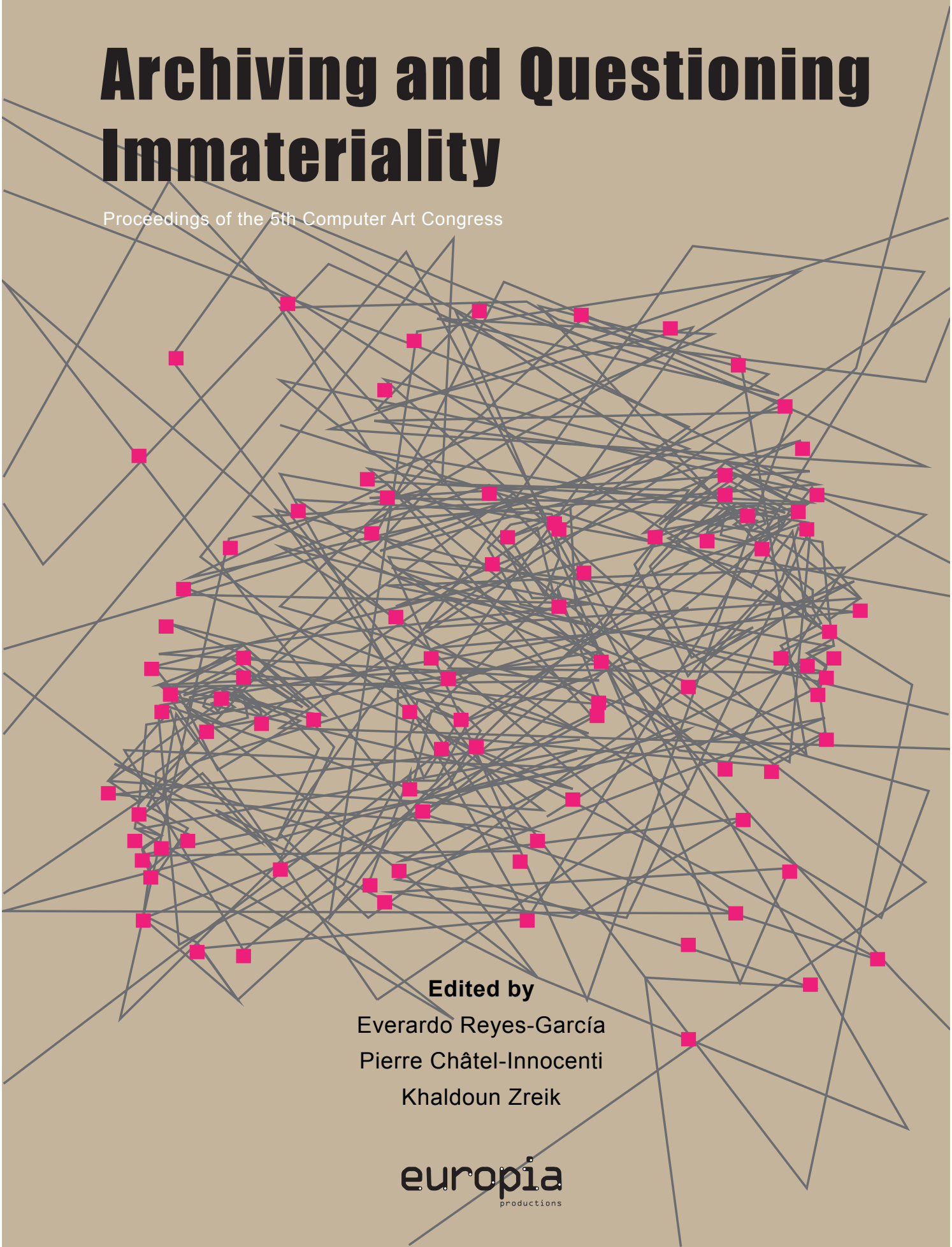
# Archiving and Questioning Immateriality

Proceedings of the 5th Computer Art Congress



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# Konrad Zuse: enabler of computational arts?

Andrés Burbano & Esteban García Bravo

**Abstract**

Konrad Zuse is known for building a programmable binary computer as early as 1941 and for designing and implementing the first high-level programming language called Plankalkül. However, his ideas and advanced projections about the potential of computer-aided art are still unknown among many new media researchers and media archaeologists. In this paper, we argue that the artistic use of Zuse's Graphomat Z64, one of the first flatbed drawing machines available, was not a coincidence, but rather a part of Zuse's original intent when he designed them. This study unveils rare manuscripts found at the Konrad Zuse Internet Archive, revealing the scientist's insightful thought about the future of computers in the arts. In writing, Zuse asked himself: Will technology spawn a new art movement?

