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Computer Music Experiments 1964– . . .

My initial motivation to enter the computer music field was musical rather than technical, although I had a background in both music and science. My scientific training at the Ecole Normale Supérieure in Paris was in mathematics and physics, not in computer science, a field that did not exist in the 1950s. Independently, I studied piano with Robert Trimaille, and this was an essential experience for me. I also studied harmony, counterpoint, and composition with André Jolivet. The late French composer had worked with Varèse in the 1930s; he had a strong temperament and a deep feeling for the idiosyncrasies of instruments. During a composition seminar he held in 1962 in Aix, he had Lejaren Hiller give a presentation of his work. The computer excited little musical interest in France at that time, except among a few individuals like Moles, Barbaud, Philippot, and Xenakis. My first piece for orchestra was played in 1963 at the French Radio: it reinforced my vivid interest in timbre and its capacity to convey specific musical ideas.

I wanted to increase the functional part of timbre in my composing. Yet I resisted turning to electronic music—in Paris; it was mostly Pierre Schaeffer's *musique concrète*. I felt that electronic music yielded dull sounds that could only be made lively through manipulations which, to a large extent, ruined the control the composer could have over them. On the other hand, *musique concrète* did open an infinite world of sounds for music—but the control and manipulation one could exert upon them was rudimentary with respect to the richness of the sounds, which favored an esthetics of collage. Both techniques seemed to me to rely on ready-made objects or processes, which the composer could only warp for his purposes. In 1962, I met Pierre Barbaud, the French pioneer of computer music composition, but I was not so interested in this direction.

Thanks mainly to Max Mathews, a new branch of electronic music appeared with computer synthesis of sound. I had the privilege to be able to come work with Max in 1964. My science professor, Pierre Grivet, had been impressed by the clear and lucid article Max published in *Science* in 1963: "The Computer as a Musical Instrument." With the help of John Pierce, Grivet arranged for me to get a grant from D.G.R.S.T., a French agency for research, permitting me to work at Bell Laboratories as a research-composer in residence. In this capacity, I succeeded Jim Tenney, who was, I believe, the first composer to make a significant musical use of computer synthesis of sound.

Arrival at Bell Laboratories

My arrival in the States in 1964 was an unforgettable experience. I met Max Mathews, John Pierce, Jim Tenney, Varèse, and many lively scientists and artists. Max had several ideas for research, including computer composition, but I elected to focus on timbre. The palette of computer sound, potentially boundless, was in fact quite restricted, and one did not know how to generate certain sounds.

In particular, brassy sounds resisted synthesis efforts. I had to convince myself that the recipes of respected acoustics treatises (like H. F. Olson's) did not work. As one may judge from tones synthesized from such recipes, they did not (cf. Sound Example 1). So I began a study on the correlates of trumpet tone quality. I recorded trumpet samples, analyzed them with the sound spectrograph and with the computer, displaying the evolution in time of individual harmonics' amplitudes. From this analysis, it was possible to imitate isolated tones with the help of the Music V program, written by Joan Miller and Max. I used a different envelope function for each harmonic, approximating the curves yielded by the analysis in terms of piecewise linear func-

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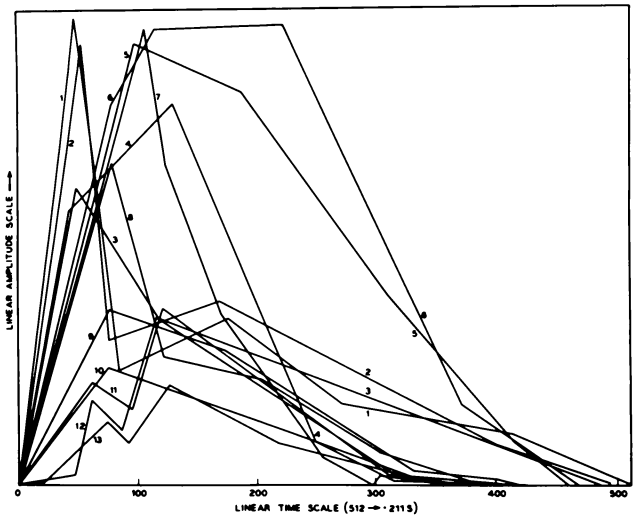
Fig. 1. Jean-Claude Risset, 1984.

