Vladimir Bonačić: Computer-Generated Works Made within Zagreb's New Tendencies Network (1961–1973)

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A B S T R A C T

Scientist Vladimir Bonačić began his artistic career in 1968 under the auspices of the international New Tendencies movement (NT). From 1968 to 1971 Bonačić created a series of "dynamic objects" —interactive computer-generated light installations, five of which were set up in public spaces. The author shows the context of Bonačić's work within the Zagreb cultural environment dominated by the New Tendencies movement and network (1961–1973). The paper shows his theoretical and practical criticism of the use of randomness in computer-generated art and describes his working methods as combining the algebra of Galois fields and an anti-commercial approach with custom-made hardware. It seems that Bonačić's work fulfills and develops Matko Meštrović's proposition that "in order to enrich that which is human, art must start to penetrate the extra-poetic and the extra-human."

Vladimir Bonačić (1938–1999) worked at the Ruđer Bošković Croatian National Research Institute in Zagreb from 1964 to 1973; there he headed the Laboratory of Cybernetics from 1969 to 1973. He earned his Ph.D. in 1967 in the field of pattern recognition, studying the visual and audible representation of hidden data structures. In 1968 he began his artistic career under the auspices of the international movement New Tendencies (NT), at the Gallery of Contemporary Art of Zagreb, which had pushed for his inclusion [1].

The Gallery of Contemporary Art organized five New Tendencies exhibitions in Zagreb from 1961 to 1973; in addition, large-scale international exhibitions were held in Paris, Venice and Leverkusen, West Germany. The movement was truly international, both transgressing Cold War blocs and including South American and, later, Asian artists. That situation, unique within the Cold War context, was possible due to Zagreb's position in then-socialist but non-aligned Yugoslavia. From 1961 to 1965 New Tendencies both stood for a kind of art and acted as an umbrella network for approximately 250 artists, critics and art groups. The latter included Groupe de Recherche d'Art Visuel (GRAV) of France; Equipo 57 of Spain; Gruppo N, Gruppo T, MID, Gruppo 63, Operativo R and Azimuth of Italy; Zero of Germany; Anonima Group of the U.S.A.; and Dviženije of the U.S.S.R. With an emphasis toward providing a scientific dimension to art, NT from the very beginning focused on experiments on visual perception based on Gestalt theory and different aspects of "rational" art: *arte programmata,* lumino-kinetic art, *gestalt kunst,* neo-constructivist and concrete art and the like; later it was given the collective name of NT or simply *visual research.* In the later phase of the movement (1968–1973) Tendencies dropped "New" from its title. Over that period a second wave of 58 artists and groups exhibited computer-generated works, and finally in 1973 Tendencies presented, alongside the first phase of NT visual research, this second grouping of computer-based visual research and conce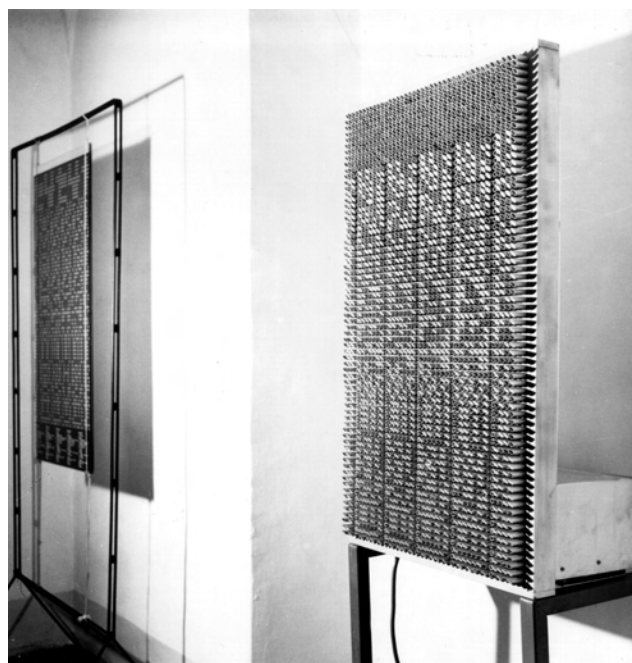ptual art as well. The statement of Brazilian artist and active NT participant Waldemar Cordeiro, that computer art had replaced constructivist art [2], found its proof in Bonačić's early artworks.

In the mid-1960s the ideas and aesthetics of the NT movement entered the mainstream and were simplified, while its dominant social engagement was put aside. Symptoms of this change were noticed at the Responsive Eye exhibition at the Museum of Modern Art in New York (1965), where many NT artists were exhibited, but their works were

Fig. 1. Installation view from the exhibition Computers and Visual Research/Tendencies 4, at the Museum of Contemporary Art in Zagreb, 1969. (left) Tendencies 4 exhibition poster designed by Ivan Picelj, silkscreen, 97 x 49 cm, 1968–1969. (right) Vladimir Bonačić and Ivan Picelj, *t4*, computer-controlled dynamic object, aluminum, light bulbs, electric parts, $70 \times 50 \times 6$ cm, 1968–1969, Museum of Contemporary Art Zagreb. (© Museum of Contemporary Art Zagreb. Photo: Marija Braut, Museum of Contemporary Art Zagreb Archive.)

