CENTRO DI SONOLOGIA COMPUTAZIONALE C.S.C.

UNIVERSITY OF PADOVA

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1. General Information

Activity in the field of computer music at the University of Padua began in 1972, using the experience aquired in the field of voice synthesis and analysis. The Centro di Sonologia Computazionale (C.S.C.) was formally instituted in 1979 with three fundamental purposes: scientific research, teaching and the creation of musical works, so as to assure production, the transmission and utilization of such knowledge.

In figure 1, the main achievements of the C.S.C. from the beginning of its activity up to today are shown regarding its financial relationships and cooperation with other institutions, teaching ac-

Historical Survey

Beginning Year of	Cooperation Support	Didactis	Research Systems	Composers
1971	Musical Institute Vicenza (up to 76)	Seminar on Music Language	Speech Synthesis	
1972	Electronic Inst. Padua University		MUSICA Language	
1974	Computer Center Padua University		Table Look-up Synthesis	
1975	Padua Conservatory	Electronic Music Course	MUSIC(4BF,360, 5) Synthesis	Dashow
1976	Venice Conservatory	Electronic Music Course	I C M S	Rampazzi
1977	C.N.R.		EMUS Language	Dalla Vecchia
1978		1978 UNESCO Worshop	MUSICA System	Graziani, Patella
1979	C.S.C. (formal) establishment	Undergraduate Course of CM	Synthesis Techniques	Baggiani-Nottoli Torresan
1980	Biennale of Venice LIMB		LPC Analysis/ Synthesis	Doati, Howe Jr., Razzi
1981	M.P.I. AIMI	1981 LIMB Seminar	EV Digital Synthesizer	Ambrosini, Melby Clementi, Pasquotti
1982	IRCAM Paris	ICMC '82	4i System	Motz, Stroppa
1983		Sum. CM Course 83 LIMB Seminar	MV4I Language	Behrman, Chadabe Teitelbaum
1984	SGS-ATES		4i Real Time Gesture Control	Donatoni, Nono

fig. 1

tivity, research and systems development. As for the production of original musical works, the principle composers who have worked with the C.S.C. are indicated.

We have aimed at creating an interdisciplinary environment in which abilities of both a scientific and musical nature could mix. For this reason, we have opened the C.S.C. to cooperation with the music Conservatories in Padua and Venice (in addition to University researchers and students), making available its resources for teaching electronic music courses; it is also open for work with the Music Sector of the Venice Biennale, which in 1980 instituted the Computer Music Laboratory (LIMB) and has commissioned various works of computer music carried out at the C.S.C.

In this context, profitable work began with the IRCAM in Paris towards the development of a real-time system based on the 4i processor of G. Di Giugno.

At present, we are collaborating on a project with the musical instrument industry in order to create specialized digital circuits for sound synthesis.

We have also tried to offer the greatest possible space to individual composers and researchers who do not fit into the above-mentioned institutions' categories of activities. These people can utilize the resources of the C.S.C. to carry out personal projects, which quite often become extremely relevant to the development of the C.S.C., too.

The principle teaching activities and the working relationships which have been created during these years of life at the C.S.C. are shown in figure 2.

2. Teaching and Production of Musical Works

Teaching has been given special importance so as to assure the diffusion of capabilities which have matured through production and research activity.

Such activity moves in two directions: one for musicians who want to familiarize themselves with new techniques of composition and performances, another for students from scientific disciplines who want to specialize in the computer music field.

For this purpose, wide-ranging meetings and seminars are organized, together with the Italian Computer Music Association (AIMI), in which both composers and researchers present their most recent work, work in progress and other activity. Introductory meetings and broad overviews of topics of general interest are organized for a less specialized user-audience.

Music students can familiarize themselves with computer music by attending courses at the Conservatories in Venice and Padua in which the C.S.C.'s laboratory is used for practice, thus introducing them to a research and production environment rich in stimuli.