Fig. 2. Line-segment functions that approximate the evolution in time of 13 harmonics of a D4 trumpet tone lasting 0.2 sec. I have used such functions, drawn from analysis of real tones, to control the harmonic amplitudes of synthetic tones (Risset 1965).



tions (Fig. 2). (Despite the long turnaround time of the computer center, I was lucky to have the converter down the hall, while Jim Randall, Hubert Howe, the late Godfrey Winham, and others had to come from Princeton to use the converters) But the descriptions of the tones were very complex, and varied from one tone to another. I had to try to reduce this information to the essential, that is, to those features that are the most significant to the ear. I checked by synthesis the aural relevance of several aspects, and I found that the most salient characteristic of brass tones was the fact that the spectrum varied with loudness, so as to increase the proportion of high-frequency energy when the loudness increases. Thus the timbre is mainly characterized here by a property, a law of variation, a relationship between physical parameters, rather than by a physical invariant such as a spectrum (Risset 1965; Risset and Mathews 1969; Risset and Wessel 1982). This nonlinear behavior, later studied by James Beauchamp, was operational over a rather wide range to obtain brassy sounds. Robert Moog designed a voltage-controlled filter whose bandwidth increased with the control voltage. It generated brassy sounds by deriving the control voltage from the amplitude envelope of the input. John Chowning (1973) implemented this characteristic in a very elegant fashion using frequency modulation (FM). Dexter Morrill has used this very effectively in his synthesis work. The point of instrumental imitation is not only instrument duplication, of course. In particular, it sheds light on properties that can endow sounds with naturalness, richness, and also give them a characteristic identity.

Despite Varèse's assistance, my efforts to postpone my military service to continue this work were in vain, and I had to come back to France in 1965, so I could not exploit this study and compose pieces at that time. I obtained my "Thèse d'Etat" in Orsay in 1967. My thesis centered on this trumpet study and on previous studies of auditory processes.

I returned in 1967 to Bell Laboratories, where I stayed two years. When I arrived, Vladimir Ussachevsky was working there, and I enjoyed and benefited by interacting with him. At that time, Max Mathews had designed Music V as a more easily portable music compiler, and the program coding was nearly completed thanks to Dick Moore, whom I met then, and Joan Miller (Mathews et al. 1969). I helped complete and debug the program, and I tried a number of sonic structures I had in mind.

Many of the processes I worked on then were intended for *Little Boy*, a play by Pierre Halet (1968). My contribution was more than plain incidental

Fig. 3. Spectral analysis of a chord. Successive harmonics of each tone of the chord appear successively in decreasing order, at different rates for different notes of the chord (cf. Sound Example 3).

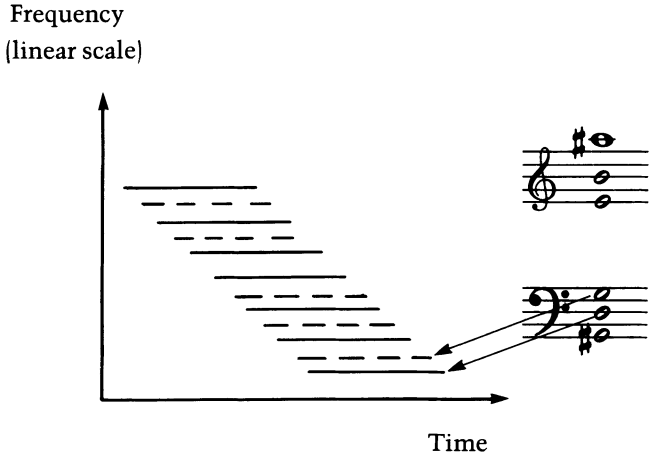
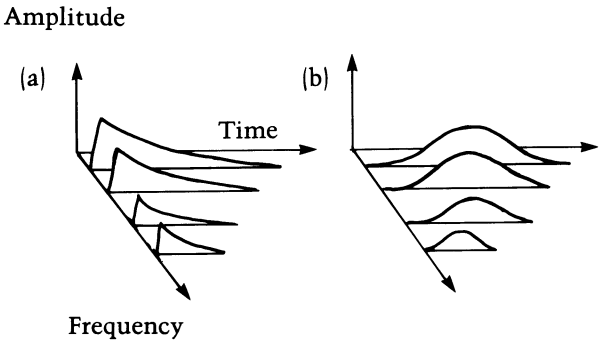