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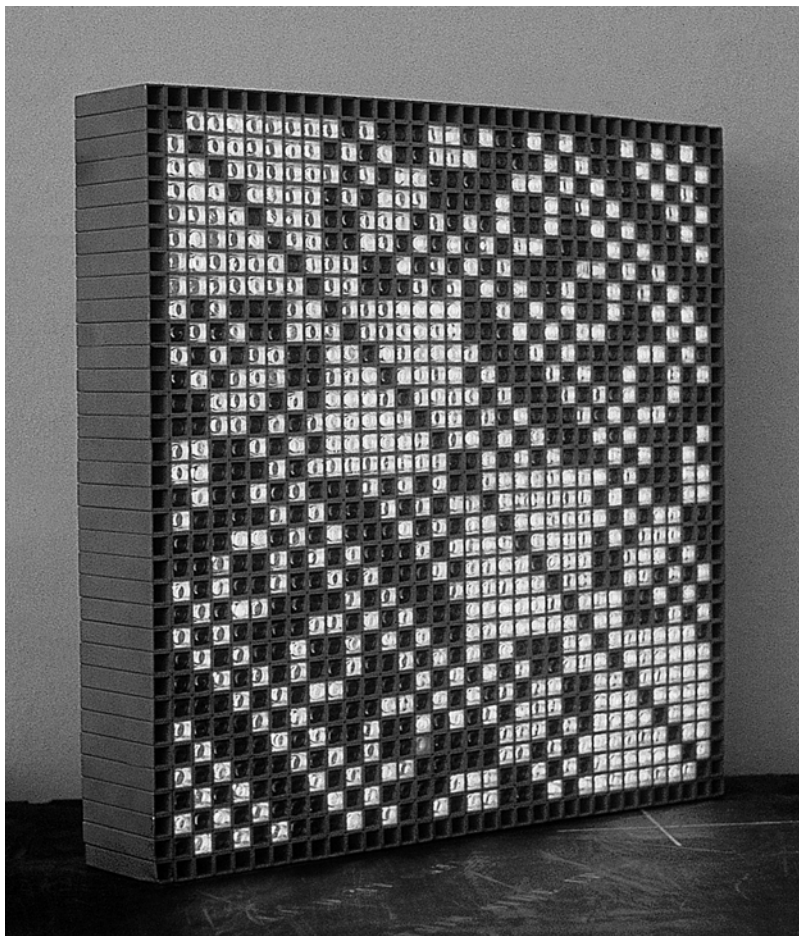
Fig. 2. Vladimir Bonačić, *GF.E 32-S*, computer-controlled dynamic object, aluminum, light bulbs, electric parts, 68 × 68 × 12 cm, 1969–1970. (© Dunja Donassy-Bonačić—bcd cybernetic art team. Photo © Vladimir Bonačić—bcd cybernetic art team Archive.)
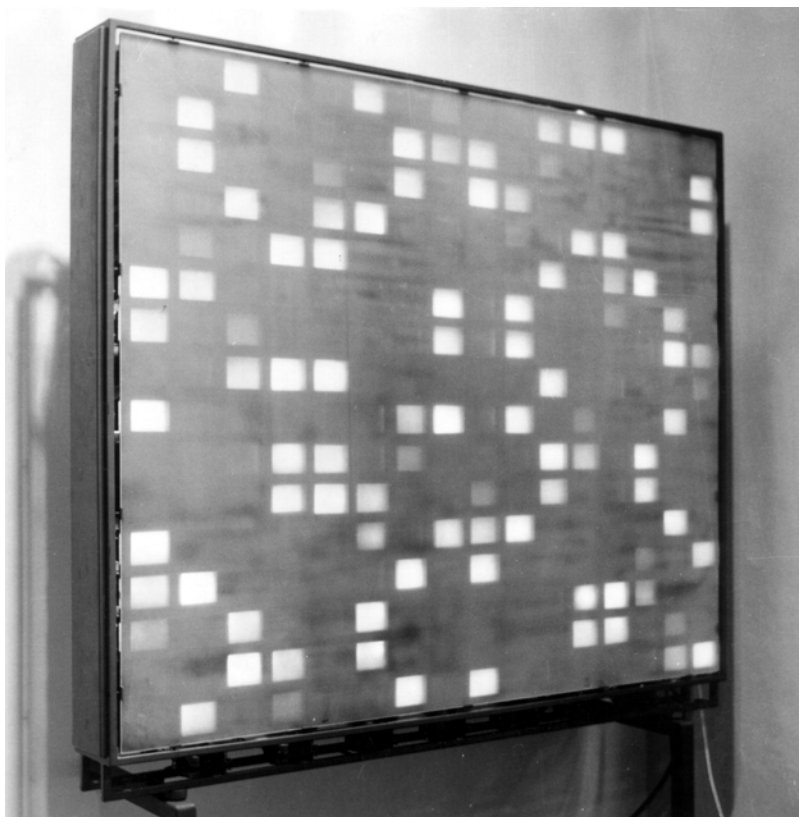

