Chapter 10

SPATIAL MOTION

Perceptions of space in Sonic Art

In listening to Western instrumental music either live or over loudspeakers various conceptions of space enter into our perception of the events. Musicians have always implicitly accepted some kind of metaphorical or analogical link between perceived pitch and height. We speak about 'high' pitches and 'low' pitches and about melodic lines or portamenti going 'upwards' or 'downwards'. As we have seen, it is fairly easy to hold to this metaphor when one is dealing with a set of sounds of fixed timbre. There are, however, two components to its perception: one to do with what Shepard has called the *chroma* of a note (i.e. whether we perceive it as C, C sharp, D, E flat etc.) and the other to do with where the energy is concentrated in the spectrum. As can be demonstrated with the Shepard tone, it is possible to make the chroma and the spectral 'height' move in opposite directions, yielding the aural paradox of a sound which moves up and moves down simultaneously. Clearly, then, the association of high pitch with physical height is not unequivocal. We might ask why things are perceived this way round rather than the other, i.e. why do we not consider a glissando moving from 1600 Hz towards 16 Hz (and whose spectral energy does not change in a contradictory way) as moving 'upwards' instead of 'downwards'? I am not certain if anyone has proposed a solution to this quandary, but I would suggest that there would be an environmental metaphor involved. Any creature which wishes to take to the air, with one or two exceptions, needs to have a small body weight and therefore tends to have a small sound-producing organ and produce high frequency vocalisations. Conversely, any large and heavy creature is essentially confined to the surface of the earth and at the same time will possess a correspondingly larger sound-producing organ and a consequently deeper voice. Crudely speaking, airborne creatures have high voices and earth-bound creatures low voices. Whatever the explanation of this musical phenomenon, composers of instrumental music have often exploited the spatial metaphor or analogy. For example, the open textures of some of

Sibelius' orchestral writing where a low bass line moves against a high melody with little or nothing in the intervening 'space' generates a sense of a vast and empty 'landscape' (Example 10.1).

Stereo reproduction on loudspeakers offers us, as we have discussed previously, a virtual acoustic space with both width and depth. There are, however, certain limitations to our perception of this (or any other) space. We can locate the direction of origin of high-frequency sounds fairly easily (our brain detects phase differences between the signals arriving at the two ears and other factors) but low frequency sounds with little energy in higher partials are very difficult to localise. In some multi-loudspeaker reproduction systems such as the *Gmebaphone*, developed by the *Groupe de Musique Expérimentale de Bourges*, the lower bass frequencies are therefore reproduced on a single large bass speaker placed directly in front of the listener, whilst higher frequency signals are distributed on loudspeakers placed in the conventional way, symmetrically to the right and left of the listener. The sense of spatial depth which, as discussed previously, may be generated in the stereo field by correlations between falling off in amplitude and high-frequency roll-off (and in certain cases reverberation) can be further extended in a multi-loudspeaker system by using planes of loudspeakers at different distances from the audience. The sound-image may thus be moved literally backwards and forwards by cross-fading from one set of loudspeakers to another (see Figure 10.1).

In certain circumstances the spatial metaphor associated with frequency may interact with real spatial motion in stereo space. I remember particularly a performance of Denis Smalley's *Orouboros* in which noise-based sounds which rose and fell in frequency band height in an undulating manner moved forward and outwards through the stereo space, creating the impression that the sound was tumbling towards the listener (see Figure 10.2). In our discussion of spatial motion in the current chapter we shall assume that the apparent location of a sound-object is unequivocal and that its motion can be adequately described. The ideas developed however cannot be applied uncritically (i.e. without listening) to arbitrary sound-material as the internal evolution of the spectrum of the sound-material may well affect the perceived motion.

A virtual acoustic space may be created all around the listener using four loudspeakers, a quadraphonic format.[1] The generation of an illusion of depth as in the stereo case allows us to expand the perceived virtual space out beyond the rectangle defined by the loudspeakers. Another perceptual problem arises in quadraphonic space. As in the real world it is not always

[1] Or even just three loudspeakers, in principle.

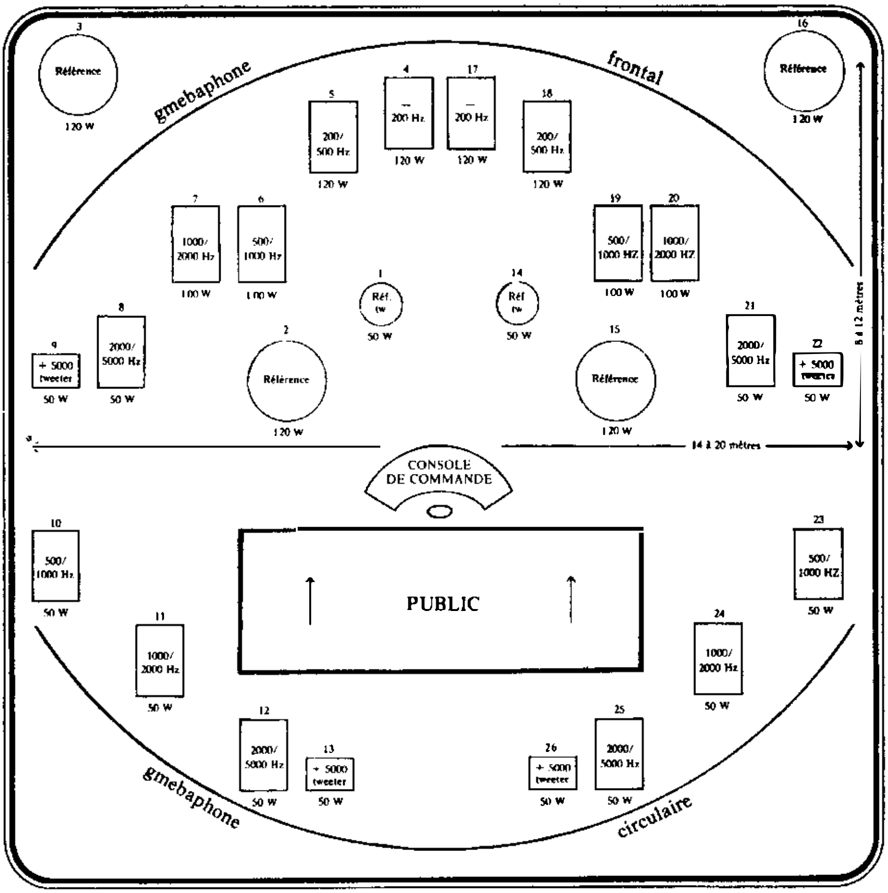

Figure 10.1 The Gmebaphone (schematic).