Fig. 4. Belllike tones (a) transformed into fluid textures (b). The unequally spaced components of the bellliketones have different durations but the same amplitude envelope: a short attack followed by an exponential decay. (b) is deduced from (a) by changing the envelope to a smooth belllike shape. The various components reach their maximum amplitude at different times. Hence, instead of fusing into a belllike attack, they yield textures in which the components are dispersed like white light through a prism (cf. Sound Example 5).



music. I worked with the playwright while he was writing, before the intervention of any stage director. The theme was the bombing of Hiroshima, revived through the phantasms of the pilot Eatherly—hence the music was to include realistic sound effects, but in close relation to the instrumental part—soprano and chamber ensemble as well as computer-synthesized tape (*Voice of the Computer*, Decca Records DL 710180). So, for example (Sound Example 2), a jazzlike theme, initially played by the instruments, is messed up in the agitated mind of the pilot: the instrumentlike synthetic sounds run wild and turn into gunfire. Also I used harmonic arpeggios, to make textures emanate from a given chord. In Sound Example 3, the harmonics of different notes of a chord appear in succession as shown by Fig. 3, with a gradual attack and decay. The rate of succession is different for different notes of the chord. Only at the end is the underlying harmony clearly revealed. (I called this process *spectral analysis* of a chord.) Then slowly gliding sounds take over in the example, suggesting plane noises but based on the same chord. I used such gliding inharmonic chords—maintaining a fixed frequency difference between the components, as hinted by John Clough—in nested structures. The relationship between the frequencies of the components is reproduced in the relationship between the frequencies of the tones.

If I change some of the harmonic envelopes into percussive ones, I get a new harmonic arpeggio—related but different (Sound Example 4). I am interested in these kinds of intimate transformations that change certain aspects while preserving others. Synthesis makes this easy. To do it from recorded sounds, one has to warp the synthesis parameters after a preliminary analysis, as can be done with linear predictive coding (LPC) or the phase vocoder. Similarly, I took advantage of synthesis to turn belllike sounds into fluid textures. The percussive, synchronous attack biased the listener toward synthetic perception of "bells," while a gradual bell-shaped curve makes amplitude behavior asynchronous for the components that have different durations (Fig. 4). Thus it biases the listener toward a more analytic perception of the sound "content." (This can be heard in Sound Example 5.) I used these transformations in *Little Boy*, *Mutations*, and other pieces, specially *Inharmonique* and *Mirages*. At the beginning of my piece *Mutations*, commissioned by the Groupe de Récherches Musicales and realized at Bell Laboratories in 1969 (INA-GRM recording AM 546 09), an arpeggioed chord is followed by a gong-like sound, composed like a chord, with the same implicit harmony. Here harmony is prolonged to become timbre, and timbre can become harmonically functional (Sound Example 6).

Back to *Little Boy*. The play by Pierre Halet staged the fall of the bomb. This fall was in fact only in the mind of the pilot, who identified himself with "Little Boy," the actual code name of the bomb.

