of the just-forming MIT Media Lab, where Marvin and Seymour were part of the founding faculty.

Hal Abelson joined the MIT AI Lab's Logo Group when it was first formed in 1969 and was a major contributor to the development of turtles and turtle geometry. As a professor he and Gerry Sussman, one of Marvin's outstanding undergraduate and graduate students, developed the introductory MIT programming course 6.001. As part of the AI Lab, Hal influenced and was influenced by Marvin.

Gary Stager is a wonderful outspoken advocate for children. He has been a major contributor to the Logo community since the early 1980s through his writings and workshops. He worked closely with Seymour and was one of the main teachers in Seymour's Maine juvenile jail project. There, his students' projects included a range of programming projects, self-reflective writing, and robotics. His Constructing Modern Knowledge summer workshop was held for the tenth consecutive year in July 2017. Marvin participated in the first eight workshops where participants spent an evening at the MIT Media Lab and an hour with Marvin asking him questions on an open range of topics.

Brian Silverman, as an undergraduate at MIT, built with Danny Hillis a tic-tac-toe computer out of Tinkertoy parts. Along with Danny, Margaret Minsky, and other MIT classmates, he had several discussions about this book with Marvin. In the late 1970s,

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with Marvin. I had caught her drawing in a sketchbook while in his living room, and so I enticed her to illustrate this book.

Marvin and Education

In these six essays, Marvin shares his wisdom about children, learning, school, and computation. He emphasizes computers not only as tools for learning typical subject areas like math but also as offering opportunities for children to learn "*good ways to think about thinking*" itself. One way of doing this, Marvin suggests, is "to get children to think of themselves as though they were programmed computers" (essay 4). For instance, in my Logo classes children were asked to "play turtle" or to become researchers collecting both computer and human bugs, to talk about necessary debugging steps, and at times to recognize that some bugs can be features.

Another one of Marvin's ever-sharp observations is about teaching: "instead of promoting inventiveness, we focus on preventing mistakes." In teaching children arithmetic, he suspected that "this negative emphasis leads many children not only to dislike Arithmetic, but also later to become averse to everything else that smells of technology (essay 2).

Unsurprisingly, these essays are relevant to today's discussions about school, computers, and learning. I assume most readers have thought about the issues raised here; Marvin adds a refreshing perspective. We leave it to you to bring in your knowledge of other writers and researchers offering similar, or contrary, points of view. Enjoy Marvin's wisdom.

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Introduction

Mike Travers

> When your ideas seem inadequate, remember someone more expert at this, and imagine what that person would do.
>
> —Marvin Minsky (Essay 4)

We have some preconceived ideas about genius—that it is a divine mystery, a gift given to just a few, something both inexplicable and inaccessible to ordinary people. Marvin Minsky was a recognized genius, but it was the nature of his particular form of genius to question the very idea of innate talent and aptitude and the mystifications that surround it. To Marvin, the idea that the mind (or anything else) was beyond explanation was an affront and a challenge.

Marvin was brilliant in numerous ways aside from the work on artificial intelligence for which he is best known: he was an accomplished inventor, mathematician, and musician. But his big trick was to face squarely the mechanical nature of the human mind and not be alarmed by it. Indeed, he found it rather delightful and intriguing. This put him at odds with standard-issue humanists, which suited him just fine. But Marvin himself was not in any way inhuman, far from it. He was an extremely warm and welcoming individual, and always willing to engage

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with anyone's open mind. For example, he was active in Usenet discussion groups (chiefly comp.ai.philosophy), where he would explain or argue his views on AI with all comers regardless of their academic qualifications.

Marvin had a unique talent for reflecting on mental processes and coming up with plausible mechanisms that might explain how they worked. He applied this ability to his own mind, of course, but also to the thinking of his students, mentors, colleagues, and friends. He delighted in the cleverness of mental machinery, and sought to understand it by modeling it and encouraging others to share in the task of self-understanding.

Minsky is usually identified with computer technology and artificial intelligence, but there is little in the following essays that is specifically about digital technology or, indeed, technology of any sort. Their focus is on the psychology of learning, and the nature of systems that are capable of learning. He hoped to build computers along these lines, but his inspiration was the human mind, and these essays are both reflections on how minds work and concrete suggestions for ways to reorganize education to better support them—in some cases by involving the intelligent deployment of computer technology, to be sure, but never as the central focus. Technology is merely a tool in pursuit of better understandings, and computer programming merely the best available language for expressing new ideas about how minds work.

Minsky's last two books, *Society of Mind* (SOM) and *The Emotion Machine* (TEM), were both crammed with simple, concrete, and powerful ideas for how minds—both natural and artificial—might be constructed, distilled from decades of work building computational models and guiding the work of others. Both were essentially technical books written in nontechnical language—

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a choice that may have caused some problems with their reception, as people did not quite know how to read them. But in this and in many other ways, Marvin gleefully ignored the standard boundaries and rules.

Situating These Essays

Five of the essays collected here emerged from Marvin's participation in the One Laptop per Child (OLPC) project, a massive effort to put computational technology in the hands of the world's children.[1] Marvin saw this as an opportunity to fix some of the ingrained bad habits of the educational system. For instance, essay 5 opens with the suggestion that the educational focus on broad general education is misplaced, and children would be better served by a system that allowed them to specialize and dive into a single topic they cared about deeply.

