

Computer Graphic Re-Visited: The Virtual Reconstruction of One of the First Computer Art Exhibitions

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I. BACKGROUND

A. Beginnings of Computer Art

Most of the pioneers of computer art were mathematicians, engineers, and the first programmers, who worked for large companies (Boeing Company,¹ AT&T's Bell Laboratories, Siemens AG) or who worked at universities (University of Stuttgart, University of Erlangen, Ohio State University, and University of Toronto) where they had access to computers.² In 1965, around the time of the first exhibitions of computer art, few knew what a computer or a program was. Computer monitors barely existed and ordinary people did not own computers.³ We can therefore conclude that the development of computer art in its first decade emerged within a narrow circle of specially educated professionals who had access to the first computers due to their affiliation with privileged technical and research institutions.

This article describes a reconstruction of the *Computer Graphic*, one of the first computer art exhibitions, staged in [former] Czechoslovakia in 1968, utilizing the technology of fully immersive virtual reality.

¹William Alan Fetter, artistic director for Boeing Company, co-authored the concept of computer graphics and authored the first computer graphic: Human Figure (also known as Boeing Man) Although Boeing Man was created as a standard figure of a pilot in aircraft models, it was presented at the two largest computer art exhibitions: *Cybernetic Serendipity* in London, U.K. and *Tendencies 4* in Zagreb, Croatia. Fetter created his computer graphics with IBM 7094 and CDC 6600 computers, and printed them on a Gerber Plotter: compArt daDA: The database Digital Art. *First Boeing Man by William Alan Fetter*. Accessed: Sep. 16, 2018. [Online]. Available: <http://dada.compartment-bremen.de/item/artwork/240>

²A. M. Noll, "The beginnings of computer art in the United States: A memoir," *Leonardo*, vol. 27, no. 1, pp. 39–44, 1994.

³F. Nake, "Roots and randomness—A perspective on the beginning of digital art," in *Digital Art* (Atlasbooks Dist Serv), 2009, p. 48.

Digital Object Identifier 10.1109/JPROC.2019.2893780

B. Information and Generative Esthetics

The theoretical background for early computer art was formulated by Max Bense and Abraham A. Moles, who, influenced by cybernetics and theories of information and structuralism, elaborated information and generative esthetics. Bense, who worked from 1949 to 1978 at the Technical University of Stuttgart (Technische Hochschule Stuttgart), influenced the conceptual approach of the German circle of computer art pioneers. He argued that modern art cannot be understood by applying categories used for the exact evaluation of classical works, such as proportion, symmetry, and harmony, because they emphasized contrasts and overlooked standards. In his theory of "information esthetics,"⁴ he tried to systematize some basic

esthetic principles which would make it possible to precisely describe modern works of art, i.e., "esthetic objects" in the terminology of information esthetics, and to exclude from this process the subjective, unscientific perspective of the recipient. Working with probability theory and categories such as randomness and indeterminacy, he based his theory on a statistical analysis of artistic objects, often

⁴Max Bense first proposed information aesthetics in a lecture at Stuttgart Technical University in 1957 and subsequently published *Aesthetica (III). Ästhetik und Zivilisation. Theorie der ästhetischen Zivilisation*, Agis, Krefeld/Baden-Baden, 1958. C. Giannetti, *Cybernetic Aesthetics and Communication* (undated). Accessed: Sep. 19, 2018. [Online]. Available: http://www.medienkunstnetz.de/themes/aesthetics_of_the_digital/cybernetic_aesthetics/scroll/

Table 1 Selected Exhibitions in the First Decade of Computer Art (in Chronological Order)

Name	Venue	Curators	Exhibiting Artists	Year
Georg Nees: Computer Graphics (1 st computer art exhibition in the world.)	<i>Technische Hochschule Stuttgart</i> , Germany. (Hahn-Hochhaus, 8 th floor, Study Gallery of the Institute of Philosophy)	Max Bense, Siegfried Maser	Georg Nees	1965 (9–15 February)
Computer Generated Pictures (1 st computer art exhibition in US)	Howard Wise Gallery, Manhattan, New York, US	Howard Wise	A. Michael Noll, Bela Julesz	1965 (6–24 April)
<i>Computer-Grafik Programme</i> (1 st exhibition of computer art outside of a university, in an art gallery.)	<i>Galerie Wendelin Niedlich</i> , Stuttgart, Germany	Frieder Nake	Frieder Nake, Nees	1965 (5–26 November)
<i>Programm-Information PI-21</i> . (Full title: Production of graphic renderings, audio sequences, and texts by electronic computers [German: <i>Herstellung von zeichnerischen Darstellungen, Tonfolgen und Texten mit elektronischen Rechenanlagen</i>] (Probably 1 st exhibition of computer art presenting graphics, music, and poetry.)	<i>Deutsches Rechenzentrum</i> , Darmstadt, Germany	Nake	Nake (computer graphics), Gerhardt Stickel (computer poetry), Max V. Matthews, Ben Deutchman (computer music).	1966 (15 January–15 February)
<i>Computer Graphic</i> (1st exhibition of computer art in the countries of the so-called Eastern Bloc.)	<i>Brno House of Arts</i> , Brno, Czech Republic (then the Czechoslovak Socialist Republic).	Jiří Valoch	Charles Csuri, Leslie Mezei, Nake, Nees, Noll, Lubomír Sochor	1968 (5 February–3 March)
<i>Cybernetic Serendipity: The Computer and the Arts</i> (The largest and most well-known exhibition of computer art that was the crowning event of the first decade of its development.)	<i>Institute of Contemporary Arts</i> , Nash House, London, United Kingdom	Jasia Reichardt (and Frank Friedman Oppenheimer, Renato Danise)	A total of 89 exhibitors, including Ben Laposky, Noll, Mezei, Csuri, Nake, Nees. [6]	1968 (2 August – 20 October)
<i>Tendencije 4, Kompjutori i vizuelna istraživanja</i> (Tendencies 4. Computers and Visual Research) (The exhibition was part of an international conference of the same name.)	<i>Center for Culture and Information</i> (1968) and subsequently <i>Museum of Contemporary Art Zagreb</i> , Croatia, former Yugoslavia.	Abraham André Moles, Boris Kelemen, Dimitrije Bašičević, Ivan Picelj, Matko Mestrovic, Radoslav Putar, Vjenceslav Richter [7]	A total of 26 exhibitors, including Noll, Csuri, Nees, Nake, Mezei.	1968 and 1969 (2–8 August 1968; 5 May–30 August, 1969).

Compilers: Jana Horáková and Jiří Mucha

using terminology such as “redundancy” or “entropy,” which revealed his inspiration by Wiener’s cybernetics. Later, he introduced the term “generative esthetics” as a designation for a combination of all operations, rules, and theorems, which, when deliberately and systematically applied to a number of material elements, should function as characteristics bearing esthetic information.