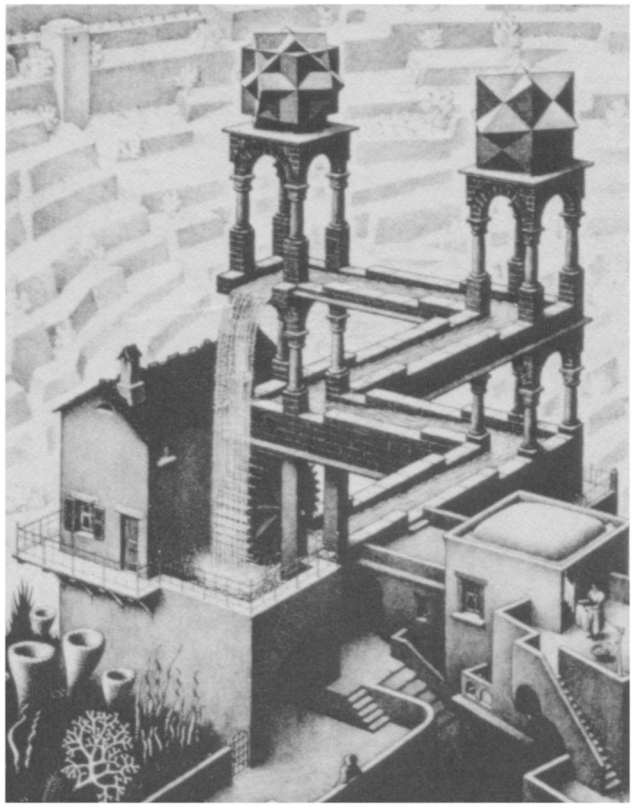


Fig. 5. Escher's waterfall in perpetual motion. I have synthesized tones behaving similarly to the flow of water, e.g., going up the scale but getting lower in pitch (cf. Sound Example 8).

Thus the fall did not reach any bottom, and I endeavoured to convey this feeling with the music. At Bell Laboratories in 1964, Roger Shepard synthesized endlessly ascending successions of chromatic tones. These tones were made up of octave components, with a bell-shaped spectrum tapering down at both ends. But I wanted gliding tones, not chromatic scales. Roger believed that a gap was needed between tones to achieve the illusion. Joe Kruskal did not succeed in making endless glissandi. I generated the effect by dynamically changing frequencies and amplitudes in the Pass III of Music V, by increasing the spectral attenuation at the ends of the spectrum and by keeping a slow enough descent. I also obtained a quasi-spatial effect by delaying one track with respect with the other. Sound Example 7 presents in succession two portions of this "fall." In the first one, the tone descends in large spirals that are passed by some fast objects. In the second example, the context is a bit more complex, with some Shepardlike chromatic tones but also some gliding choruslike textures.

For the end of the play, I generated inverted *pitch helices*—sounds that go up the scale while getting lower, in a way similar to the flow of water in the drawing by Escher (Fig. 5). This was done by shifting down the spectral distribution while all components go up. Sound Example 8 is actually drawn from *Mutations* (1969). It begins with such an unusual sound, then followed by tones with spectral scanning taking advantage of Chowning's frequency modulation (FM) technique. I met John Chowning in 1967. He explained his ongoing experiments on illusory moving sound sources and on spectral change through high-speed frequency modulation. He gave me his data together with a tape, so I could use the process right away.

Other Sound Paradoxes

The sound paradoxes I developed following Shepard interested me for *Little Boy*, but also for themselves, since they are produced by independently controlling cues for two complementary aspects of pitch: tonal pitch, related to Cness, and spectral pitch, related to timbre. I studied the phenomenon, playing various stimuli with conflicting cues to a number of listeners (including Stokowski, Berio, and others). Evidently various people weigh these attributes differently. Musically trained people always attribute a more or less substantial importance to tonal pitch, while a surprisingly large proportion of listeners (including music lovers and hi-fi fans) appear to be tonedeaf (Charbonneau and Risset 1975; Risset 1969a, 1971, 1978; Wessel and Risset 1979). This gives a dizzying feeling about the distance between what the musician intends and what is really perceived.