Incidentally, around this time, pioneering artists such as Georg Nees, Frieder Nake and Jens Harke started to experiment with the Graphomat Z64. The fact that these artists and Zuse both saw the artistic potential of the machine independently of one another leads to an important question: Do notable developments in art occur because artists see opportunities within existing technologies? Or because creative scientists such as Zuse enable art through their machine designs? Zuse's participation in "Impulsos: arte y ordenador," a 1972 symposium and exhibit on computer art, at the Instituto Alemán in Madrid, also gives an account of Zuse's long-standing interest in the intersection of art and technology.

In this paper, we raise questions about innovation through technology and art and discuss how both are articulated in the origins of computer graphics. We trace the work of engineers, artists, technologists and mathematicians that converge at the dawn of computational arts.

**Keywords**

Graphomat Z64, Konrad Zuse, Georg Nees, Frieder Nake, Computer Graphics, Computer Art

## 1. Zuse's computers

Konrad Zuse's work, while well documented, had always played somewhat of a secondary role in the predominant narratives in the history of computing. However, in the last few decades, Zuse has received a renewed attention for the revolutionary contributions that he made to the development of informatics and computer culture in the 20th century (Rojas, 2002). Revealing documents have revitalized interest in Zuse's computer designs, thanks to the digitization of primary source materials at the Konrad Zuse Internet Archive. According to the Archive, his impact might have been downplayed "due to WWII, for a long time only few people knew about Zuse's work" (Konrad Zuse Internet Archive,

Accessed August 31, 2016 ). For this paper, we used rare manuscripts and images from the Konrad Zuse Internet Archive collection and complemented them with secondary sources to aid in the understanding of these materials.

Most are not aware of Zuse's pioneering role in computing, or that he built the first functional, programmable computer. Zuse's Z1, created at the end of the 1930s, was fully mechanical, demonstrating that Charles Babbage's idea of a mechanical computer was in fact possible. Later on, based on the use of telephone relays, Zuse built an electromechanical working computer called the Z3. This machine utilized a punched film stock system, a system developed by Zuse to enable the user to to store information and input code. The Z3 also shared aspects of what later became known as Von Neumann computer architecture -for instance the separation between processor and memory (Burbano, 2014). As his work progressed designing computers after WWII, Zuse focused on ways to be more efficient in controlling the machines he created. He thus implemented what is recognized as the first programming language: the Plan Calculus or Plankalkül (Bauer, 2002). In 1949, Zuse founded the ZUSE KG in Berlin, a company that would develop new computers for industry applications (Zuse, 1993, p 119).

## 2. Graphomat Z64 impact in the early computer art in Europe

In his autobiography Zuse describes his teenage years as being undecided between studying engineering or fine arts. During this period he made several sketches on paper and attended painting classes and art openings. Also during this time period, after seeing the film "Metropolis" in 1927, Zuse was inspired to design his own city for a school project. In Figure 1, we see Zuse's almost premonitory design, bridging engineering with aesthetics through what could arguably be a prototype for an algorithmic visualization. Zuse ultimately chose a career in engineering - he explains, "In the end, the engineer in me won out" (Zuse, 1993, p. 10). Still, in spite of his ultimately decided career path, we are able to see his general tendencies toward artistic visualization.

Many years later, Zuse would intently design a machine for systematic drawing. In 1961, the ZUSE KG released the new Graphomat Z64 at the Hannover Fair (Horst 2016) & CompArt). This machine embodies Zuse's creativity applied in computer graphics specifically. At the beginning of the 1960s, the field was incipient, and the applications for industry were yet to be envisioned. Still, Zuse was particularly interested in the relationship between machines and the visual arts: "What we today call computer graphics would not be popular for a long time and was discussed and practiced only by an interested few." (Zuse, 1993, p 130).

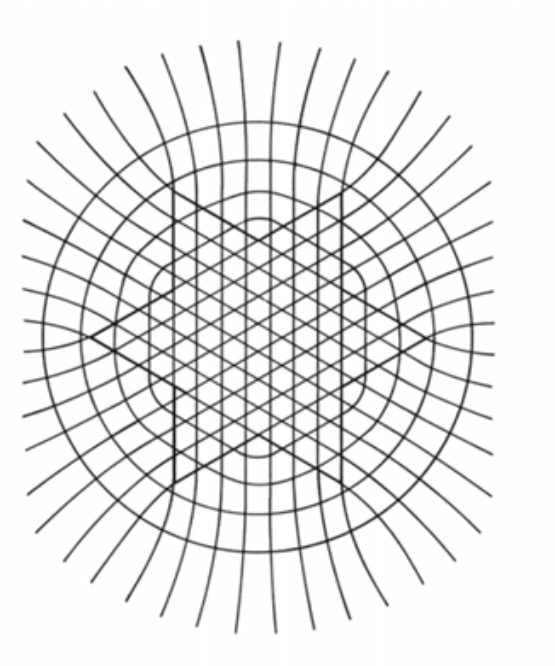


*Figure 1. Zuse's City design. © Konrad Zuse*

The Graphomat Z64 introduced Computer Aided Design (CAD) in Europe for diverse fields such as geodesy, meteorology, and road construction. Later on, it was used in the textile industry (according to Horst Zuse's site accessed in 2016). Mittelsten-Scheid, a carpet manufacturer, approached Zuse in 1961 to automate the control of carpet looms. In his own words, Zuse explains his philosophy towards computer tools for artists:

"He (Mittelsten-Scheid) wasn't particularly excited when I suggested including the artistic design of the pattern in the automation process. This was the only way I thought I could do the work. It never would have occurred to me to want to make the artist superfluous. On the contrary, I just wanted to place a new tool in his hand" (Zuse, 1993, p 130).

Although Zuse himself explains the machines were originally "developed primarily for technical ends," he explained that "the method can also be applied to artistic objects" (Zuse, 1969). For the sake of context, it is important to highlight that in 1961, graphic and text output was "literally peripheral" to computers as they did not necessarily provide the user with a screen or a printer (Patterson, 2015). Concurrently, in the United States, CalComp was manufacturing some of the first computer pen plotters. CalComp rendered graphics through a process that involved calculations within a mainframe computer. In contrast, the Graphomat Z64 constituted an ingenious apparatus that was able to both process and draw within the same machine. The

Graphomat Z64 was an "automatic drawing board" that was controlled by punched cards. Although the machine was extremely heavy (1,400 Kg), it was a stand-alone machine that materialized Zuse's intent to enable industry through computer graphics techniques. Graphomat Z64 had two stepper motors that moved along the X and Y axes with the option of 4 interchangeable pens. The Graphomat Z64 software allowed the plotting of dots, curves, and symbols (Zuse, 2016). Figure 2 shows one Zuse's diagrams to design the Graphomat Z64. One can see the plotter bed on the lower left and how it was connected to the X and Y stepper motors and relays.

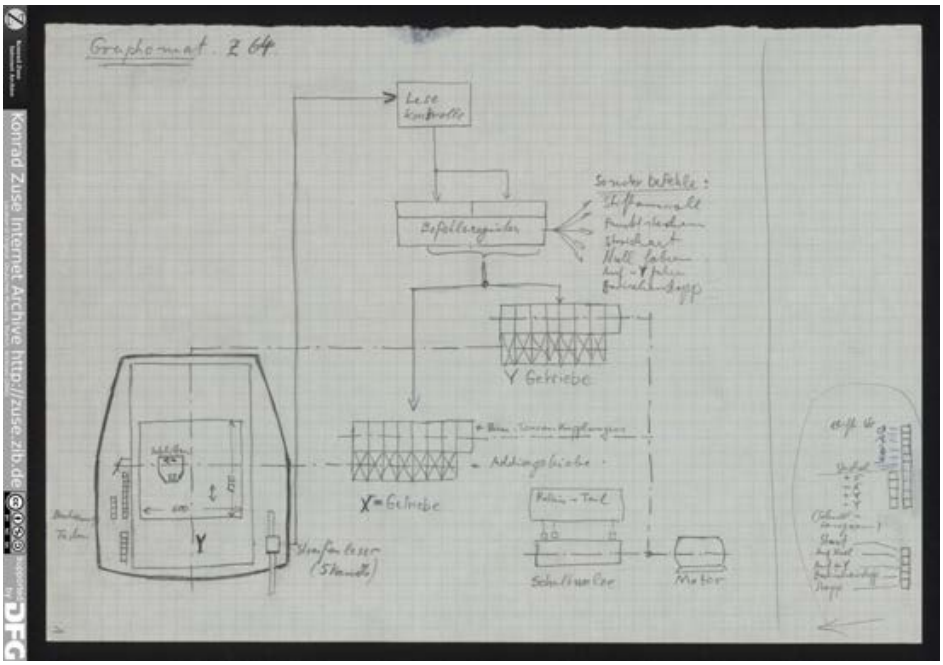



*Figure 2. Zuse's graphomat Z64 design*

The Graphomat Z64 was **implemented** by artists who wanted to explore programmatic thought and algorithmic visual compositions. At the University of Stuttgart, Georg Nees and Frieder Nake were inspired by Max Bense's informational aesthetics classes (Castaños Alés, 2001, p.34). By 1965, Nees and Nake were exhibiting some of the first computer-assisted drawings and paintings in the world. Nake recalls his first computer graphic in 1963 at Technische Hochschule of the Stuttgart Polytechnic (Castaños Alés, 2001, p.36) (Nake, 2012)(Kane 2014). He used an artistic process that included intuition and chance in programming and execution (Nake, 1968). This involved creating computer plots on paper that were later modified by painting. Other times, he also used the multi-color pen option provided by the Graphomat Z64. Figure 3 Shows "Hommage à Paul Klee", a plot from Frieder Nake from 1966 (Nake, 2009).

