Music without Musicians ... but with Scientists, Technicians and Computer Companies

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In the early days of music technologies the collaboration between musicians, scientists, technicians and equipment producers was very close. How did this collaboration develop? Why did scientific, business, and musical agendas converge towards a common goal? Was there a mutual exchange of skills and expertise? To answer these questions this article will consider a case study in early computer music. It will examine the career of the Italian cellist and composer Pietro Grossi (1917–2002), who explored computer music with the support of mainframe manufacturers, industrial R&D, and scientific institutions. During the 1970s, Grossi became an eager programmer and achieved a first-hand experience of computer music, writing several software packages. Grossi was interested in avant-garde music as an opportunity to make 'music without musicians'. He aimed at a music composed and performed by machines, and eventually, he achieved this result with his music software. However, to accomplish it, Grossi could not be a lonely pioneer; he had to become a member, albeit an atypical one, of the Italian computing community of the time. Grossi's story, thus, can tell us much about the collaborative efforts stimulated by the use of early computer technologies in sound research, and how these efforts developed at the intersection of science, art and industry.

1. ELECTROACOUSTIC MUSIC AS A COLLABORATIVE ENDEAVOUR

Since the beginning of the twentieth century, technology has become increasingly important in the arts. It has radically changed how artists perform their work and how they relate to their public. Walter Benjamin's essay 'The Work of Art in the Age of Its Technological Reproducibility' is an early record of this transformation (Benjamin 1936). Written and rewritten during the 1930s, the essay examined photography and film as prominent examples of the transformations brought by technology in twentieth-century art. With the privilege of hindsight, we can argue that during the past century technology has produced in music changes as significant as the ones examined by Benjamin for the visual arts. Electronic and digital tools have deeply reshaped the key practices of sound production, reproduction and reception in the second half of the twentieth century. Furthermore, they have contributed 'to bring the arts much closer together', so that 'poetry, painting and sculpture' deserved at least an appendix in the *International Electronic Music Catalog* compiled by Hugh Davies in the 1960s (Davies 1968: v).

The use of electronic and computer technologies has transformed what counts as a musical instrument, the skills and requisites to compose and perform music, how music is experienced by the public, and how it is distributed. There is therefore scope for an investigation of musical developments grounded 'not only in history, society, and culture, but also in science and technology and its machines and ways of knowing and interacting' (Pinch and Bijsterveld 2004: 636). The use of electronic and computer equipment in sound research has forced musicians to build bridges with other communities, and they have begun to work with scientists, technicians and equipment producers to explore new soundscapes. The musical curriculum has also changed over time to include teaching in mathematics, acoustics and informatics. Musicians have embraced new skills, such as programming, and live coding is now a recognised practice in music (Nilson 2007).

Alternative histories can emerge by approaching electroacoustic music as a collaborative effort of several actors: musicians, scientists, technicians and producers of electronic and computer technologies. These histories will consider the moral and material economies that governed access to technologies, and the part that equipment manufactures played in these economies; they will explore how musicians, physicists, engineers and computer scientists pooled their knowledge to achieve innovative results in sound research; they will consider how these interactions shaped and re-shaped scientific and musical careers; they will examine the role that technicians had in assisting musicians. In turn, these histories of electroacoustic music can benefit science and technology studies, because they improve our understanding of the mutual interactions between technology and society. Notable is the case of the Moog synthesiser (Pinch and Trocco 2002). This instrument

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emerged from the collaboration of engineers, musicians and salespeople; in its design and development, users' requests shaped engineers' choices, and the synthesiser became a boundary object that moved across musical communities and acquired different meanings. Only by examining the collaborative effort behind the Moog, and the flexibility that the instrument derived from it, can we account for the ubiquitous presence of the synthesiser in very different music cultures and its ambiguous status as both instrument and machine.

The story of the Moog synthesiser belongs to the 'analog days' of electronic music. In contrast, this article will address the close collaboration between musicians, scientists and equipment producers in the early 'digital days' of music technologies. Back in the 1950s, 1960s and 1970s, computers were not yet personal, off-the-shelf music software did not exist, and the majority of traditional music institutions could not afford a mainframe. Musicians therefore had to forge new alliances to explore the world of digital sound. How did these collaborations develop? Why did scientific, business and musical agendas converge towards a common goal? Was there a mutual exchange of skills and expertise? To answer these questions this article will consider a case study in early computer music. It will discuss the career in avant-garde music of the Italian cellist and composer Pietro Grossi (1917–2002). Grossi struggled to gain access to computers, because in Italy the mainframe industry had only marginally developed and music schools were not interested in a systematic investigation of digital technologies. The Italian musician was able to move into the field only with the support of computer companies and scientific institutions that granted him access to mainframes and had available programming expertise. Eventually, he turned himself into an eager programmer to achieve a first-hand experience of computer music.