Sound Example 9 presents two weird sounds; more people hear the first one higher in pitch than the second one, but a few hear the contrary. The physical relation between these sounds may not be obvious: the second sound is obtained from the first one by doubling all its frequencies. Here is a sound that goes down for most listeners when one doubles

the speed of the tape recorder! It shows that, especially for inharmonic sounds, pitch is not isomorphous to frequency, and more generally that auditory perception implies complex and specific procedures that should be taken into account.

I further investigated these paradoxes with Gérard Charbonneau in France, through multidimensional scaling and also evaluation of ear differences (Charbonneau and Risset 1975). In 1974, I heard an endlessly speeded pulse generated by Kenneth Knowlton. The year after in Marseille, I separated rhythmic cues just as I had with pitch cues. I produced, for instance, a rotating sound that goes up and down in pitch, but also with a beat that constantly speeds up while gradually getting slower (Sound Example 10). I used this in *Moments Newtoniens* (1977), a programmatic piece purporting to present musical analogs for some of Newton's scientific achievements (INA-GRM AM 546 09).

The Catalog of Computer-synthesized Sounds

In the spring of 1969, Max Mathews went to Stanford University to participate in one of the earliest computer music courses. He asked me for data about various sound structures I had been synthesizing for *Little Boy* and *Mutations*. I hastily assembled a recording of excerpts, with the Music V scores and some words of explanation. I entitled this document "An Introductory Catalog of Computer-synthesized Sounds" (Risset 1969b). My examples, of course, were meant as instances, as points of departure for developing timbres or sonic processes, and by no means as models. I believe such documents can be very useful. I often find it difficult to get started making a sound. Within a certain class of timbres it is easier to tune an instrument to one's specific desires. Throughout the music community, programs had been widely distributed (Music IV, Music 4BF, Music V, Music 360) but not synthesis data. Yet I had been impressed with the efficiency of communication when John Chowning left his data at Bell Laboratories. The input data for programs like Music V give a thorough record of the physical structure of the sounds and of their combination—a genuine score for the control of the sound structure.

I never really updated this catalog as I intended to, although I have been distributing some computer scores. At IRCAM, Denis Lorrain prepared such a catalog of my piece *Inharmonique* (Lorrain 1969) intended for student composers. Such documents are still not widespread enough in my opinion, although more and more have been coming out since my catalog and John Chowning's classic article on frequency modulation (1973), for instance Stanley Haynes's IRCAM reports and the data published in *Computer Music Journal* by Grey, Moorer, Morrill, Schottstaedt and others.

In 1968, Max Mathews and Dick Moore developed the real-time GROOVE system (Mathews and Moore 1970), while I was doing Music V synthesis. Pierre Ruiz and I adapted Music V to a minicomputer—actually a midicomputer, a Honeywell DDP-224, a 24-bit machine. (I realized *Mutations* on the 224 in 1969.)

Return to France

My return to France in 1969 was difficult. I keep good memories of a UNESCO conference on Music and Technology held in Stockholm in 1970. Max Mathews and Pierre Schaeffer were there, as well as Peter Zinovieff, Gustav Ciamaga, Herbert Brün, Murray Schaeffer, Lars Gunnar Bodin, and Jon Appleton (UNESCO 1971). Also the development of FM by John Chowning comforted me in the hope that computer synthesis could become simpler and cheaper, but there was no computer music system available. After one year of fund-raising, I implemented music synthesis in 1970 on a Hewlett-Packard computer in Orsay with the help of Gérard Charbonneau and Pierre Karatchenzeff. I believe this was the first installation in Europe. However, the Electronics Institute where this happened was not congenial to music. I went to Marseille in 1972 as professor in a short-lived music department. There I was helped by the artistically-inclined physicist Daniel Kastler to raise funds for a computer to equip a music research laboratory at the Centre Universitaire de Luminy. (I made the application with Alain Colmeraurer, the author of the Prolog programming language.) Eventually we got a Telemeca-

nique T 1600 in 1974. (I used it until 1983.) With the help of Françoise Nayroles and Pierre Karatchenzeff, we got the first sounds from the T 1600 in 1975. John Chowning was visiting at this time. Despite the slow speed of the T 1600, I have realized several pieces on this machine with the Music V program. Sound Examples 11 and 12 present two excerpts from *Dialogues*, realized in 1975 (INA-GRM AM 546 09), a piece that attempts to closely intertwine instrumental and computer sounds. The computer begins and the instruments sneak in (Sound Example 11). In a later section, one hears a dialogue between piano and celesta—in chromatic scale—and high pitched computer sounds—in a linear scale: the computer plays harmonics of the notes D, F-sharp, G-sharp, A-sharp, C-sharp (Sound Example 12).