Regardless of the practicality of this idea, it's notable in what it indicates about his approach to learning. To Marvin, students were not empty vessels to be filled with knowledge, nor poor approximations of fully developed adults, but instead understood as fully active agents and creators of their own minds. As such, they needed to hone their mental skills on the kind of demanding tasks that come with intense pursuit of some personal goal. Traditional education provides content, but creators require methods and tools.

Marvin was finely attuned to the power of ideas, both good and bad, and the OLPC project was a chance "*to provide our children with ideas they could use to invent their own theories about themselves*" (essay 6).This was a call for a model of education entirely in tune with the ancient Greek injunction to "know thyself." Marvin saw that computers and computational ideas have

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Minsky details some of his early fascination with the construction sets of his childhood: Tinkertoy, Meccano, and so on. From this came the central insight that simple parts could be used to construct arbitrarily complex structures, and that these structures had properties of their own, independent of the nature of their components. Brains, minds, and computers all share this compositional quality, although with the latter we have the advantage of being able to know exactly what the parts are, how they behave, and how they relate to each other and to the overall properties of the system.

Programming languages are also construction kits, with parts that children can recombine in novel ways. Systems like Logo and Scratch act as procedural Tinkertoys, enabling exploration, modeling, and discovery in a new and dynamic domain.

A computer made out of Tinkertoys can implement the exact same computation as one made out of circuitry—and so we assume a properly constructed computer could implement the same kinds of mental processes as the brain. With systems composed of parts, the important thing is the relationship between them, not the physical substrate they are made of.

The universality and substrate-independence of computation, the equivalence of computation to any effective process, and the equivalence of computation and mental activity are all deep, powerful, and in some cases controversial ideas. In an educational context, we do not expect to settle these questions—but giving children the tools to make models of their own thinking and behavior allows even the very young to engage with these fundamental issues.

Other Minds

Social processes are crucial to developing high-level goals, and Marvin has a number of insightful critiques and proposals in

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this area. Consider a term he coined: *imprimers*—the people from whom one learns foundational goals and values. These can be parents, teachers, or peers, but in any case they play a key role in learning because the goals they impart serve to focus and drive everything else a mind does.

Marvin's emphasis on the social nature of learning might come as a surprise to those accustomed to the usual emphasis on the mechanisms of individual minds that is the default methodological stance of AI. Certainly the AI of Marvin's period of greatest activity did not pay a great deal of attention to the social embeddedness of learning and intelligence. But Marvin was not one to let the current limits of computation interfere with his forward-looking theories of mind. More recently, the social transmission of goals has resurfaced as the focus of attempts to mitigate the supposed existential risks of AIs by achieving "value alignment."[2]

Networks as Escape

The vision of OLPC was to build not only a computer for all the world's children but also a network that would connect them with each other and with the wider culture. Marvin saw this as an opportunity for the intellectually inclined student—so often neglected and bullied in mainstream school culture—to find remote mentors or peers on the net. This vision has been realized to some extent by the later development of online learning communities,[3] such as the one centered around the Scratch programming environment from the Lifelong Kindergarten Group at the MIT Media Lab (http://scratch.mit.edu).

Multiplicity

> Until you understand something more than one way, you don't really understand it.[4]

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> It's also important to know multiple ways to represent things, so that if one method gets stuck, you can switch to another.
>
> —Marvin Minsky (Essay 5)

Individual minds are composed of a multiplicity of different parts that are skilled in different ways of thinking. And because everyone's mix is different, individual learners must necessarily develop their own cognitive styles.

One recurrent theme of Marvin's writing on learning is how wonderful it is to find new, nonstandard ways of solving problems—and how the standard model of education tends to suppress such methodological creativity in favor of teaching a single, supposedly right way to do things. The constructionist model of education upends this approach by giving learners a rich set of combinatorial parts that facilitates exploring a space of possible approaches.[5]

The Centrality of Reflection

> Human Minds think about what they're thinking about. … I'm convinced that these "self-reflective" processes are the principal ones that people use for *developing new ways to think*.
>
> —Marvin Minsky (Essay 6)

If there is one grand unifying idea to Marvin's techniques for generating insight and his proposals to fix education (and he might have denied that there was), it is the central importance of reflection: thinking about thinking. Everyone necessarily has to think about their own thinking—it's part of being a human being—but most of our ideas about ourselves are not that good and can be improved.

Minsky believed that computers could be a tool for reflection but also that reflexive heuristics could be identified, named, and

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taught. The role of computers in education is not merely to be a substitute for teachers or libraries but to be a language and toolkit for creating models, and particularly self-reflective models. And the product of the attempts of Minsky and Papert and their many students to realize this vision is not improved math scores but children who can think deeply about processes, systems, and themselves.

Conclusion

Digital technology has revolutionized the world in many ways and is continuing to do so as it evolves. But one of the key insights of the early AI days seems in danger of getting lost—that computational ways of thinking are powerful intellectual tools, not just for building games and websites but for understanding complex systems, especially minds.

Computation, in other words, provides a sophisticated language for modeling, and one that is accessible to the young and naive. The trick is to encourage children to think of themselves as computers, and to think of computers as potentially human. It was obvious to Marvin (and Seymour) that this idea was not merely valid but enormously *generative* of new insights. Unsurprisingly, it ran counter to cultural prejudices, which viewed machinery as inherently antihuman. To call something mechanical, in common usage, carries strong connotations of mindlessness. Marvin fought against this dichotomy all of his life, and devoted most of his career to figuring out how to make mindful machines.

There are many reasons to pursue the dream of artificial intelligence, whether they be scientific, economic, or simply deriving from whatever force causes life and intelligence to try to

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