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Maiden Voyages: A Score Produced with MP1

MP1 is a program for computer-assisted composition. The program, in use since 1973, includes both deterministic and stochastic procedures (Tipei 1975). Among the higher level restrictions that can be applied to the stochastic option are *sieves* (Hiller and Isaacson 1959; Xenakis 1971), and *patterns* (Tipei 1981). MP1 is a "work in progress" in the sense that new features are added continuously. The program is written in Fortran and runs both on a CYBER 175 mainframe computer and on the CRAY X-MP supercomputer at the University of Illinois at Urbana-Champaign. What follows is an example of how some of MP1's capabilities were put to work during the realization of a piece, *Maiden Voyages*, for trumpet, piano, three slide projectors, and tape, written for the "25th Anniversary of the Experimental Music Studios" concert, University of Illinois, February 1984 (Tipei 1984).

Ethics and Aesthetics—A Point of View

The computer can assist a composer by performing restricted tasks of local scope and consequence (e.g., permute a tone row). After a number of such tasks have been accomplished, the composer weaves the results along with other elements into the fabric of the work. Alternatively, a program can be written to generate all aspects of a composition in a comprehensive approach that does not require the composer's intervention after the code is written and the initial data is entered. Most such programs rely on a random-number generator when choosing an element from a list of alternatives. Because of this random behavior, the composer is dissociated from the artistic product or, at least, from the details that make one realization different from all the other possible realizations. This implies a certain aesthetics, mainly an unromantic attitude that considers the writing of a new work to resemble a scientific experiment.

In this case, the computer is used not only to speed up a tedious process but also to perform a task which no human can really perform well: simulating chance. Moreover, by delegating the task of deciding the actual details of a particular work, the composer can concentrate attention on a more abstract level. In other words, a comprehensive program making use of a random-number generator allows the composer to create a "class of compositions" instead of writing a "piece." The issue is sometimes muddled because, more often than not, only one member of the class of compositions is produced—which does not change the problem.

It is this composer's opinion that tampering with the output of such a program is both foolish and dishonest. Foolish, because it cancels the most important gain offered by this kind of endeavor, that of a qualitatively different approach to composition. Dishonest, because it interferes with the experiment by altering the outcome to make it fit a preconceived image of the piece. If the resulting music is not merely unexpected (a desirable situation) but contradicts the original intent, then, a way should be found of modifying either the code or the data as to eliminate whatever produced the discrepancy. But changing the rules in the middle of the game—or after the game is over—amounts to simpleminded cheating.

Maiden Voyages is a class of compositions. Two realizations have been produced so far, one of which is recorded (Tipei 1984). At the time of the writing of this article, a third realization is contemplated for which the instrumental sounds will be synthesized using M4C, a general-purpose music synthesis program developed at the Computer Music Project of the School of Music, University of Illinois. The scores for *Maiden Voyages* were entirely generated with MP1 and no adjustments of the computer output were made.

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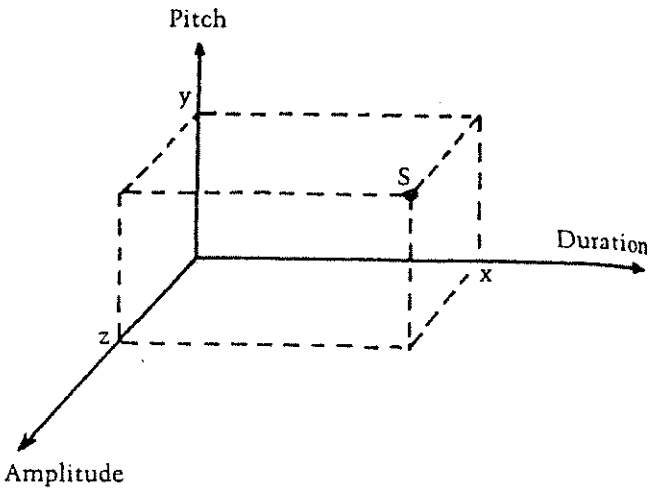


Fig. 1. A musical event viewed as a vector in a three-dimensional space.

Table 1. Parts and parameters in *Maiden Voyages*

Parts	*Parameters*
1. Trumpet	1. Time (durations)
2. Piano right hand	2. Pitch
3. Piano left hand	3. Intensity
4. Slide projector right	4. Timbre/semantics
5. Slide projector center	5. "Effects"
6. Slide projector left	
7. Tape channel right	
8. Tape channel left	

Vector Space

Maiden Voyages is scored for eight parts sharing five parameters, as shown in Table 1. The basic structure of MP1 reflects the assumption that music can be described as a collection of events in a multidimensional vector space (Xenakis 1971). Figure 1 is a representation of a sound of a certain duration x, frequency y, and average amplitude z. Other parameters, or sound qualities are added in most compositions, increasing the number of dimensions (or bases) of the vector space.