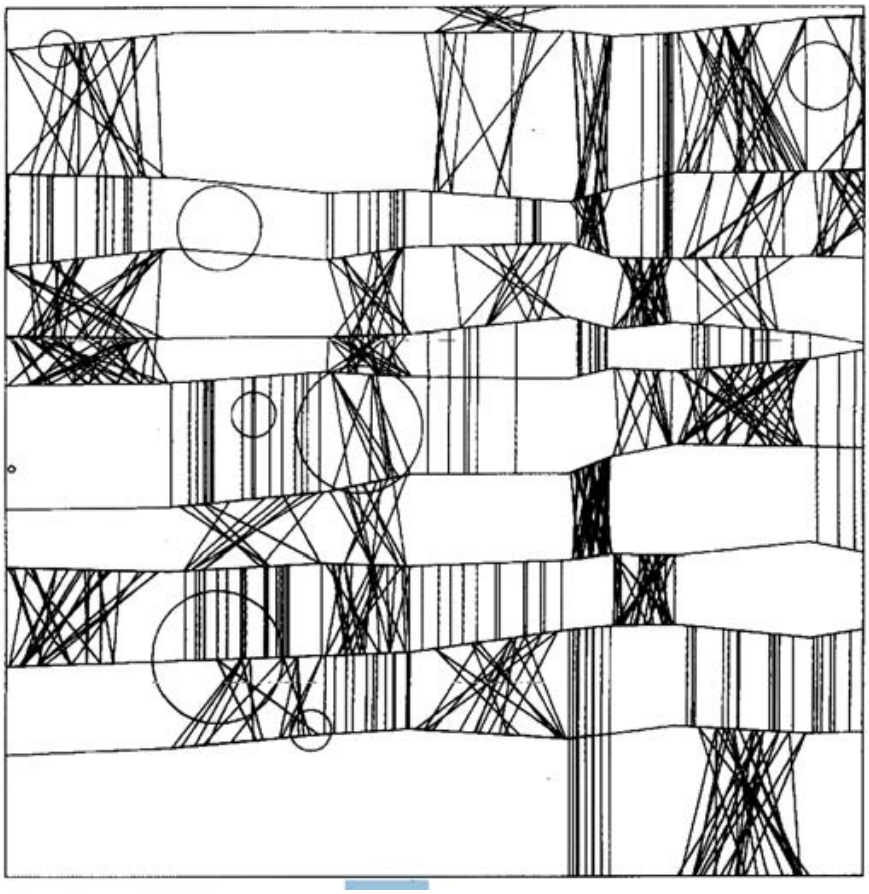
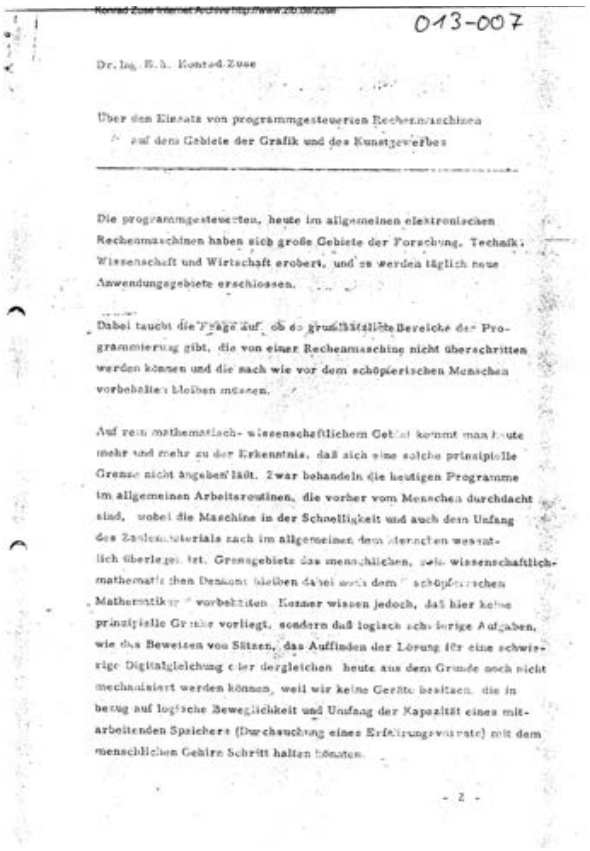


*Figure 3. Hommage à Paul Klee , © Frieder Nake 1966*

Evoking the lyricism of Klee's sensible geometric abstraction, "Klee" exemplifies how Nake used generative algorithms to achieve aesthetic forms. Other examples of Nake's work include painted over plots, using China ink.