By approaching sound research through mainframes, Grossi envisioned the opportunity to make music without musicians. He aimed at a music composed and performed by machines, and shared through digital technologies. To achieve this result, Grossi became a participant, albeit an atypical one, of the Italian computing community of the time. Computer companies – such as Olivetti-General Electric (OGE) and the Italian branch of IBM – and scientific institutions devoted to computing – in particular the Centro Nazionale Universitario di Calcolo Elettronico (CNUCE) and the Istituto per l'Elaborazione dell'Informazione (IEI), both based in Pisa – looked at Grossi's work with curiosity and interest. Although they did not share Grossi's musical agenda, these companies and institutions valued his research in computer music for the challenges it presented to hardware and software development. Even decades later, the Italian IT community has not forgotten Grossi's experiments in sound research. In 2008, the Italian association of IT professionals (AICA) distributed a DVD copy of the *GE-115 Computer Concerto* recorded by Grossi to the participants of the IFIP World Computer Congress held in Milan. In 1967, the manufacturer of the GE-115 mainframe had done the same, using Grossi's computer music as a Christmas gift for its customers. Grossi's story, thus, can tell us much about the collaborative efforts stimulated by the use of early computer technologies in sound research and how these efforts developed at the intersection of science, art and industry. To explore this story, I will briefly introduce Pietro Grossi and describe how his venture into electronic music quickly turned towards computers. I will then discuss his experience with mainframes in collaboration with OGE and his long-term involvement with CNUCE for making computer music. I will focus on how Grossi acquired programming skills and how his work in software development fulfilled both his musical agenda and the expectations of his scientific partners.

2. FROM TAPE RECORDERS TO MAINFRAMES

During the 1960s, Pietro Grossi turned his career as a classical musician upside-down.[1] Grossi was trained in cello and composition in Bologna during the 1920s and 1930s and began to play with the orchestra of the Teatro Comunale in Florence in 1936. As a middle-aged man, after three decades spent with the Florentine orchestra, he came to set aside his cello, which was eventually sold, and devoted more and more time to making music with electronic technologies and, later, with digital computers. His first hands-on experience with music technologies took place in 1961, when he spent two weeks in the electronic music studio set up in Milan by RAI, the Italian public broadcasting corporation. Founded in the mid-1950s, the Milan studio was an important centre for electroacoustic music composition for almost two decades (Donati and Pacetti 2002; Manning 2004: 68–72; Novati and Dack 2012). Its facilities were extensive for the time and Grossi used them to create his first electronic music composition, *Progetto 2/3*, based on combinatorics (Giomi and Ligabue 1999: 34–5).

In Milan the studio equipment had been custom-made by Alfredo Lietti, who began to work for RAI as a radio operator in 1938 (Rodà 2012). While Lietti was working for RAI, he graduated in physics and was promoted to higher technical roles within the company. Lietti followed the evolution of the electronic music

[1]There is no book-length biography of Grossi, but there is a long life story (in Italian) published a few years before his death (Giomi and Ligabue 1999). There are also contributions on Grossi written by musicians and composers, who were Grossi's co-workers or former students (Giomi 1995, 1996; Mayr 2011). In writing this article, I mainly relied on primary sources: scientific reports published by the CNUCE musicology division; two oral histories (with Ferruccio Zulian and Leonello Tarabella); and correspondence between Grossi and Jon Phetteplace (a cellist and avant-garde musician who studied with Grossi in Florence).

studio from its inception until 1961, when he resigned and went to work in a Swiss scientific laboratory. In designing the studio equipment, Lietti was inspired by the principle that electronic technologies could serve their purpose in a music studio only when there was 'an effort at mutual understanding' between the musician, concerned with aesthetic problems, and the engineer, interested in the technological issues posed by sound generation (Lietti quoted in Manning 2004: 70). Lietti's machines proved his point. They were created to respond to the requests made by the musicians who used the facilities in Milan, in particular Luciano Berio, who was the studio co-director alongside Bruno Maderna. Lietti's machines remained in use for several years, either in their original form or renovated using transistors, which in the 1960s became the mainstream devices for electronics.

In the Milan studio Grossi did not work alone. He had the assistance of a technician, Marino Zuccheri, who was the only permanent staff member of the studio.[2] Zuccheri had previously been employed by RAI as a sound technician and helped the composers who visited the studio with their recordings. He taught them how to generate and modify sounds with the equipment available, how to mix them, how to cut and reassemble the magnetic tape. He also helped them when they could not autonomously control all the equipment. Lietti and Zuccheri were both non-musicians, but they contributed substantially to the electronic music experience in Milan. Although they pursued scientific and technical rather than artistic careers, their skills and expertise were essential to designing the equipment and promoting its use among musicians. When Grossi decided to set up his own electronic music studio in Florence after his experience in Milan, he was faced with the necessity of finding similar scientific and technical co-workers.