MP1 allows the number of parameters to vary from work to work as long as the following two conditions are satisfied: the total number should be equal to or larger than two, and time should be included as the first parameter. The maximum number of dimensions is restricted only by compositional criteria or by concerns of a practical nature such as availability of computer time and memory. As a general comment, one should be aware that the sound parameters considered represent an analytical/creative tool and they do not attempt to be an accurate picture of the physical (acoustical) phenomena. Their choice becomes part of the subjective compositional process whose scope is to create a world parallel to what is usually called reality.

An obvious advantage of basing the computations on the abstract concept of vector space is that it allows the handling of any type of event taking place in time, including "nonmusical" ones, like slide projections. In *Maiden Voyages* the slides are treated in the same way sounds are (events in a five-dimensional vector space) and analogies between sounds and slides are established at each parameter. The strictest and most elaborate correspondence between instrumental sounds and slides occurs at the fourth parameter, linking timbres with the meaning (semantics) or content of the slides (Table 2).

The piano is partially prepared (see Fig. 2). The timbres generated by both piano and trumpet have been arranged in an ordered sequence that goes from "dry" and distorted sounds to "richer," undistorted natural sounds. The content of the slides is also arranged in an ordered sequence starting with events of planetary consequence (sunsets) and getting closer and closer to the world of human beings. The move is, in both instances, from alien to common.

Ranges

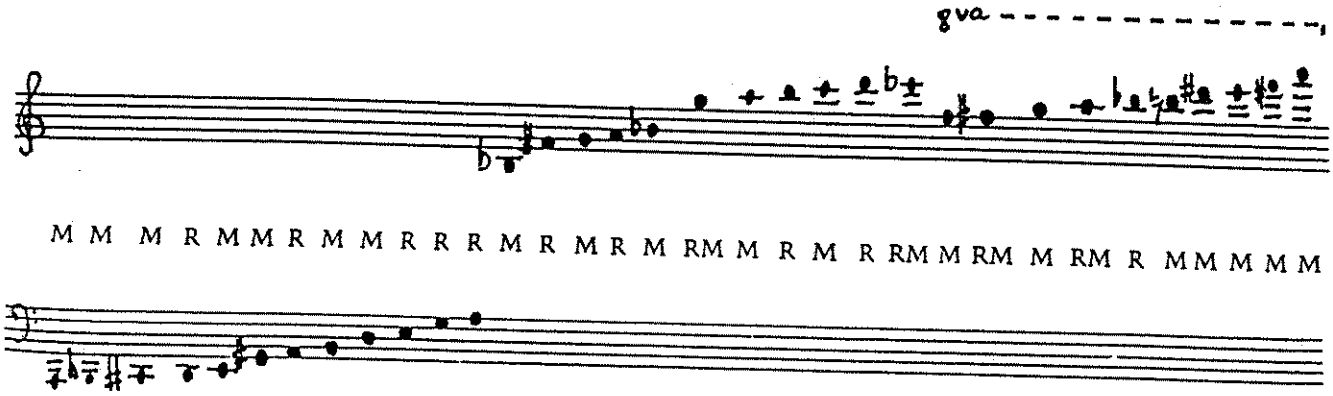
One of the simplest ways of controlling the musical material in MP1 is by regulating the ranges of values that can be assigned on each base of the vector space at a given moment. The ranges vary according to the part and parameter considered (minimum and maximum values valid for the entire work), but they can also fluctuate according to what is needed in different sections of the piece. For instance, in

Fig. 2. Preparation of piano strings. R = rubber pieces of eraser, M = metal, RM = both.

Table 2. Correspondence between timbres and slide image semantics

	Piano	*Trumpet*	*Slides*	*Symbol*	
0	Percussion wood	Mouth piece	Sunsets/dark	WOOD	0
1	Percussion pins	Valve click	Mountains	PRCP	1
2	Percussion metal	Ring	Winter scenes	PRCM	2
3	Plucked string	Cuivre	Water/stones	PS/C	3
4	Gliss on string	Sound bend	Reflections in water	BEND	4
5	Harmonics	Multiphonics	Trees and water	HARM	5
6	Prepared rubber	—	Trees in season	RUBR	6
7	Prepared metal	—	Ruins	PREM	7
8	Stopped string	Mute 1	Streets	MUT1	8
9	Una corda	Mute 2	Social/political	MUT2	9
10	Ordinario	Ordinario	Nudes	ORDP	10

Fig. 2



Maiden Voyages, the pitch material for both trumpet and piano constantly expands from a rather limited number of possibilities in the first bars, to all pitches available on these instruments at the end. A quick look at the kind of durations—minimum/maximum values for the entire piece—used for all parts shows that, although slides are scored like sounds, the ranges of their durations set them apart from the instrumental sounds. Also, the longest durations (Fig. 3) belong to the tape, which consists only of drones made out of filtered noise. These drones "bathe" the background of the entire piece. Their frequency band varies considerably but in slow motion compared to other events.