## 3 Documents by Zuse about computers and the arts, design, and architecture

Rare manuscripts found at the Konrad Zuse Internet Archive raise deep questions about Zuse's original intent with the Graphomat Z64. The first document is a fourteen-page facsimile, typewritten in German, with a title that translates to "On the use of program-controlled calculating machines in the domain of graphics and the applied arts"(see Figure 4). Written in 1964, three years after Zuse launched the Graphomat Z64, this document clearly exposes Zuse's ideas and intentions regarding the possible interactions between visual arts, plotters, and computers. It should be noted that at this time there is no evidence that Zuse was aware of Nees and Nakes' artistic endeavors with his Graphomat Z64 (Zuse, 1964).



Konrad Zuse Internet Archive http://www.zib.de/zuse

013-007

Dr. Ing. E. h. Konrad Zuse

Über den Einsatz von programmgesteuerten Rechenmaschinen auf dem Gebiete der Grafik und des Kunstgewerbes

Die programmgesteuerten, heute im allgemeinen elektronischen Rechenmaschinen haben sich große Gebiete der Forschung, Technik, Wissenschaft und Wirtschaft erobert, und es werden täglich neue Anwendungsgebiete erschlossen.

Dabei taucht die Frage auf, ob es grundsätzliche Bereiche der Programmierung gibt, die von einer Rechenmaschine nicht überschritten werden können und die auch wie vor dem schöpferischen Menschen vorbehalten bleiben müssen.

Auf rein mathematisch-wissenschaftlichem Gebiet kommt man heute mehr und mehr zu der Erkenntnis, daß sich eine solche prinzipielle Grenze nicht angeben läßt. Zwar behandeln die heutigen Programme im allgemeinen Arbeitsroutinen, die vorher vom Menschen durchdacht sind, wobei die Maschine in der Schnelligkeit und auch dem Umfang des Zahlenmaterials nach im allgemeinen dem Menschen wesentlich überlegen ist. Grenzgebiete des menschlichen, rein wissenschaftlich-mathematischen Denkens bleiben dabei noch dem schöpferischen Mathematiker vorbehalten. Kenner wissen jedoch, daß hier keine prinzipielle Grenze vorliegt, sondern daß logisch schwierige Aufgaben, wie das Beweisen von Sätzen, das Auffinden der Lösung für eine schwierige Digitalgleichung oder dergleichen heute aus dem Grunde noch nicht mechanisiert werden können, weil wir keine Geräte besitzen, die in bezug auf logische Beweglichkeit und Umfang der Kapazität eines mitarbeitenden Speichers (Durchsuchung eines Erfahrungsvorrats) mit dem menschlichen Gehirn Schritt halten könnten.

- 2 -

*Figure 4. "On the use of program-controlled calculating machine in the domain of graphics and the applied arts", 1964*

The text is composed of five sections which discuss respectively: (1) the relationship/conflict between creativity and computation; (2) the areas within the applied arts and design where computers could have a place; (3) detailed capabilities of the Graphomat Z64; (4) proto-generative art ideas; and (5) other possibilities of interaction between computers and the arts, for instance, the use of TV screens and glass.

In the first section, Zuse explains that computer machines could perform operations thought before to be unique of human intellect, including those reserved for creative people. Zuse emphasizes that many of the tasks considered part of human thought, like calculations, are already performed by machines. He explains that placing this question in the creative arts scene is polemic, and therefore focuses on examples that could be relatively more familiar connecting computers with creation: in particular, music composition and electronic music. Zuse mentions that despite the fact that there was some work on computational creativity, examples such as music composition were not necessarily convincing because the creative element seems to be missing. According to Zuse, those compositions described are essentially based on

statistical processes that are nurtured with random numbers, and have an additionally programmed “irregular” element..

In the second section, Zuse quotes texts that anticipated questions about computers and the arts such as: "Computers and Automation" and "Computer Art Concert." He goes back to the ontological question of “What is art?”, arguing that in principle, it is a controversial discussion, and is therefore a fertile ground for new ideas. Zuse identifies more specific fields in the visual arts where there is a clear interaction between arts and mathematics, such as pattern design. Zuse analyzes tasks that could be performed with software, which would play a supplemental role in the execution of creative ideas. Additionally, he explains why software design could be essential in this role, more so than the hardware.