Grossi's studio, called Studio di Fonologia Musicale di Firenze (S2FM), opened in 1963. The musician invested his own money in the studio. He purchased some commercial equipment and commissioned the design of a few sine-wave generators from two technicians, who also helped him to set up the whole studio. The S2FM equipment eventually consisted of 'sixteen sine-wave generators, some filters, a frequency meter, a white noise generator and a set of very good tape recorders' (Giomi and Ligabue 1999: 36, my translation). In 1965 the studio moved from the musician's house, where it was originally based, to the Conservatorio Cherubini, the music school in Florence where Grossi had been teaching cello since the 1940s, and where he also began teaching a course in electronic music in 1965. At the music school, the S2FM facilities were extended with more custom-made pieces designed by two technicians, Paolo del Canto and Luigi Pelosini. Grossi also commissioned the RAI technicians in Milan to build an instrument for regulating the speed of tape recorders (Giomi and Ligabue 1999: 36–7). The students of Grossi's electronic music course had access to these facilities. They learnt how to use the equipment and received instruction in acoustics, mathematics and composition. The course also included seminars given by artists, philosophers and scientists (Giomi and Ligabue 1999: 44 (image)). Grossi's electronic music teaching was open to both musicians and non-musicians, because Grossi believed that anyone should take part in the experience if interested in sound phenomena and be able to use the tools available in the studio. Engineers and visual artists joined Grossi's course as students and worked alongside musicians, contributing to the activity of S2FM. Even though not every student completed the course or produced an original composition, the plurality of the students' backgrounds facilitated dialogue between music and these other disciplines interested in sound production through electronic equipment (Mayr 2007: 94–5). A few of Grossi's students continued their venture in electronic music, while others turned to visual arts. It is more difficult to follow the path of the people who embarked on a scientific career after attending Grossi's electronic music course. In his life story, Grossi mentions explicitly only Riccardo Andreoni, who ended up working for the computing centre of the Arcetri Astrophysical Observatory in Florence. Andreoni learnt how to program attending some classes organised by Grossi in 1969/1970. The classes were taught by a mathematician and sponsored by the IBM R&D division in Pisa (Giomi and Ligabue 1999: 23).

Davies's *International Electronic Music Catalog*, published in 1968, provides a comprehensive list of the compositions produced by S2FM (Davies 1968: 100–1). By the time the catalogue appeared in print, Grossi's experience in electronic music was drawing to a close. Grossi had been attracted to electronic music at the beginning of the 1960s because it offered the opportunity to extend sound research beyond the 12-tone equal temperament scale, and at the same time liberated the musician from the time-consuming and tiring manual training required to perform classical pieces. However, by the mid-1960s, Grossi did not feel that electronic music could accomplish his project to make music without musicians. He began to regard electronic music only as a moment of transition towards the automation of musical performance and composition realised with digital computers (Camilleri, Carrera and Mayr 1987: 38–9).

When Grossi approached computer music in the late 1960s, the discipline had already begun to develop. The first experiences in computer music took place in the 1950s. In 1957 the composers Lejaren Hiller and Leonard

[2]Technicians were often key figures in electronic music studios, where they taught musicians how to use the equipment and helped them to turn knobs and switches. They have also remained key figures in computer music, as discussed by Zattra and Donin (2016), but the case study examined in this article does not deal with them explicitly.

Isaacson produced the *Illiac Suite for String Quartet* with the assistance of the ILLIAC mainframe available at the University of Illinois (Hiller and Isaacson 1957; Chadabe 1997: 273–4). In the same year Max Mathews, a researcher who worked at the Bell Telephone Laboratories, completed the development of MUSIC-I with the assistance of his co-workers. This was the first software for digital sound synthesis and the first member of the MUSIC-N family of computer programs, which were very influential in the international developments of computer music (Mathews 1963, 1969; Doornbusch 2012: 47–9).

Grossi occasionally used computers in the early 1960s, when he was already actively involved in electronic music. The algorithmic pieces he presented at the Biennale in Venice in 1964 were realised with analog equipment, but sound, pitch and duration were computed on a mainframe at the University of Florence. Grossi had begun to calculate these values by hand using logarithmic tables, but by using the computer was able to speed up the computations (Giomi 1996: 180 (Fig. 1c); Giomi and Ligabue 1999: 40–1). Gaining access to digital technologies, however, was much more difficult than setting up an electronic music studio. The basic components of an electronic music studio, in fact, were not inexpensive, but they remained affordable even for an individual musician as proved by Grossi's ability to create S2FM. The expertise necessary to use this equipment was also easy to acquire with some hands-on work. For instance, Grossi was able to work alone and teach his students in Florence after only two weeks spent in the Milan studio. Even the University of Indiana in Bloomington found Grossi's expertise satisfactory and invited him to teach the first formal courses in electronic music when the university opened a studio in 1966.[3]

As someone who was venturing into computer music, instead, Grossi met greater challenges because he could not purchase his own computer nor did he have the programming skills to develop software tools. He needed partners to do so, but he could not find them within the Italian musical community, who were uninterested in computers. He had to look for collaborators among the few Italian scientific institutions and business organisations which had access to mainframes and in-house competences to work with them. How could Grossi approach these companies and institutions? How could he find a space for his musical research within their agendas? To answer these questions I will examine how Grossi's computer music was produced with the support of computer companies and in association with several research centres.

3. MAKING MUSIC WITH THE GE-115 MAINFRAME

The Olivetti company was founded at the beginning of the twentieth century in Ivrea, a small town near Turin. In just a few decades, Olivetti became an international business company known worldwide for its typewriters and calculating machines (Caizzi 1962; Ochetto 1985). Olivetti's products were praised for their design and technical features, and Olivetti was a solid and enterprising business in the aftermath of the Second World War. Its general manager, Adriano Olivetti, was a visionary entrepreneur and decided to invest in computers, almost unknown in Italy at the time.[4] In the mid-1950s Olivetti opened its R&D division with the aim of designing a commercial mainframe. The mission was successfully accomplished, and by the early 1960s Olivetti was the only Italian company producing mainframes and doing research in hardware and software development (Parolini 2015). Olivetti's experience as a mainframe manufacturer, however, was short-lived. In 1964 Olivetti sold a large part of its computer business to the US company General Electric (GE) and created the joint company OGE. Four years later, it left the mainframe sector for good and sold the remaining share in the joint company to the US partner.