As shown in Fig. 4, the piano has the most extended pitch range and that of the trumpet includes pedal tones.

Similarly, the intensity assigned to the slide projectors is kept constant (at the maximum luminosity available) while the tape plays all the time *ppp*, one step softer than the softest instrumental sound. Finally, at the fourth parameter, the tape has again a constant value and so does part number five, the central projection. The reason is a compositional one: the central projection does not display realistic pictures of nature, humans or objects, like the other two, but consists of sketches, diagrams, and pages of computer output related to the way the piece was composed—a self-referential commentary reminiscent of conceptual art.

Fig. 3. Ranges of durations for the parts.

Fig. 4. Ranges of pitches for the parts.

Fig. 5. Ranges of "effects" for the parts.

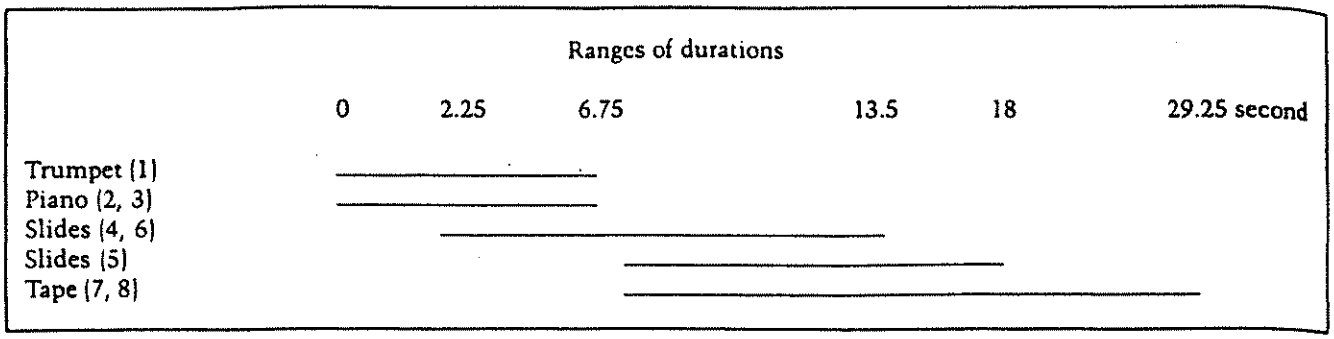


Fig. 4

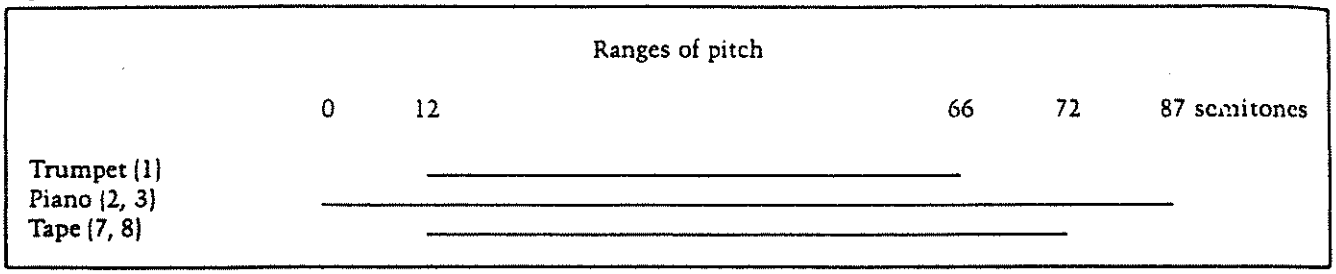


Fig. 5

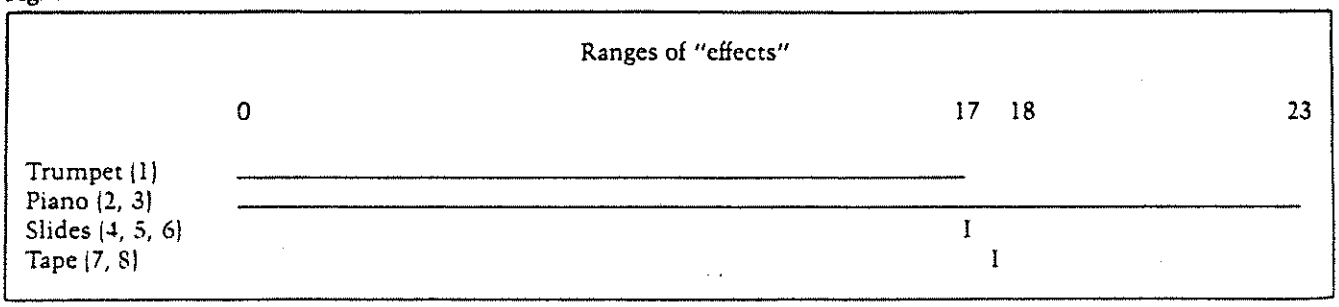


Table 3. Listing of trumpet and piano effects, sorted into the effects *n* and the events that can be applied to *k*

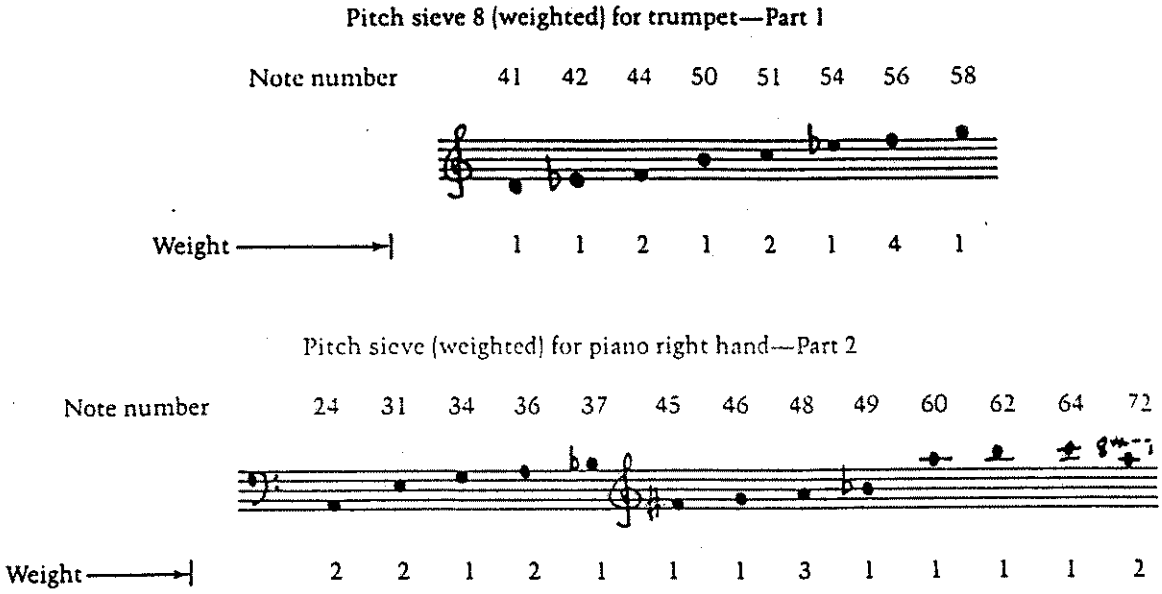
n	*k*
0 Non vibrato	0 Single note
1 Poco vibrato	1 Interval
2 Vibrato molto	2 Cluster/Chord
3 Tremolo (ord.)	
4 Tremolo wire brush	
5 Tremolo finger nails	
6 Tremolo finger (flesh)	
7 Tremolo mallet(s)	