In the third section, Zuse introduces his Graphomat Z64, the device he conceived, designed and produced, which works in combination with a computer that is controlled by punched tape. Zuse describes the technical implementation and the properties of the machine such as accuracy and speed. According to Zuse, the Graphomat Z64 could plot with different colors and draw patterns or mosaics. Zuse focuses on describing the characteristics of the graphics when plotted with the device, such as hue, brightness, shape, fill, border, line width, curves, and mosaic-like composition. He emphasizes the potential use of perspective systems and projections of 3D shapes to represent graphics in a 2D plane. He imagines practical applications of the Graphomat Z64, such as drawing patterns for carpet and wallpaper design, and even programmed abstract art. One of the most interesting points is when Zuse describes basic generative possibilities that could be applied to the visual arts with these machines. He explains that the designer would still develop the shapes to a certain extent and control the combinations based on variable parameters. Additionally, he talks about concrete uses like drawing arbitrary curves and use the computer to perform the necessary interpolation calculations.

The last section describes other possibilities in the interaction between computers and images. Zuse compares the Graphomat Z64 with other products recently available in the market such as printers explaining that though the printers were conceived to work with characters, they can be used to draw patterns too and envisions the possibility of displaying images in Braun tubes or TV screens. This possibility was more unusual than plotting the images on paper, given that those devices would display images in an invisible grid. Probably the most premonitory example is the idea of using the patterns to create colored windows with the glass and other transparent materials

producing unusual visual effects. By today's standards LCD and LED displays are an ubiquitous form of presenting "digital" images. It is important to consider that raster, or pixel-based images were not accessible until the early 1980s, when the first color displays came out to the market (Garcia Bravo, 2015). In other words, Zuse's ideas in relation to computer graphics were about twenty years ahead.

A second manuscript found at the Zuse archives was "The Computer as a Tool for the Artist." This short text was published in 1969 in the journal Umschau In Wissenschaft und Technik. Unlike the aforementioned text written in 1964, this paper is not directly related to one of his machines or products and instead presents information about new technical advancements and equipment in general. Zuse introduces his arguments explaining the extended use of computers in several aspects of research, especially engineering. Alternatively, Zuse introduces again the idea of computers in the arts, and he exposes two clear options to explore this relationship. The first is the possibility of generative processes in human computer interaction and the second one refers to the use of the computer as tool by the artist, focusing on computer-assisted practices that we now call CAD. In regard to these points, Zuse explained that; "the first case is related to define aesthetic laws, or parameters, formulated mathematically to design the artistic product" and that "the computer, with some peripherals, is used by the artists as a series of technical extensions and is used as a new tool by the artist" (Zuse, 1969).

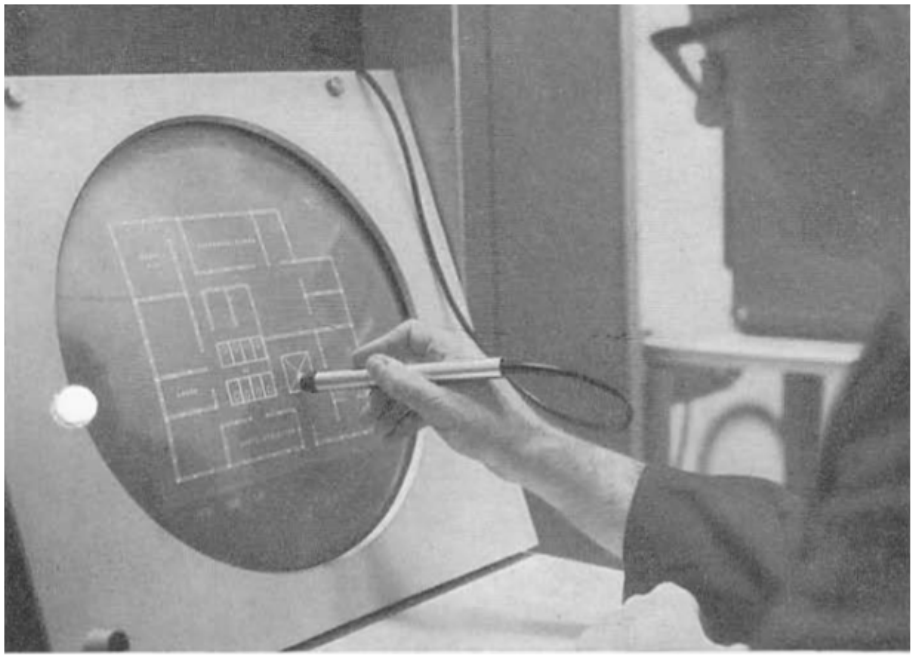


*Figure 5. "The Computer as a Tool for the Artist", 1969*

Zuse stated the purpose of this text was to describe in depth the second possibility and not the first. It is unfortunate that the first possibility was not further explored, but he likely took this approach so it would sound more familiar and less esoteric to the reader. Still, it is apparent that he was interested in the generative/parametric aspect. The text exemplifies his reflections with the novel interaction with visual, touch interfaces. The article is illustrated with a photo of Zuse interacting with an architectural plan displayed on a screen with an optical pen in his hand. According to his words, he was "collaborating" with the computer, and he reminds the reader that this kind of interaction could happen not only architectural plans, but also with artistic objects. At the technical level, Zuse considers this process as a dialog between the human and the computer in which the user can configure, complement and change the drawings, hence "working together" with the computer.