⁵J. Reichardt, Ed., *Cybernetic Serendipity: The Computer and the Arts: A Studio International Special Issue*. London–New York, 1968. Accessed: Sep. 19, 2018. [Online]. Available: https://monoskop.org/images/2/25/Reichardt_Jasia_ed_Cybernetic_Serendipidity_The_Computer_and_the_Arts.pdf

⁶M. Rosen, D. Fritz, and P. Weibel, Eds., *Bit International*. [Nove] *Tendencije Computer und Visuelle Forschung, Zagreb 1961–1973*, ZKM | Centre for Art and Media Karlsruhe, Medienmuseum, 23 Feb. 2008–18 Jan. 2009. Accessed: Sep. 16, 2018. [Online]. Available: http://www06.zkm.de/zkmarchive/www02_bit/bit/index_com_content_view_72_93_en.html

C. First Exhibitions of Computer Art

The first exhibitions of computer art took place between 1965 and 1968. In 1968, the first phase of computer art culminated in the acclaimed exhibition *Cybernetic Serendipity* in London, U.K. and in the international scientific symposium connected to the exhibition *Tendencies 4. Computer and Visual Research*, which took place in Zagreb, Croatia (see Table 1). Computer-generated graphics were presented at many other exhibitions as well: Frieder Nake attests to showing his works at more than 19 exhibitions over three years.⁷

⁷Nake, *OP Cit*, p. 50

D. Situation in the Former Czechoslovakia

The narrative of the Cold War that depicts Western Europe as wealthy, free, and progressive, on the one hand, and the Eastern Europe as impoverished, totalitarian, and backward is too schematic to reflect the situation of computer art in former Czechoslovakia.⁸ Despite the intolerance of the Soviet-aligned communist regimes toward modern art, and the scarcity of access to computers for artists, computer art was produced in Czechoslovakia as early as the 1960s.⁹ This initiative was the result of the network of contacts with western and Yugoslavian progressive artists and theorists, stimulated by the “New Tendencies” symposia and exhibitions that took place in Zagreb between 1961 and 1973. Contributions from these symposia were featured in *Bit International*, which was published between 1968 and 1972 by Zagreb Gallery (*Galerije grada Zagreba*). It is particularly worth mentioning the symposium and two exhibitions of *Tendencies 4. Computers and Visual Research* that were held in 1968 and 1969 (see Table 1). Contributions from this symposium were published in the first issue of *Bit International*, which included studies by Max Bense and Abraham A. Moles.¹⁰ The foreword referred to the overlap between science and art, and technology and society. Theories of information, exact esthetics, design, communication, mass media, and visual and related objects were the focus of the authors’ studies. The publications did not mention the economic and political differences between the East and the West. Moreover, these international symposia, exhibitions, and journal publications placed Zagreb at the center of global developments in computer art, understood as an extension of constructive, conceptual, concrete, and kinetic art movements.

Information about exact esthetics, especially with regard to its manifestations in the experimental poetry of that period, was mediated by Bohumila Grögerová and Karel Hiršal, who were in contact with Bense.¹¹ They influenced Jiří Valoch, an author and theorist of experimental poetry, and apparently drew Bense’s attention to the work of Czech painter Zdeněk Sýkora. Sýkora, who switched from landscape painting to working with rasters and a combinatorial play with the basic elements of visual language, is considered the world’s first artist to integrate the computer into the process of art production.¹² In 1964,

⁸M. Šperka, “The origins of computer graphics in the Czech and Slovak Republic,” *Leonardo*, vol. 27, no. 1, pp. 45–50, 1994.

⁹T. Bozhinov, “Behind the silicon curtain. Computer art in the East Bloc,” M.S. thesis, Univ. Arts Bremen, Bremen, Germany, 2015. Accessed: Nov. 28, 2018. [Online]. Available: http://www.academia.edu/25189050/Behind_the_Silicon_Curtain_Computer_Art_in_the_Eastern_Bloc

¹⁰*BIT International*. [Online]. Available: https://monoskop.org/New_Tendencies#mediaviewer/File:Bit_International_1_The_Theory_of_Information_and_the_New_Aesthetics_1968.jpg https://monoskop.org/New_Tendencies#Magazine

¹¹J. Hiršal and B. Grögerová, *Let Let [Years Fly]*. Prague, Czech Republic: Torst, 2007.

¹²See, for example, the catalog of the retrospective exhibition *Sýkora 90*, which took place 19 February–2 May 2010 in Prague City Gallery, Municipal Library: P. Kappel, *Zdeněk Sýkora 90*. Prague, Czech Republic: Verzone, 2010.

in collaboration with the mathematician Jaroslav Blažek and with the use of an LGP-30 computer, he created the first constructivist paintings based on computer-generated formulas described in alphanumeric code. Sýkora then transferred the created patterns onto canvas or placed them in public spaces in the form of glass and ceramic mosaics.¹³ He also presented his work in Zagreb at the symposia *New Tendencies 3* in 1965 and *Tendencies 4* in 1968–1969. While Sýkora was the only representative of the Czechoslovak Socialist Republic to participate in this event in 1965, other Czechs and Slovaks exhibited there in 1968–1969, including art theorist Jiří Valoch, as a representative of the Concretist Club (Klub Konkretistů) and for his role as curator of the exhibition *Computer Graphic*.¹⁴

The multitalented Czech artist and theorist Miroslav Klivar¹⁵ first exhibited his computer graphics in 1965 at the collective exhibition *New Graphics* on Kampa Island in Prague. Two years later, Valoch sent a proposal to the Brno House of Arts to mount an exhibition of computer graphics, which was accepted and staged in February 1968 (see below). That September, Klivar hosted a *Computer and Art* exhibition at the Prague Film Club¹⁶, where he presented the works of George Neese and Frieder Nake from Germany and Kerry Strand from the United States along with his own computer graphics. In 1969, Valoch organized another exhibition of computer graphics. This time it was an individual exposition of the work of Serbian artist Petar Milojevic, which was held in Brno at the *Exposition of Experimental Music*.¹⁷ Klivar organized other exhibitions of computer graphics that often focused on their use in applied art, in cooperation with Zdeňka Čechová. Čechová was head of experimental studies at the Institute of Housing and Clothing Culture in Prague (UBOK), and in 1971 became the first person in former Czechoslovakia to start using computers to generate graphic designs for applied art, wallpaper, fabrics, and porcelain.¹⁸ Other artists also continued to utilize computers in the process of creating art, including Jozef Jankovič, collaborated with computer scientist Imrich Bartók, and Daniel Fišer, collaborated with programmer Pavel Fišer. In the field of architectural

¹³His constructivist composition was first transferred to an architectural space in 1967–1968 in the form of tiles on a tunnel ventilation chimney at Letná in Prague and a ceramic wall at the Polish Information Centre on Jindřišská Street in Prague.

¹⁴A. Medosch, *New Tendencies: Art at the Threshold of the Information Revolution (1961–1978)*. MIT Press, 2016, p. 175.

¹⁵M. Klivar, “České počítačové umění (2),” *Chůdové Kořeny*, vol. 2, no. 3, Oct. 2003. Accessed: Sep. 16, 2018. [Online]. Available: http://www.v-art.cz/chudove_koreny/r02c03/intermezzo/klivar/klivar.htm

¹⁶*Ibid.*

¹⁷J. Valoch, “Computer graphics,” in *Orbis Fictus-New Media in Contemporary Art*, L. Hlaváček, M. Smolíková, Eds. Prague, Czech Republic: Soros Centre for Contemporary Arts, 1995, p. 82.

¹⁸Čechová’s younger colleagues also used computers in applied arts: L. Dvořáková, Z. Frýbl, I. Ponikelská, K. Skoumalová, and E. Šnejdarová, *Computer Art in the ČSSR and the World/III. National Exhibition With International Participation* (The Palace of Culture, Prague, Apr. 11–16, 1989). Prague, Czech Republic: The House of Technology ČSVTS, 1989.

design, Jan Moučka exploited the potential of computers. Notable devotees of computer art from the younger generation include Aleš Svoboda (a pupil of Sýkora), Stanislav Zippe, and Pavel Rudolf, who worked with the programmer Ivo Serba.¹⁹

Computer art in Czechoslovakia, as it developed between 1965 and 1971, was tolerated by the totalitarian regime for several reasons. There had been a loosening of political restrictions—at least, up until the 1968 occupation—but it was also a period when high hopes were invested in technological progress. Moreover, these art experiments usually took place outside of the government's art institutions and, therefore, out of the sight of state authorities.