Fig. 3. Vladimir Bonačić, *DIN. GF 100*, computer-controlled dynamic object, 147 × 123 × 12 cm, 1969. (© Museum of Contemporary Art Zagreb. Photo: Marija Braut, Museum of Contemporary Art Zagreb Archive.)

appropriated within a commercial context that focused on retinal effects rather than their social dimension. After this exhibition the term *Op art* was coined. Looking back on this aesthetic crisis that NT faced for several years, one of the curators of NT, Radoslav Putar, wrote in the preface to the 1968–1969 exhibition catalogue for Tendencies 4, which inaugurated computer-based artwork within NT:

> The forms that have characterized NT from the beginning, as well as the phenomena that had preceded them, have been marked by an approach to machines, and this fascination has now, unexpectedly to many, suddenly undergone an expansion of undreamt-of dimensions.... Even before the 1960s K[arl] Gerstner spoke of the programming of procedures of encoding of picture elements; U[li] Pohl spoke about anonymity and the exclusion of subjectivity during NT-2 (1963); everybody discussed the extinction of the meaning of the unique and irreproducible creative act of an individual genius; they talked of team work that would perform instances of visualization of plastic ideas; many followers of the NT have tried to give their work the habitus of the machine or else have based their procedures on the use of mechanical or electric devices; they have all dreamt of machines—and now the machines have arrived. And they have arrived from a direction that was somewhat unexpected, and accompanied by people who were neither painters nor sculptors.... Even further: The machines have, as it were, proposed the possibility of assignments and of solutions that the followers of NT did not take into account. Everything has been shifted sideways and everything has been illuminated by a new light we had not expected. And, yet, there are threads linking the events within the frames of NT and the new stage dominated by computers. Although it might seem that a tradition choked by its own projection of futurity has been brutally stopped, its positive negation is possible: in a new effort of organized penetration into the unknown [3].

Within the New Tendencies movement, information aesthetics and relations between cybernetics and art were introduced by Abraham Moles during a 1965 colloquy as part of the third New Tendencies exhibition. Tendencies 4 was realized during 1968 and 1969 as an extensive program of exhibitions and conferences called Computers and Visual Research, alongside two exhibitions of previous NT orientations that used analog media for its visual research: a retro-

Fig. 4. Vladimir Bonačić, *DIN. PR 18* (NaMa I), computer-controlled dynamic object/light installation in the storefront of NaMa in Zagreb, Kvaternikov Square, 18 elements, each 48 × 88 × 25 cm (matrix 3 × 5), 1969. (© Dunja Donassy-Bonačić—bcd cybernetic art team. Photo © Marija Braut, Museum of Contemporary Art Zagreb Archive.)

spective and one of recent work. In 1968 the Contemporary Art Gallery launched the magazine *Bit International* as a bulletin of the new orientation [4]. During the preparation of Tendencies 4, organizers from the Zagreb Gallery of Contemporary Art sought collaborators at three science centers in then-Yugoslavia that used computers for visual research. In pursuing their previous goal of the synergy of art and science they had already collaborated with the Ruđer Bošković Institute in the past.

Alongside other scientists who were to take part in the symposia, NT organizers met the young scientist Bonačić at the Institute, who used visual research in his science research and had strong affiliations to photography and contemporary art. Also at this time, Ivan Picelj of Zagreb, an artist and NT's primary graphic designer, was making a collage of computer punch cards at the Institute; this collage would be used for the poster for Tendencies 4. Picelj had the idea to take his work a step further and to produce a light object following his *Surface* series of reliefs in wood and bronze, which he had been developing since 1961. Here Vladimir Bonačić entered the scene, and they began the

collaboration that resulted in the electronic object *T4*, which was presented in 1969 (Fig. 1). Its title referred to the Tendencies 4 event series. The front panel of the object is made of a grid of round aluminum tubes, each housing a small light bulb. Each tube is cut at an angle to improve light reflection. The upper part displays the characters *t4t4t4t4,* animated to move from left to right and in other animations similar to those commonly seen in LED displays. The rest of the panel lights up following a pseudo-random program that Bonačić was developing in his science work. Bonačić's experience in physics and electronics helped a great deal, as did the excellent production conditions in the workshops of the Ruđer Bošković Institute. From 1968 to 1971 Bonačić created a series of similar "dynamic objects" consisting of different computer-programmed light patterns displayed on screens of different shapes and sizes. Different patterns flash in a kind of animation and thus have an additional quality of variation dependent on "clock" adjustment, that is, the speed of the pattern's appearance. *T4* allowed the interaction via the adjustment of different pattern series with four knobs found on

