The Technological Roots of Computer Graphics

Eduardo Perez Molina

To determine the technologies at the origin of computer graphics, this analysis focuses on prior art documents cited in patent publications from 1940s and 1950s technologies that, together, led to the emergence of computer graphics in the 1960s. The key finding is that, in addition to computing and television, computer graphics has deep roots in radar-related technologies and aircraft instrumentation.

In an effort to identify the technological roots of computer graphics (CG)—in other words, to identify the technology existing in the years before CG emerged as a new field that led to the generation of images with computers—I examined the technology present in the 1940s and 1950s that is inextricably linked with the CG techniques to come in the early 1960s. Although the literature on the history of CG certainly points to the influence of other technologies on its origins, previous studies have been rather generic, viewed in the context of broad categories such as military or defense. This article adds to the existing literature by providing a comprehensive view of the technology existing in the 1940s and 1950s, not focusing on computing in particular, and explicitly identifying the technologies and companies that led to the emergency of CG techniques in the 1960s.

In this work, I have focused on patent publications instead of academic articles, graduate theses, or books (nonpatent literature) because patents have features that make them particularly attractive for the study of a technology’s history and evolution. As with other technical documents, patent publications contain a publication date, author name and affiliation, title, abstract, text, and illustrations. However, unlike nonpatent literature, every patent contains classification information indicating the technical field or fields where it “belongs.” Classification schemes have been recognized by numerous historians and philosophers of technology as valuable tools for historical studies. Moreover, the patent document also contains a list of publications related to the patent and which is the result of the prior art search; this list consists of documents relevant to evaluating the patent’s difference, in terms of novelty and inventive step, from prior technologies. Although both pieces of information, the classification codes and the cited documents, are part of the patent publication, they are not the responsibility of the author (the inventor), but of the patent office, an independent authority in charge of the patent granting and publishing procedure.

Every patent publication is classified in the International Patent Classification (IPC, www.wipo.int/classifications/ipc/en/), a technical classification scheme common to virtually all patent offices in the world, which is an interesting feature for the study of relations between technical fields. Using this classification scheme, we can easily aggregate technical fields of patent publications from different geographic sources, languages, and time periods, making it possible analyze the technology related to a patent, group of patents, or technical field, as I have done with CG. Furthermore, this classification scheme is hierarchical, which facilitates the aggregation of technical fields at different levels of granularity. On the other hand, intrinsic features of all classification systems—namely, the fuzziness of the scheme, the difficulty of evolution, and the consistency between classifiers—must be considered when such a tool is used. In the specific case of the IPC, these factors are indeed present. In fact, the interrelation between technologies makes fuzziness not only unavoidable but necessary: patent literature is a fast-changing body, and consistency between classifiers in an internationally managed system is a challenging target. This
is why I have analyzed the classification codes at a broad level of resolution and why I have also aggregated different classification codes to represent particular technologies that are poorly represented by the IPC scheme.

The list of related documents published in a patent publication is produced by the patent examiner in order to evaluate whether the subject matter disclosed in the patent application is novel and inventive with respect to the technology known at that time, thus fundamentally linking the patent application with the available technology. Both concepts (novelty and inventive step) are of interest in studying a technology’s evolution because they point to time and conceptual proximity, giving us an explicit connection between the present, the patent application, and the past—the prior art.8

My analysis in this article exploits prior art lists of documents and classification codes at different levels. First, I identify CG patents using classification codes, and then I look backward in time by reconstructing the network of associated citations. Finally, I identify technologies using classification codes at different levels of aggregation. (See the “Related Work in Computer Graphics History” sidebar for earlier work on the evolution of CG.)

Data Collection Methodology

I carried out my study using patent publications cited in prior art searches made by the patent offices to evaluate the novelty and inventive step of patent applications in the CG field.9–11 My data collection methodology is based on the hypothesis that the documents cited in the search reports by patent examiners against patent applications in a particular (new) technology link the emerging techniques to conventional, existing ones, and therefore an analysis of these documents will point to the roots of the new technology.

