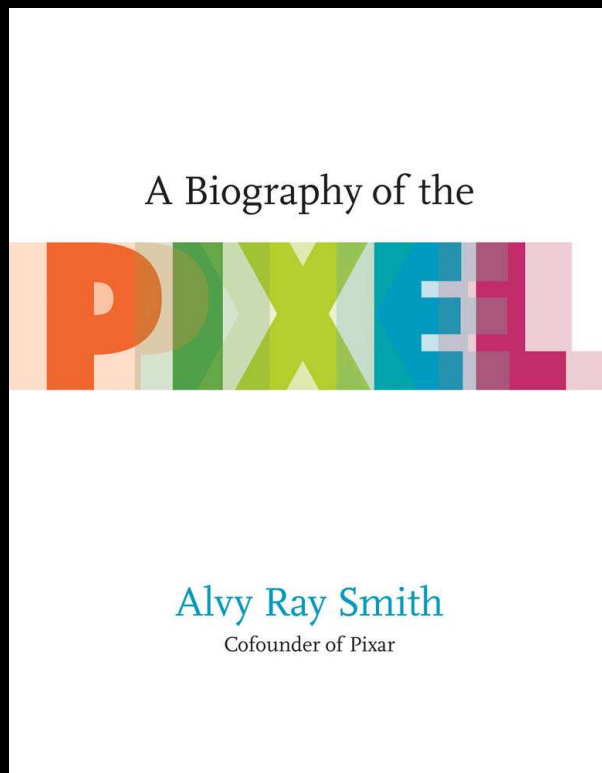




A Biography of the Pixel

by Alvy Ray Smith, published 3 Aug 2021

from MIT Press (Leonardo Series)

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[Middleton Book Award finalist](#)

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THE ANNOTATIONS

These are the full annotations of *A Biography of the Pixel*. They are available online only.

Each note is indexed by the page number of the printed book, followed by the opening words (in *italics*) of the corresponding paragraph.

[Math] indicates the presence of mathematics in the subsequent note.

Includes also a full bibliography for both the printed book and the online annotations,
and picture credits for the online annotations.

[download annotations](#)

electronically published 29 June 2023

Adobe Acrobat .pdf format: 404 pages, 2.77 megabytes, 19 pictures

SUPPLEMENTAL CHAPTER

5b Television and Video: Sampling Spacetime

This chapter was originally Chapter 6 in the manuscript of my book, *A Biography of the Pixel* (MIT Press, 2021), where Chapter 5 was devoted to Movies and Animation, Chapter 6 to Television and Video, and Chapters 7 and 8 to Digital Light. It was dropped from the final publication to shorten the book to marketable size. Here I awkwardly rename it Chapter 5b to indicate its logical ordering within the book had it been included in the published version.

Includes also annotations, endnotes, bibliography, and picture credits for the chapter.

[download Chapter 5b](#)

electronically published 30 Mar 2022

Adobe Acrobat .pdf format: 127 pages, 7.04 megabytes, 13 pictures

Blurbs

"Alvy Ray Smith is a magician who overturns the visible world and reenvisions everything that happens on a screen. His innovative history of the pixel is remarkable: there are brilliant insights on every page."

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—Kevin Kelly, Senior Maverick for *Wired* Magazine; author of *The Inevitable*

"We spend half our day staring at a screen, but where do the images on it come from? This engaging, thoroughly researched book by a pioneer of digital image making explains the history, theory, and technology of every image you see through a computer screen."

—Peter Norvig, Director of Research at Google

"Alvy Ray Smith's authoritative exploration of the history and technology of pixel-based picture making is not only instructive but eminently readable, and indeed, fun!" [\[see expanded version below\]](#)

—Andries Van Dam, Thomas J. Watson Jr. University Professor of Technology and Education and Professor of Computer Science at Brown University; coauthor of *Computer Graphics: Principles and Practice*

"Until I read this book, I would have been hard pressed to define the pixel as a unified technology that creates everything on television and animated films. Thanks to the father of the pixel, Alvy Ray Smith, for giving me greater insight into the exotic components of our everyday world."

—Marina von Neumann Whitman, Professor Emerita of Business Administration and Public Policy at the University of Michigan; author of *The Martian's Daughter*

"Alvy Ray Smith has done a masterful job of weaving his own contribution in helping bring color to computer graphics into this compelling history of our modern digital media world."

—John Markoff, author of *Machines of Loving Grace*

"The history and technology of arguably the greatest of human inventions, the digital computer, has been well documented. Now Alvy Ray Smith has augmented that story with an eminently readable ('no mathematics required'), indeed fun exploration of both the history and the technology of pixel-based computer graphics, today's dominant means for human-computer interaction."