The C.S.C. organizes summer computer music courses on its own, structured in independent, intensive teaching modules which allow the study program to be formed according to one's needs and skills. For example, a first module on general topics could be

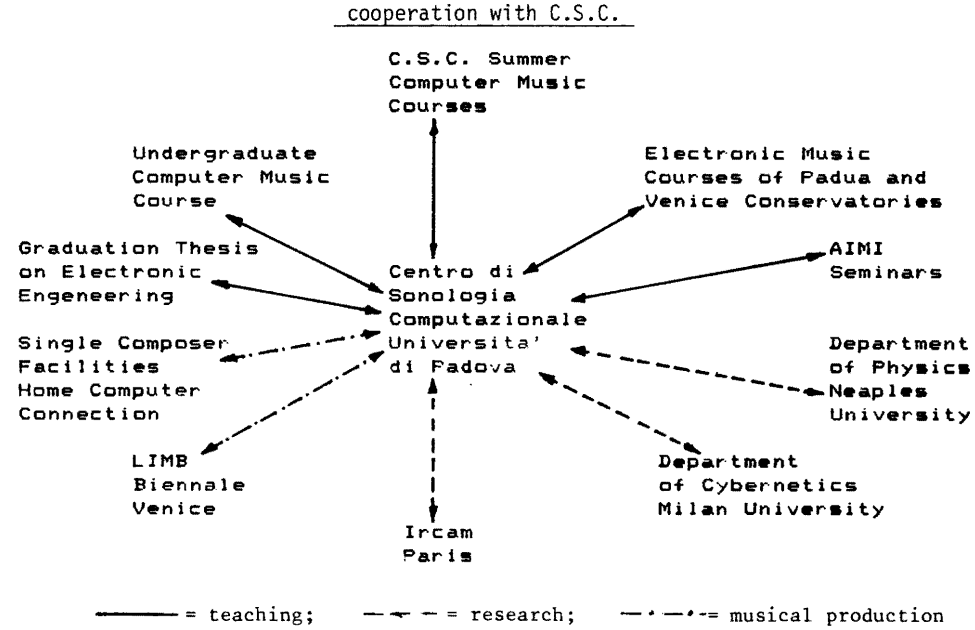

fig. 2

followed by one on real-time synthesis systems, or voice and song synthesis, or the analysis of computer music works, or psychoacoustic investigations, not to mention extensive laboratories on various techniques of numerical sound synthesis and manipulation.

Whoever is interested in a technological/scientific approach can attend the computer music course at the Faculty of Electronic Engineering in which computer students specialize in the hardware and software of computer music. Many of these students continue their specialization in this sector through degree theses which range from experimental to theoretical fields, giving a valuable contribution to systems development and research activities.

As for the production of musical works, from 1975 to date, more than fifty musical works have been completed; these utilize the computers in various ways (sound synthesis, assisted composition, natural sounds processing, mixed compositions for tape and acoustic instruments, live computer music,etc.) and have received ample recognition and numerous performances. Various works have been put in record series.

A list of the principle compositions created at the C.S.C. and a complete recording list are included in a following Section.

3. Research Activity

Research activity is divided in four main areas: sound synthesis and analysis, computer assisted composition, music theory, and computer music systems research and development. These research activities cover various aspects of computer music, constitute the necessary premise for teaching, and become a source of stimuli for the production of musical works. The most important results are constantly integrated throughout the entire system of equipment and programs available to users.

The C.S.C. computer music laboratory makes use of both the computers of the University's Centro di Calcolo (an IBM 370/158, that soon will be replaced, and a VAX 11/780) as well as mini-computers dedicated exclusively to musical applications (Digital PDP 11/34 and IBM S/7). The hardware equipment with interconnections between the various computing systems, the two numerical sound processors (4i and EV), and the D/A - A/D conversion systems are outlined in fig. 3.