This methodology has similarities with exploiting bibliographic references on papers, theses, and books to trace a technology but the results are fundamentally different, mainly because—contrary to the bibliography—the documents cited in the search reports are made by the patent examiner independently of the author (the inventor). An author cites a reference in a technical publication largely to justify some choices or hypothesis.12 The patent examiner, on the other hand, cites publications in the search report to evaluate the novelty and inventive step, and therefore his aim is to link a piece of new technology with the previous ones (the prior art).6,11,13

The first patent publication classified in the field of computer-generated images at the European Patent Office (EPO) was US351997,14 filed in 1961. Numerous other documents have portrayed the early 1960s as the time when computers were used to generate images.2,15 I analyzed the technology preceding 1960 to find the technological roots of CG—that is, the technical fields, systems, and applications that made CG’s emergence possible. I therefore collected and analyzed all the patents filed before 1960 and cited in the search reports of the patent publications on CG in order to focus on its prehistory. The selection of documents was made using the EPO Espacenet database (www.espacenet.com). This database offers free access on the Internet to virtually all the patent literature published in the world and provides classification information, administrative data, text, images, and citations.

The diagram in Figure 1 summarizes the selection procedure for patent publications to be analyzed. First, I selected all the patent publications classified in CG until 1990—namely, the publications classified in the groups G06T11 (2D Image Generation), G06T13 (Animation), G06T15 (3D Image Rendering), G06T17 (3D Modeling for Computer Graphics), and G06T19 (Manipulating 3D Models or Images for Computer Graphics), which cover systems, devices, methods, computer architectures, and algorithms applied to image generation with computers. This set contained 2,019 documents. Then, I collected all the patent publications cited in the documents’ search reports. That resulted in a first
Related Work in Computer Graphics History

Numerous publications have described the evolution of computer graphics (CG) from the earliest days. Few, however, have detailed the technologies at CG’s origin by going back to the technology available in those years before the emergence of CG and unveiling the technological problems that had been faced earlier and the solutions proposed. Jan Hurst and colleagues outlined the origins of CG from the pioneer’s point of view. Dan Ryan presented his first experiences and the computer technology in the late 1950s. Wayne Carlson illustrated the evolution of the key research labs and identified the technical problems that were tackled for some of them in the 1950s. Tom Sito pointed out the importance of US government funding in the 1940s and 1950s in CG and animation techniques. Arthur Norberg and Judy O’Neill presented the first years of CG in the context of the evolution of computers and defense-related projects.

The value of patent citations in the studies of science and technology was identified by Eugene Garfield in 1957. Furthermore, in 1960 Nathan Reingold highlighted patent collections as source material for historians of technology, and many authors have reviewed patent publications for illustrating the evolution of particular technologies, such as the work of Brian Spear on virtual reality, Masatsura Igami on nanotechnology, and Show-Ling Jang on flat-panel displays.

Since then, an extensive body of literature on the use of patent citations in economy, science, and technology has been established, particularly in the context of bibliometrics studies. Patent citations have been used as a popular indicator of different aspects of technology—namely, technology importance, technology dependency, or technology proximity. At the same time, patent classification codes have been employed to measure relatedness between technical fields and to point out interconnections between technologies. These studies using patent collections, citations, and classification as indicators of science and technology are principally aimed at forecasting emerging technologies and trends or assessing technological impacts and importance, rather than identifying the origins or foundations of technologies.

Although some of these authors cite particularly relevant patents on CG to my knowledge, none of them use a methodology based on patent classification and backward citations to identify the technological foundations, the roots in the prehistory of a technical field in general, or the roots of CG in particular.

References
collection consisting of 5,507 documents (see “1st Collection” in Figure 1). To dig deeper, I enriched the initial selection, based only on CG classification codes, with a second collection made with the documents cited in the search reports of the first collection’s patent publications (see “2nd Collection” in Figure 1). That produced a set of 16,642 publications. Finally, I made one more collection with documents from both collections filed before 1960 (see “Final Collection” in Figure 1), which resulted in a total of 1,316 patent publications.

I analyzed this final set of prior art documents at three levels. First, I studied them as an aggregation from the classification perspective to figure out the technical fields and specific technologies at the origin of CG. Second, I identified the firms behind these patents, and finally, I browsed the set of documents to look for relevant individual publications and their relation to the image computation techniques to come.