Although short-lived, Olivetti's involvement in the mainframe business was crucial for Pietro Grossi's first approach to computer music. The industrial facilities created by Olivetti – in particular, the R&D centre in Pregnana Milanese – did not close after the merger, and OGE offered Grossi the support of its R&D staff and the GE-115 mainframe to do musical research. The collaboration between Grossi and the computer company started in 1967, while the musician was engaged in the preparation of a radio programme called *Musica ex machina*. The programme, co-authored by Grossi and the composer Domenico Guaccero, was broadcast by RAI between March 1967 and May 1968. The episodes gave an overview of international and Italian experiences in electronic and computer music, and Grossi asked OGE to collaborate in the preparation of some pieces for the episode on computer music (Giomi and Ligabue 1999: 50–1).

The company did not have any specific interest in computer music, but accepted Grossi's request because it was an opportunity to advertise its mainframes. During the 1960s, computers were still uncommon in Italy and the company was trying to create a market for them. Thus, it had to convince potential customers that computers were powerful machines, able to perform complex tasks such as playing music, and significantly superior to the punched-card office equipment that was still widespread in business companies and

[3]On Grossi's work at Indiana University see Indiana University Archives, Accn. 2001/031, Box. 3. Grossi had already served in the faculty of the Indiana Music School in 1957, when he taught a cello summer course.

[4]In Italy the first mainframes (manufactured abroad) were set up in 1954/55 (Bonfanti 2004).

public institutions. Grossi's radio programme could reach a large audience and support the company's marketing strategy. As such, it was an opportunity not to be missed.

Although computer music did not have a place in OGE's scientific agenda, the collaboration with Grossi was successful due to a chance event and a distinctive feature of early mainframes. In the early days of computing, mainframes did not have a screen to allow the operator to check whether computing processes were running smoothly. Computer technicians needed alternative means to monitor the functioning of the machines. At the time, computing speed was still low and the mainframe central processing unit emitted frequencies in the audible range. Therefore, loudspeakers were placed on the mainframe, in key positions where instructions were executed, and used to check whether the flow of information was regular or whether an instruction had gone into a loop and jammed the system.[5] Ferruccio Zulian, a staff member of the OGE R&D division in Pregnana Milanese, decided to play music with these loudspeakers. Zulian was a young physicist employed as systems designer. He did not have any musical training – 'I just knew that the notes in the twelve-tone equal temperament had a constant ratio and after twelve notes the frequency doubled.' To play his first piece of computer music, someone had to give him a score and teach him how to read it. Despite his lack of musical training, Zulian was keen to experiment with sounds:

> My first idea was to employ the 'move' instruction, which was used to transfer characters. When I changed the number of characters to be transferred, the sound frequency changed. In this way, however, I produced an asymmetric square wave [which could not be used to play music]. Then I decided to use a signal already available in the mainframe, a signal I could command with an instruction. It worked this way: I started the signal, then the computer executed a loop during which there was a countdown (beginning from $n/2$) and then the system jumped to level zero, the signal was switched off and the loop was repeated generating a symmetric square wave. The period of the square wave depended from the number n and it was repeated m times, with m being the ratio between sound duration and period. Every sound was identified by these two parameters, m and n, and I could produce 1300 audible frequencies using this procedure.[6]

Zulian's hobby became known within the company and the OGE headquarters in Florence put Grossi in contact with the R&D division. Grossi needed the approval of the OGE's external relations manager and the R&D management before he could begin his collaboration with Zulian. From time to time Grossi travelled to Pregnana Milanese to work with the researcher on the computer music software. At this stage Grossi had no familiarity with software and the GE-115 was still programmed in machine code, harder to use than any high-level programming language. Therefore, it was Zulian who realised Grossi's musical ideas. The researcher wrote several computer programs to play pieces of classical music or to generate original compositions suggested by Grossi. Even though he was unable to program the machine, Grossi had direct involvement in the transcription of the classical pieces and in the preparation of the punched-cards (Figure 1) used to feed these data into the computer (Giomi and Ligabue 1999: 52). The musician also published a detailed description of the programs developed by Zulian to record their collaboration (Camilleri et al. 1987: 33–6).

When the GE-115 eventually played music, the sound quality was poor. The square-wave timbre was rough and largely unsatisfactory, but Grossi did not mind. Despite the evident technological limitations, he saw enormous potential in computer music. The GE-115 could play Paganini's *Caprice* No. 5 – one of the first pieces transcribed for the mainframe – at speeds forbidden to any violinist, and it could explore sound permutations without the constraints of the 12-tone equal temperament. Grossi believed that technological progress would have improved sound quality and 'once the monodic limits and the invariability of the timbre have been overcome the computer will become an extremely faithful performer (performer, and not instrument, acting on the basis of a program-score and not manual commands) of any music – even if completely removed from the limits attached to the manual playing of traditional instruments'.[7] Not on aesthetic, but on technological grounds, OGE shared Grossi's positive thinking about computer music and produced, with the pieces played by the mainframe, a 45 rpm vinyl entitled *GE-115 Computer Concerto* (Olivetti–General Electric and S2FM 1967). The company sent it to its customers for Christmas 1967 and presented it as the outcome of the collaboration between OGE and S2FM. Side 1 contained a few classical pieces (Bach, Paganini), while Side 2 included three pieces: one obtained by the superposition of several performances of Paganini's *Caprice* No. 5 played at different speeds, one a cyclic permutation of five sounds, and the last a special interpolation of ascending and descending scales.