the back of the object. During Tendencies 4, Bonačić showed not only *T4* but a total of 17 works [5] and was awarded one of the prizes for "computer and visual research" [6]. The Tendencies 4 exhibition presented 189 computer-generated works in total by 33 artists or artist groups from 12 countries. The jury, consisting of Umberto Eco, Karl Gerstner, Vera Horvat-Pintarić, Boris Kelemen and Martin Krampen, appreciated

the harmony between the mathematical consequences within the programming and the visualizing of the process resulting from the programming. We praise especially Bonačić's new approach entailing the solving of problems by including a picture and not a number as a parameter, rendering possible thereby the solution of much more complicated problems [7].

The "Galois field," named after mathematician Evariste Galois (1811–1832), was a source of general inspiration to Bonačić. In abstract algebra, finite fields are known as Galois fields, and Bonačić studied them in connection with his work on the roots of polynomial equations. In 1974 Bonačić wrote, "One of the most interesting aspects of this work [in Galois

Fig. 5. Vladimir Bonačić, *DIN. PR 18* (NaMa I), detail, 1969. (© Dunja Donassy-Bonačić—bcd cybernetic art team. Photo © Marija Braut, Museum of Contemporary Art Zagreb Archive.)

fields] is the demonstration of the different visual appearance of the patterns resulting from the polynomials that had not been noted before by mathematicians who have studied Galois fields" [8].

All of the "dynamic objects" Bonačić made in Zagreb from 1968 to 1971 made use of the pseudo-random algebra of Galois fields (GF) or polynomials (PLN). The letters and numbers in the works' titles show their exact mathematical approaches. For example, *I.R. PLNS* stands for "Irreducible Polynomial Non-Symmetric," and the number next to it is the number of the polynomial's degree(s). The software programmer was Miroljub Cimerman, using an SDS-930 computer [9]. Bonačić used custom-made hardware for all his dynamic objects [10]. They were embodied statements of what he later elaborated in his critique of the influence on the computer-based arts of

commercially available display equipment [11].

The dynamic object *GF.E 32-S* (1969–1970) (Fig. 2) generates four consecutive symmetrical patterns. The front panel of the object resembles a screen made of a 32 x 32 grid of squared aluminum tubes containing light bulbs. The total "screen resolution" is made of 1,024 white-light "pixels." The field generator is part of a special-purpose computer located inside the object. The unit is self-contained and performs the generation of Galois fields. The clock that controls the rhythm of the appearance of the visual patterns is variable, and the rhythm can be adjusted by the observer between 0.1 seconds and 5 seconds. At a frequency range of 2 seconds the same pattern will repeat itself in approximately 274 years. On the rear of the object the observer finds "manual controls to start, stop and control for the

selecting or reading out of any patterns. With binary notation, 32 light indicators and 32 push buttons enable any pattern from the sequence to be read or set" [12]. From a contemporary perspective, this work is a pioneering example of use of interactivity in computer-based art.

The dynamic Object *DIN. GF 100* (1969) (Fig. 3) is made of 256 light elements in 16 different colors. There are 65,535 different pictures/patterns produced. Depending on the user/observer, the image changes according to the clock every 200 milliseconds or 2 seconds, introducing the observer into a pseudo-random process. The observer can adjust or stop by remote control the sequence's speed rate and can manually operate sequences step by step.

From 1969 to 1971, Bonačić developed a higher level of interactivity in the work *GF. E /16,4/* [13]. The field of the inter-

action extends from the sole object, as was the case with *GF.E 32-S* [14]. *GF. E /16,4/* is 187 x 187 x 30 cm in size and half a ton in weight. The front panel shows a relief structure made of 1,024 light fields in 16 colors. Three Galois field generators operate to light the grid in different patterns. Those generators interact with other generators controlling the sound played through four loudspeakers, which create a quadraphonic sound system within the installation space. The viewer can influence both sound and image either manually or by remote control. Sound can be manipulated by the exclusion of some tones. The speed of the visual display can be adjusted as well by looping the selected sequences. The observer cannot change the logic. The entire "composition" of this audio-visual spectacle, which consists of 1,048,576 different visual patterns and 64 independent sound oscillators, can be played within 6 seconds or with a duration of 24 days [15].