Technologies at the Origin of CG

A look at the International Classification Codes (www.wipo.int/classifications/ipc/en/) allocated to the final set of prior art documents I had collected shows that they were classified chiefly in computer-related technologies (Computing–G06 and Information Storage–G11), electronics and electricity (Basic Electronic Circuitry–H03, Basic Electric Elements–H01, Electric Communications–H04, Controlling and Regulating–G05, and Machine Tools–B23), and image-related technologies (Optics–G02 and Photography–G03). However, a significant number of documents dealt with measuring technics (Measuring–G01) and a heterogeneous group of technologies (Education, Cryptography, Display, Advertising and Seals–G09). (See the top histogram in Figure 2.) Table 1 lists the IPC classes.

Refining the classification analysis to identify more specific technologies that led to the origin of CG reveals that the documents classified within G01 largely involve radar systems (G01S) and, to a lesser extent, systems for the study of materials (G01N) using different signals, in particular sonic or ultrasonic waves, x-rays, and infrared, visible, or ultraviolet light. The documents from G09 belong to display technology (G09G) and educational systems (G09B). The documents classified within H04, under the rather generic title of “Electric Communication Technique,” disclose what were, fundamentally, television systems (H04N). In the electricity classification (H01), the documents present improvements in discharge tubes (H01J). Finally, the documents classified in G05 and B23 primarily involve control and regulating systems in general (G05B) and machine tools in general (B23Q).

![Figure 1. Selection of patent publications from the European Patent Office (EPO) Espacenet database. The final set of documents consists of patent publications cited as prior art in computer graphics related patents and filed before 1960.](image1)

![Figure 2. Frequency of occurrences in patents from the final study collection: (top) IPC classes and (bottom) technologies represented in the IPC classes.](image2)
Focusing the analysis only on single classification codes gives us an approximate idea for identifying the importance of particular technologies because, to a greater or lesser extent, “real world” techniques are not perfectly mapped to, or covered by, a single classification code but rather by a set of codes. For example, although television is covered by (and mentioned in the title of) the subclass H04N—namely, “H04N Pictorial Communication, e.g., Television”—it is, in fact, fully covered only by the groups H04N3 to H04N21, whereas the group H04N1 covers fax technology. Table 2 provides a full list of television IPC classes.

Analyzing only individual classification codes could eclipse technologies that are deeply “transversal” to the classification scheme and that are therefore “distributed” in several distant classes. This is indeed the case for display and printer technologies.

Displays belong to the G09G group specifically regarding control circuits for displays, but other aspects of this technology are spread over different classification codes. In particular, documents disclosing the display as a computer output device (group G06F3/14) and documents disclosing cathode ray tubes—namely, control circuits in relation to CRTs (groups G09G1 and G09G5), CRT devices (H01J29 and H01J31), CRTs for radar visualization (G01S7/06) and CRTs for visualizing electrical variables or waveforms (G01R13).

Printer technologies in general belong to the B41 group (Printing; Lining Machines; Typewriters and Stamps); however, documents related to printers in relation with computers are further classified in the groups (G06K3, G06K15, G06F3/09, and G06F3/12).

The technological foundations of CG were formed, first, by a group of basic technologies in three areas: computation, electronics, and image production. Second, we can see a group of applied technologies incorporating those three components in some way. We know this because of document groupings under different classification codes representing particular technologies (see the bottom histogram in Figure 2 and Table 3). The first grouping is formed by documents relating to computer systems, displays, electronic circuitry, information storage, control and regulation, and optics; the second group is formed by documents relating to television, photography, radar, educational, medical systems, and fax technologies.