Three working methodologies are possible, and can be applied separately or together during the various phases of project realization: batch, interactive mode and real-time work. These correspond to three systems, which are autonomous, yet connected to each other: the MUSICA System, the Interactive Computer Music System (ICMS) and the 4i System.

3.1 The Musica System

The Musica System consists of a coordinated system of batch programs implemented on an IBM 370/158 computer and which allows the elaboration of musical structures (EMUS), the coding of traditional music scores (MUSICA), and the synthesis (MUSIC 5, MUSIC 360, MUSIC 4BF), analysis (SPECTRE, LPCAN) and sound processing.

EMUS
EMUS processes musical structures by means of a structural score. This program has three functions, non necessarily sequential:

- definition or generation of symbolically based material with numeric, graphic or pseudo-aleatoric methods;
- organization of such materials into hierarchical structures, which are then temporally distributed according to the composer's requirements;
- translation of the symbols contained in the temporal structure into the operational score.

The composer can control each function at any point in order to define precisely the final results without working at operational levels.

MUSICA and NOTE
The language MUSICA permits the transcription of any musical text in traditional staff notation into an alpha-numeric code isomorphic to the original. This program generates an operational score for synthesis programs by means of a translating procedure, and codes any other alpha-numeric information in order to modify the translating phase and to implement the operational score. The language NOTE interprets a symbolic score coded with the language MUSICA, and provides the operational score for MUSIC5.

MUSIC
For batch synthesis the well-known programs MUSIC5, MUSIC360 and MUSIC4BF offer the advantage of a possible integration of uses. The two procedures MU45 and MU54 permit the sharing of data. These programs permit the composer to create instruments by means of modules, obtaining very complex sounds and a large number of simultaneous voices.

Analysis programs
Besides the more specifically music programs there is a series of programs about acoustical analysis. SPECTRE allows the spectral sound analysis through Fourier transform, the harmonic contents being given also in temperate scale. It allows also the harmonic grouping of each fundamental and shows the time behaviour of each partial amplitude. So it can be utilized for complex, in particular multiphonic, sound analysis.