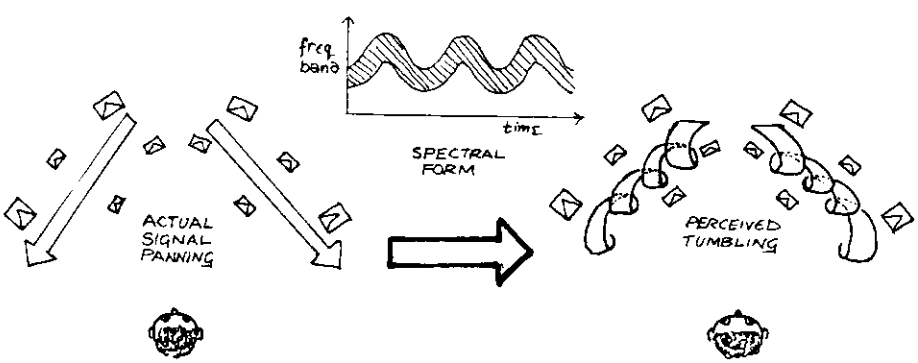

Figure 10.2 Tumbling effect produced by spatial and spectral changes.

easy to distinguish whether a sound emanates from a direction forward of the head or to the rear of the head. The doubt can usually only be resolved by moving the head itself.

Although a satisfactory quadraphonic illusion can be created through an expansion of the techniques we have described for stereo, some more refined approaches have been suggested. Through a precise analysis of the exact relationship between the fall-off in amplitude of a sound, its loss of high-frequency content and changes in its reverberance properties, John Chowning at Stanford developed a computer program to control more precisely the illusion of motion in the virtual acoustic space defined by four loudspeakers (see Chowning 1971).[2] The program also models the Doppler effect: when a sound-source moves towards us its apparent wavelength is shortened; conversely, when it moves away from us its apparent wavelength is lengthened. Thus any sound passing the hearer appears to fall in pitch (from higher as it approaches to lower as it retreats). Ambisonics on the other hand relies on phase differences generated at the different loudspeakers to convey information about the spatial location of a sound object. In some ways it may be regarded as a technical refinement of quadraphony. Ambisonic technology, however, allows the spatial image to be rotated, expanded, contracted or (if used in three dimensions) tumbled, in a technologically quite straightforward way. Recently more refined computer models of spatial encoding in loudspeaker projection have been developed.

Finally, virtual acoustic space may be expanded into three dimensions with as few as four loudspeakers (in a tetrahedral arrangement) or, more typically, eight forming a quadraphonic rectangle at ground level and a second above the audience. More ambitious three-dimensional systems have been presented. The spherical concert hall of the German pavilion at the Osaka World's Fair in 1970 had a whole network of loudspeakers distributed around the spherical surface of the auditorium walls, including beneath the platform on which the performers were suspended. The auditorium was used for performances of Stockhausen's *Spiral*[3] in which the sounds produced

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[2] Chowning (1971) deals, strictly speaking, with an illusory space *outside of* the square defined by the loudspeakers. Other theories (ambisonics, for example) have tried to overcome some of the ambiguities which occur within the square (three distinct ways of localising a sound at the centre point of the square, for example). This does not invalidate the principles of the author's spatial morphologies, although many of the examples could not strictly be synthesised using Chowning's algorithms (*Ed.*).

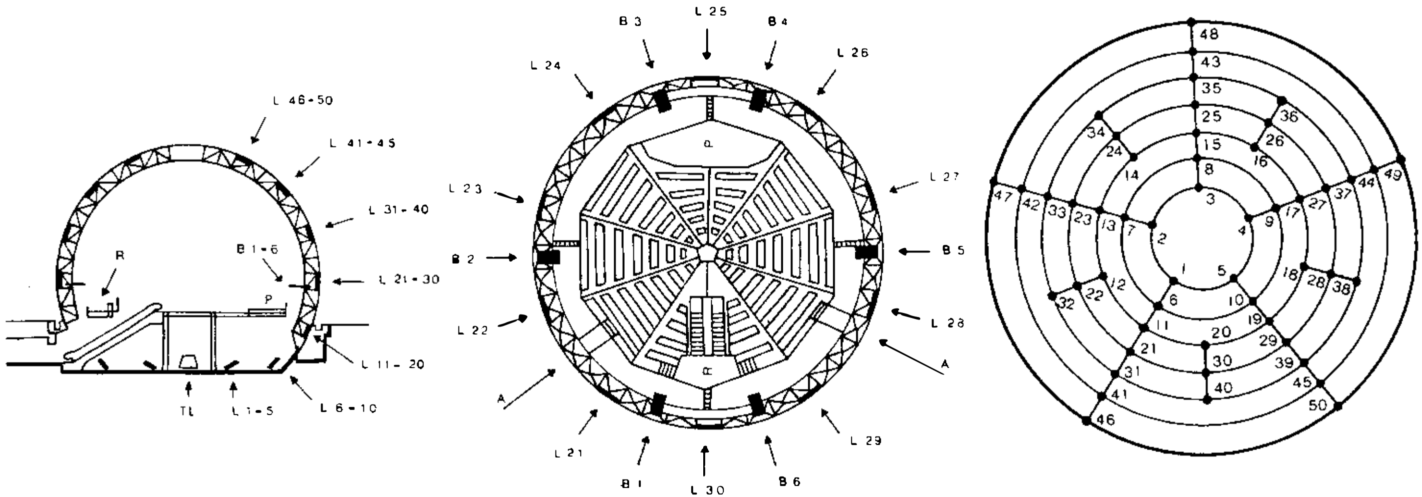
[3] In fact Stockhausen's group performed many programmes of his works throughout their residency at the Osaka World's Fair. For a description of Stockhausen's spatial 'mill' see Cott, 1974: 45–6 (*Ed.*).

by the performers were picked up by microphones and made to move across the surface of the sphere. Such a multi-loudspeaker system (see Figure 10.3) conveys much more accurate information about the direction of a sound-object than any technology developed on fewer loudspeakers can. In recent years the cinema has moved from mono to stereo to surround reproduction of sound and we can expect the technology of sound location in space to develop rapidly in the coming years, particularly with the possibilities offered by computer modelling and control.

Aesthetic functions of spatial motion

In the previous chapters we have outlined one primary use of spatial localisation and spatial motion of sound-objects in the definition and transformation of musical landscape. Certain sounds (e.g. the fly) even need a spatial motion component in order to be recognisable. Spatial motion may also be used to underline contrapuntal developments and interactions between different streams of sound. At the opening of the piece *Vox I* a single stream of multiplexed vocal sounds (generated by four voices) emerges from the tape background and begins to transform and differentiate. Gradually there is a separation into a higher register stream (carried by two female voices) and a low register stream (carried by two male voices) with somewhat different timbral materials. The sense that the sound-stream has differentiated into two distinct entities (the model of growth and division of cells was consciously used) is underlined by the spatial division of the sound-stream as it moves from front centre stage through the listener and back to two separate locations on the two front loudspeakers (see Figure 10.4). One sound-object generates two sound-objects. In a similar way spatial convergence might be used to underline timbral convergence of two musical streams.