By applying the classification scheme's granularity to examine these technologies

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**Table 1. IPC classes.**

<table>
<thead>
<tr>
<th>Class number</th>
<th>Class title</th>
</tr>
</thead>
<tbody>
<tr>
<td>G01</td>
<td>Measuring and Testing</td>
</tr>
<tr>
<td>G06</td>
<td>Computing</td>
</tr>
<tr>
<td>H04</td>
<td>Electric Communications</td>
</tr>
<tr>
<td>G03</td>
<td>Photography</td>
</tr>
<tr>
<td>G09</td>
<td>Educational, Cryptography, Display, ...</td>
</tr>
<tr>
<td>H03</td>
<td>Electronic Circuits</td>
</tr>
<tr>
<td>G11</td>
<td>Information Storage</td>
</tr>
<tr>
<td>H01</td>
<td>Electric Elements</td>
</tr>
<tr>
<td>A61</td>
<td>Medical</td>
</tr>
<tr>
<td>G02</td>
<td>Optics</td>
</tr>
<tr>
<td>B41</td>
<td>Printing</td>
</tr>
<tr>
<td>G05</td>
<td>Control and Regulation</td>
</tr>
<tr>
<td>B23</td>
<td>Machine Tools</td>
</tr>
</tbody>
</table>

**Table 2. Television IPC classes.**

<table>
<thead>
<tr>
<th>Class number</th>
<th>Class title</th>
</tr>
</thead>
<tbody>
<tr>
<td>H04N3</td>
<td>Scanning Details of Television Systems</td>
</tr>
<tr>
<td>H04N5</td>
<td>Details of Television Systems</td>
</tr>
<tr>
<td>H04N7</td>
<td>Television Systems</td>
</tr>
<tr>
<td>H04N9</td>
<td>Details of Colour Television Systems</td>
</tr>
<tr>
<td>H04N11</td>
<td>Colour Television Systems</td>
</tr>
<tr>
<td>H04N13</td>
<td>Stereoscopic Television Systems</td>
</tr>
<tr>
<td>H04N17</td>
<td>Stereoscopic Colour Television Systems</td>
</tr>
<tr>
<td>H04N19</td>
<td>Diagnosis, Testing or Measuring for Television Systems or Their Details</td>
</tr>
<tr>
<td>H04N21</td>
<td>Selective Content Distribution</td>
</tr>
</tbody>
</table>

**Table 3. Aggregation of IPC classes per technology.**

<table>
<thead>
<tr>
<th>Subject</th>
<th>Related IPC class numbers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Television</td>
<td>H04N3, H04N5, H04N7, H04N9, H04N11, H04N13, H04N17, H04N19, H04N21</td>
</tr>
<tr>
<td>Photography</td>
<td>G03</td>
</tr>
<tr>
<td>Radar</td>
<td>G01S</td>
</tr>
<tr>
<td>Displays</td>
<td>G09G, H01J29, H01J31, G01S7/06, G01R13, G06F3/14</td>
</tr>
<tr>
<td>Electronic Circuitry</td>
<td>H03</td>
</tr>
<tr>
<td>Educational Systems</td>
<td>G09B</td>
</tr>
<tr>
<td>Information Storage</td>
<td>G11, G06F12, G06F13</td>
</tr>
<tr>
<td>Control, Regulation, and Machine Tools</td>
<td>B23, G05</td>
</tr>
<tr>
<td>Medical Systems</td>
<td>A61</td>
</tr>
<tr>
<td>Optics</td>
<td>G02</td>
</tr>
<tr>
<td>Fax</td>
<td>H04N1</td>
</tr>
</tbody>
</table>
and thus determine CG’s roots in more detail, I noticed that most of the documents associated with computers in fact deal with digital data-processing circuits (group G06F)—in particular, data comparators and sorting (group G06F7), analog computers (G06G), and pattern recognition (group G06K9). The patents on electronics focus on circuits for generating pulses (group H03K)—namely, monostable, bistable, or multistable circuits. The educational systems mostly involve simulators (group G09B9), and virtually all of them deal with aircraft simulators (group G09B9/08). The medical systems involve diagnosis systems using x-rays and, to a lesser extent, mechanical waves (sonic and ultrasonic). Finally, documents concerning printing focus largely on printer control (group B41B27).

**Companies behind the Patents**

With respect to the firms associated with these patents, I found that 11 out of a total of 392 companies accounted for 30 percent of the patent collection. Those companies each had more than 10 patents. In decreasing order of filing, the companies are RCA, IBM, Bell Telephone, ITT, GE, General Precision, Sperry Rand, Eastman Kodak, EMI, General Dynamics, and Westinghouse. Out of the total set, 381 companies accounted for 45 percent of the patent collection. Only 21 companies owned between five and 10 patents, and 360 companies had fewer than five patents. Finally, private inventors filed 25 percent of the total patent collection.