The VAI7 system (VIDE, ASEQ, INTR) for interactive

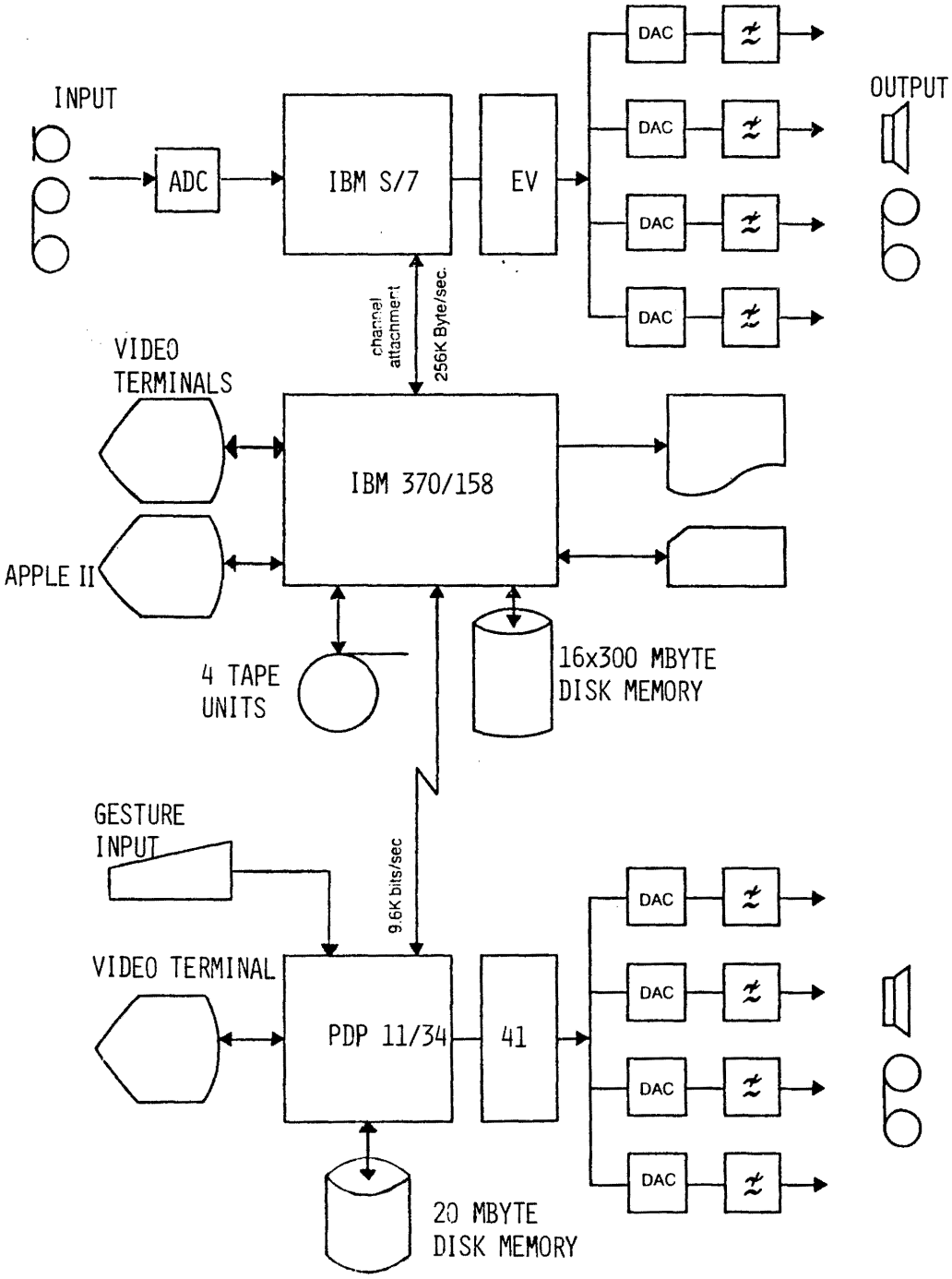
INPUT
ADC
IBM S/7
EV
DAC
DAC
DAC
DAC
OUTPUT
channel attachment
256K Byte/sec.
VIDEO TERMINALS
IBM 370/158
APPLE II
4 TAPE UNITS
16x300 MBYTE DISK MEMORY
GESTURE INPUT
9.6K bits/sec
VIDEO TERMINAL
PDP 11/34
41
DAC
DAC
DAC
DAC
20 MBYTE DISK MEMORY

fig. 3

analysis and sound segmentation, analysis and synthesis program by means of linear prediction code techniques (LPCAN), other programs for digital si - gnal processing are the result of research in speech synthesis.

Sounds may be heard through a 16-bit quadriphonic convertion system by utilizing an IBM S/7 computer which is connected via channel to the S/370. In the same way an A/D convertion system is provided for analysis and processing of acoustic sounds. The ample space of the direct-access disk memory and the rapid link of the two computers allow immediate listening of sound files. Thus, the batch mode is not penalized at all.

3.2 The ICMS System

The ICMS System operates on the same computers in a multi-programming environment and performs the following functions:

- double modulating FM sound synthesis, able to modify some timbric parameters in real time;
- editing of sound files to be mixed, reverberation and spacial distribution on four channels;
- sound analysis and synthesis with the LPC, using any sound source as stimulus;
- availability of a diphone repertory for text synthesis and for parameter articulation and modification either explicitly or using a phonological processor.

Particular care has been given to man-machine interaction through easy commands and graphic visualization.

3.3 The 4i System

The 4i System consists of a 4i sound processor controlled by a PDP 11/34 with an input console for manual operations. This system synthesizes sounds using data coming from both coded scores and gestural commands. The latter can also be memorized so as to create a new score. Through listening, therefore, the editing and performance of scores in real time becomes extremely easy. The interactive composition program, POD, developed by B. Truax, is available on the same computer.