II. COMPUTER GRAPHIC (1968)

A. Exhibition

The exhibition *Computer Graphic*, curated by Jiří Valoch, took place in the Brno House of Arts in former Czechoslovakia in 1968, 3 years after the first exhibition of computer graphics in Stuttgart (1965), and a few months before much larger exhibitions of computer art, like *Cybernetic Serendipity* in London (1968) and *Tendencies 4. Computers and Visual Research* in Zagreb (1968). It was the first exhibition of its kind to take place in the countries of the Eastern Bloc but has so far largely escaped the attention of art historians.²⁰ We attempted to fill in this gap in the history of new media art in our research experiment.

The exhibition *Computer Graphic* was presented at three exhibition venues. It was first exhibited in the Brno House of Arts between February 5 and March 3, 1968, after which it was transferred to the Regional Gallery of the Bohemian-Moravian Highlands in Jihlava, where it was on show March 10–31, 1968. Its final destination was the Regional Gallery of Fine Arts in Gottwaldov (today's Zlín), from April 25 to June 2, 1968.

Valoch obtained graphic works for the exhibition from leading figures of the first generation of computer artists. From North America, A. Michael Noll (USA) provided three works, Charles Csuri (USA) two works, and Leslie Mezei (Canada) six graphic works. From Europe, Frieder Nake (Germany) sent Valoch as many as 36 works, Georg Nees (Germany) contributed seven, and the only local artist, Lubomír Sochor (Czechoslovakia), provided the curator with 27 graphic works. In total, Valoch staged 81 exhibits for visitors.

From surviving sources, we know that Nake attended the exhibition opening in Jihlava which included computer-generated music and poetry.²¹ Nake played a

gramophone record with the computer compositions of Max Matthews and Ben Deutshman, and introduced visitors to Gerhardt Stickel's generated poetry,²² which he had previously exhibited at the *ProgrammInformation PI-21* in Darmstadt (January 15–February 15, 1968), where he was both an exhibitor of his own computer graphics and the curator (see Table 1).

A slender catalog was published in Czech to accompany the exhibition.²³ It contained an introductory text by Valoch entitled *Programmed Art*; Max Bense's shortened version of *The Projects of Generative Aesthetics (Projekte generativer Ästhetik)*; Nake and Sochor's descriptions of the process of creating computer graphics; profiles of the exhibiting artists; and six untitled reproductions of computer graphics credited to their authors.

B. Authors of the Computer Graphics

In the catalog, Valoch introduced the creators of the computer graphics not as artists, but as program authors. At the same time, he emphasized the principal role of computers in executing the programs to create the exhibited works. The importance that Valoch attributed to the process of creating graphic works is also evident from his correspondence,²⁴ in which he encouraged exhibitors to describe their creative process for the catalog. Valoch emphasized that a computer graphic work is the result of the endeavors of a creative team consisting of “a human (programmer) + a machine (computer)” together with a plotter (drawing machine), which transposes the finished graphics or drawing from computer memory (punched tape or punched card) into a definitive visual form.²⁵ Therefore, the following introduction of the exhibiting artists also refers to the names of the computers, plotters, and programs used, wherever it was possible to trace them.

*Charles A. Csuri (*1922, Grant Town, WV, USA):* A pioneer of computer graphics, known primarily for computer animations, which he started creating in 1965. He was the only exhibitor who had an art education. He created his early works on an IBM 7094 computer with FORTRAN, using an IBM 1130 computer to control the plotter.

*Leslie Mezei (*1931, Budapest, Hungary):* A war orphan from Hungary who went to Canada and studied physics and mathematics. From 1954 to 1964, he worked as a programmer, systems analyst, and manager. Mezei developed the SPARTA graphics programming language and ARTA interactive animation system. He used an IBM

²²Correspondence between Horáková and Nake.

²³J. Valoch, *Computer Graphic* (Exhibition Catalogue), Archive of the Brno House of Arts. Accessed Sep. 16, 2018. [Online]. Available: https://monoskop.org/images/1/17/Valoch%2C_Ji%C5%99%C3%AD_%281968%2C_ed.%29_-_Computer_Graphic%2C_catalogue_%28Czech%29.pdf

²⁴Jiří Valoch's personal archive is stored in the Moravian Gallery in Brno.

²⁵J. Valoch, “Art and Computers,” *Sešit pro Literaturu a Diskusi*, no. 31, 1969, p. 42.

¹⁹Klivar, *op cit.*; Šperka, *op cit.*; Valoch, *op cit.*

²⁰Bozhinov, *op cit.*; Valoch, *op cit.*; Šperka, *op cit.*

²¹Invitation to the opening of the exhibition at the Regional Gallery of the Bohemian-Moravian Highlands in Jihlava: Archive of J. Valoch, Moravian Gallery in Brno. Photos from the opening: Archive of the Regional Gallery Highlands of the Bohemian-Moravian in Jihlava; correspondence between Jana Horáková and Frieder Nake.

1094 model II computer and a Calcomp 565 plotter for his early graphics.

*Frieder Nake (*1938, Stuttgart, Germany):* One of the leading pioneers of computer art, whose works were exhibited at almost all of the early exhibitions of computer art. While studying mathematics at the Technical University in Stuttgart, he attended the lectures of Max Bense, which had a strong influence on him. He worked successively with an SEL ER56 a Telefunken TR4, and an IBM 360 computer. Like Georg Nees, he used a Graphomat Z64 plotter.

Georg Nees (1926–2016, Nuremberg, Germany): The first author whose computer graphics were publicly exhibited (Stuttgart, 1965). Nees studied mathematics, physics, and philosophy at the University of Erlangen, and in 1969 obtained a doctorate in philosophy under the supervision of Max Bense at the University of Stuttgart with the defense of his dissertation “Generative Computer Graphics.” He spent his career as an industrial mathematician for Siemens. For his early works, he used the ALGOL 60 program, a Siemens 4004 computer, and a Graphomat Z64 plotter.

*A. Michael Noll (*1939, Newark, NJ, USA):* Created his first works as a researcher at Bell Telephone Laboratories in 1962. In 1964–1965, he created the first static and moving stereographic images, and in 1975, he created a system that can be considered the forerunner of digital virtual reality. Noll worked with IBM 7090 and 7094 computers and a Stromberg Carlson SC-4020 plotter, which he replaced, in 1968, with a Stromberg DatagraphiX SD-4360.²⁶

*Lubomír Sochor (*1938, Prague, Czechoslovakia):* Studied electrical engineering at the Industrial High School of electrotechnical communications (Střední průmyslová škola elektrotechnická) in Prague. After graduating, Sochor worked at the Research Institute of Communication Technologies (VÚST) in Prague on servomechanisms, automation, and analog technology. In 1966, he moved to the Analogue Computing Centre of the Military Hospital in Prague as an operator and, after training, became a programmer. He exhibited his computer graphics for the first time at Valoch’s exhibition, using an S.E.A. NADAC 100 analog computer, before abandoning the world of art.

C. Jiří Valoch and Computer Graphics

Jiří Valoch (*1946, Brno) is an art theorist, curator, and conceptual artist. In 1963, he started creating visual poetry and later also focused on concrete poetry and conceptual art. He organized the exhibition *Computer Graphic* when he was just 22 years old, during his university studies. He graduated from the Faculty of Arts of Masaryk University in 1970, qualifying in the field of Teaching for Secondary Schools and specializing in Czech and German languages. Valoch wrote his master’s thesis on the development and

typology of visual and phonic poetry. From 1972 to 2001, he worked as a theorist and curator at the Brno House of Arts, organizing dozens of exhibitions of prominent Czech and international artists. Valoch collaborated on various unofficial exhibitions, samizdat catalogs, and collections, and wrote several monographs and catalog texts.