Bonačić explored interactivity on a social level as well, installing computer-based light installations in public spaces. As part of the Tendencies 4 exhibition in 1969, he set up the large-scale dynamic object *DIN. PR 18* on the façade of the NaMa department store on Kvaternik square in Zagreb (Figs 4 and 5). The 36-m-long installation consisted of 18 elements; each element had a 3 x 5 grid light matrix. The installation performed a light show that flickered patterns of the irreducible 18th-degree polynomial. At that time the square was rather dark, with little public lighting, so the installation also acted as additional illumination. Art critic and curator Želimir Koščević published in a daily newspaper an affirmative evaluation of the "message" of this public light system, used for an aesthetic rather than commercial purpose, as opposed to the lit signs of companies that had started to appear in Zagreb's city cen-

Fig. 6. Vladimir Bonačić, *DIN. PR 16* **(NaMa III) (replacement of** *DIN. PR 18)***, computer-controlled dynamic object/light installation in the storefront of NaMa in Zagreb, Kvaternikov Square, 48 elements, each 48 × 88 × 25 cm (matrix 3 × 5), 1971. (© Dunja Donassy-Bonačić—bcd cybernetic art team. Photo: Petar Dabac—bcd cybernetic art team Archive.)**

Fig. 7. Vladimir Bonačić, *DIN. PR 10* (NaMa II), computer-controlled dynamic object/light installation at the storefront of NaMa in Zagreb, Ilica Street, 100 elements, each 88 × 48 × 25 cm (matrix 5 × 3), 1971. (© Dunja Donassy-Bonačić—bcd cybernetic art team. Photo: Petar Dabac—bcd cybernetic art team Archive.)

Fig. 8. Vladimir Bonačić, *Kreditna Banka*, 18 elements, each 48 × 88 × 25 cm (matrix 3 × 5), 1969–1971, computer-controlled dynamic object/light installation at the Kreditna Banka in Zagreb, Ban Jelačić Square. (© Dunja Donassy-Bonačić— bcd cybernetic art team. Photo: Museum of Contemporary Art Zagreb Archive.)

ter. Koščević also found that this public installation showed a refinement of the idea of democratization of art within the context of the New Tendencies movement [16].

This installation was replaced in 1971 with the more complex dynamic object *DIN. PR 16* (Fig. 6) (an individual project, supported, however, by Božo Beck of Zagreb City Galleries, one of the organizers of New Tendencies). This work appeared exactly at the top of the building that had shown the previous one and occupied an extra space within the façade. In the 4th Triennial of Yugoslavian Art, Belgrade 1970, another dynamic object was set up in the façade of the Museum of Contemporary Art in Belgrade. In 1971 the dynamic object *DIN. PR 10* (Fig. 7) was set up over the whole façade of the NaMa department store on Ilica Street during the Art and Computer 71 colloquy in Zagreb, one of many New Tendency events. Another dynamic object took place only 100 meters further at the façade of the Kreditna Banka building on the main square in Zagreb (Fig. 8). None of the works mentioned that were set up in public spaces are still in place, nor are their original elements currently traceable. At least, however, all Bonačić's smaller dynamic objects have been located and are in good condition; as such they belong to, if they do not wholly comprise, the small group of computer-generated interactive objects from the 1960s that are still functioning today.

Bonačić criticized the use of randomness in computer-based art, as he considered humans to be simply better than computers at "making the 'aesthetic program' relevant for human beings." Referring to the dictum of Abraham Moles that redundancy creates structure at the expense of originality, Bonačić wrote:

> Observing [the qualitative results of aesthetic measurements], we come to conclude that the maximal originality (that is, disorder created by random selection of symbols) brings immense aesthetic value. Let us suppose we have created the program in some other way; still it is the program that will result in an aesthetic object. Using the random generator we shall carry on with random distribution of the existent information. While consistent in use of the random generator, we speak of "maximal originality," no matter what the results of the program might be. The random generator creates the accidental and unique presentation, which has neither value nor importance for human beings. Such information can evoke various associations in the observer. But a computer used in such a way lags far behind the human being. Even if the expressive potentialities of the computer were equal to those of a human
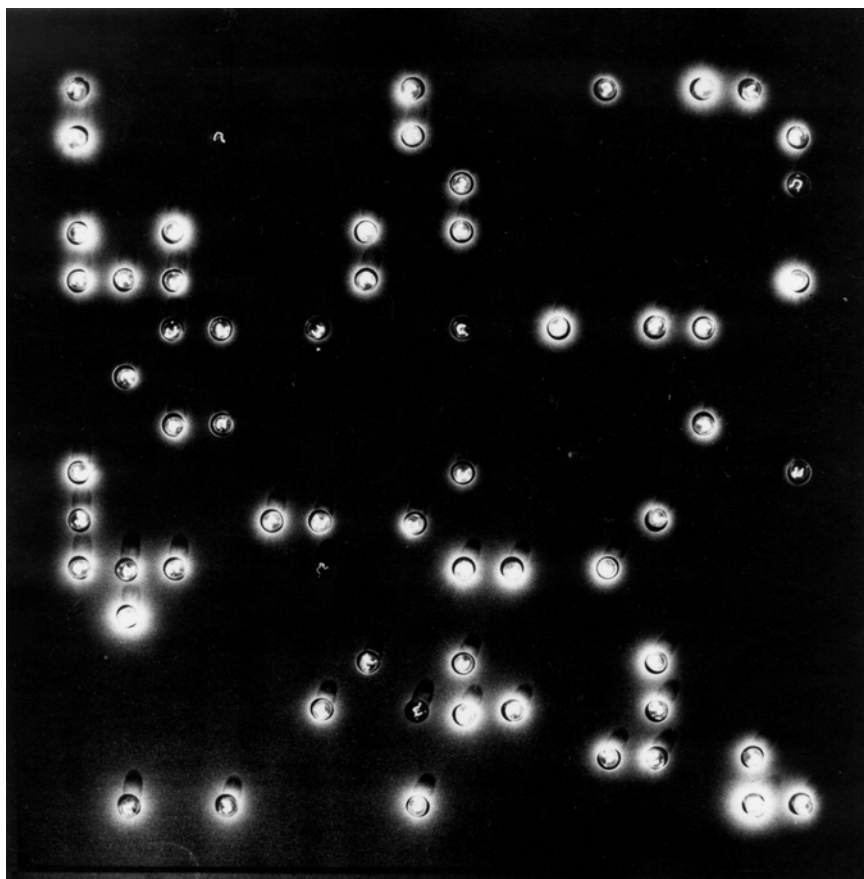
Fig. 9. Vladimir Bonačić, *Random 63*, 63 true random generators, light bulbs, aluminum, 76 × 76 × 7 cm, 1969. (© Dunja Donassy-Bonačić—bcd cybernetic art team. Photo: Vladimir Bonačić—bcd cybernetic art team Archive.)

being, the essence of Pollock's world and creation would not be surpassed, regardless of the complexity of future computers or peripheral units. That, of course, does not mean that a man (or a monkey or other animal) aided by a computer could not create an aesthetically relevant object if they consciously or unconsciously act in obedience of the law of accident [17].

This critique inspired the creation of the object *Random 63* (1969) (Fig. 9), making use of 63 independent *true* random generators that each caused the activation of an electric light bulb (glow or gas-discharge bulbs were used). The placement of the light bulbs (a static aspect of the work) was calculated with a PDP-8 computer using the pseudo-randomness of the Galois fields. This is the only piece by Vladimir Bonačić that makes use of true randomness, which can lead us to aesthetic enjoyment or irritation. All his other "dynamic objects" utilize pseudo-randomness, which in principle allows observation of mathematical laws, that is, a heuristic approach to new cognition that results in expanding the observer's knowledge with exact and immediate experience.

As I have shown, from the start Bonačić

had a critical view of the use of the computer in art for the simulation of reality. He also criticized Michael Noll's experiment with a Mondrian-like drawing that he generated using a computer simulation. Bonačić said:

> The computer must not remain simply a tool for the simulation of what exists in a new form. It should not be used to paint in the way Mondrian did or to compose music as Beethoven did. The computer gives us a new substance; it uncovers a new world before our eyes. In that world, at long last, scientists and artists will meet again on common ground, stimulated by their common desire for knowledge [18].

Contradicting Bonačić's wishes of 1968, computer-generated art pursued a different path. Computer graphics explored the possibilities of computer-generated figurative visuals and entered —with the provision of animation and special effects for the mainstream film industry—the commercial world as well as the military sector, advancing virtual-reality techniques that mimic "real life." This development, within the context of the dominance of emerging practices of conceptual and non-object art that

utilized post-Duchampian ideas of art and representation, led to computer-generated art's almost-total exclusion from the contemporary art scene around the mid-1970s. This development was propelled by rising anti-computer sentiment among the majority of the new generation of artists, in view of the negative impact of the use of science and technology by the military-academic-corporate complex in the Vietnam War and elsewhere. Artist Gustav Metzger, who took part in both the Tendencies 4 exhibition and a symposium the same year with computer-generated work and a manifesto on the subject, wrote in March 1969 that "The waves of protest in the States against manufacturers of war materials should lead E.A.T. to refuse to collaborate with firms producing napalm and bombs for Vietnam" and continued, "Forty-five professors at MIT have announced a one-day 'research stoppage' for March 4 in protest against government misuse of science and technology." Such a misuse has been recently described by Richard Barbrook:

> M.I.T. modernization theory would prove [U.S.] superiority over the Maoist peasant revolution.... Since the information society was the next stage in human development, the convergence of media, telecommunications and computing must be able to provide the technological fix for anti-imperialist nationalism in Vietnam. During the late 1960s and early 1970s, the U.S. military made strenuous efforts to construct an electronic barrier blocking the supply routes between the liberated north and the occupied south. Within minutes of enemy forces being detected by its AD-SID sensors, IBM System/360 mainframes calculated their location and dispatched B-52 bombers to destroy them [19].