—Andries Van Dam, Thomas J. Watson Jr. University Professor of Technology and Education and Professor of Computer Science at Brown University; coauthor of *Computer Graphics: Principles and Practice*

Additional Reviews

See many more at the Amazon site

—Timothy E. Johnson, MIT, creator of Sketchpad III, architecture faculty member

This marvel of a book is full of unexpected surprises drawing upon seemingly unrelated empire histories and organized by an unusual philosophical scaffolding that proves to be unflappable, even up to the very last page. The spirit of the book is entertaining and introduces several valuable teaching moments without resorting to mathematics, mainly by camouflaging any equations with high quality inventive graphics (thankfully printed on premium stock).

The formation of Pixar is covered frankly by its co-founder, but very few resulting modeling breakthrough characters make it into the book, except for Sulley from Monsters Inc. with his most unusual teal colored, lustrous, simulated long hair, or is it fur.

"A Biography of the Pixel" pointedly revolves around the dawning of "Digital Light" - coined by the author as - "the vast pictorial domain mediated by pixels which dominates the modern visual world". Digital Light was made possible by exponentially increasing computer speed and capacity during the last half-century, until all media was touched by its unimaginable heights.

The scaffolding that looms behind many technical discoveries is the Idea-Chaos-Tyrant triangle used by the author to introduce the three foundational "Ideas" that led to the pixel and digital light. He begins with a well-researched yet entertaining behind-the-scenes telling of French revolutionary/aristocrat Joseph Fourier's notion that all sound and light is made of a sum of regular component waves. The 'Chaos' was, of course, the French Revolution, and the 'Tyrant' was Napoleon himself who continually threatened to destroy the enigmatic Fourier.

Then in 1933 the Russian Vladimir Kotelnikov built on Fourier's wave ideas with his breakthrough Sampling Theorem (also called the Shannon-Kotelnikov theorem in the US, although Shannon just started his U of M studies around 1933). Kotelnikov showed a smoothly varying wave could be fully represented with surprisingly few instantaneous time samples. Perfect for the future Information Age where resources would become limited. His 'Chaos' was the Russian revolution and the 'Tyrant' was Stalin's eventual successor who was held at bay by a clever protectress.

The pinnacle achievement belonged to the U.K.'s Alan Turing, who unified machine processing just in time for the 'Chaos' of WWII. Turing singlehandedly invented the concept of the stored program computer, and computation as we now know it. His 'Tyrant' was Great Britain's Official Secrets Act, that prevented him from telling how he saved the country by breaking the Nazi Enigma code - only to be met by a jail term for homosexuality.

Meanwhile, back in America, John von Neumann took a turn at speeding up Turing's snail-slow concept machine with electronic hardware. A U.K. team beat him to it in 1947-48 with the first stored program electronic computer called Baby. In a rush to get America on the scoreboard, von Neumann successfully modified an earlier patch-cord machine called Eniac with stored program hardware according to Smith. John von Neumann went on to help create today's computer architecture composed of a Central Processing Unit, a Control Unit, an Arithmetic Logic unit, and an Accumulator feeding a Memory, which in Baby's case, was a Cathode Ray Tube. The author noted the CRT memory glowed with the first Digital Light. He goes on to document the post-war rush to inexpensive, general-purpose computers.

Digital light is used as a Segway to escort the reader into the colorful history of the early movies. The important question we all ask as a child - how do the movies work? - is inevitably raised. The short answer is ... it's a wonderment. It's not just that our persistence of vision does the blending from one static frame to the next. Our brain must still transform this information into a flowing perceived motion by using all the visual cues it can encompass, like motion blur, continuity, eclipsing, perspective, and in the case of animation, tricks discovered by the masters thru trial and error, like "squash and stretch" for depicting rapid changes in velocity.

Smith names some well-known bygone movie figures, starting with Thomas Edison, as the tyrants of Movie technology. Edison was really a talented marketer who stood for the real inventors in his employ. Smith even publishes the famous "Napoleon of Invention" photograph of Edison scowling across the 19th century to make the point. Then we cross the Atlantic to pick up on the equally duplicitous movie invention race going on in France. We meet the Lumières, and Charles Pathé among others who "borrowed" from each other to get ahead. The real creation story of the influential Disney Company is used as the informative fini of the Movie history segment.

What shape constitutes a beautiful, smoothly varying curve found in industrial forms like boat hulls, cars, and airplanes? This question serves to route the reader into 3D modeling which became the driver for early Computer Aided Design. Centuries before computers, Naval architects lofted the smooth curves used to define a hull by bending long, narrow strips of wood around nails pounded into a drafting floor at points where the hull section had to pass. The wood relaxed into a pleasing curve by minimizing its bending stresses. We have come to accept this assumed shape as graceful, and named it a spline. Chapter 6 shows how the spline and the related Bézier Curve, as featured in the Adobe Illustrator app, made the transition to surfaces and internal structures stored inside a computer. Smith then adds some punch by telling the curve designer's colorful backstories.

In 1957 the Idea-Chaos-Tyrant triangle reappeared when the USSR's Sputnik suddenly orbited overhead announcing the start of the space race. The 'Idea' in Smith's words was "that internal models of fictional worlds made of fictional objects can be rendered into two-dimensional pictures", and I would add 'and simulations'. The 'Chaos' was the Soviet threat, and the race to the moon. The 'Tyrant' was the wealthy U.S. national security system.