Valoch’s education in philology and his experience as a creator of visual and concrete poetry enabled him to recognize the specific benefits of artistic techniques introduced by working with a computer. He did not understand computer graphics as images, but rather as the final stages of processes carried out by a computer. In his proposal for the exhibition, he had already written about computer graphics not as of a collection of works but as of a “series of variations.”²⁷ Valoch was, therefore, aware that computer graphics do not exist as unique works, but rather as a family of graphical outputs that are the results of the work of a program. He tried to convey this aspect of computer art to the exhibition’s visitors, who were confronted by the 36 works by Frieder Nake and the 27 works by Lubomír Sochor: that is, dozens of graphic works created by the processing of a single program. Valoch understood computer graphics as enriching a vast array of concrete art. He described the works of Nake and Nees as “stochastic graphic works,” since both authors used the computer to generate random numbers which were subsequently used to make calculations, or they created options from which the computer randomly selected the possible solutions, that is, the graphical representations.

III. COMPUTER GRAPHIC RE-VISITED

A. Data

The virtual reconstruction of the exhibition *Computer Graphic* that was curated by Jiří Valoch, titled *Computer Graphic Re-Visited*, was held at the 4th International Conference on the History and Philosophy of Computing (HaPoC 4) between October 3 and 6, 2017 at Masaryk University.²⁸ The installation was located in the entrance hall of Brno House of Arts, that is, the site of Valoch’s exhibition in 1968. The virtual exhibition opened at 5 p.m. on October 5, 2017 and was attended by Valoch and Nake.²⁹

The success of this virtual exhibition led to an agreement between the creators and the institution’s management to put on an extended version in the spring of 2018, from 21 March to 22 April, almost exactly 50 years from the date of Valoch’s original exhibition. For organizational reasons, this time the installation was not located in the entrance hall, but in Procházka Hall. In addition to technically improved virtual reality, this second version,

²⁷A letter addressed to the Brno House of Arts, Brno House of Arts archive, file on Jiří Valoch, *Computer Graphic*.

²⁸J. Raclavský, H. Durnová, and J. Horáková, in *Proc. 4th Int. Conf. History Philos. Comput. (HaPoC-4)*, 2017. Accessed: Sep. 20, 2018. [Online]. Available: <https://hapoc2017.sciencesconf.org/>

²⁹J. Horáková and J. Mucha, *Computer Graphic Re-Visited (Exhibition)*, The Brno House of Arts, Oct. 2017. Accessed Sep. 16, 2018. [Online]. Available: <http://www.dum-umeni.cz/en/vystavy/detail/id/290>

²⁶Noll, *op cit.*, p. 39.



Fig. 1. Photograph of Jiří Valoch aged 22 at the exhibition *Computer Graphic in Jihlava*. Source: Archive of the Regional Gallery of the Bohemian-Moravian Highlands in Jihlava.

entitled *Computer Graphic Re-Visited 2.0*, included the placing of exhibits in the gallery space, namely, computer graphics, computer music, and poetry generated by a computer of the period, and an animated flowchart depicting the process of creating Nake's graphic work, *Walk Through Raster*.³⁰

Both of these research-curatorial projects were created by Jana Horáková and Jiří Mucha, initially conceived as the theme of a master's thesis,³¹ but which gradually outgrew the parameters of the thesis and blossomed into a creative collaboration.

B. Entry Inputs and Project Parameters

Computer Graphic Re-Visited was conceived as an art history experiment in which we tried to effectively combine artworks with sources stored in the archives of the relevant

³⁰J. Horáková and J. Mucha, *Computer Graphic Re-Visited 2.0 (Exhibition)*, The Brno House of Arts, Mar.–Apr. 2018. Accessed: Sep. 16, 2018. [Online]. Available: <http://www.dum-umeni.cz/en/vystavy/detail/id/322>

³¹J. Mucha, *Computer Graphic*, 1968. *Rekonstrukce první výstavy počítačem generovaného umění v bývalém Československu*. [Reconstruction of the first exhibition of computer-generated art in the former Czechoslovakia], M.S. thesis, Masaryk Univ., Brno, Czech Republic, Feb. 5, 2018. Accessed: Sep. 16, 2018. [Online]. Available: https://is.muni.cz/auth/th/iuskh/Jiri_Mucha_diplomova_prace.pdf



Fig. 2. Opening of the virtual exhibition *Computer Graphic Re-Visited*, Brno House of Arts, October 5, 2017. Photograph: Frieder Nake with VR glasses and visitors at the opening.

institutions³² with virtual reality technology. During the project, we discovered that the creation of a simulation of an exhibition requires much more research, with an eye for both detail and context, that is needed to write an article. The creative process led us to ask such questions as, What were the floor tiles in the exhibition hall like? What was the texture and color of the walls? What could a visitor see through the glass panels in the walls? These details may seem trivial from the perspective of art history, but they contributed to the visitor's experience, and significantly influenced impressions of the installation and exhibited works. In relation to the reconstruction of the exhibition, we asked three principal questions: What works were exhibited (artifacts), where was the exhibition held (venue), and how were the computer graphics displayed (installations)?

C. Artifacts

There is no surviving list of the exhibited works. We had only the handover protocol that was exchanged between Valoch and the galleries in Jihlava and Gottwaldov, stating the number of exhibited works by individual authors, but without their titles. Therefore, we had to identify the works using circumstantial evidence. Several works were used to illustrate the surviving catalog of the exhibition. We found photographs of two graphic works in the archive of the Brno House of Arts, other works we recognized in photographs from the Jihlava opening of the exhibition, and we found other titles in the personal correspondence between Valoch and the exhibiting authors. An important source of information was also e-mail communication with Charles Csuri and especially Frieder Nake.³³

Nake kindly provided us with 22 high-quality scans of his works, including titles and exact dimensions. Michael

³²These were the mainly archives of exhibition institutions: Jiří Valoch's personal archive in the Moravian Gallery in Brno; and the archives of the Brno House of Arts, the Regional Gallery of the Bohemian-Moravian Highlands in Jihlava, and the Regional Gallery of Fine Arts in Zlín (formerly Gottwaldov).

³³Unfortunately, Jiří Valoch is not in good health; the testimonies of the exhibiting artists proved to be more useful.

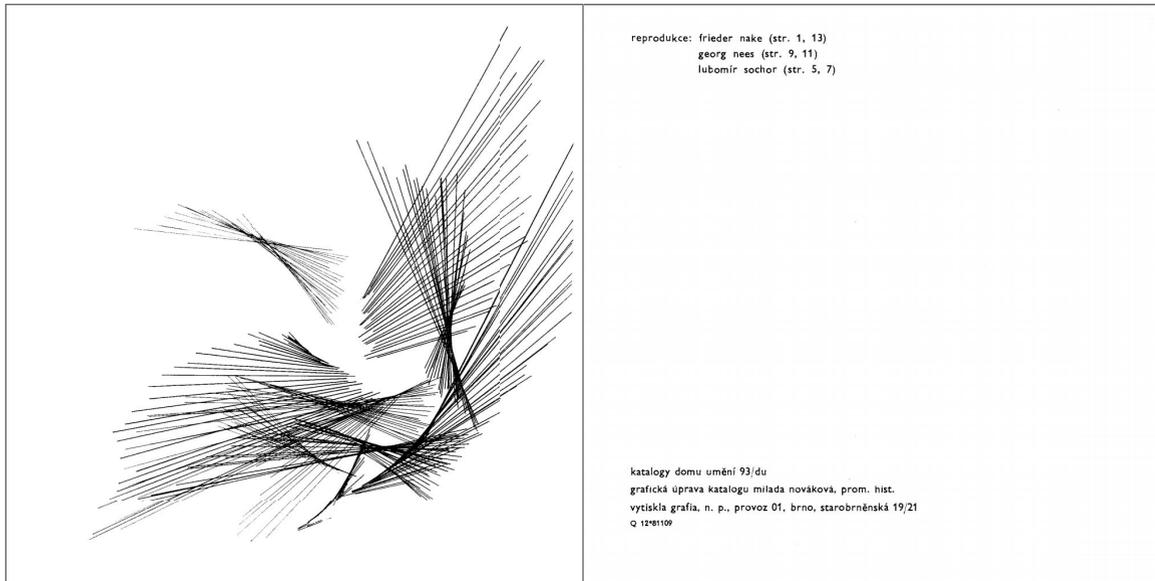


Fig. 3. Front and back cover of the catalog of Computer Graphic, 1968.