In the mid-1970s, major protagonists of computer art, such as Metzger and Jack Burnham, turned their backs on it. In Zagreb the NT movement also drew back: Tendencies 6 started with the conference Art and Society in 1978, but the planned exhibition never took place. As the focus had shifted to video, conceptual and non-object art, a different exhibition was shown. Nevertheless, following the spirit of the time, Bonačić (now part of the bcd cybernetic art team) participated in the T6 conference with the paper "Man, Language, Matter—The Dematerialization of Art."

It took about 20 years before computer-based art found its place again in the contemporary art scene within a new geopolitical situation and cultural climate. Bonačić was one of the rare artists who found and constantly reinvented

Fig. 10. Vladimir Bonačić in interaction with *GF. E /16,4/*, **computer-controlled dynamic object/light and sound installation, SC Gallery, Zagreb, 187 × 187 × 30 cm, 1969–1971. (© Dunja Donassy-Bonačić—bcd cybernetic art team. Photo: Petar Dabac.)**

a way to use computers and cybernetic art for humanistic purposes. After the period of the first series of dynamic objects, Bonačić's work from 1971 occurred within the bcd cybernetic art team with Miroljub Cimerman and Dunja Donassy. In 1972 Bonačić founded the Jerusalem Program in Art and Science, an interdisciplinary program for study and research at the Bezalel Academy of Art and Design in Jerusalem, of which he was director until 1977. The Program collaborated with the Hebrew University and the Israel Museum. In 1974 he organized an international seminar on "The Interaction of Art and Science," in which several "Tendency" protagonists, such as Benthall, Franke, Malina, Moles, Noll and Whitney, participated. The Art and Science program was awarded the Erasmus prize for 1975 on Willem Sandberg's recommendation. Within the program the bcd team made several upgrades to the dynamic

object *GF. E /16,4/* that extended its interactivity level with the use of an external computer and combined a light pen with an interactive computer monitor as a new interface (Fig. 10). They also developed projects such as a new design of a computable traffic-light system and, within the Art and Science program, the first functional digitization of the Arabic alphabet [20]. From 1977 to 1979 the bcd cybernetic art team, in collaboration with Israel Shahak, chairman of the Israel League for Human and Civil Rights, realized a humanitarian, socially engaged project, *Palestine Homeland Denied.* The project consisted of 35 printed posters, including both Arabic and Hebrew alphabets and photographs of 385 destroyed Palestinian villages. All visuals used in the posters were processed through Galois field generators and transformers. The group's work continued in Germany in the 1980s, where they

developed for the German national television network ARD the first data monitoring system for real-time display of dynamic results of the federal elections. Since 1984 the considerations concerning the concept of the dynamic object have shifted from mainframe computers to minis and then to personal computers.

To return to the 1960s and Tendencies, computer-art pioneer Georg Nees exhibited at both Tendencies 4 and 5 in 1969 and 1973 and published the paper "Computer Graphics and Visual Art" in *Bit International* in 1968. In the paper, Nees asked,

> Shouldn't information aesthetics be able to use certain modeling techniques? The information it should model is aesthetic information, such as appears in nature and art. However, the dependency of aesthetic information on processes should be modeled as well, while conceiving the processes themselves as temporarily dependent information [21].

Similar ideas are found in writings by Jonathan Benthall, who participated in two Tendencies conferences and observed,

Max Bense writes that mathematical aesthetics is a process which is "devoid of subjective interpretation and deals objectively with specific elements of the 'aesthetic state' or as one might say the specific elements of the 'aesthetic reality.'" These elements include meanings as well as sensuous or formal qualities. Bense proposes a "generative aesthetics" which would explain how aesthetic states are generated in the same way as a generative grammar in linguistics attempts to explain the logical processes by which sentences are performed and interpreted; but a prior stage of analytical aesthetics is held to be necessary. The main mathematical techniques proposed by Bense are semiotic (the study of signs, originated by C.S. Peirce and others), metrical (concerned with forms, figures and structures), statistical (concerned with the probability of appearance of elements) and topological (concerned with the relations between *sets* of elements).... Vladimir Bonačić is skeptical about the applicability of information theory to aesthetics, since it takes so little account of semantics. But he approaches visual phenomena in a mathematical and systematic way [22].