Looking more closely at the major players, RCA, IBM, Bell, and ITT filed considerably more patents than the other companies, with 73, 62, 47, and 35 filed, respectively. GE trailed these four with 23 patent filings. RCA patents focused on television, radar, discharge tube technologies, and digital processing circuits. IBM was clearly involved with computing technologies—in particular, character recognition, information storage, and digital data processing (I/O and arithmetic logic units [ALUs]). Bell’s patents were primarily concerned with television, character recognition, information storage, and electronic circuits (code conversion). Finally, ITT’s patents concentrated on computers—specifically, character recognition and ALUs. Other companies filing patents were involved in the fields of television, machine tools, radar and character recognition (GE); simulators (General Precision); radar and analog computers (Sperry Rand); photography and scanning (Eastman Kodak); regulation systems and color television (EMI); electrophotography (General Dynamics); and radar (Westinghouse). It is notable that a significant number of character recognition patents were owned by some of the companies in this group—notably, IBM, Bell, ITT, and GE.

Some of these corporations played a special role in CG’s first years. For example, for the SAGE project, IBM in the late 1950s built computers with CRT displays and light guns, which are considered crucial components for CG’s later development. In 1960, IBM joined GM in creating one of the first commercial CAD systems. In 1962, for example, the most popular algorithm for plotting a straight line was developed by an IBM engineer, Jack E. Bresenham, who became a leading figure in CG’s early years. In 1964, IBM released the first vector graphics terminal (the IBM2250), and in 1968 another IBM engineer, Arthur Appel, developed the first ray-casting algorithm for rendering.

Bell Labs encouraged experiments in computer graphics and animation from the mid-1950s by artists such as Mary Ellen Bute and later by scientists such as Edward E. Zajac or Ken Knowlton, who developed the first computer animated film and the first programming language for bitmap computers, respectively. GE produced the first computer generated imagery (CGI) systems for the space program and also developed flight simulators. General Precision merged in the late 1950s with Link Aviation and developed one of the first real-time flight simulators, the Link Mark I computer. Later, the company produced one of the first CGI systems in the 1970s; moreover, its engineers coined the word “pixel.” Sperry Rand was involved in graphics projects from the early 1960s; in 1964, the company developed the Rand tablet and GRAIL, a graphical input device and graphic input language, respectively. General Dynamics bought Stromberg-Carlson in 1955 and developed the first microfilm recorders used in the first computer-produced movies by Knowlton. Finally, Godfrey Hounsfield at EMI began to develop computerized tomography in the early 1960s and, in so doing, revolutionized the role of computers in medical imaging.

In the complete list of companies, we can see some corporations with interesting connections to CG. Philco, which had eight patents in my study collection, constructed the first fabricated head-mounted display in 1961. In 1969, Sylvania Electric (seven
In the mid-1950s, the patent documents show that computer-user interaction began to be viewed as “graphic” to explicitly improve speed and ease of use.

Furthermore, it is interesting to note the presence in the collection of companies in semiconductors (Fairchild, Texas Instruments, and Beckman Industries), geophysics (Schlumberger, Mobil, and Philips Petroleum), computers (Burroughs, ICT, and CDC), electronics (LFE and Hazeltine), avionics (North American Aviation, Kaiser industries, Hughes, and Northrop), and radar (Raytheon and Barrow Beacons).

Interesting Patent Publications
I also browsed the study collection looking for documents containing hints leading eventually to the generation of pictures with computers. Ultimately, I found that the documents from the early 1940s indicate that the cited prior art did not disclose improvements or solutions to problems directly related to computations for image generation. Instead, they deal fundamentally with improvements in electric computers—for example, dividers for solving trigonometric functions (see patent publication US245266417), conversion from binary to decimal form (see patent publication US244404218), or a relay-based accumulator with sign indication (see patent publication US236454019). Prior art also revealed improvements in optical instruments; for example, a reflector sight with a collimating lens system of small aperture (see patent publication US246420920) or a camera having a right angle prism or mirror (see patent publication US2415424).21

In the late 1940s, the cited prior art chiefly documented improvements in radar, television, optics, and computers. Interestingly, computers started to be presented as totally electric at that time and therefore free of mechanical elements; they were also portrayed as universal machines. For example, computer circuits were described as “electrical circuit network devices for carrying out mathematical operations by the movement of simple electromagnetic means without the use of gear trains, number wheels, cams, or other mechanical elements” (see patent publication US267997722).