Noll provided the titles of his exhibited works and gave his permission for the relevant museums to send us digital reproductions. The graphics by Georg Neese and Lubomír Sochor that were identified in the exhibition catalog and in the article by Valoch we digitized on a scanner. As we were unable to obtain the graphics by Mezei and Csuri in high resolution, they could not be included in the virtual exhibition.

Since not all of the works in Valoch's exhibition were available in the required quality, we decided to limit the scope of the reconstruction of the exhibition as a historically faithful fragment of the original. Four of the six artists were represented: Nees, Nake, Noll, and Sochor. Of the original 81 graphic works, 20 were exhibited. In order to maintain a reasonably proportionate number of works exhibited by the individual authors, we selected eleven graphic works by Nake, and three works apiece by Nees, Noll, and Sochor (see Table 2).

D. Venue

The discovery that Valoch's exhibition was held in the entrance hall of the Brno House of Arts led us to approach its archive for the architectural drawings of the hall and some photographs of the interior from that period. We were primarily interested in how the place was fit out, including floor tiles, the paint on the walls, window frames, type of lighting, and the areas around the building that were visible through the window panes. We obtained other information about the room dimensions, such as the height of windows and width of sills and ledges, with a laser distance meter.

E. Installation

There is no information available concerning the curatorial concept of the exhibition, nor are there text

descriptions, drawings, or photographs of the first exhibition in Brno. However, in photographs of the Jihlava exhibition, we can see the graphic works positioned not only on the walls but also in glass display tables. The graphics were displayed without frames, between panes of glass, and sometimes on black paper, which accentuated the contrast and thus the distinctness of the artwork. Some of the Jihlava photographs capture the atmosphere of the exhibition opening, which was attended by Valoch, Nake, and his wife, Ursula Nake Geschke. We, therefore, decided to promote the vibrancy of the visitors' experience by putting into the virtual model seven photographs from that time, which show, for example, visitors viewing the graphics, a cluster of guests talking together, and Nake and Valoch conversing.

IV. VIRTUAL RECONSTRUCTION OF THE EXHIBITION *COMPUTER GRAPHIC*

For the virtual reconstruction of the exhibition, it was necessary to:

- 1) obtain the exhibited works in a high-quality digital format and modify them so they would fit into a 3-D model of the exhibition space;

³⁴A digital copy was obtained by scanning an illustration in the exhibition catalogue, which is preserved in the Brno House of Arts archive.

³⁵*Ibid.*

³⁶A digital copy of a photograph of a picture stored in the Brno House of Arts archive with the name of the author.

³⁷Los Angeles County Museum of Art.

³⁸Victoria & Albert Museum in London.

³⁹A digital copy was obtained by scanning an illustration in the exhibition catalogue, which is preserved in the Brno House of Arts archive.

⁴⁰*Ibid.*

⁴¹*Ibid.*

Table 2 List of Works Exhibited in the Virtual Reconstruction of the Exhibition *Computer Graphic*

Author	Artwork	Year	Size
Frieder Nake	<i>Walk Through Raster 2.5-5</i>	1966	44 x 44 cm
	<i>Walk Through Raster 7.1-6</i>	1966	31 x 31 cm
	<i>Walk Through Raster 2.1-6, 1, 5, 4</i>	1966	40 x 40 cm
	<i>Matrizenmultiplikation Serie 31</i>	1967	50 x 50 cm
	<i>Verteilungelementarer Zeichen</i>	13. 9. 1965	51 x 51 cm
	<i>Hommage à Paul Klee</i>	13. 9. 1965	40 x 40 cm
	<i>Rechteckschraffuren</i>	30. 3. 1965	20 x 30 cm
	<i>Zufälliger Polygonzug</i>	13. 9. 1965	43 x 43,1 cm
	<i>Zufälliger Geradenscharen</i>	12. 7. 1965	85,5 x 70 cm
	<i>Rechteckschraffuren in feldern</i>	2. 9. 1965	40 x 21,5 cm
	<i>Zufälliger Polygonzug C-Zahlen</i>	16. 3. 1965	20 x 20 cm
Georg Nees	<i>Polygons</i> [34]	1965	50 cm width
	<i>Irrweg</i> [35]	1968	50 cm width
	(title not found) [36]	1966	50 cm
A. Michael Noll	<i>Gaussian-Quadratic</i> [37]	1963	21.8 x 21.8 cm
	<i>Vertical-Horizontal Number Three</i>	1964	21.8 x 21.8 cm
	<i>Computer Composition With Lines</i> [38]	1964	76.2 x 76.2 cm
Lubomír Sochor	(untitled) [39]		50 cm width
	(untitled) [40]		30 cm width
	(untitled) [41]		30 cm width

Compilers: Jana Horáková and Jiří Mucha

- 2) create a 3-D model of the exhibition space and put the exhibited works into it;
- 3) export the 3-D model to a game engine and add interactive (game) elements; and
- 4) save the result on a computer and install it, together with the VR headsets and other hardware in the exhibition hall.

A. Digitization and Preparation of Computer Graphics

It was necessary to acquire the selected works in a digital format in a resolution of 600 dpi or convert them into this form. In the preparations to exhibit them in the 3-D model, it was necessary to unify the format and resolution and remove the blemishes that some works had picked up over time. For each of the images, a transparent background was created. Then, we focused them, balanced the contrast and brightness, and converted each image to a resolution that matched the original dimensions of the work. For this purpose, the Adobe Photoshop CC 2015 program was used.⁴² The images were then exported to a TIFF format.

⁴²In October 2017 and January 2018, the latest version of Adobe Photoshop was released as Photoshop CC.

The modified computer graphics were inserted into modeled 70 cm × 70 cm, 3-D black frames.⁴³ The contrasting frame ensured that the images were defined clearly even after they had been placed in virtual reality and, at the same time, suited the format of the computer graphics, which essentially corresponded to the plotter parameters of that period. The works were also accompanied by captions listing the title, name of the author, and the year in which they were created. The selected photographs from the Jihlava exhibition opening were scanned in high resolution and treated the same way as the graphic works.

B. Creating a 3-D Model of the Exhibition Space

The model of the exhibition space was designed by the architect Josef Pospíšil using Autodesk 3ds Max.⁴⁴ First, he created the skeleton of the virtual model of the entrance hall. The next step was the preparation of the UV maps

⁴³In this case, we abandoned the effort to maintain the model's historical accuracy in favour of user-friendliness.

⁴⁴The version Autodesk 3ds Max 2018 that we worked with is made for Windows 7, 8, and 10. In March 2018, the latest version, 3ds MAX 2019, was released.