[5]Grossi had already heard sounds produced by the central processing unit of a mainframe in 1962, during a visit to the computing centre of the Monte dei Paschi in Siena. The bank had an ELEA 9003, a mainframe manufactured by Olivetti (Giomi and Ligabue 1999: 55). Grossi described this experience in the leaflet that accompanied the recording of the *GE-115 Computer Concerto*: 'Many people will recall those [sounds] emitted by the Elea 9003's central processor and the way these sounds varied and described typical sequences according to the different jobs performed.'

[6]This quotation and the one above are excerpts from a written interview with Zulian (March 2016). The English translation is mine.

[7]The quotation is taken from the presentation of the *GE-115 Computer Concerto* (printed in English, Italian and French). Grossi wrote the presentation, but he did not sign it, nor did he add his name to the cover of the record.

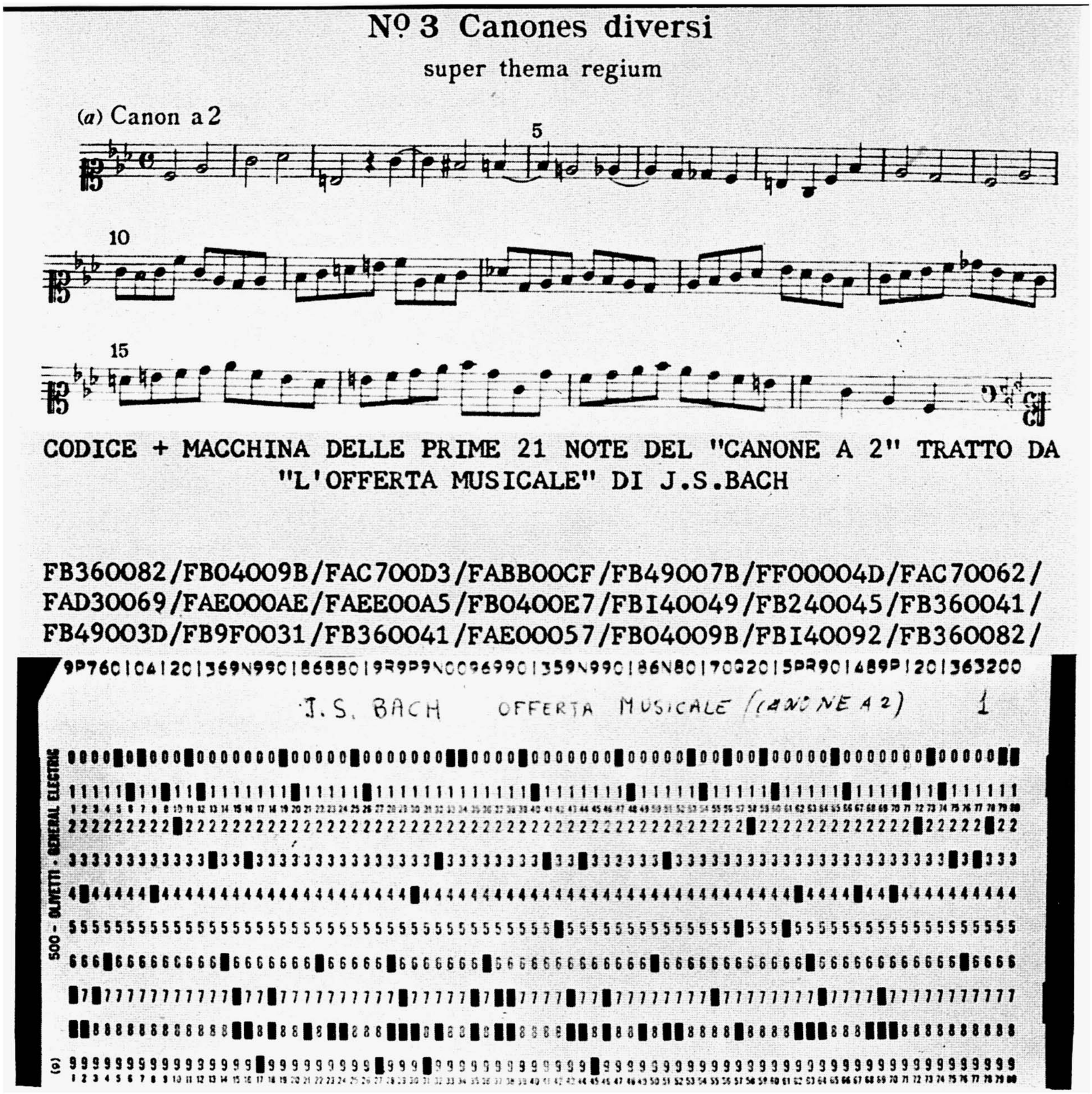

Figure 1. The image summarises the transcription process required to play music with the GE-115. On top there is the musical score, a canon from Bach's *Musical Offering*; in the middle is the transcription in machine language (hexadecimal notation) of the first 21 notes in Bach's score; at the bottom there is the punched-card used to input the data. The numbers *m* and *n* were inputted in the GE-115 in binary code (e.g. FB360082). Each number required two bytes (e.g. FB-36 identified the frequency, while 00-82 determined the sound duration). A 80-column punched-card, as the one in the picture, could be used to input up to 20 notes. The image was originally published in the Italian magazine *Comma – Prospettive di Cultura* (February/March 1968).