More generally, we may look on spatial movements as (musical) gestures, consider the typology and implications of different types of spatial gesture and how the spatial motion of one sound-object might relate to the spatial motion of others, and thus build up a concept of counterpoint of spatial gestures. In fact the concepts of transformation and gesture developed in earlier chapters might be extended so that gestural articulation in space might be added to our repertoire of possibilities for developing an articulate contrapuntal music. We could consider using spatial gesture independently of other musical parameters or in a way which reinforced, contradicted or complemented other gestural features of the sound-objects. The gestures of spatial motion (as opposed to the articulation of different spatial locations) occurs in Stockhausen's works



OSAKA AUDITORIUM

CROSS-SECTION

TL = Low frequency loudspeaker

VIEW FROM ABOVE of the audience platform with the centrally arranged rows of cushions

A = Exit

L = loudspeaker

B = soloists' balcony

P = musicians' podium (c. 25 cm high)

R = control desk; in front of the control desk the double escalator by which the public entered. (Entry every 15 to 35 minutes, after a work or a section of a work; each performance was announced in English and Japanese, during a performance the auditorium lights were dimmed and only individual spotlights were focused on the soloists)

LOUDSPEAKER DISTRIBUTION

Loudspeakers L 1-5 lowest circle, beneath the audience

L 46-50 highest circle, at the zenith of the dome.

The control desk was near L 30, above the escalator

Figure 10.3 The spherical auditorium at the Osaka World's Fair.

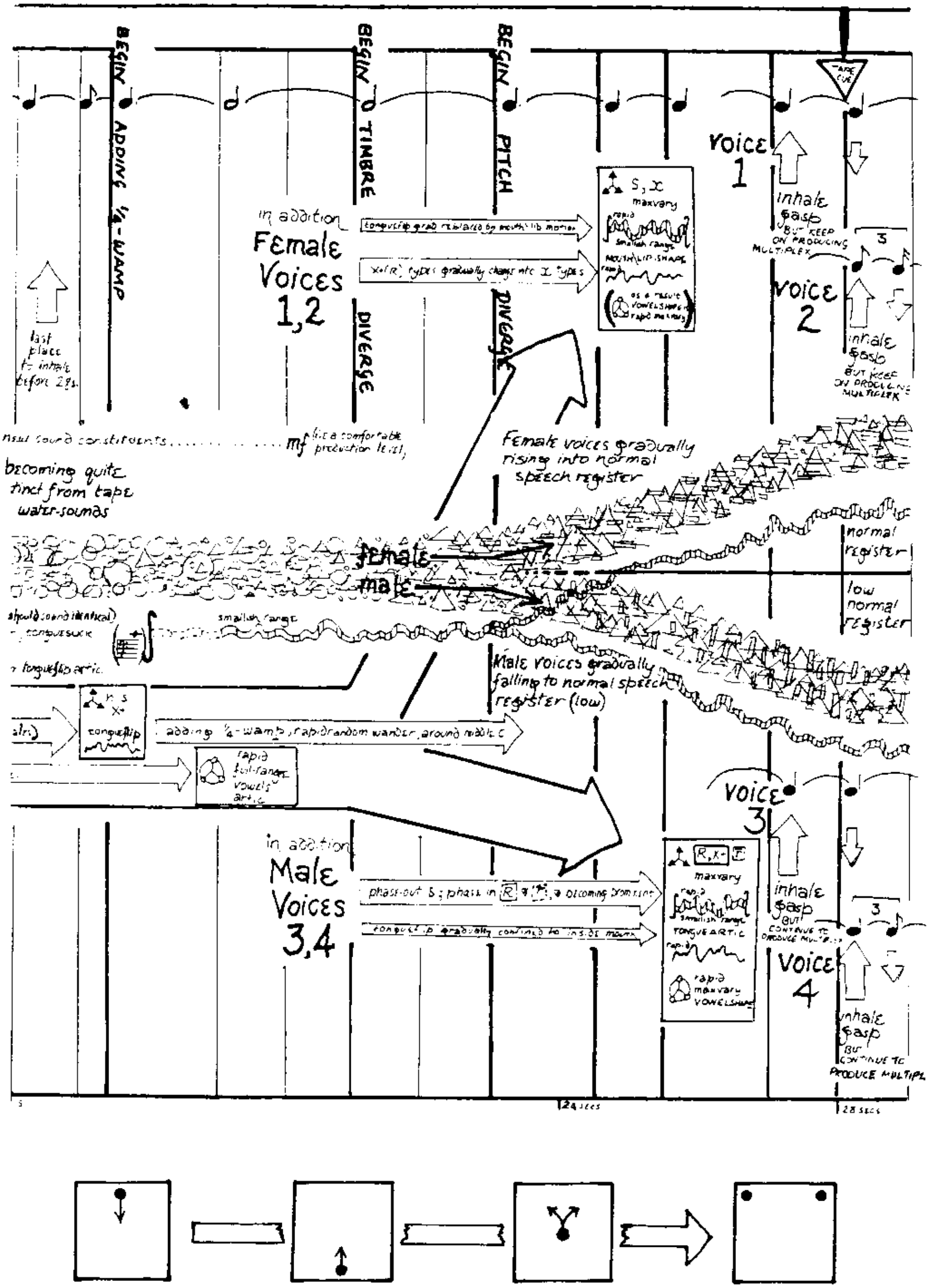


Figure 10.4 Spatial motion and sound evolution at start of *Vox-I*.

Gruppen and *Carré* where sounds are passed from one instrumental or vocal group to another, sometimes circling around the audience. In the piece *Spiral*, projected in the spherical auditorium at Osaka, spatial gestures played an essential part in the projection of the music. In this case the gestures were entirely improvised. Here we are going to attempt to analyse spatial gestures in more detail with a view to understanding the 'vocabulary' of motion but not as yet attempting to define any language.

To simplify our discussion we will confine ourselves to an analysis of the two-dimensional horizontal plane. Motions in the up-down (vertical) dimension will be referred to in passing. Furthermore we will confine ourselves to looking at connected paths, i.e. if a sound is to move from point A to point B it must pass through all locations on some line connecting these points in sequential order. That line may be as complicated or convoluted as we wish (Figure 10.5). A sound, however, which appears at A and reappears at B has not followed any connected path (this is more like a switching operation than a spatial motion). Clearly we might consider the latter kind of discontinuous motion as a special category and even consider an intermediate type of motion which traces out a path from one point to another but by a series of discrete leaps. There is of course nothing inherently impossible or unmusical about any of these kinds of motion but for the moment we shall leave them out of our discussion (Figure 10.6).