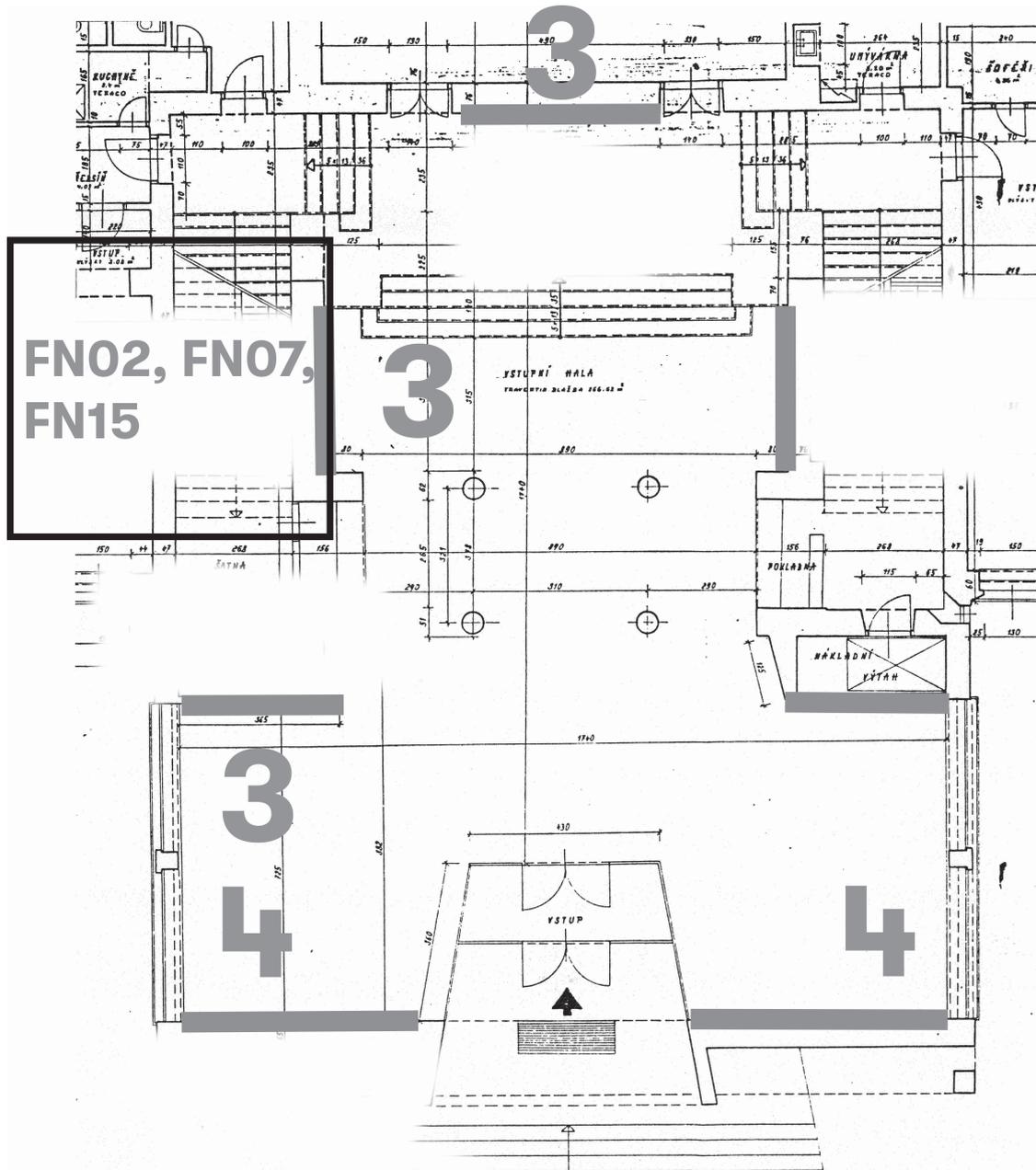


Fig. 4. Cross section from an architectural drawing of the entrance hall of Brno House of Arts from 1968. The numbers indicate the positioning of computer graphics in the VR model of the hall.

to be used in the 3-D model. One set constituted the different textures used in the interior design (floor, walls, window frames, etc.). Another set consisted of lightmaps. The effect of light was calculated in advance, reducing the load on the computer running the VR model in the gallery.

The 3ds Max model of the exhibition also needed components simulating areas around the House of Arts, which are visible from inside the hall through the plate glass windows. This required photos of Mahen Theatre, which is adjacent to the House of Arts, and the offices of Brno City Municipality, which can be seen through the glass entrance doors. Each of these buildings had

to be photographed in parts that were fused to form one image. In postproduction, the pictures were modified further. The buildings, which were built at the end of the 19th century, are still well-preserved, but some elements in the pictures had to be removed; for example, modern cars, pedestrians wearing contemporary fashions, and traffic signs. The sky in the pictures was replaced with a transparent layer, so it could be subsequently overlaid with a springtime sky. Finally, these images were also saved in TIFF format, so that they could be later embedded in the 3-D model and supplemented with 3-D graphic elements, such as bushes, trees, grass, sky, and pavement.



Fig. 5. Exhibition Computer Graphic at the gallery in Jihlava in 1968. Photograph of an unknown visitor viewing some artworks (possibly by L. Sochor). Source: Archive of the Regional Gallery of the Bohemian-Moravian Highlands in Jihlava.

C. Transforming the 3-D Model Into a Virtual Reality Game Environment

The completed model of the exhibition hall and its surroundings was exported in parts, according to the type of material, and imported into a game engine environment,⁴⁵ specifically Unreal Engine version 4.16. At this stage, the framed computer graphic works were placed in the interior of the hall, accompanied by captions positioned ten centimeters from the bottom right-hand corner of each picture. The graphics were installed on the walls and arranged in groups, according to the author. Eight pictures by Noll were placed to the left and right of entrance doors. Three images by Sochor were positioned in the

⁴⁵J. Wilson, "Unreal Engine 4.18," Unreal Engine, Epic Games, 2017. Accessed: Sep. 20, 2018. [Online]. Available: <http://www.unrealengine.com/en-US/blog/unreal-engine-4-18-released>



Fig. 6. Opening of the exhibition Computer Graphic in Jihlava. Photograph of Frieder Noll (center left, in profile) and Jiří Valoch (center right, in profile). Source: Archive of the Regional Gallery of the Bohemian-Moravian Highlands in Jihlava.

western wing of the hall and three pictures by Nees in the eastern wing. Three paintings by Noll were installed opposite the entrance door. Three paintings by Noll were located on the left of the sidewall of the entrance hall, and archive photographs from the exhibition opening in Jihlava were positioned on the right side. Once the pictures were installed, the prepared UV maps with the textures for each part of the model were exported into Unreal Engine. Daylight was substituted for by the appropriate set of lightmaps.

There are two ways of using Unreal Engine 4.16. One is to program in the language C++. The second, which we used, is through "blueprints" that allow for visual scripting by means of nodes. The nodes define object-oriented classes. Each of these nodes has its own name, function, input, and output. Nodes can be selected either by the category and name, or they can be inserted into a 3-D environment using a designated abbreviation. One cannot interconnect nodes of different types in this environment. Unreal Engine 4.16 contains several predefined templates which make it much easier to work with the software. For example, the user can choose a template that defines the view of the first person, as in our case, and thus avoid protracted coding. For each of the templates, a level is also created in which can be found the basic models of the objects such as cubes, blocks, and so on. The template for the third person also includes a figure that has predefined movement and animation.

In the virtual simulation of *Computer Graphic*, we used the basic function of gaming software, movement modeled from the perspective of the first person, thereby allowing

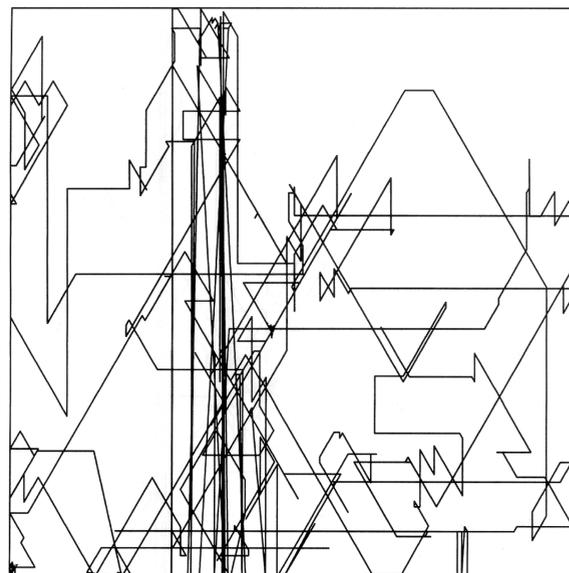


Fig. 7. Computer graphic by Frieder Noll (*Zuffälliger Polygonzug*, 1965) ready for placement in the VR model.