In another publication, a computing machine was described as “utilizing electronically produced pulses to represent digits and numbers, and using such pulses to control and programming operations, thus obviating the need for mechanically moving parts for this purpose.” Furthermore, “this machine, herein referred to as ENIAC ... is extremely flexible, and is not fundamentally restricted to any given class of problems” (see patent publication US312060623).

Also in the late 1940s, the cited prior art began to focus on solving problems related directly to image generation computations, particularly in radar or airborne applications. For example, patent publication US258459924 describes a system for “visually indicating deviation of a mobile craft from a prescribed path or course,” or a runway (see top of Figure 3).

In another cited patent publication,25 US2648061 documents a system for “three dimensional display of positional, numerical,
or like data on the uni-planar luminescent screen of a cathode ray tube.” Patent publication US2553245, from 1946 (see the bottom of Figure 3), documents a tool for drawing onto the screen, a sort of light-pen described as a tracing system ... for transmitting, writing or sketches or other graphical material to a remote receiving station while it is being drawn at a transmitting station... the graph pattern to be transmitted is traced by a manually operated stylus which does not actually contact with the semi-transparent wall but which throws a beam of light on the exterior surface thereof thus releasing electrons in the stream at the region of incidence of the light beam upon the cathode.26

By analyzing particular documents that had been filed in the early 1950s, I noted that the CRT became a computer output device particularly adapted to addressing the need for rapidly visualizing data from ever faster computers. For example, patent US2920312 describes a system for generating symbols in a CRT using “a rectangular array of uniform static magnetic memory-type toroidal cores” and “is utilized as the matrix for symbol storage.” The system is presented as particularly adapted to digital computing machines due to the speed of visualization: “As a result, the symbol generator may be used directly as the final output for electronic computation apparatus.”

The cited prior art also discloses new user interaction systems as applied to radar systems: for example, patent publication US2903690 describes a “light gun” device to select targets on a PPI (Plan Position Indicator) radar scope (see the top of Figure 4).28

In the mid-1950s, the patent documents show that computer-user interaction began to be viewed as “graphic” to explicitly improve speed and ease of use. This is the case with patent publication US3037192, which discloses a computer workstation applied to air traffic control. It consisted of a CRT and a “light sensor” to facilitate the user interaction and adapted to the speed of computers. The CRT and the “light sensor” are
presented as the output and input devices, respectively, and a sort of GUI is sketched in the patent document.

[The] desired information resulting from the computer operation is visually displayed ... (on the) CRT from the buffer storage ... the operator monitoring the display points the (light) sensing device at an item of the display such as a dot or code symbol about with some action is to be taken. By sensing this item, the sensing means identifies it to the computer ... Accordingly, it is possible to render the computer readily and almost instantly responsive to varying requirements as desired on the basis of what is displaying.29

This patent is one of the most often cited in the collection I studied. It is cited as prior art of the patent publication US3534396,30 one of the first patents of General Motors Research labs listing Don E. Hart and Ed L. Jacks as inventors, both leaders of that company’s “computer data” group in charge of CG developments from the early 1960s.16

The document collection I analyzed also contained in the mid-1950s patent documents disclosing the computation of curves for control and regulation systems and for machine tools. For example, in 1962 US306686831 disclosed the interpolation computations for a system that digitally controls the motion of a machine tool along a continuous curve. This particular system had already introduced the use of spline fitting, and this patent is cited in the prior art search of US351999714 in 1970 by Fetter, whom many believe coined the expression “computer graphics.”