Characteristics of horizontal space

We are going to analyse the situation in which the listener is situated at the centre of a virtual acoustic space so that sound-objects may appear in front, to the left, to the right and behind the listener (see Figure 10.7). The listener, in fact, forms a frame of reference for this space which allows us to talk about

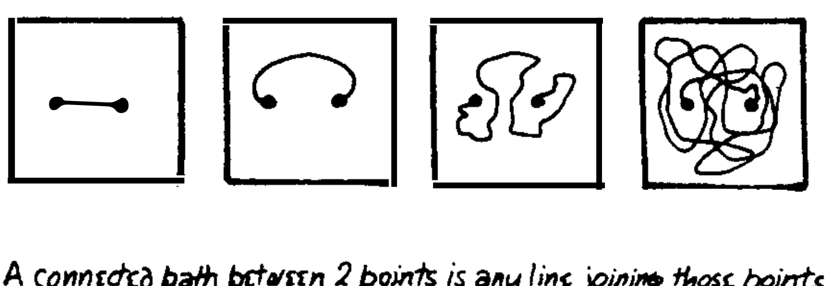


Figure 10.5 A variety of connected paths.

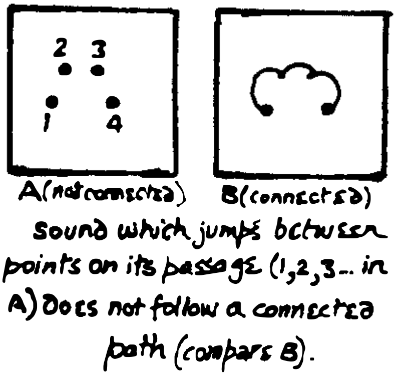


Figure 10.6 Non-connected and connected paths.

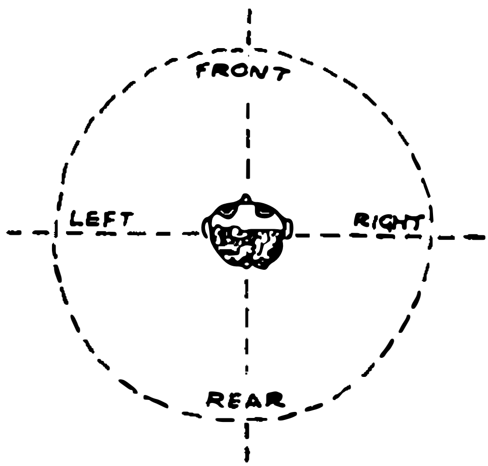


Figure 10.7 Oriented acoustic space around the listener.

'in front', 'behind', 'left', 'right'. From a purely geometric point of view the space is entirely symmetrical and there are no preferred directions. For the listener, however, certain directions have different psychological implications to others so that the frame of reference we are imposing on the space is not just a convention related to the ear-geometry of the head but a psychological/aesthetic aspect of our perception.

The principal distinction to be made is between 'in front' and 'behind'. In purely perceptual terms it can often be difficult to decide whether a stationary sound is located in front or behind the head. Motion of the sound (or the head), however, usually allows this distinction to be made. There is a slight difference in quality between the same sound heard from in front of the head and from behind the head. The orientation of the pinna and masking effects of the head itself tends to mean that most sounds are heard most clearly (in greater detail) when we turn our face towards them. More important, however, in its natural environment, on hearing a sound — particularly an unusual or frightening sound — an animal or bird will orient its face towards the direction from which the sound comes in order to be able to see the source of the sound. In the case of a sound coming from in front the creature will have probably seen the source of the sound before the sound is heard, but this is not the case with sounds coming from behind. Such sounds, therefore, tend to be more stressful, mysterious or frightening.

This separation of 'in front' and 'behind' also has a social dimension for most higher animals. We almost always turn to face the person with whom we are conversing. Sounds heard from behind may be 'overheard' or 'commands' but not usually part of a mutual discourse. At a concert or poetry reading we sit facing the performers. Metaphorically we 'face up to things' or 'face the music' and suspect things that happen 'behind our back'. The distinction, therefore, between sounds heard from in front and sounds heard from behind is not merely a function of the geometrical asymmetry of the human body in the front-back direction (as opposed to the left-right direction) but the psychological/aesthetic dimension of perception. The distinction between left and right on the other hand is not so critical. Not only is the body symmetrical in the left-right direction but (apart from sounds with no high-frequency components) it is normally very straightforward for us to differentiate between left and right in locating the source of a sound and there is no essential qualitative difference between the same sound heard from a similar angle in front, to the left or to the right.

In certain artificial test situations using specially synchronised tones played on headphones it can be shown that right-handed individuals have a tendency to orient their perception such that, for example, high-frequency sounds are assigned to the right side of the head and low frequency sounds to the left side of the head, even when such an assignment is contradicted by the physical placement of the sources. In our normal acoustic experience, however, we may assume that such effects are marginal, particularly if, like myself, you are left-handed! From an aesthetic viewpoint, therefore, a sound heard on the left, or moving from left to right does not have different implications to a sound heard from the right or moving from right to left. The distinction will only be of significance where we have different sounds placed or moving in the same space. Then, for example, a movement from left to right may be counterpointed with a movement from right to left.

Except in very special circumstances, however, playing an entire composition with the two loudspeakers switched around will not alter our aesthetic perception of the piece.

The distinction between 'above' and 'level' (or 'below'), on the other hand, has quite different psychological implications, at least for earthbound human beings (it might well become different for astronauts). Because we live on the surface of the planet to which we are bound by gravity, energy is required for any object to move upwards, whereas objects above us, unless constrained, will naturally fall down. Sounds moving upwards therefore will be linked metaphorically to flight or at least with the requirement of energy input. A sound which moves upwards, slows down and then descends has in some sense a 'natural' motion. A sound which appears from above and descends may suggest 'supernatural' or at least 'extraterrestrial' origins as it enters the horizontal plane of our normal acoustic perceptions from a plane (above) which is normally outside those perceptions. Although I have overstressed these distinctions in an exaggerated poetic way, these gravity-related orientation distinctions between 'above', 'level' and 'below' will enter into our aesthetic experience of sounds using the up-down dimension, even where the symbolic elaboration of these distinctions plays no part.