At that time, I was keen on a project I discussed with Max Mathews and John Chowning: to "marry" GROOVE and Music V, that is, to extract performance information to control non-real-time synthesis of a possibly different and complex nature. I never had a chance to really implement it, but I am glad to see that this kind of approach is being developed now, as exemplified by several papers presented at the 1983 International Computer Music Conference.

Founding of IRCAM

In 1972, Pierre Boulez had sketched his project for the Institut de Récherche et Coordination Acoustique/Musique (IRCAM), and he asked me to participate. Although I had just settled in Marseille, this was an irresistible call. IRCAM seemed a very unlikely venture, especially in France, but Boulez was in a position to demand its existence. From 1972 on, meetings were held to plan and prepare the Institute. As Pierre Boulez wrote (1973): "The creator's intuition alone is powerless to provide a comprehensive translation of musical invention. It is thus necessary for him to collaborate with the scientific research worker in order to envision the distant future, to imagine less personal, and thus broader, solutions." IRCAM was initially structured in departments. I headed the Computer Department, which was to be well equipped. The other department heads were Vinko Globokar (instruments and voice), Luciano Berio (electronics), Gerald Bennett ("diagonal"), and Michel Decoust (pedagogy).

I moved to Paris in 1975, and we started to implement music on a DEC PDP-10 and on PDP-11 computers. We got much help from Stanford's Center for Computer Research in Music and Acoustics (CCRMA) and from Max Mathews, who for a few years advised on the project in the capacity of scientific director. With very good people like Jim Lawson, John Gardner, and Brian Harvey—succeeded in 1977 by Jean-Louis Richer, Philippe Prévot, Raymond Bara—we had computer-generated sound in 1976 and we moved into the new IRCAM building in 1977. Peppino DiGiugno had started his work on real-time digital processors in the electronics department, which thus went digital, and David Wessel had joined the diagonal department, followed in 1977 by Andy Moorer, who was to leave in 1979. IRCAM gave many concerts, with the series "Passage du XX° siècle" in 1977, and started to build tools and conduct research. Despite too many distractions, in particular an endless flow of visitors (25,000 persons visit the Centre Pompidou every day—fortunately only a small proportion go through IRCAM), I managed to do a few experiments and pieces (mostly during the quietest periods of the summer). I realized *Inharmonique*, *Moments Newtoniens*, and *Mirages*, from which I abstracted *Songes*. (See the soundsheet in *Computer Music Journal* 7[1], 1983, and also the record *IRCAM: un portrait* distributed by IRCAM.) However, I soon became impatient with the difficulty of working quietly and maintaining my longterm research. In 1978 I decided—to Pierre Boulez's surprise—to resign in 1979. Pierre later changed the structure of IRCAM.

Even though I disagreed with some options at IRCAM—especially the too great subordination of research activity to musical production priorities—I view IRCAM as an exciting institution. A number of computer music pieces have been realized and performed there, mostly with non-real-time programs like Music V or Music 10, but also with DiGiugno's powerful 4C and 4X processors. Important research has been performed and is under

way, for example, experiments on reverberation and sound processing (Moorer), vocal synthesis (Sundberg, Chowning, Rodet, Bennett), musical perception (Wessel, McAdams), fast real-time digital processors (DiGiugno, Boulez, Gerszo, Machover), and advanced music languages (Abbott, Rodet and his collaborators of the FORMES project), to give instances of only computer-related research.