3.4 Computer Music Representation Levels

The various software elements that make up the above-listed systems and their connections are illu - strated in fig. 4. Input/output data on the various programs are shown in the figure at various levels, furnishing a graphic representation of what has been said above. For example, the analysis data obtained using LPC or FFT programs on stored sound samples constitute the symbolic information which can then be utilized by the ICMS system, together with the specific operational data and the symbolic data coded using the MUSIC program.

In conclusion, the three Systems can compatibly interchange information on scores and sound files, and in addition, are linked to a local network that goes from the Apple II personal computer to the VAX 11/780. Thus, there is greater ease of access for a larger number of users that can even operate in different locations, choosing the means that is best suited to any particular application.

3.5 Hardware Research

Hardware research has led to the creation of a "Elaboratore Veloce" (E.V.) for real-time sound synthesis. Such a computer is designed to function as a slave computer to any other master computer, which must supply the E.V. with data and instructions which constitute a sound generation program. There are two separate memories in the E.V., so that while one is sending a previously-memorized program to be carried out, the other can be refreshed by the "master" with new data and instructions. A two-level pipelining technique allows up to 6 actions to be carried out simultaneously in a single machine-cycle lasting 140 ns. Furthermore, a special feature of the phase register permits faster linear-interpolation operations of tabulated waveforms. E.g. a simple amplitude and frequency controlled oscillator can be realized using only 4 instructions (2 sums and 2 multiplications). The synthesizer can be programed using all of the known sound-synthesis techniques and can generate up to 40 interpolated simple oscillators.

A manual command system has also been studied and planned for remote control of the 4i Processor. Such a system allows the transmission of any "on-off" type or continual-variation type commands (potentiometers, joysticks, etc.) through serial transmission of numerical data following C.C.I.T.T. norms, at any distance, using a normal telephonic support. Although originally conceived to satisfy the demands of the 4i Processor, system features were later developed so as to meet most musical instrument and synthesizer applications.

The project for a digital sound-synthesis proces - sor, which is to be integrated by the SGS-ATES semi-conductor company, is in its final stages of development; its characteristics are listed below:

- 8 poliphonic-politimbric voices;
- stereo digital output to external DAC;
- 20kHz internally generated sampling frequency;
- synthesis methods: table look up, waveform filtering, AM, ring modulation, FM, waveshaping; pseudo-random noise generator;
- 8 bit input bus control;
- effects of poliphonic tremolo, vibrato, and portamento; dynamic keyboard (velocity and after