In order to analyse the qualitatively different types of motion in the two dimensional plane, I am going to assume a grid of nine distinguishable positions (see Figure 10.8). It is assumed that the listener is at the position marked 'centre', looking towards the position marked 'front'. Assuming a quadraphonic array of loudspeakers placed in the front and rear corners of the room, it should not necessarily be assumed that the positions 'front right' and 'front left' (for example) in our diagram correspond to the positions of two such loudspeakers. We are discussing positions in the

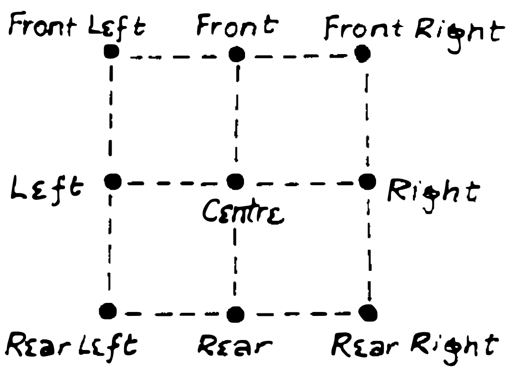


Figure 10.8 Grid of nine distinguishable spatial positions.

virtual space created by the loudspeakers and this virtual space may be much larger than the actual rectangle formed by the loudspeakers themselves (for example, by using amplitude, high-frequency roll-off and reverberation to create the illusion of depth beyond the frame of the loudspeakers). In many cases, we will be able to distinguish many more directions and distances from the centre position than these nine. This grid has been chosen for two reasons. First of all in order to make qualitative distinctions between types of motion we must be able to define the start and end points of a motion. Two motions will only be distinct (in purely spatial terms) if they start or end at positions which are qualitatively different to the listener. This grid gives us the simplest qualitative division of the acoustic space into perceptually distinguishable and qualitatively different positions. At the same time our aural discrimination of spatial position is not so refined as, for example, our discrimination of pitch. Particularly where the virtual acoustic space is projected on a limited number of loudspeakers (e.g. stereo or quadraphonic projection). Advances in computer simulation of spatial position or the general development of multi-loudspeaker concert halls may soon improve this position. However, even with just nine positions, we will find that the analysis is quite complicated enough! For the moment motion between points intermediate to the grid points may be regarded as segments of larger motions from one grid point to another (see Figure 10.9).

Considering both the perceptual limitations of the ear and the mathematics of curves it will be possible to describe all distinguishable types of motion in terms of straight line or circular motion, or some combination of these. We will also introduce the idea of random fluctuations in a motion. Finally, we may distinguish between the motion of an object and the motion of the frame (of reference). Clearly from a purely mathematical point of view, the motion of the object and the motion of the frame are but two representations of the same motion (see Figure 10.10(a)). Perceptually,

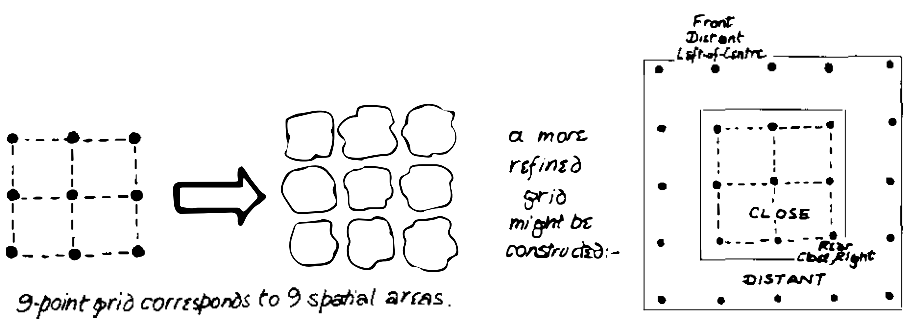


Figure 10.9 Nine-point spatial grid corresponds to nine spatial areas.

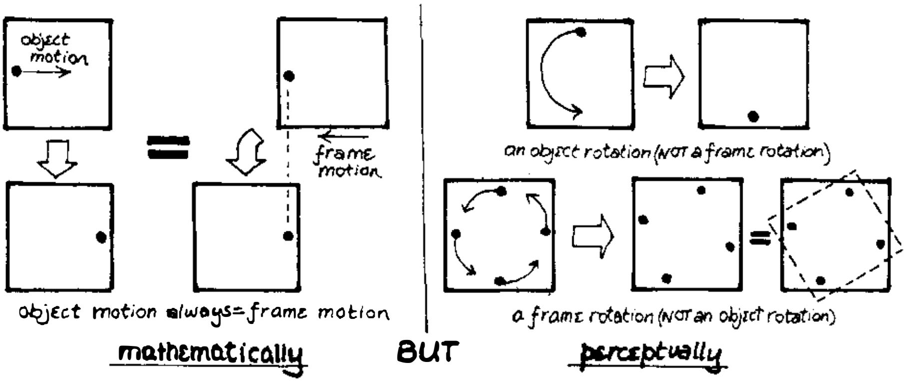


Figure 10.10 Object and frame rotations: distinction of the mathematical and the perceptual.

however, we can make a distinction between, for example, the rotation of a single object and the co-ordinated rotation of all the sound-objects in an acoustic space. The former we will refer to merely as a rotation and the latter as a frame rotation (see Figure 10.10(b)). Clearly there will be borderline cases where it is difficult to say whether we perceive the motion of objects or the motion of the frame, and certain kinds of complex motions among a group of objects may have the characteristics of both modes of perception. We will adopt what seems to be the most perceptually relevant description, indicating areas of ambiguity where these might arise.

Finally, two points should be stressed. Our analysis is a qualitative, not a mathematical, analysis. Mathematically speaking any motion in the two-dimensional plane can be expressed in terms of two separate motions along straight lines (and in many other ways). Furthermore the analysis aims at a qualitative understanding of our perception of motion in acoustic space and not as a formalisation of compositional procedures.

Direct motions

Given the left-right symmetric, front-back asymmetric nature of the acoustic space (see above) we can define just three straight-line (non-diagonal) spatial paths which pass through the listener (see Figure 10.11(a)). In the diagrams dotted line arrows indicate paths which are aesthetically equivalent to accompanying solid line arrows. However, there are four such paths along the edge of the space as motion across the front can be distinguished from motion across the back (by front-back asymmetry) and forward motion can be distinguished from backward motion (again by front-back asymmetry) (Figure 10.11(b) and 10.11(c)).

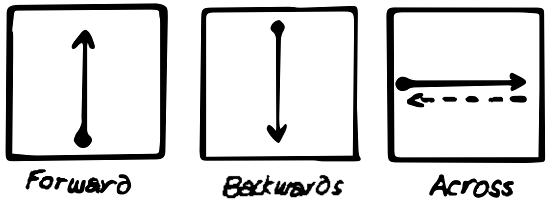


Figure 10.11a Straight line motion: centre-crossing.