The record gratified Grossi's ambitions and increased his interest in computer music. At the same time it offered OGE several opportunities to advertise its mainframes. In January 1968, RAI broadcast the episode of the programme *Musica ex machina* about computer music, and later in the year the broadcasting corporation interviewed Grossi and Zulian about their collaboration. In 1968 the ability to produce music with the GE-115 was publicly demonstrated in Florence and Como during musical festivals. In both cases the computer company offered all the technical support required for the public display and enjoyed a celebrity that it would not have accomplished if it had provided the public with a technical explanation of the mainframe's potentialities.

4. THE MUSICIAN AS PROGRAMMER

In 1968 the collaboration between Grossi and Zulian ended because 'the computer music work in Pregnana was slowed down by technical and organisational issues'

(Giomi and Ligabue 1999: 55, my translation). Indirectly, however, this first experience in computer music facilitated Grossi's access to scientific institutions based in Pisa. The Olivetti R&D division had been located near Pisa during the 1950s and had pooled resources with the local university for the computing project of the Calcolatrice Elettronica Pisana (De Marco, Mainetto, Pisani and Savino 1999: 32–3). The University of Pisa fully exploited this early start in mainframe research and was the first Italian institution to create a degree in computer science in 1969. Leonello Tarabella, one of Grossi's youngest co-workers at CNUCE, benefited from this training.[8] The very existence of CNUCE, a major computing centre, was indebted to the know-how available at the University of Pisa and to the funding provided by the computer company IBM. IBM established its Italian R&D activities on the second floor of the CNUCE building and collaborated closely with the centre's staff.

Grossi approached CNUCE's scientific management through mutual acquaintances. He was then invited to present a formal request for collaboration to the director, Alessandro Faedo, a mathematician who had a key role in establishing Pisa as a research centre for computer science. According to Grossi's reminiscences, IBM was a major player in accepting his proposal for collaboration because the company, the only business competitor of OGE/GE in Italy, had resented Grossi's computer music research with the GE-115 mainframe and the visibility that this collaboration had brought to OGE (Giomi and Ligabue 1999: 56). Grossi welcomed the opportunity to continue his work on computer music in Pisa. The musician had personal and professional commitments in Florence and travelling to Milan to work with Zulian had been inconvenient. Pisa, instead, was ideally located. Grossi could remain in Florence with his family, keep his teaching appointment at the Conservatorio Cherubini, and commute regularly to Pisa. Grossi's collaboration with CNUCE began in 1969, and in the next few years a small musicology division was constituted and worked under the musician's direction. This research in computer music did not encounter obstacles even when CNUCE became an institute of the Italian research council (CNR) in 1974.

Although Grossi's division was hosted by CNUCE, his work in computer music benefited from the cooperation of other scientific partners located in Pisa. First of all, Grossi had the support of the computer company IBM. IBM was in charge of the maintenance of the CNUCE computer systems and constantly updated the hardware available in the centre. The first music software created in Pisa in 1969/70, the Digital Computer Music Program (DCMP) (Table 1), was originally developed for the IBM 7090 mainframe, a machine for which there was not yet software portability. However, in the early 1970s, IBM provided CNUCE with several versions of the System/360 (Campbell-Kelly, Aspray, Ensmenger and Yoost 2014: ch. 6) the first compatible series sold by the company (i.e. the same software could run, with only minimal adjustments, on different computers of the series). By 1975 the DCMP could run on three different System/360 – 360/30, 360/44 and 360/67 – (Grossi and Sommi 1974), a feature that facilitated public demonstrations of the software. IBM also made available to the centre an IBM 1800 data acquisition and control system which had some digital-to-analog converters. The converters were especially valuable for computer music research because they permitted finer control of sound variables. To maximise the performance of this IBM system, Grossi and co-workers began to develop the music software PLAY 1800 in 1970/71 (Table 1) (Baruzzi, Grossi and Milani 1975: 15–20). Both DCMP and PLAY 1800 were designed to play music in real-time. This was a considerable technical challenge in the 1970s because music software is computing-intensive, and only state-of-the-art hardware could generate sound soon after its elaboration without major disruptions. Grossi was aware of his debt to IBM and commented in 1973: 'The research team in Pisa is now very active, because we have available powerful and flexible computers and so it is possible to think and make the unthinkable' (Grossi 1973, my translation).