Zuse envisioned the many things an artist could do such as visualizing different perspectives of an architectural plan, or defining with a program the basic parameters of a visual composition. The artist could determine the rules and the amount of randomness to combine strokes in the best way possible. Zuse argues that the computer representations are not artworks in their own right, pointing to the limitations of the available plotters and other instruments of that time. Independently of software and hardware limitations of only drawing lines, dots and curves, he envisioned that a new artistic movement could emerge from these experiments. For this to happen, it would be necessary for people who understand visual representation to learn programming, and to have the time to adapt to it. Another limitation that he discussed was the costly equipment and the fact that it was still in development. Zuse also pointed out the absence of a market interested in those kind of experiments.

The tone of Zuse's words and his descriptions of the possibilities, always in future tense, shows that he was not aware that an artistic movement was already emerging, and that some of the artists, capable of visual representation were learning programming at the same time. He was also unaware that artists like Nees, Nake and Harke were actually using his Graphomat Z64. By 1969, the use of computers in the arts had already proliferated, although modestly, in diverse nodes such as in research centers and Universities in the United States, Tokyo, Madrid, Stuttgart, Zagreb and Brazil.

Whether Zuse did or did not know that there were in fact visual artists who programmed software when he wrote that article in 1969, he eventually became a participant of the computer art scene himself. In 1972, he made part in a pivotal computer art event in Madrid called "Impulsos: Arte y Ordenador." The event was organized by the Centro de Cálculo de la Universidad de Madrid

(CCUM) and it took place at the Instituto Aléman (German Institute) of Madrid (Castaños Alés, 2001). The event consisted of a symposium and an art exhibit. Zuse was invited to give a presentation at this event. His talk was titled "Del computador a los grafismos de computador" (From the computer to computer graphics) and it took place on February 28 of 1972 (Castaños Alés, 2001, p. 120). The art exhibit gathered some of the most recognized pioneers of computer graphics in the world, including works by Charles Csuri, Herbert Franke, Kenneth Knowlton, Georg Nees, Manfred Mohr, Frieder Nake, Michael Noll and Lillian Schwartz among many others. In the exhibit catalog, Zuse contributed a text that summarized the history of computing from Charles Babbage to modern day. He also establishes a distant connection with the first calculating machines from the 17th Century, towards the development of binary code. Zuse explains the idea of a "universal algorithmic language" capable of algebraic operations, introduced in by him 1945. It consists of a language that did not literally speak the machine code, but was mediated by a compiler that translated the information typed by the user. Since 1955, these concepts are familiar for anyone who uses computer languages to design software. In his manuscript, Zuse emphasizes on the importance of software design towards human-computer interaction. At the very end of this text, Zuse revisits his three ideal methods of "collaboration" between man and machine: 1. Formal languages, 2. Visual light displays (like TVs) and 3. Automatic drawing devices (such as the Graphomat Z64) (Zuse, 1972).

**4. Discussion: reflecting on the origins of computer arts**

The story of Zuse's Graphomat Z64 and his visionary approach towards graphics demonstrates a paradox in the way that artists approach new technologies. Two standpoints may be theorized about this relationship: on one hand, there is the view that artists discover a new aesthetic vocabulary, having been presented "misusing" or "bending" technological systems to produce unintended effects (glitches). (Blais & Ippolito, 2006). This approach takes into account artists who work only after the technological artifact is ready for public distribution. On the other hand, there is a perspective that technologies can emerge as the result of an art-science collaboration and fulfill an innovation cycle. One example of this dialogue could be appreciated at the Bell Labs in the beginning of the 1960s. Bell Labs, emphasized on interdisciplinary research between artists and scientists to design and create satellite communication, digital photography and incidentally, another branch of Computer Art.

Neither of these claims about the relationship between the artists and the technology is absolute, and should not eclipse each other.In fact, in our view, neither of them describes accurately what happened with the Graphomat Z64.