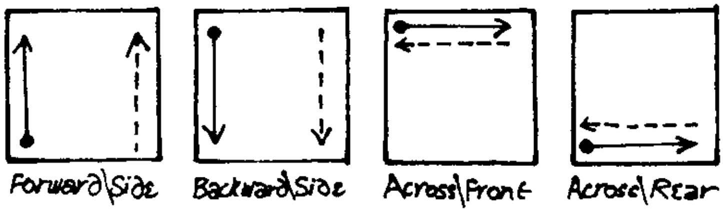


Figure 10.11b Straight line motion: edge-hugging.

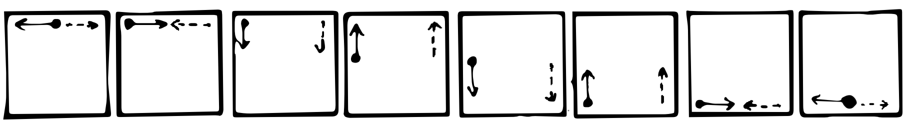


Figure 10.11c Straight line motion: edge-hugging partial motions.

In the case of paths which pass through the listener's head, it is perceptually quite clear whether the path is a straight line or not as we can use front-back and left-right cues. Paths which pass along the edge of the space, however, are more difficult to judge in this respect as we must rely purely on distance criteria (which are not so clear-cut). We shall, therefore, for the moment assume that straight lines and arcs which do not pass through the listener's head are at least similar in their aesthetic impact. However, arcs which do pass through the listener's head will be clearly distinguishable from straight paths and we may distinguish four paths of this type (see Figure 10.12).

A second set of paths moves simultaneously along the left-right and front-back axes. We will call these diagonal paths. Backward moving and forward moving diagonals are clearly distinguishable (front-back asymmetry) and we may in fact distinguish seven types of diagonal motion (see Figure 10.13). For these paths which do not pass through the listener's head the same comments about lines and arcs apply. This means, however, that we

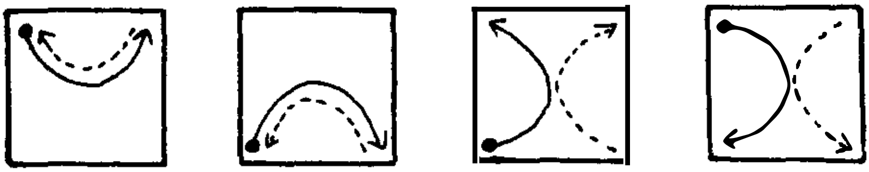


Figure 10.12 Centre-crossing arc motions.

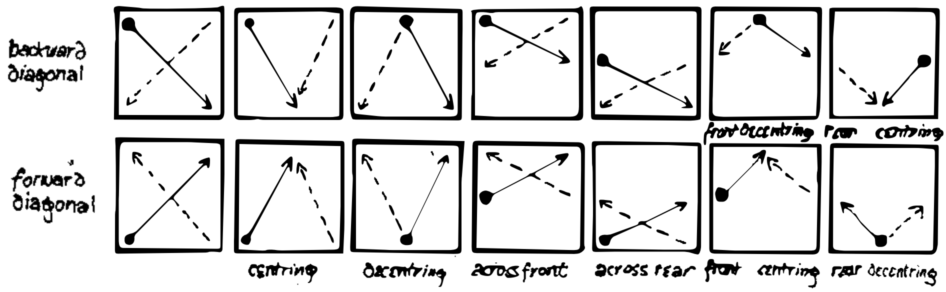


Figure 10.13 Diagonal paths.

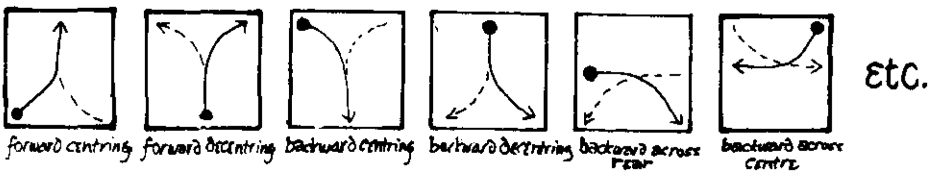


Figure 10.14 Centre-hugging diagonal paths.

must distinguish a further set of diagonal paths which arc through the listener's head (see Figure 10.14). In a sense, these 'centre-hugging' diagonals may be regarded as spatial articulations of the direct diagonals, a spatial gestural-articulation imposed on a spatial motion type.

A further class of movements is concerned with motion to and from the centre of the space (centring and decentring respectively). These are illustrated in Figure 10.15. Again, as these motions move to and from the listener's head, arc-like motions can be distinguished from straight lines and so we must also consider the set of spatial gestural-articulations of these ten types where the straight lines are replaced by arcs of various depths. Note that when the motion is to or from the front centre or rear centre positions (see Figure 10.16) we need make no aesthetic distinction between arcs which move out to the left or to the right; but in all other cases the initial

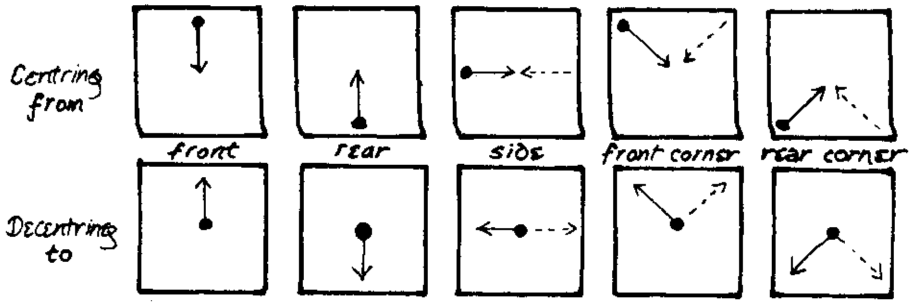


Figure 10.15 Centring and decentring motions.

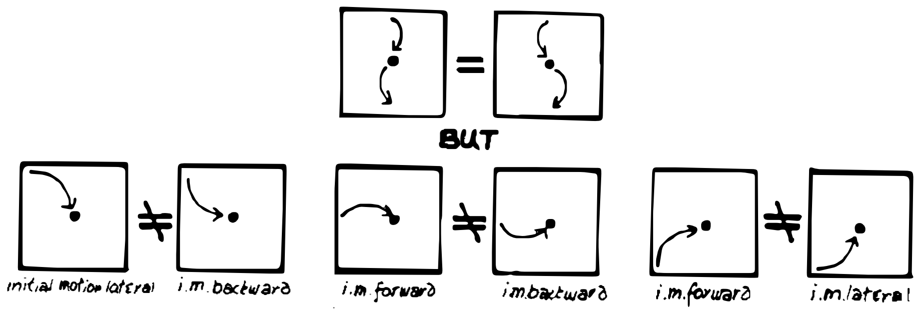


Figure 10.16 Equivalence and non-equivalence of centring arcs.

(or final) direction of the arc is of great importance because forward and backward motion are both quite different from lateral motion (Figure 10.16).