Apart from IBM, IEI was the other main partner in Grossi's computer music research in Pisa. IEI was a twin centre of CNUCE, but had a broader mission in the study of information processes and also did some hardware development. Its researchers designed, assembled and maintained the synthesiser TAU2 (Bertini, Chimenti and Denoth 1977) used by Grossi and co-workers from 1975 onwards. The TAU2 offered a significant improvement in sound quality, even compared to the digital-to-analog converters of the IBM 1800. The synthesiser was also a more economic and effective solution for playing music in real-time: it limited the computing time required to run the music software because sound was produced by the analog system rather than converting digital inputs (Camilleri et al. 1987: 69–71). This was not irrelevant in the 1970s, when computing time was still very expensive. In the following years the main effort of Grossi's division was the development of the software TAUMUS (Table 1) used to control the TAU2 synthesiser (Bolognesi and Grossi 1979). In the mid-1980s, the users, who had access to early data networks and had received permission from the musicology division, could connect remotely to the computer music programs available at CNUCE using the software TELETAU (Table 1) (Nencini 1986).

All the software packages developed in Pisa by Grossi and his co-workers had three main technical features: performance in real-time, automation and interactivity (Baruzzi et al. 1975: 1–2). These three technical requirements responded to Grossi's aesthetic

[8]Oral history with L. Tarabella, July 2016.

Table 1. Software developed by the CNUCE Musicology Division.

Software name	Suitable for	Developers	Main features
DCMP	IBM/7090; IBM 360/30, 360/44, 360/67	Cesare Chignoli (IBM); Giorgio Sommi (IBM); Pietro Grossi (CNUCE); Carlo Paoli (IBM)	The software elaborated and played monodic music in real time (the music was inputted by the user or auto-generated by the DCMP). The software could also manage an archive of musical pieces and perform these pieces with modifications (slower or faster, in random arrangement, with changed frequencies, adding pauses etc.). Frequency and duration were the only sound parameters controlled by the program.
PLAY 1800	IBM 1800	Pietro Grossi (CNUCE); Silvio Farese (CNUCE)	The software had features similar to the DCMP, but controlled timbre and pitch in addition to sound frequency and duration.
TAUMUS	IBM 370/168	Pietro Grossi; Tommaso Bolognesi; Mario Milani; Carlo Paoli; Raffaello Porinelli; Leonardo Tarabella; Leonello Tarabella. All CNUCE staff.	The software was developed for the synthesiser TAU2. The TAU2/TAUMUS system performed the same tasks of DCMP and PLAY, but the sound was much more refined, because the system was polyphonic and polytimbric. It offered a more accurate control of sound frequency, duration, timbre and pitch. In addition, the TAUMUS software auto-generated music (using random numbers) more efficiently than DCMP and PLAY software packages.
TELETAU	EARN-BITNET-NORTHNET Network	Giovanni Nencini (CNUCE) (Pietro Grossi also contributed ideas)	The software enabled remote users to access the TAU2/TAUMUS system available at CNUCE via data networks.

ideas about computer music. According to Grossi, computer music had to be played in real time to mark a discontinuity with traditional musical practices. The computer user had the right to immediately hear the piece of music selected from an archive or generated with an algorithm. Music software also had to automatise the processes of execution and composition to achieve the aim of making music without musicians. Grossi already had these goals in mind when he wrote the presentation of the *GE-115 Computer Concerto*: 'A future slogan might well be "Compose your music by yourself and have it performed by your computer (or by the terminal connecting you to it)".' Last but not least, computer music had to enhance the participation of the listener and provide facilities to modify pieces or play them with a different tempo.

In Pisa, Grossi's role quickly shifted from that of the musician, who merely suggests ideas, to that of the programmer. Apart from the first version of the DCMP, completed by early 1970, Grossi directly contributed to all the other main software projects developed by the musicology division. Unlike the GE-115, the IBM mainframes available at CNUCE could be programmed using high-level languages, a considerable facilitation for Grossi who also received the support of IBM staff, in particular Giorgio Sommi and Cesare Chignoli. Upon Grossi's request, Chignoli also taught a few classes on Fortran programming at the Conservatorio Cherubini. Despite his age, Grossi learnt quickly, alongside the students. By October 1969, he had written to his former pupil, Jon Phetteplace: '[In Pisa] We carry on our work with computers. We are making progress in software development and we are doing interesting things. I learnt to program and I believe that it is not possible to go back' (Grossi 1969, my translation). In the following months and years, Grossi kept Phetteplace informed about the work done in Pisa and encouraged him to take up programming because 'there is no doubt that the computer will soon be of the highest importance in music' (Grossi 1970, my translation). Grossi always tried to bring his experience in computer music back into the musicians' community. His students at the Conservatorio Cherubini were already receiving some informal teaching in computer music during the 1970s, although an official course in musical informatics was opened only in the 1980s. There were also public presentations of Grossi's software packages during festivals of contemporary music and in collaboration with music institutions in Italy and abroad.