As described by Bonačić, the dynamic object was "the new concept in art, in which impregnable unity is established between the computer system and the work of art; the artist and the work of art are able to communicate using the common language between human and artificial systems" [23]. The "scientification of art," theoretically elaborated by Matko Meštrović within the framework of NT [24], finds its infinite reflection in Bonačić's working process, which one can see as the "aestheticization of science." It seems that Bonačić's work fulfills and develops Meštrović's idea of 1963, that "in order to enrich that which is human, art must start to penetrate the extra-poetic and the extra-human" [25].

References and Notes

1. Letter by Boris Kelemen to Jasia Reichardt, 22 September 1968, archives of the Museum of Contemporary Art, Zagreb. On the New Tendency movement, see Jerko Denegri, *Umjetnost konstruktivnog pristupa* (Zagreb: Horetzky, 2000). For information on Bonačić, see pp. 490–497. Published in English as *The Constructive Approach to Art: Exat 51 and New Tendencies* (Zagreb: Horetzky, 2004).

2. "Constructive art belongs to the past, its contents corresponding to the Paleocibernetic Period being those of the Computer Art." Waldemar Cordeiro, "Analogical and/or Digital Art," paper read at "The Rational and Irrational in Visual Research Today / Match of Ideas," Symposium T–5, 2 June 1973, Zagreb. Abstract published in the symposium reader (Zagreb: Gallery of Contemporary Art, 1973) n.p. Cordeiro exhibited his works in NT exhibitions in Zagreb in 1965, 1969 and 1973, and participated in two related symposia in 1969 and 1973.

3. Radoslav Putar, no title, *Tendencies 4*, 1968–1969, exh. cat. (Zagreb: Gallery of Contemporary Art, 1970) n.p.

4. *Bit International,* Nos. 1–9 (1968–1972), approximately 1,400 pages in total.

5. Bonačić showed the relief sculpture *R. GF100—13*; photographs *PLNOO74—2, IR. PLNS. 0044, 7714, 7554, 7744—3; RS. PLMS. 0374, 0124, 0064—4; PLN—5, PLN—6, PLN—7, PLN—8, PLN—9* and *PLNO434—10*; color slides *GF0000—11* and *GF1110—12*; and dynamic objects *GF100—14* and *PR 18—15*, all programmed on a PDP-8 and an SDS-930 computer.

6. Bonačić received the prize together with Marc Adrian and the group Compos 68.

7. "Computers and Visual Research, Decision of the Competition Jury," *Tendencies 4* [3].

8. Vladimir Bonačić, "Kinetic Art: Application of Abstract Algebra to Objects with Computer-Controlled Flashing Lights and Sound Combinations," *Leonardo* **7**, No. 3, 193–200 (1974).

9. In 1971 in Jerusalem, bcd—cybernetic art team was founded, consisting of Bonačić, Cimerman and the architect Dunja Donassy. They would work together until Bonačić's death in 1999.

10. All electronic objects by Bonačić up to 1973 were realized in the Ruđer Bošković Croatian National Research Institute. Public installations were logistically supported by Božo Beck of the Gallery of Contemporary Art Zagreb in collaboration with respected institutions where the works were set up.

11. Bonačić [8].

12. Bonačić [8] p. 195.

13. This computer sculpture was first exhibited at the Paris Biennale 1971 and later in UNESCO, Paris, on the occasion of the 25th anniversary of the organization.

14. In his *Leonardo* article, Bonačić elaborates those different kinds of interaction from a practical and theoretical point of view and also considers the use of brainwaves in artistic practice. Bonačić [8] pp. 195 and 196.

15. Bonačić [8]; Herbert W. Franke and Gottfried Jäger, *Apparative Kunst* (Cologne, West Germany: M. DuMont, 1973) pp. 214–217; *Computerkunst* (IBM France, 1975) (German Ed. 1978) p. 54.

16. Želimir Koščević, "Svjetlost nove urbane kulture" (The Light of the New Urban Culture), *Telegram*, No. 479 (4 July 1969) p. 17.

17. Vladimir Bonačić, "Arts as Function of Subject, Cognition, and Time," paper read at the symposium Computers and Visual Research, Zagreb, 5–6 May 1969, published in *Bit International*, No. 7, "Dialogue with the Machine" (1971) pp. 129–142.

18. Vladimir Bonačić, "Possibilities for Computer Applications in Visual Research," paper read at the colloquium "Computers and Visual Research," Zagreb, 4–5 August 1968, published in *Bit International*, No. 3 (1971) pp. 45–58.

19. G. Metzger, "Automata in History," *Studio International* (London, 1969) pp. 107–109; Richard Barbrook, *Imaginary Futures*, <www.imaginaryfutures.net> (2005), pp. 177 and 182; (London: Pluto Press, 2007); see also Anne Collins Goodyear, "From Technophilia to Technophobia: The Impact of the Vietnam War on the Reception of 'Art and Technology," in this issue of *Leonardo*.

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