By the end of the 1950s, the collection of cited prior art takes another step toward CG by disclosing the generation of complex images, using textures, computing perspective effects, and changing the generated...
images according to physical parameters. This complex visualization appeared mainly in aircraft instruments such as the patent publication US2967263 (see bottom of Figure 4), which describes a flight instrument presenting on a CRT a series of lines to represent a grid pattern of the ground in perspective. The horizontal lines move downwardly at a rate proportional to the speed of the craft to pictorially indicate to the pilot the speed at which the aircraft is flying. The display moves upward (or downward) the grid an amount corresponding to the change in pitch altitude.32

The patent publication US3012729 describes “a voltage signal generating circuits which, when applied to a CRT, will provide simulations corresponding to radioactive particle distribution in an atomic cloud, displacement of a particle with respect to the vertical axis of the cloud and the effect of the horizontal winds acting on the particle.”33 This publication shows a clear case of complex computer-generated imagery although limited to the technology available at that time; in fact, the computation was made by a set of circuits forming an analog computer (see the top of Figure 5).

The patent publication US3098929 discloses an “airborne instrumentation for visually illustrating the instantaneous posture of the aircraft with respect to the earth’s surface.”34 The publication justified the need for a complex visualization, rather than traditional numeric indications on the basis that “human capabilities for acting in response to perception of a given color, or a picture is markedly more rapid than that which follows an attempt to read data such as decimal numbers from a conventional gauge.” The technical solution presented is “computing and exploiting linear and trigonometric analogue functions of conventionally sampled flight-variables for the purpose of producing a perspective grid pattern with a CRT.”

Another example of an early patent foretelling CG is the patent publication US3093822,35 which describes a system for rendering images with complex textures, in this case generating some visual cues into the image of an aircraft display system. “With the incorporation of these basic visual cues into a common display, the pilot’s reaction time to an existing flight condition may be materially decreased.”35 The patent applicant also justifies the need for graphical indicators and realistic visualization to improve the pilot’s reading and integration of the information on the instruments in relation to conventional meters. These cues are the flight path superposed to the sky texture, the horizon line, and ground texture: “the texture of the ground is comprised of symbols which vary in size with the altitude of the aircraft and which move across the ground texture to create the illusion of movement of the aircraft relative to the ground” (see the bottom of Figure 5).

Conclusion
Based on patent classification and prior art backward citations, the new methodology used here has helped identify the technologies at the origin of CG. The analysis of patent publications used as prior art in applications related to CG and filed before 1960 shows that CG’s technological foundations were formed by two groups. The first consists of basic technologies related to computation, electronics, and image production—namely, analog computers and digital data processing circuits (comparators and sorters), displays, electronic circuitry (chiefly circuits for generating pulses), information storage, control and regulation, and optics. The second group of applied technologies combines in some proportion those three components—computation, electronics, and image production—to improve character recognition, television, photography, radar, flight simulators, medical systems, and fax technologies.
The companies behind the patents were led by RCA, IBM, Bell, ITT, GE, General Precision, Sperry Rand, Eastman Kodak, EMI, General Dynamics, and Westinghouse. These were followed by myriad companies with just a few patents each. However, some of these companies played an important role in CG later in the 1960s and 1970s: for instance, Philco, GM, Bendix, and Xerox.

In browsing the prior art collection, I found that in the late 1940s prior art started to disclose the first image-related publications coming largely from radar technology. In the 1950s, the patent literature in early computer-generated imaging revealed the CRT as a computer output device, and computer-user interaction began to be viewed as “graphical,” particularly as it applied to radar and airborne display systems. From the mid-1950s on, prior art revealed the computation of curves for the control of machine tools. In the late 1950s, the first publications disclosing the generation of complex images, using computed textures and “realistic” visualization of the ground, appeared in aircraft instrumentation. All these demanding computations were implemented in analog computers or dedicated electronic circuitry.

The methodology I have presented here, although applied to identify the roots of CG, can potentially be applied to the study of numerous other technology origins.

References and Notes

1. This work is not supported by any organization or institution.
9. A prior art search in the context of patent offices is the collection of evidence, usually technical publications (papers, technical reports, theses, or patents), used by the patent examiners in the evaluation of novelty and inventive step of patent applications.


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