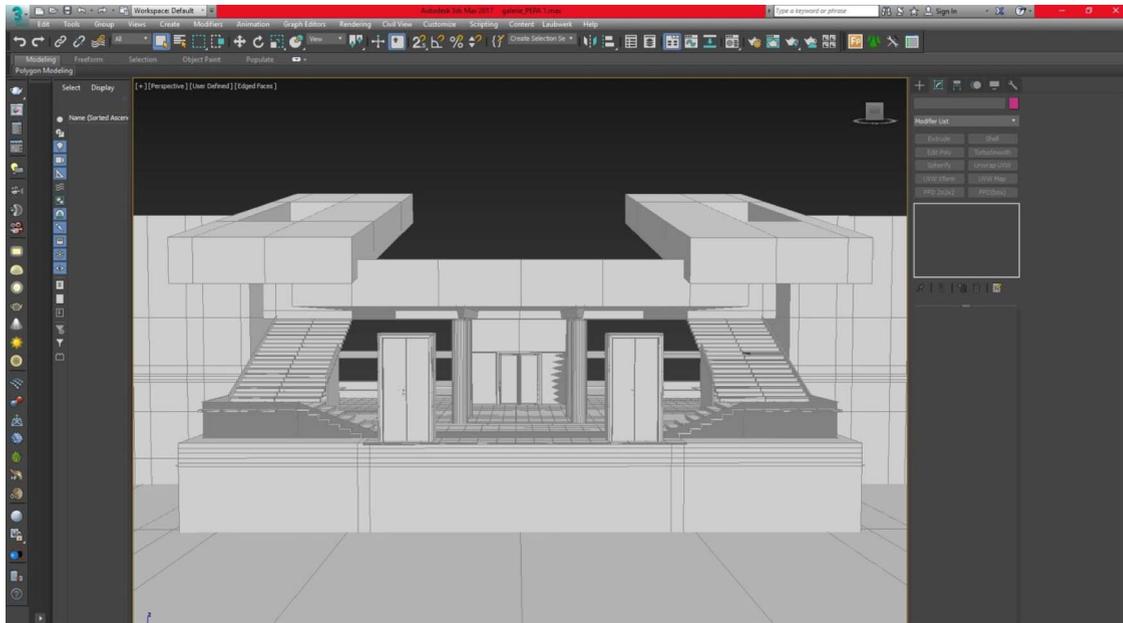


Fig. 8. Basic skeleton of the 3-D model of the exhibition space, created in the program 3-Ds Max.

the visitors to the VR exhibition to move around the room and view works from near or far, and from different angles. The rendering of the completed project used graphic cards and took over 70 h to process. The final file was saved in executable format as an .exe file.

D. Installation and Hardware

The first installation of the virtual exhibition *Computer Graphic Re-Visited* was situated in the center of the entrance hall of Brno House of Arts, where four evenly positioned

columns mark out a space of 3 m × 3 m. In the middle, there was a white locker for hiding the computer, resembling a pedestal for a statue, on which rested a VR headset⁴⁶ and a control. The visitor, or immersant, was able to move around the VR exhibition by means of a hardware interface created by the headset, linked

⁴⁶We used the HTC Vive VR headset developed by HTC and Valve Corporation in 2017 because of the high quality of image it provides, the refresh rate, and 360-degree viewing capability. Compatibility with Unreal Engine 4 gaming software and the 4.6 × 4.6-metre space for movement also played a role.

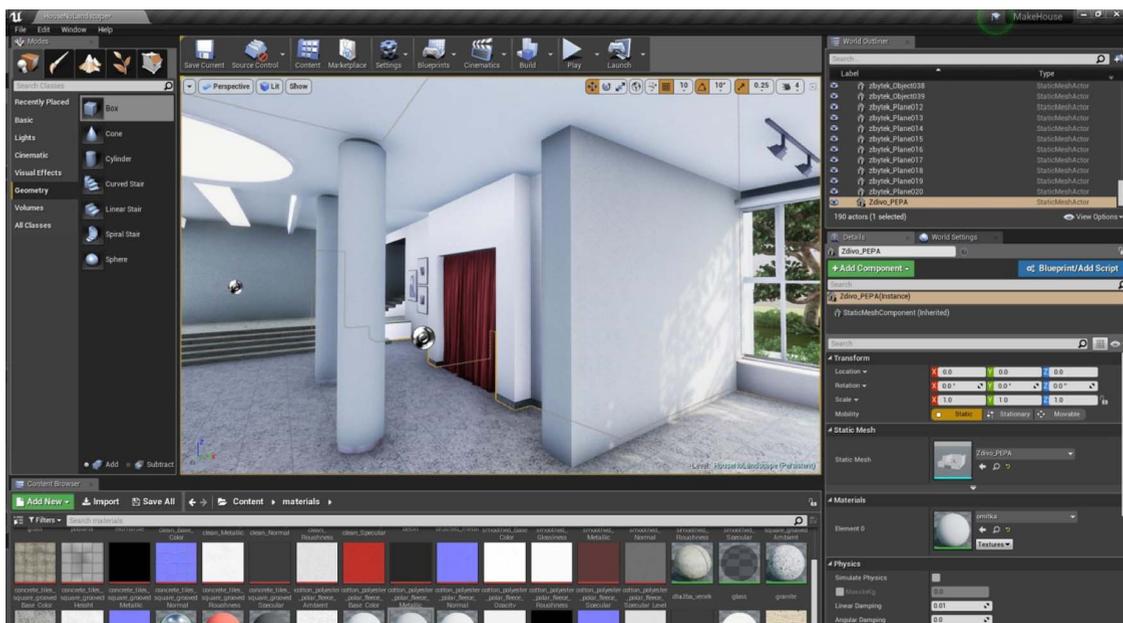


Fig. 9. Work in progress on the exhibition model in Unreal Engine 4.16.

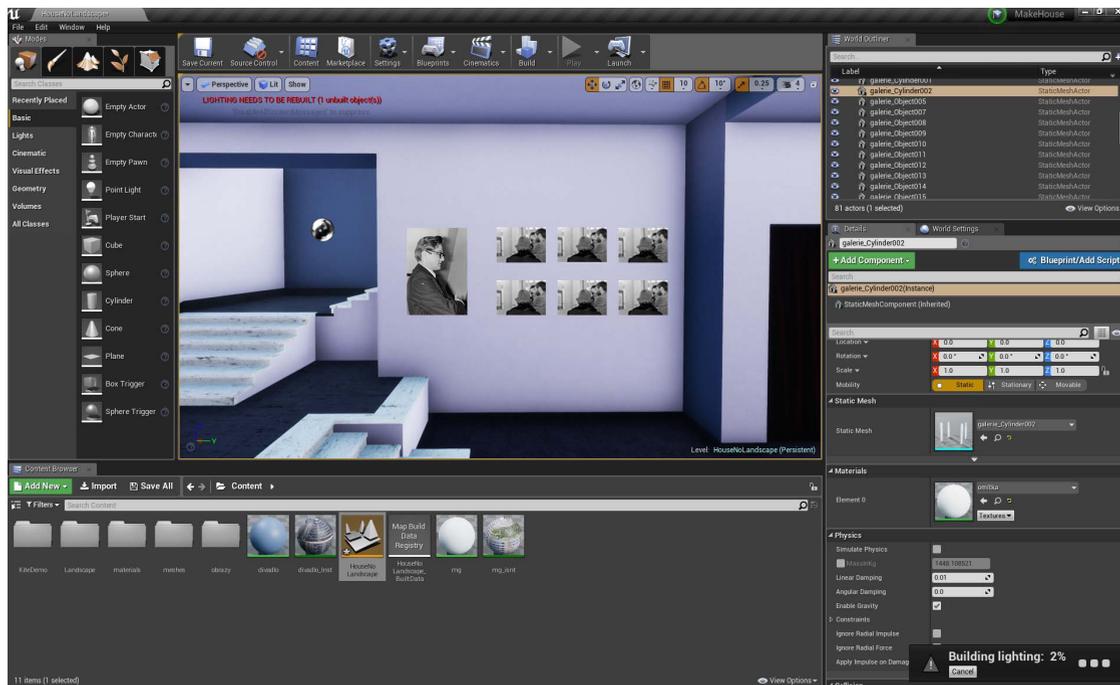


Fig. 10. Work in progress on the exhibition model in Unreal Engine 4.16.

to the computer and motion detectors (lighthouse transmitters), using the mouse. Other visitors to the exhibition were able to follow the immersant's movements in virtual reality as they were projected on the opposite wall.