Cyclical and oscillatory motions

Next we must consider circular motion. This is the first example of a motion type which is (potentially) *cyclic*. The motions we have discussed up to this point we shall call *direct* as they trace out a path from one distinct point to a different point and therefore must take a finite time to execute. Cyclic motions, however, continually retrace the same path and therefore may continue ad infinitum. Cyclic motions have different possibilities to direct motions. In particular, they may be combined with each other or with direct motions to produce qualitatively different classes of motion (see below). In this respect they are similar to randomly wandering motions which, however, differ in that they are not cyclic. In a superficial sense diagonal motion may be regarded as qualitatively distinct from, yet derivable from, front-back and lateral motion. Although this is true, I would not regard diagonal motion as belonging to an altogether different class of motion from front-back and lateral motions. I cannot in the end give any hard and fast criteria for these distinctions; they are matters of aesthetic judgement. We might also argue that diagonal motion is nothing more than centring followed by decentring (see Figure 10.17). This is a slightly different matter, however. Whether we observe a motion as diagonal or a centring followed by a decentring in the same direction depends upon how we perceptually divide up the spatial motion into distinct spatial-gestural events; this has partly to do with the sound-material involved but also with the temporal evolution of the motions involved. This will be discussed further below.

Because left-right/front-back cues are much more reliable than distance cues, circular motion is most easily recognised when it passes right around the head of the listener (central circular motion). Circular motion which does not do this (peripheral circular motion) is much more difficult to establish in the listener's perception. The motion may however go right around the listener's head without being centred upon it (eccentric circular motion) so that in any event we can define a number of perceptually distinct circular motions (Figure 10.18). For the moment we will also not make a distinction between motions along particular closed polygons (see Figure 10.19) and related circular motions. The straight-line paths will either be distinct because of their time (and sonic) articulation, in which case we can regard the motion as a set of distinct direct motions, or these

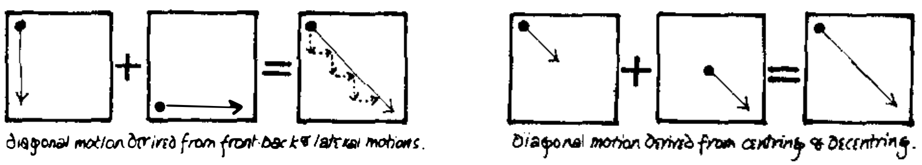


Figure 10.17 Possible derivations of diagonal motion.

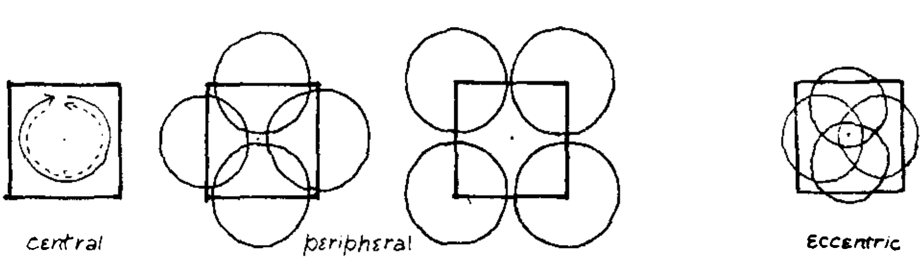


Figure 10.18 Circular motion types.

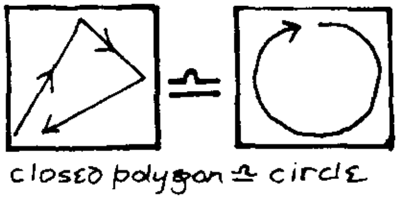


Figure 10.19 Equivalence of closed polygon and circle.

clear articulations will not be made, in which case distinguishing the polygon from motion along an arc will be quite difficult.

It is of course possible to take any direct motion and retrace the path in the opposite direction, thereafter repeating this cycle. I would, however, prefer to call this motion an *oscillation*. The motion is partly defined by its two end points and essentially oscillates between these two positions. There is no such sense of oscillation in circular motion. As all points along the circle are equivalent, there is no 'turning point'. Again, this is not a mathematical or a semantic distinction but a question of the aesthetic import of such motions. We might liken circular motion to the motion of a Shepard tone which, though apparently continually rising, never in fact moves out of its initial tessitura. An oscillation, on the other hand, is much more like a trill or vibrato. If we imagine a circular motion in which the diameter of the circle successively decreases and increases in a cyclic fashion, then the circular motion would take on the character of an oscillation. These distinctions begin to blur when we consider eccentric circular motion or narrow eccentric ellipses (see Figure 10.20).

A related movement type is spiral motion (see Figure 10.21). An inward spiral which approaches the centre slowly may be perceived as a circular motion in which the frame is contracting towards the centre (see Figure 10.22). More commonly, however, spiral motion will be perceived as direct, as it has a definite start and end point: it is not cyclic. This is

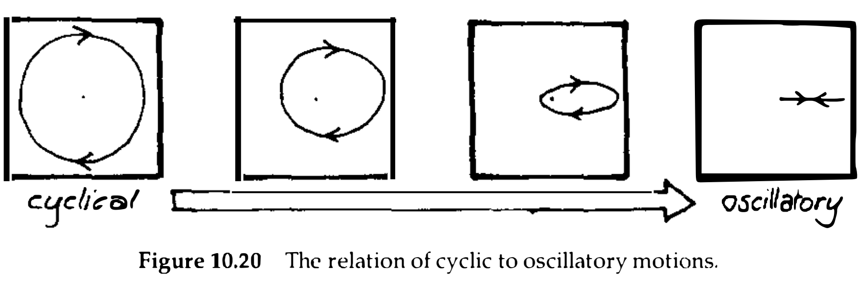


Figure 10.20 The relation of cyclic to oscillatory motions.

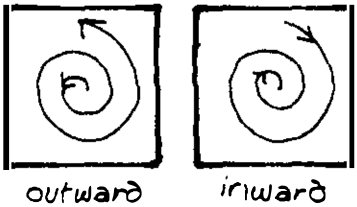


Figure 10.21 Spiral motion.