The fifth parameter, loosely called "effects" for a lack of a better term (Table 1), applies only to the trumpet and piano, since the slides and tape are given constant values.

Congruence Relations Modulo *m*

In the tempered system, a pitch can be written as $a = km + n$ where n is the pitch class, k the octave number, and $m = 12$. Such congruence or equivalence relations modulo m are tools that musicians use often. MP1's operations allow for their presence in all parameters (Tipei 1975). Table 3 describes the

Fig. 6. Pitch sieves used in the first measures of Maiden Voyages.



"effects" parameter and illustrates an ordering which involves an equivalence relation. The point of a congruence or equivalence relation is that a non vibrato event, whether it is a single pitch, a two-note interval, or a chord/cluster, remains a non vibrato event. Figure 5 shows the ranges of values used at this parameter for the trumpet and piano while the slides and tape remain constant at 17 and 18, respectively. Here, $m = 8$, $17 = 2 \times 8 + 1$, and $18 = 2 \times 8 + 2$, which is to say that the value assigned to the slides is equivalent to a cluster played in normal fashion (poco vibrato) and the value assigned to the tape is equivalent to a cluster with a lot of reverberation. Congruence relations represent different levels of approximation the composer can structure independently, and in *Maiden Voyages* they are defined for parameters 1, 2, and 5 (time, pitch, and "effects").