It would take decades to fully realize this dream of an Idea. Chapter 6 also starts the modern reporting on its awakening. Ivan Sutherland is introduced as the MIT thesis student who got the ball rolling in 1963 with his 2-D interactive, drawing program called "Sketchpad". Smith notes there were no off-the-shelf parts or program libraries for computer graphics, so everything out of the ordinary had to be made or adapted from scratch: the TX-2 computer built by MIT's Lincoln Lab's technical/design staff, an appropriately large high-speed graphic display, a miniature electric-eye like drawing pen, and even free-spinning flywheels attached to digital converters for indirectly rotating or magnifying graphical elements. The thin program libraries were augmented by Ivan, including the building blocks for a data structure that stored a drawing's parameters and topology, and an operating system he invented that properly handled all the real-time events springing from these objects. If that wasn't enough, he linked up two MIT thesis students that shared his interests: TE Johnson who went on to build Sketchpad III, the first real-time program for accurately drawing wire-frames in 3-D, and Larry Roberts who unified perspective transformations with his innovative matrix math that became the virtual camera in Sketchpad III.

Admirably, Alvy Ray Smith covers nearly all the computer graphics bases laid out by the pioneers, from Herbert Freeman in the early 50s to Ron Baecker in the late 60s in this meticulously researched book.

[...I can't objectively comment on Chapter 7 "Shades of Meaning", and Chapter 8 "The Millennium and The Movie" covering Smith's important Pixar origin time-line since, during that time, I had moved back into architecture....]

Finalist for the Middleton Book Prize

The IEEE History Committee chose *A Biography of the Pixel* as a finalist for the Middleton Book Prize of 2022. The letter informing me of this stated, "the IEEE William and Joyce Middleton Electrical Engineering History Award, established in 2014 by a gift from the estates of long-time IEEE leader William W. Middleton and his wife Joyce F. Middleton . . . recognizes annually the author of a book (published within the previous three years) in the history of an IEEE-related technology that both exemplifies exceptional scholarship and reaches beyond academic communities toward a broad public audience."

MISCELLANEOUS DOCUMENTS

Associated Papers

The Dawn of Digital Light

His Just Deserts: A Review of Four Turing Books

How Pixar Used Moore's Law to Predict the Future

Why Do Movies Move?

Shuttering Mechanisms of Zoetrope and Zoopraxiscope

Associated Genealogies

William Kennedy Laurie Dickson

Alexander Schure

Associated Documents

Proposal to the NEA by Smith and DiFrancesco (Xerox PARC), 1974

Alvy's Xerox PARC diary, 8 May 1974 - 16 Jan 1975

Alvy's Xerox PARC hiring Purchase Order, 12 Aug 1974

CAPS Proposal by Alvy (Lucasfilm) to Disney, 30 Jan 1985

Executive Summary of CAPS by Alvy (Pixar) to Pixar, 4 May 1986

Intention Letter to Proceed with CAPS from Disney to Alvy (Pixar), 12 Sept 1986

Management Structure of Pixar, listing Ed and Alvy as the cofounders, 1985-1989

Universal Turing Machine Business Cards

Creative Commons Licenses

Associated Papers (Details)

The Dawn of Digital Light

in *IEEE Annals of the History of Computing*, Oct.-Dec. 2016, vol. 38, no. 4, pp. 74-91.

Abstract. The pixel serves as a unifying concept bringing computer graphics and image processing, indeed all pixel-mediated fields, into a single world called digital light. This article utilizes known instances and original research to reunify the early history of digital light. It shows that the first pictures, video games, and computer animations were in fact created on the earliest computers. A scholarly presentation of chapter 4 (Dawn).

His Just Deserts: A Review of Four Turing Books

in *Notices of the AMS*, Sept. 2014, vol. 61, no. 8, pp. 891-895. A review of four books about Alan Turing. AMS = American Mathematical Society. [Cover design](#) based on the article, and [About the cover](#) for it. Based on part of chapter 3 (Turing).

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How Pixar Used Moore's Law to Predict the Future

in *Wired Online*, www.wired.com, Opinion, 17 Apr. 2013. Based on part of chapter 6 (Shapes).

[download](#)

Why Do Movies Move?

in *This Explains Everything: Deep, Beautiful, and Elegant Theories of How the World Works*. John Brockman, ed. New York: Harper Perennial, 2013. pp. 269-272.

Extract. Movies are not smooth. The time between frames is empty. . . . How can we explain this? . . . the explanation is rather important, and one of my favorites. Based on part of chapter 5 (Movies).

[download preprint](#)

Shuttering Mechanisms of Zoetrope and Zoopraxiscope

2015

Abstract. Careful simulations of the mechanisms of two early cinema machines, the zoetrope and the zoopraxiscope, reveal how the shuttering actually works.

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