Work at Marseille

Meanwhile the T 1600 computer in Marseille did not stay idle. In 1975, Barry Conyngham synthesized sounds that he incorporated into an opera presented in Australia. In 1976, Denis Lorrain synthesized a computer version of his stochastic composition *P-A*, initially for eight voices. And in 1978, Marc Battier realized his piece *Géométrie d'hiver*. Bernard Nayroles, Director of the Laboratoire de Mécanique et d'Acoustique of the C.N.R.S. (Centre National de la Récherche Scientifique) in Marseille, welcomed computer music research in his laboratory, and he was instrumental in getting a research position for Daniel Arfib (in 1977). It is a great pleasure to collaborate with Daniel, an inspired and inspiring person. Daniel has been doing outstanding work, including research on nonlinear distortion or waveshaping (Arfib 1979) as well as computer pieces marked with his own imprint (*Musique numérique*, available from the composer at LMA-CNRS, B.P. 71, 13277 Marseille, Cedex 9, France). I must make it clear that our Marseille group is financed for research, not for making music: hence we can only exceptionally have composers' work on the machine, and we cannot organize concerts. Fortunately, we have a good connection with the Groupe de Musique Expérimentale de Marseille, equipped with a tape studio and a Synclavier (among the members of the Group are Georges Boeuf, Michel Redolfi, Jacques Diennet, and Franck Royon Le Mée).

Since 1979, I have done further experimentation in Marseille on music synthesis, particularly on processes for sonic transformation and development. Some of this research has been embodied in pieces such as *Contours*, *Profils*, *Aventure de lignes*. The latter piece was written for the Electronics Instruments Ensemble of l'Itinéraire, playing together with a computer-generated tape. This tape was partly synthesized in Marseille and partly realized in Dartmouth with Jon Appleton's Synclavier II.

The last Sound Example (13) presents an excerpt of *Passages*, for flute and tape, commissioned by the Laboratorio per l'Informatica Musicale della Biennale di Venezia for the 1982 International Computer Music Conference. In this section, I used a method to evoke voicelike sounds suggested by Mike McNabb and John Chowning. The spectrum is fixed, but the fundamental frequency is gradually modulated, partly periodically and partly randomly. When the modulation becomes similar to that of a singing voice, the spectrum exhibits a suggestive voicelike quality. This transition toward vocal timbres happens in dialogue with the flute player, who occasionally sings while blowing.

A Summary

I shall now try to sum up the reasons for my interest in using computers. The computer makes it possible to work in ways I have been longing for more or less consciously. It provides a refined control over the sound structure, and it helps to extend compositional processes at the level of this sound structure, thus permitting one to compose the sounds themselves and to give some functional role to the timbre. Let me state a few compositional fantasies, some of which no longer appear to me as ever-receding goals:

- Creating a flexible sonic world that could diverge from the instrumental world but also merge with it in subtle ways
- Experimenting with the design of one's own constraints instead of having to dwell with instrumental and electronic constraints
- Assembling a personal palette of lively sounds, endowed with some characteristic of identity, but also very ductile, thus susceptible to intimate transformations that preserve certain characteristics and alter others (for instance,

crystallization or melting of a preserved "substance")

Taking advantage of the operational power of the computer to suggest and achieve specific compositional transformations, thus extending the role of structural notation

Evoking a suggestive yet illusory world, free of material constraints, by playing directly, so to speak, upon perceptual mechanisms, thus unveiling perceptual "primitives" and guiding perception toward one mode or another (e.g., synthetic versus analytic)

I shall not be more specific about music here. I think the music should speak for itself. Yet I want to state that I intend to do more work to relate compositional processes to the sound material and its structure, using the computer for this purpose, as I mentioned above (extending the role of structural notation). This requires advanced music input languages, which are beginning to come of age. I would like to make a plea for compatibility and transportability, so that such languages can be used in other places besides a couple of large centers.

The contribution of more and more people is essential in making the computer music field practicable and fertile. Much progress has been made and is being made, and I am confident that the members of the computer music community, and especially the bright young talents that are not in the least intimidated by computers, are leading a genuine mutation for music.

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