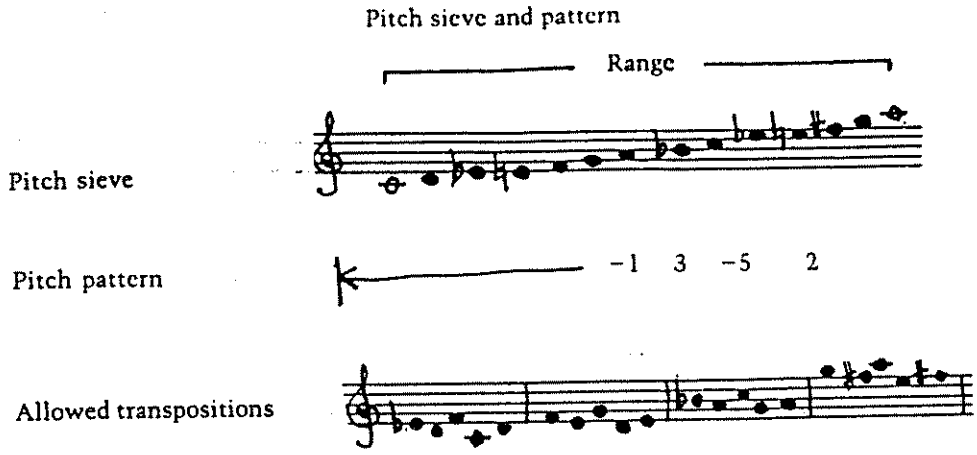
Sieves and Patterns

The handling of sieves in MP1 has been discussed in a previous paper (Tipei 1981). *Maiden Voyages* uses 43 weighted sieves that help organize the piece both by carving into the available material and by imposing an hierarchy on those elements that are allowed to pass through the sieve. The pitch sieves shown in Fig. 6 are employed in the first bars of the piece. Note the emphasis, through the assigned weights, on F–C for the trumpet and on A–E in the piano part.

Sieves are efficient for correlating two or more parameters. Such a link is established in the trumpet or the piano parts, in the fourth and the fifth parameters (timbre/semantics and "effects") in order to discard impossible pairs like "sound bend/interval" for trumpet, and "plucked string/wire brush tremolo" for piano. That is, one cannot both bend a single pitch and play a two-note interval, or pluck a string and create a wire brush tremolo on the piano.

More complex situations appear when sieves are used concurrently with patterns, the other higher-order restriction that can modulate MP1's stochastic backbone. A pattern can be described as a motive, theme, tone row, etc. depending on its length and function in the piece. In more general terms, it is a recognizable figure, defined for all parameters, which is entered before the computations begin and can be reproduced with various degrees of accuracy (Tipei 1975). When the accuracy is low, only isolated intervals or short strings of sound are repro-

Fig. 7. Hypothetical pitch sieve, pitch pattern, and allowed transpositions.



duced—a situation that might interest the composer in search of either smooth transitions from one pattern to another, or of ways to create distortions (variations) of a given entity. If 100% accuracy is desired, the usual pattern algorithm is abandoned and a special accurate reproduction subroutine, called UPDATE, takes over. In *Maiden Voyages* all sieves are constructed in such a way as to accommodate the patterns that are used at the same time. However, satisfying the dual requirement of exactly copying a pattern in the context of a complex sieve is not a trivial task.

For instance, it is easy to match a sieve containing most elements possible in the range with a tightly packed pattern of only a few notes. In Fig. 7, a hypothetical pitch sieve allows 14 elements to pass, out of a total of 21 possible between C4 and A5. A short pattern made out of the intervals −1, 3, −5, 2 is in effect at the same time. UPDATE tries to match the sequence of intervals with the available pitches and finds out that there are four possible transpositions of the given pattern that can be accommodated by the sieve (see Fig. 7). There are also reasonable chances of success in matching either one of the following two combinations:

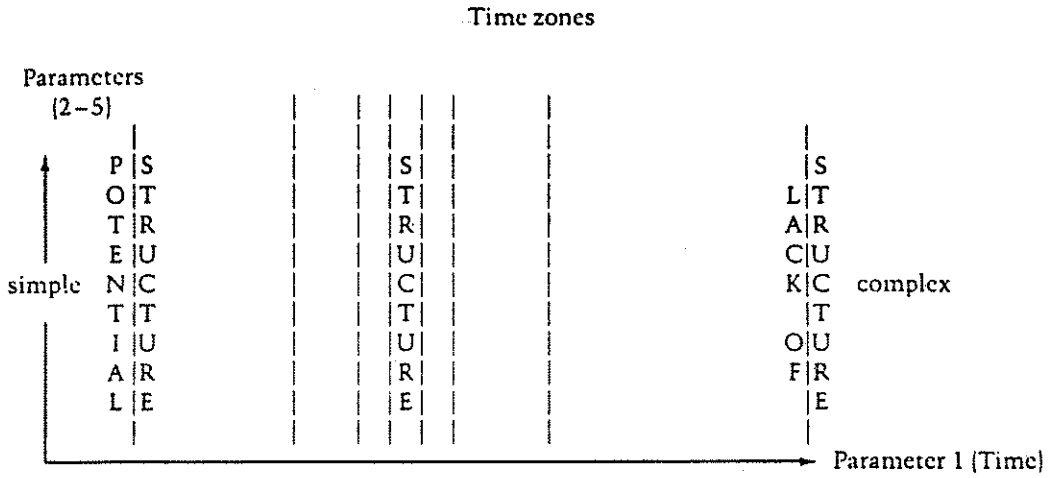
a. A sieve with a great number of elements uniformly distributed over the entire range, and a pattern with a large ambitus containing skips of an irregular size

b. A sieve with a modest number of elements unevenly scattered, and a small ambitus pattern containing stepwise motion

A problem arises, however, when the sieve has a limited number of elements erratically distributed and the pattern has a large ambitus and displays equally erratic skips. Then, UPDATE will probably fail repeatedly, unable to follow the pattern for more than a few sounds at a time. In this case, control is returned to the usual pattern algorithm, and values which do not match the pattern are assigned. But this means that precious time is wasted, and it greatly frustrates the composer's attempt to have a motive or theme placed at a precise moment or even—if the pattern is long—during a reasonably wide "window of opportunity."

The difficulties just described are compounded when all parameters are considered—as they should be, since a pattern is defined for all of them. For example, the first parameter (time/durations) adds its own specific constraints which, when combined with the demands of the pitch parameter mentioned previously, make even less probable the reproduction of a pattern with high accuracy. More precisely, if the composer wants to use not only binary divisions of the beat but also divisions by 3, 5, 6, . . . etc., a time unit comprising all of them (1/LCM) will be found by MP1. If the final product is an instrumental or vocal score written in traditional no-

Fig. 8. Organizational time zones inscribed on parameter 1 (time/durations).



tation, sieves excluding note values that can not be expressed in that notation system will be needed (Tipei 1981). Moreover, a pattern utilizing such divisions can start only in a very few places in a bar due to the same fact: not all the ordinal fractions between 1/LCM and 1 can be represented in that system. Subroutine METER will make sure that only durations for which corresponding symbols or groups of symbols exist will be taken into consideration.

Most sieves and patterns in *Maiden Voyages* fall under this "worst scenario" alternative. It became necessary then to develop a feature of UPDATE already present in an embryonic state, a *tracking mechanism* that compares the way a pattern is actually reproduced with the ideal situation of an exact copy. In the case of minor discrepancies, adjustments are made and the pattern is not abandoned. However, these adjustments may not be enough when the actual and the ideal versions are too far apart, or when they transform the pattern too much. That's why a new precaution was introduced: When a pattern starts being reproduced with 100% accuracy, a thorough check is performed to find out either if its exact realization is possible, or if only modifications of its first elements will suffice. The search is exhaustive, encompassing all possibilities within the given range, at all parameters. Only the successful tries are retained and a random procedure, which may or may not take into account a ranking of the valid alternatives, decides which variant will be adopted.