To carry out the project, we used an HTC Vive VR headset that uses "room scale tracking" technology, which provides interactive movement in 3-D. The headset is equipped with 70 sensors that enable 360-degree viewing in real time. The headset is equipped with two 1080 × 1200 pixel OLED displays, which together create a picture of 2160 × 1200 pixel resolution with an aspect ratio of 9:5. Its 90-Hz refresh rate and 110-degree field of view

prevent dizziness. In addition, the headset is equipped with a camera that can detect objects and prevent the immersant from colliding with them.

The functionality of the VR headset was achieved by interfacing it with the lighthouse transmitters attached to the columns in the center of the hall. This made it possible to track the exact position of the immersant's head, and, thus, his or her view. With this data, the image that the immersant was looking at was updated in real time. The turning and tilting of the headset determined the direction of movement and the view of the immersant. The mouse was used primarily to speed up and make safer movements over longer distances. Nevertheless,



Fig. 11. Rendition of the virtual exhibition. View of the entrance doors and computer graphics suspended on the walls and areas around the building.



Fig. 12. Rendition of the virtual exhibition. View of the entrance doors and computer graphics suspended on the walls and areas around the building.



Fig. 13. Rendition of the virtual exhibition. View of the entrance doors and computer graphics suspended on the walls and areas around the building.

the immersant could also move in the virtual exhibition just by moving her or his body.

To ensure the smooth operation of the simulation, a powerful computer was needed. We used a six-core (12 virtual cores) Intel Core i7 processor with a GeForce GTX 1080 graphics card.

V. NEXT STEPS

In the second showing of the virtual exhibition, *Computer Graphic Re-Visited 2.0*, Valoch's exhibition was once again the main focus of the project, which, for this occasion, underwent some minor modifications aimed at improving the user experience. For moving in the space over longer distances, the mouse was replaced with an HTC controller, which had two system buttons at the top, a trackpad, two side buttons, and an analog trigger at the back. Thanks to the vibrations, the controller can also provide a tactile sensation. The render quality was improved, with a better

light calculation, and any errors in the mapped space for motion were corrected.

In addition to the pedestal concealing the computer, the VR headsets, the controller, and wall projection, black frames were hung on the hall's side walls in groups of three facing each other, each of which was reserved for one of the works of the exhibiting artists. The mattes in the frames masked the edges of LCD screens, on which the graphic works were displayed and changed at irregular intervals. The change was accompanied by a glitch effect, evoking the emancipation of the programmed objects, while referring to the "processuality" of the digital image. The exhibited works were accompanied by a projection of an animated flowchart of Nake's graphic work *Walk Through Raster* on the wall of the gallery, indicating the processes taking place in the computer when generating the computer graphics on show. In a side room, an exhibit of computer-generated poetry was animated in the form of a text projected gradually onto the wall of the gallery, as if in real time. Although Valoch's exhibition in Jihlava apparently featured the generated poetry of the German computer linguist Gerhard Stickel, since the vast majority of visitors to the exhibition were Czech, we opted for the computer-generated poetry of Brno linguist Jiří Levý and his colleague, Karel Pala, which was created around the same time. The installation also included some computer-generated music by Max V Matthews and Ben Deutschman, which was played at the Jihlava opening and which visitors could listen to through headphones. In exhibiting computer graphics, music, and poetry, we invoked the atmosphere of the original exhibition opening of *Computer Graphic* and, at the same time, tried to draw attention to the interconnectedness of digital works, whereby computer-generated images, poetry, and music share the same creative principle, programming algorithms, and bits of materiality.



Fig. 14. VR headset on a pedestal hiding the computer with the virtual exhibition, the only objects in the physical space of the gallery.

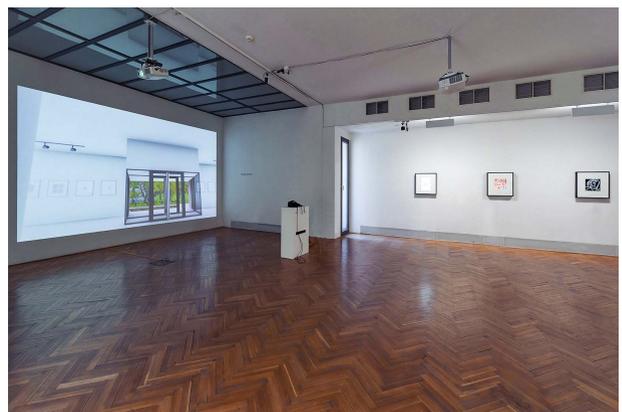


Fig. 15. Photograph of the VR exhibition and installations of *Computer Graphic Re-Visited 2.0*.



Fig. 16. Photograph of the VR exhibition and installations of Computer Graphic Re-Visited 2.0.



Fig. 17. Photograph of the VR exhibition and installations of Computer Graphic Re-Visited 2.0.

VI. CONCLUSION

Virtual reality is usually utilized to evoke a sense of traveling in space, serving as a tool for removing oneself to another distant or fantastical place. In this project, we used a virtual simulation to evoke the sense of moving in time. Visitors of the virtual exhibition found themselves in a room where *Computer Graphic* was held 50 years ago, and after donning the headset, it was if they had been transported to this extraordinary moment in the past.

The arrangement of the exhibition may be seen as a superimposition of its physical and virtual spaces, best described by the term *mise en abyme*.⁴⁷ In this case, the virtual simulation was placed within the physical space. This principle was also used in the second installation, *Computer Graphic Re-Visited 2.0*, where black frames bordering LCD screens displaying computer graphics were placed on the walls of the gallery, mimicking the frames

⁴⁷R. Greenberg, “Remembering exhibitions’: From point to line to Web,” *Tate’s Online Res. J.*, Landmark Exhibitions Issue, no. 12, 2009. Accessed: Sep. 20, 2018. [Online]. Available: <http://www.tate.org.uk/download/file/fid/7264>

used in the virtual reality. Thus, there was a physically installed exhibition, a fragment of which could be viewed by visitors after putting on the virtual reality headset. This fragment was, however, a preview of a physical exhibition.

VR technology served us as a tool for mediating the acquisition of knowledge from the history of computer art. We are convinced that a VR model is able to evoke an individual and complex experience for visitors of an exhibition. It can also serve as an effective tool for scientists involved in research into the so-called “sensory turn”⁴⁸ in the field of art history. At the same time, we perceive our project as a contribution to the development of digital humanities. We have shown that the use of digital technologies in the humanities has the potential to join together the collection of historical facts with the creative interpretation of them. We may then envisage the dawn of a new hybrid discipline, one which Ada Lovelace would have called “poetical science.” ■

⁴⁸J. Lauwrens, “Welcome to the revolution: The sensory turn and art history,” *J. Art Historiography*, no. 7, Dec. 2012. Accessed: Sep. 20, 2018. [Online]. Available: <https://arthistoriography.files.wordpress.com/2012/12/lauwrens.pdf>

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