The Italian musical community, however, was not very welcoming to Grossi. His computer music projects were better received among scientific circles (Giomi and Ligabue 1999: 53). Indeed, computer scientists began to consider Grossi a member of their own community because by the early 1970s Pietro Grossi had become a keen programmer or, as Grossi defined himself in later years, 'un artigiano informatico-musicale [an artisan of both informatics and music]' (Giomi and Ligabue 1999: 71). Grossi did not refrain from declaring his fascination for software and some of his colleagues in computer science hinted that he liked programming better than making music (Giomi and Ligabue 1999: 54). Yet Grossi was not an engineer, a physicist, a mathematician, or a computer scientist, as were his scientific co-workers at CNUCE. What did he find in software development? To answer this question, it is necessary to consider how the programmer's role has changed over time. In 1969, when Grossi learnt to program in Fortran, IBM was still selecting programmers without setting rigid qualifications in terms of degree or work experience. It rather appealed to curious minds: 'Do you enjoy algebra, geometry or other logical operations? Can you do musical composition or arrangement? Do you have an orderly mind that enjoys such games as chess, bridge or anagrams … finally do you have a lively imagination?' (Ensmenger 2010: 52, fig. 3.1). The programmer as a white collar corporate employee did not yet exist, and computer companies still valued creative individuals, such as Pietro Grossi, who conceived of programming as a form of craft. In the 1950s and 1960s programming itself was considered akin to 'art', and 'even today […] the notion that computer programming still retains an essentially artistic character is widely accepted' (Ensmenger 2010: 48). As a programmer, Grossi contributed to the institution's scientific output, like any other CNUCE researcher. The publications of the musicology division (journal articles, instruction manuals, music records) and the software packages developed there all counted as 'research results'. The drawback was that, as research products, Grossi's music records and software packages had a very limited circulation beyond scientific circles.

Grossi remained associated with the CNUCE musicology division until the mid-1980s, when he retired, but by the early 1980s the Conservatorio Cherubini in Florence had become his main workplace. From the music school, he could reach the computing facilities in Pisa via a computer terminal and in Florence he could use a synthesiser system, IRMUS, which had been built by a new scientific partner, the Istituto di Ricerca sulle Onde Elettromagnetiche (IROE). During the 1980s, Grossi'a main activities not only took place away from Pisa, but also his interests shifted from computer music to computer art, a practice that Grossi called *Homeart* (Giomi and Ligabue 1999: 75–8).

5. CONCLUSION: MEN, MACHINES AND MUSIC

Opening the black box of technology (Latour 1987; Pinch and Bijker 1987) is a recurrent theme in science and technology studies. Pinch and Trocco did so for the Moog synthesiser. Inside the machine they found a fascinating conundrum that could not be explained either in engineering, or in music, or in popular culture alone, but only by considering a wider set of social factors and dynamics of conflict, consensus and persistence (Pinch and Trocco 2002). Likewise, the case study examined in this article highlights the complex interactions between men and machines when music is at stake. On the one hand, we have a musician, Pietro Grossi, with his ideas and artistic aspirations; on the other hand, there is a machine, the general-purpose digital computer. The computer was not to be made *ex novo* as the Moog synthesiser, but was reshaped and transformed from a general-purpose machine into a music-making technology. This was not easy: the computer was not very user-friendly in the 1960s and 1970s, music software had to be written from scratch, and hardware for sound generation improved or created.

One way to describe Grossi's encounter with computer music is the one followed by a large part of the literature available on the musician (Giomi 1995, 1996; Mayr 2011). For this literature, Grossi is the lonely pioneer who conquers the machine and accomplishes his artistic ideals, despite the hostility of traditional music institutions. The existence of Grossi's allies (experts, technicians, scientific institutions, computer companies) is acknowledged, but who they are, what they do, why they do it, does not really matter. Only the musician Grossi receives attention. This article has told an alternative history of Pietro Grossi's involvement in avant-garde music. In this story, Grossi is not a lonely pioneer, but an enterprising member of scientific and musical circles. On the one hand, he enrols helpers in business and academia, and reshapes himself as a programmer and scientific researcher. On the other, he advertises his work at music festivals and teaches electronic and computer music at the Conservatorio Cherubini. In my story there are several human and non-human actors alongside Grossi. They are computer companies (OGE/GE and IBM); scientific institutions (CNUCE, IEI, IROE); researchers (Ferruccio Zulian, the IBM R&D staff in Pisa, CNUCE, IEI and IROE researchers); technicians, if we go back to Grossi's involvement in electronic music; mainframes (GE-115, IBM 7090, several System/360, IBM 1800, etc.); devices for sound generation (digital-to-analog converters, synthesisers, humble loudspeakers); software languages (machine code, Fortran); data networks, etc.

And the musicians? Where are the musicians? There are very few of them in my account because they were not crucial in Grossi's venture into computer music. They could learn from him, and many of Grossi's students have made their name in electronic and computer music. They could also offer him the opportunity to present his research in public events: the Maggio Musicale in Florence, the Autunno Musicale in Como, the Biennale in Venice, etc. But they could not grant him access to mainframes or provide the expertise necessary to use them. They were, rather, beneficiaries of Grossi's ability to build networks within the Italian computer science community. That is the reason why they remain in the background of my story. In the foreground there are instead researchers, scientific institutions and computer companies that tangibly helped Grossi. Whenever possible, I have tried to name them because they were not abstract categories – the scientist, the technician, the manager, the research centre – but real people and real institutions. In my account, Grossi the musician turns into Grossi the programmer or, better and according to his own definition, the artisan of both informatics and music, a person who can trade the cello fingerboard for the computer keyboard without regrets. Eventually, Grossi achieved his dream of making music without musicians, as all the software packages developed in Pisa included commands that enabled the computer to play and compose music automatically. However, this happened only because Grossi had been ready to jump ship, acquire new skills, and craft alliances with scientific and technological partners.

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