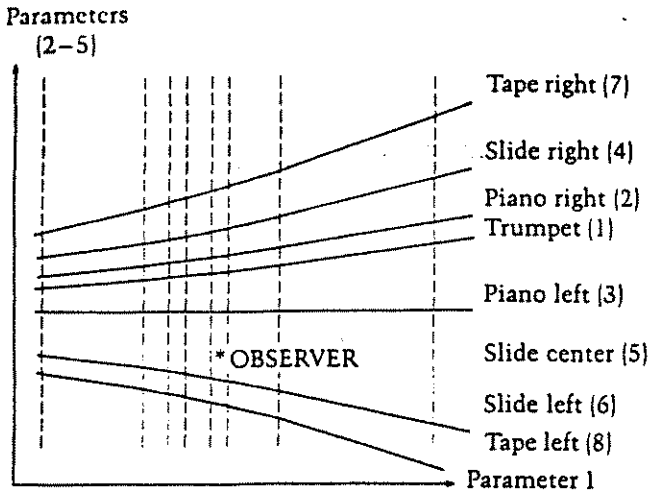
Musical Form in *Maiden Voyages*

Regardless of style, what is usually called "musical form" represents the result of changes occurring at all structural levels, a cumulative effect to which all variables contribute. Usually, clearcut alterations taking place simultaneously at most levels mark the beginning of new sections. Sometimes one level becomes predominant; for instance in late eighteenth-century music, harmonic/rhythmic progression is the decisive factor, the key to form analysis, while texture, dynamics, and instrumentation, redundantly cooperate.

There are no abrupt changes in *Maiden Voyages*, and although all of them are precisely defined and occur at a limited number of moments in the work, the redundancy between parameters is rather low. From the vantage point of traditional music, it could be described as a through-composed piece. A more accurate account should also mention that it represents a continuous process characterized by slow, smooth transformations. This process takes place in an imaginary space on which a number of *time zones* are defined (Fig. 8). The time zones show an evolution from simple to complex (i.e., from regions containing a small number of different elements to regions containing a large number of different elements), and from potential structure to lack of it, passing through an area of tightly structured events.

Seven paths traverse this imaginary space, fan-

Fig. 9. Parameter paths through the time zones.



ning out toward the right side of Fig. 9. Their musical correspondence is a collection of seven parts, with the trumpet (part 1) in the middle, surrounded by piano right hand (part 2) and piano left hand (part 3) then by the slide projection right and slide projection left (parts 4 and 6) and with the two tape channels at the extremities (parts 7 and 8). The central projection (part 5) is a fixed point situated between the slide projection left and piano left hand (part 3). The center slide's path is like the privileged point of view of an observer watching the evolution of the other seven parts, analogous to the subjective perspective of the composer while writing *Maiden Voyages*.

The OBSERVER takes its own samples of events created by the seven travels through the time zones, establishing points on the paths that are simultaneous. The measure of the distance between two adjacent samples (vertical lines) is given by the angle between them (Fig. 10). Their magnitudes are: 14°, 7°, 21°, 14°, and 34°, corresponding to the proportions: 2/13, 1/13, 3/13, 2/13, 5/13. As in the case of the time zones, a sample value is presumed to be either constant during the interval, or changing gradually until it meets the new value. It should be clear from Fig. 10 that a modification, either in the OBSERVER's position or in the orientation of the 90° angle (formed by the first and the last sample) with respect to the time zones, will result in a different perception of the seven paths.

It was mentioned before that all changes of values, for all variables, occur at moments defined as simultaneous by the OBSERVER's sampling. However, densities are the only feature that is consistent with this procedure. None of the other variables have a change of value at each of the six moments: 0°, 14°, 21°, 42°, 56°, 90°. (By "density" is meant both attack density and number of simultaneous, nonequivalent events.) This way, the form of the piece is the result of a cumulative effect, with density being its predominant component. Table 4 shows the densities that correspond to the sampling moments. The slide projection center (5) and the tape (7, 8) have no rests, so their density values are constant (1.000). For the other five parts, random numbers were used to determine the actual density, but they were modulated by a series of proportions ensuring that the average density reaches a peak at 14° and diminishes continuously up to the end of the piece, while following a wavelike movement.

The table values are valid only for narrow regions around the sampling moments. In between, they are modified to obtain a smooth transition from one value to the next. As a result, *Maiden Voyages* becomes a through-composed piece, a continuous process hiding the sectional structure of the data gathered through the OBSERVER's optic.

Homologies

Even a reader who is only marginally familiar with twentieth-century physics will detect analogies between the previous description and ideas as old as the beginning of the century. The motto on the score, a quote from A. Sommerfeld's comments on a paper by H. Minkowski, underlines such analogies: "Reciprocal relations between world-lines" (or world points) as "the most perfect expression of physical laws" (Minkowski et al. 1952).

According to Minkowski, the element of order of all real things is a "world point," that is, a place at a definite time, and the "world-line" is the history of a moving point. A world-line is shown in Fig. 11 where the three-dimensional, physical space is represented, for convenience, as having only one dimension.

Indeed, the seven paths and the observer are seven

Fig. 10. Observed paths through the time zones.