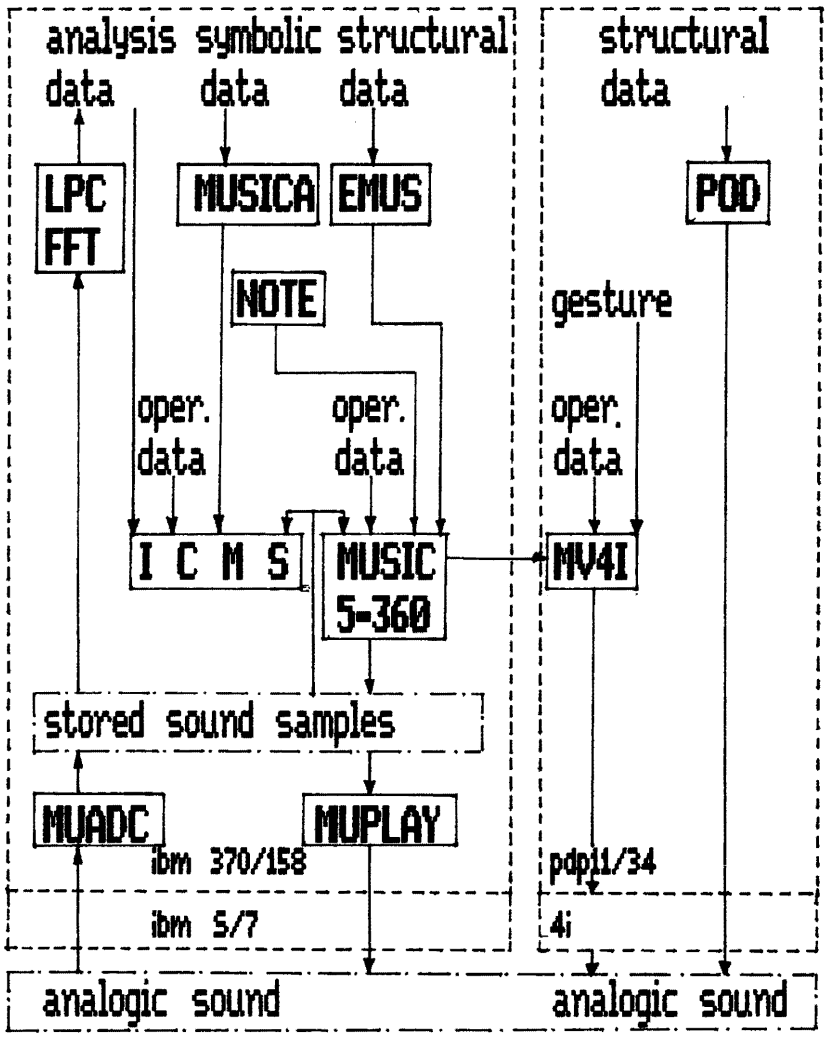

fig. 4 - Fundational relationship between different level of musical data and applicative software and systems.

touch pressure) control;
- multiple cascading of processors;
- use as preset sound generator or as programmable synthesizer.

Finally, 16-bit DAC and ADC converting system have been planned and developed.

3.6 Digital signal processing

Particular interest has been given to the digital processing of signals and to the analysis and synthesis of musical sounds, with the goal both of supplying composers with new operational techni - ques and of developing efficient algorhythms for low-cost computer music systems.

For this purpose, various synthesis techniques have been investigated, in particular those utilizing VOSIM-type oscillators or non-linear techniques.

The problem of finding parameters for a generalized VOSIM oscillator and for waveshaping has been studied. For this, equivalence relations were determined for polynomials which produce the same spectrum, but had different dynamic behavior.

The technique of non-linear distortion was applied for input consisting of the sum of two sinusoidal signals. The use of a distorting function speci - fied by the ratio between two polynomials was then proposed. Finally, a particular waveshaping was examined in which the spectrum produced also depen ded on the input frequency.

Frequency modulation was also an object of investi gation. The use of phase or frequency series modulators was studied, as well as special discrete modulation with phase distortion.

Besides non-linear synthesis techniques, much attention has been given to the analysis/synthesis of the voice and speech. Analysis parameters can be represented in various forms: as All-pole filter coefficients, as reflection coefficients of the acoustic tube corresponding to the vocal apparatus, as parameters for a cascade/parallel synthesizer, or as frequency modulation parameters in which every formant is associated with an FM group.

4. Conclusions

The C.S.C. constitutes a rather rare example, in Italian reality, of a scientific-technological research center in the musical field since no musical production or studies (if one excludes musicology) are provided for in its universities. In this situation, the bond achieved between two disciplines as distant from each other as computer science and music is particularly noteworthy. The teaching and research activity done over the years have produced important results, not only from a scientific point of view, but also from an artistic one-so much so that the music produced at the C.S.C. circulates not only in the exclusive environments of the computer music community, but are also put in wide-ranging productions in prestigious sights.

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RAMPAZZI T., BALLADORE P.: "*With the light pen*", 1976. Mention V Int. Elect. Music Compet., Bourges, Francia, 1977. Duration: 8'30".

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RAMPAZZI T.: "*Computer dances*", 1978. Mention VI Int. Elect. Music Compet., Bourges, Francia, 1978. Duration: 10'30".