Historical accounts on how computer art emerged often narrate a story of creative use of uncreative technical equipment. This was the case of Zuse's Graphomat Z64 as described on the CompArt site, a comprehensive and respectable database of digital art published by the University of Bremen:

"The ZUSE Graphomat Z64 was a flatbed drawing machine of high precision. Its engineer, famous computer pioneer Konrad Zuse, had originally intended it to be used for the production of maps and land registration purposes. Both Georg Nees and Frieder Nake did their first computer art pieces on the Graphomat. This historical fact may be seen as a case of an unintended use of technical innovation." (CompArt Center for Excellence Digital Art, Accessed March 3, 2016).

Other texts have also addressed the "unintended use" theme with the Graphomat Z64. As one example, Rhonda Bowlin explains: "A digital artifact like the Z64 is rather meaningless without the context of human intent for its use, especially when notable use diverges the original intended use."

After analyzing the found texts by Zuse in the topic of Computer Art, it is evident that the narrative of the "unintended use" of the Graphomat Z64 must be challenged. Our position contradicts the view that the use of the Graphomat by artists like Nees and Nake was simply an unintended use of technological innovation - but how do we tell the story again? Nake himself discusses the complex relationship between artists and engineers as social actors. He is clearly aware of the importance of redefining this relationship, focusing on an emerging production of art by people who were not necessarily trained as artists (Nake, 2009). Zabet Paterson explains that "the rhetoric of the day emphasises this: there were artists on one side and engineers on the other, and their collaboration was the result of fortuitous encounters. Yet this binary is a drastic simplification if not an outright historical falsification" (Paterson, 2015 p. xv).

There are some possibilities to re-think this inclusion in the origins of computer arts. One way is the idea that it was a fortuitous event that allowed computer art to happen. This school of thought would argue that despite the fact that Zuse did have artists in mind and built machines to facilitate graphics, the use by artists like Nees and Nake could have still been a mere coincidence. Two different practices and views interacted indirectly and somehow by chance, allowed a new artistic movement to be born. This is supported by the fact there is no evidence that Nake was aware of Zuse's writings about artists when he created his first plots in 1963 (Nake, 1968). There had not been an interaction between them except the one mediated by the Graphomat Z64. Zuse's

manuscript one year later, reveals that apparently he was not aware of the computer art movement that was gestating at the University of Stuttgart (Zuse, 1969). This view is reminiscent of Jasia Reichhardt's concept of "Cybernetic Serendipity," the title of a seminal exhibit of computer art from 1968. We often focus on the phenomena that directly show connections but in this story, paying attention to the broken links is equally important. In this case there are, in fact, two broken links: an engineer who built the machine who wrote about the potential artistic uses, but did not know about the artists using his equipment for such a purpose at that time; and a group of artists who cleverly used the machine and did not know about the engineer's texts or intentions. In our opinion, we are dealing with an inexplicable communication process facilitated and led by the Graphomat Z64, the artifact itself.

It is possible that the design qualities of the Graphomat Z64 itself helped to open a tangible door for the artists to approach computing. Although this view can point to technological determinism, (where art history would be explained only by the evolution of the technological devices), we believe that there is enough supporting information to claim that there were specific qualities of the Graphomat Z64 (like the accessibility, the versatility, the compactness and the transparency of the core functionalities) that aided the apparition of an avant-garde artistic movement. Was there somehow a discourse engraved in the machine that eventually artists such as Nees and Nake could read? Is it there an inherent discourse in the technological tools?

Given the conscious effort of Zuse in facilitating graphics through a combination of hardware and software, it is possible to argue that Graphomat Z64 provoked the artists. Our final thought is that the Graphomat Z64, constituted by its material configuration and its software implementation, served as a medium in an unusual, yet not accidental manner, enabling engineers' and artists' common intention of connecting machines to human thought, intentions and expression.

**Acknowledgements**

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Andrés Burbano holds a Ph.D. in Media Arts and Technology from the University of California, Santa Barbara. He's an assistant Professor in the Department of Design at the Design and Architecture School at the Universidad de los Andes, Colombia. He's also a Leonardo Education and Arts Forum International Representative. His current research projects are the following: James Bay Cultural Atlas, an audiovisual on-line database of the Cree communities from the James Bay in Northern Quebec; Sonorization, Visualization and Materialization of Biodiversity Data. FAPA, Grant for assistant professors at Universidad de los Andes, where he is the project leader.

Esteban García Bravo explores computational arts as a researcher, a practitioner and as an educator. He earned his MFA from Purdue University in 2008, and a Ph.D. in Technology, also from Purdue, in 2013. His research on computer art history and digital media art practices has been featured in the annual meetings of international organizations such as SIGGRAPH (2011,2015), ISEA (2012, 2013, 2014) and Media Art Histories-MAH (2013). His artwork has been displayed internationally in media art festivals, gallery exhibits, museums and artist-in-residence programs. Esteban is currently an Assistant Professor in the department of Computer Graphics Technology at Purdue University, where he teaches digital imaging, visualization and computational aesthetics.