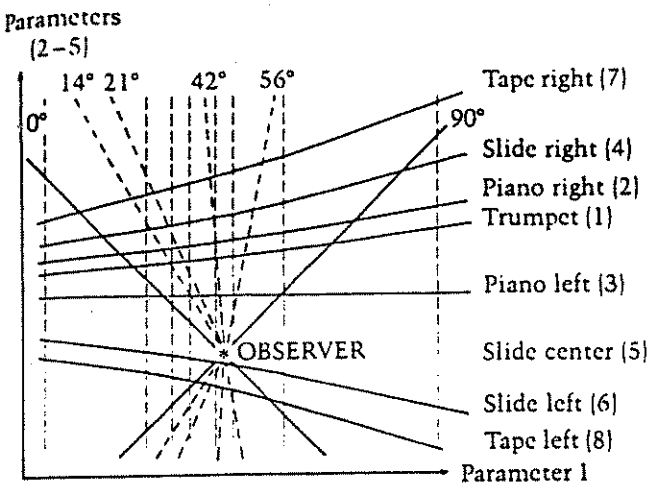


Fig. 11. Time/space world-lines.

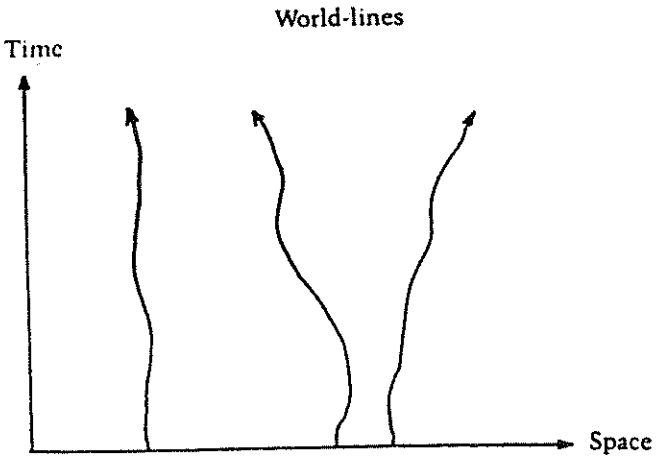


Table 4. Densities corresponding to the sampling moments (see Fig. 10)

Parts	*0°*	*14°*	*21°*	*42°*	*56°*	*90°*	
Trumpet	.083	.784	.378	.432	.176	.192	1
Piano right	.722	.976	.492	.705	.244	.444	2
Piano left	.517	.624	.402	.787	.376	.318	3
Slide right	.749	.736	.276	.952	.164	.198	4
Slide center	1.000	1.000	1.000	1.000	1.000	1.000	5
Slide left	.175	.336	.540	.744	.116	.450	6
Tape right	1.000	1.000	1.000	1.000	1.000	1.000	7
Tape left	1.000	1.000	1.000	1.000	1.000	1.000	8
	5	8	3	5	2	3	

world-lines and one world-point in the space-time defined by the vector space in which *Maiden Voyages* exists. The composition is a view of this space-time as seen by the OBSERVER. Further equivalences could be found between the drifting apart in time of the world-lines—or parts—(see Fig. 9), and the expanding universe; between the soft noise of the tape enveloping everything, and the cosmological background noise coming from all directions, residue of a primeval explosion; between the region of 100% accuracy of pattern reproduction occurring approximately 2/5 of the way into the piece, and the fact that (it seems) conditions for the appearance of intelligent life (structure, rational/deterministic thinking) become ripe somewhere around the mid-life point of a solar system; and between the ever-increasing complexity and randomness in the piece and the existence of a time asymmetry as required by Boltzmann's Second Law of Thermodynamics.

However, *Maiden Voyages* is no closer to program music than, for example, most of Edgard Varèse's pieces. In spite of their intriguing and suggestive titles, the homology is established on a more fundamental level. As Schopenhauer pointed out, music has the privilege of being capable of dealing with abstract concepts while having an immediate, sensory impact—and nothing in the evolution of music in the last hundred years has contradicted his thought. In periods such as the Middle Ages and Renaissance—to take only a familiar example—Western art music has mostly reflected the description of the world provided by religion, the molding force in the society at that time. Nowadays, science supplies a more adequate explanation of the universe and of our place in it and, while concerning itself with the phenomenal world, it includes topics considered for long the exclusive domain of mysticism, like creation. There is no reason why music should still echo the mentality of centuries ago instead of being congruent with our present understanding of the world.

Maiden Voyages is an attempt at expressing this rapport, and MP1 has proven to be a very appropriate tool when operating with notions like randomness,

entropy, chains of events, and structured patterns, as well as with smooth, continuous transformations between such states. It is a flexible and sophisticated instrument able to accurately translate into music the vision that animates *Maiden Voyages.*

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