PATELLA G.A.: "*Sinaric*", 1978. Duration: 8'.

DASHOW J.: "*Second voyage*", for tenore and computer-generated tape, 1978. Commissioned by National Endowment for the Arts. LP Record CRI SD-456, New York, USA. Duration: 17'45".

RAMPAZZI T.: "*Fluxus*", 1979. LP Record EDI-PAN PRC S 20-16, Rome, 1984. Duration: 12'30".

BAGGIANI G., NOTTOLI G.: "*Senza Voci II*", 1979. Assistent: A. Vidolin. LP Record EDI-PAN PRC S 20-15, Rome, 1984. Duration: 6'40".

RAMPAZZI T.: "*Atmen noch*", 1980. 2nd prize at VIII Int. Elect. Music Compet., Bourges, Francia, 1980. Duration: 15'10".

GRAZIANI M.: "*Winter leaves*", 1980. Mention at IX Int. Elect. Music Compet., Bourges, Francia, 1981. LP Record EDI-PAN PRC S 20-16, Rome, 1984. Duration: 8'40".

HOWE H.: "*Astrazioni*", 1980. Commissioned by La Biennale di Venezia. Duration: 11'.

RAZZI F.: "*Progetto secondo*", 1980. Commissioned by La Biennale di Venezia. Assistent: D. Torresan. LP Record EDI-PAN PRC S 20-16, Rome 1984. Duration: 12'.

DASHOW J.: "*Conditional Assemblies*", 1980. Commissioned by La Biennale di Venezia. 2nd prize at Int. Elect. Music Compet., Bourges, Francia, 1981. LP Record EDI-PAN PRC S 20-12, Rome, 1983. Duration: 19'52".

GRAZIANI M.: "*The silent god*", 1980. Commissioned by La Biennale di Venezia. Mention at XI Int. Elect. Music Compet., Bourges, 1983. Duration: 9'50".

TORRESAN D.: "*Cardo*", 1980. Duration: 5'15".

DOATI R.: "*Gioco di velocità*", 1981. LP Record EDI-PAN PRC S 20-16, Rome, 1984. Duration: 7'.

BON L.: "*Laguna*", 1981. Duration: 8'10".

FARNEDA S.: "*A little science a little magic*", 1981. Duration: 6'20".

RAMPAZZI T.: "*Danza seconda*", 1981. Duration: 8'.

RAMPAZZI T.: "*Metamorfosi*", 1981. Duration: 8'30".

DALLA VECCHIA W.: "*Atrocissime tange*", for mimo, percussions and computer-generated tape, 1981. Assistent: A. Vidolin and M. Graziani. Duration: 34'.

FARNEDA S., PAPADIA L., PATELLA G.: music for "*Libertà a Brema*" of R.W. Fassbinder, XXIV Festival dei due Mondi of Spoleto, 1981. Commissioned by: La Biennale di Venezia. Assistent: M. Graziani. Duration: 19'30".

MELBY J.: "*Layers*", 1981. Commissioned by: La Biennale di Venezia. Mention at X Int. Elect. Music Compet., Bourges, Francia, 1982. Duration: 9'51".

PASQUOTTI C.: "*Forma magistra ludi*", 1981. Commissioned by: La Biennale di Venezia. Assistent: G.A. Patella. Duration: 15'.

AMBROSINI C.: "*Cadenza estesa e coda*", for flute and computer-generated tape, 1981. Commissioned by: La Biennale di Venezia. Assistent: D. Torresan. Duration: 17'30".

BON L.: "*Tarot*", 1981. Duration: 7'30".

CANANZI A.: "*Epigenesi*", 1982. Duration: 10'40".

DOATI R.: "*Una pulce da sabbia*", 1982. Duration: 8'.

RAMPAZZI T.: "*Geometrie in moto*", 1982. Duration: 11'40".

RAMPAZZI T.: "*Requiem per Ananda*", 1982. Duration: 8'15".

MENEGHETTI R.: "*Insania*", for saxophone and computer-generated tape, 1982. LP Record, PANARECORDS 3371, 1982. Assistent: M. Graziani. Duration: 35'

MOTZ W.: "*Sotto Pressione*", for 2 oboi and computer-generated tape. Mention at XI Int. Elect. Music Compet., Bourges, 1983. 1st Prize at Stuttgard City Competition (1983). Duration: 8'22".

GRAZIANI M.: "*Landin*", 1982. Mention at XI Int. Elect. Music. Compet., Bourges, 1983. Duration: 8'40".

DASHOW J.: "*Il Geografo*", from 'Il piccolo Principe', for 2 voices and computer-generated tape, 1982. Commissioned by: La Biennale di Venezia. Duration: 10'.

RAZZI F.: "*A voi che lavorate sulla terra*", for

voice and computer-generated tape, text of Alfonso Gatto, 1982. Assistent; D. Torresan. Commissioned by: La Biennale di Venezia. Duration: 15'.

CLEMENTI A.: "*Fantasia su roBErto FABbriCiAni*", for flute and computer-generated tape, 1982. Commissioned by: La Biennale di Venezia. Assistent: M. Graziani. LP Record PHILIPS 411066-1, 1983. Duration: 17'10".

GRAZIANI M.: "*Trasparenza*", 1983. Commissioned by: RAI. Duration: 22'40".

STROPPA M.: "*Traiettoria.....deviata*", for piano and computer-generated tape, 1983. Commissioned by: RAI. Duration: 6'23".

RAMPAZZI T.: "*Spettri*", 1983. Duration: 9'46".

BON L.: "*Shift of emphasis*", 1983. 3rd Prize at 5° Int. Compet. 'L. Russolo', Varese 1983. Duration: 8'25".

MAYER A.: "*Hora harmonica*", 1983. Duration: 60'.

CHADABE J.: "*Canzona veneziana*", for live 4i System, 1983. Commissioned by: La Biennale di Venezia. Assistent: M. Graziani. Duration: 9'20".

BEHRMAN D.: "*Oracolo*", for live 4i System, 1983. Commissioned by: La Biennale di Venezia. Assistent: G. Tissato. Duration: 10'20".

TEITELBAUM R.: "*Barcarola*", for live 4i System, 1983. Commissioned by: La Biennale di Venezia. Assistent: S. Sapir, A. Vidolin. Duration 15'.

BON L.: "*Transient*", 1984. Duration: 8'30".

STROPPA M.: "*Dialoghi*", for piano and computer-generated tape. Duration; 13'.

CAPPUCCIO S.: "*Tra le quinte*", 1984. Duration: 8'05".

DASHOW J.: "*Sequence Symbols*", 1984. Duration: 13'.

DOATI R., PATELLA G.A., TORRESAN D.: "*La materia è sorda*", 1984. Commissioned by: RAI. Duration: 14'14".

GRAZIANI M.: "*Wires*", 1984. Duration: 10'30".

NONO L.: "*Prometeo*", for soli, coro, orchester, live electronics and for live 4i System, 1984. Commissioned by: La Biennale di Venezia and Teatro alla Scala di Milano. Assistent: S. Sapir A. Vidolin, M. Graziani.

GRAZIANI M.: "*Untitled N. 1 (4i studio)*", for live 4i System, 1984. Duration: 10'.

DONATONI F.: computer generated tape for the opera "*Atem*", 1985. Commissioned by: Teatro alla Scala of Milan. Assistent: M. Graziani, A. Vidolin.

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D'EMILIO F.: "*Untitled*", 1985. Duration: 8'30".

KARPEN R.: "*The vision*", 1985. Duration: 15'.

DOATI R.: "*Deve essere tenuto lontatno da fonti di luce*", 1985. Duration: 9'.

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