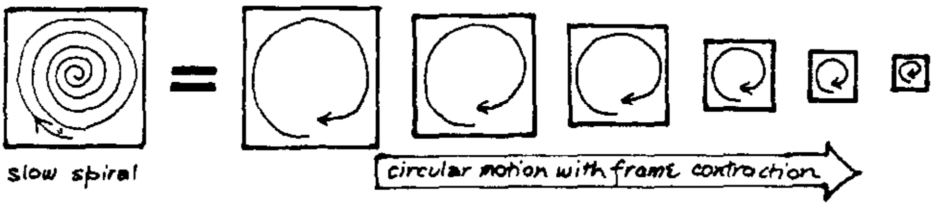


Figure 10.22 Relation of slow spiral to circular motion.

particularly evident in the case of a very shallow spiral (Figure 10.23) which is more like a mellifluous spatial ornamentation of linear motion. In between the two extremes, the spiral displays some characteristics of both circular and direct motion. Like circular motion it tends to negate the orientation of the space, making all directions equivalent. In its place, however, and unlike circular motion, it establishes inwards and outwards motion as significant. Motions which spiral inward and then outward or vice versa (see Figure 10.24) should also be distinguished. Where this motion is extended into an oscillation (inwards to outwards to inwards to outwards etc.) we have the oscillating circular motion discussed previously. It seems to me unlikely that in two-dimensional acoustic space, spiral motion which is not centred on the listener's head can effectively convey the vortex feeling of spiralling.

Finally, let us consider motion along a figure-of-eight. There are two symmetric figure-of-eight pathways (see Figure 10.25). Motion along these

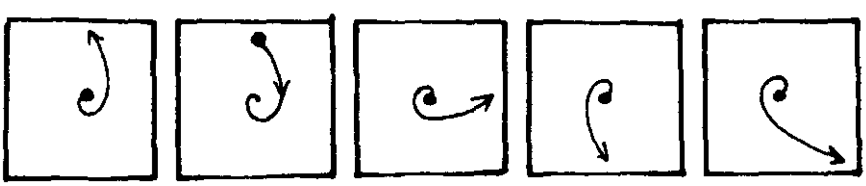


Figure 10.23 Shallow spirals.

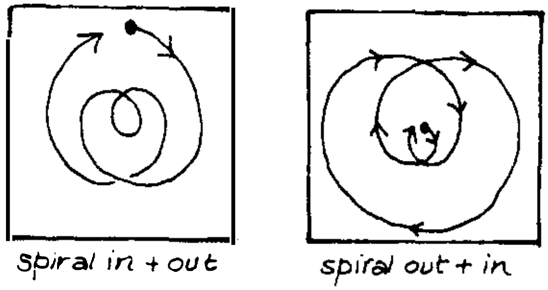


Figure 10.24 Inward and outwards spirals.

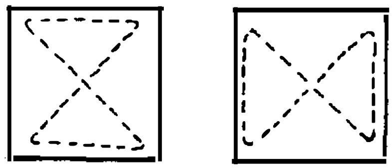


Figure 10.25 Two types of figure-of-eight motion.

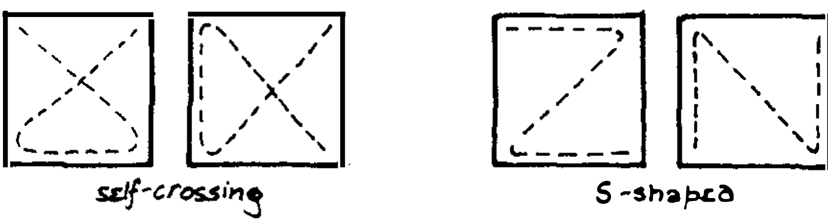


Figure 10.26 Types of pathway around figure-of-eight.

paths illustrates very well the oriented asymmetry of acoustic space. Non-cyclic paths may be divided into self-crossing and S-shaped (Figure 10.26). The important difference between these is that self-crossing paths pass through the centre of the space twice and S-shaped paths only once. Motion along an S-shaped path will be differently perceived in one direction than the other because the sound will pass either front-to-back or back-to-front through the listener, depending upon the direction of motion (see Figure 10.27). With self-crossing paths, however, there is a difference between motions which move along the edge (lateral) and motions which move along the front or back. Lateral paths pass through the centre twice in the same direction, which will be either twice forwards or twice backwards, depending upon the direction of motion along the path (Figure 10.27). With

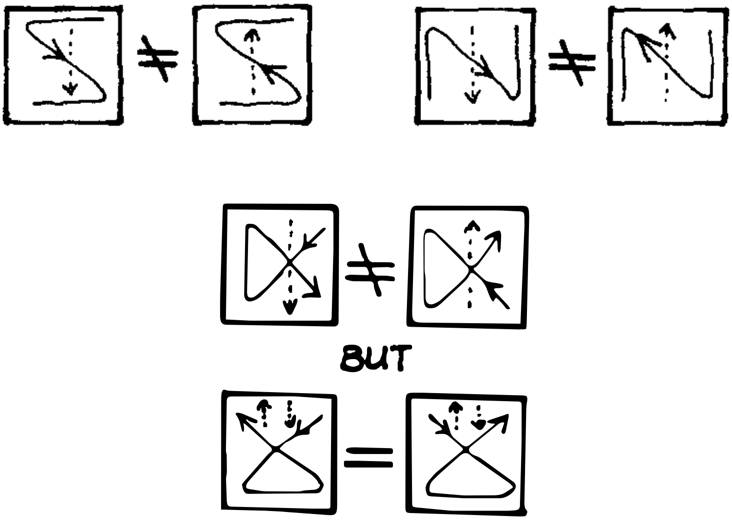


Figure 10.27 Symmetric and asymmetric motions around figure-of-eight paths.

backward self-crossing motion, however, the path crosses the listener's head in both directions — first front-to-back and then back-to-front — and, thus reversing the direction of motion, does not alter the aesthetic impact of the path (only the left-right symmetry). It does, however, make a difference whether we begin at the back of the space or the front of the space.

We can therefore classify the non-cyclic figure-of-eight motions as shown in Figures 10.28 and 10.29. Cyclic figure-of-eight motions are affected by the same asymmetry considerations so that motions which move across the front and rear of the space pass through the centre in both directions, whereas motions which pass along the sides of the space pass through the

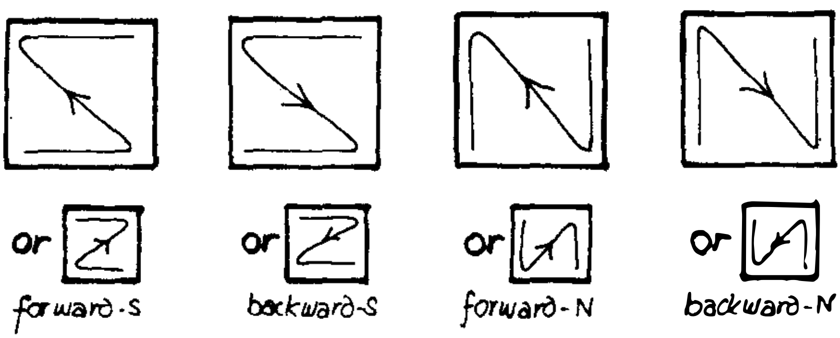


Figure 10.28 Typology of S-shape figure-of-eight motions.

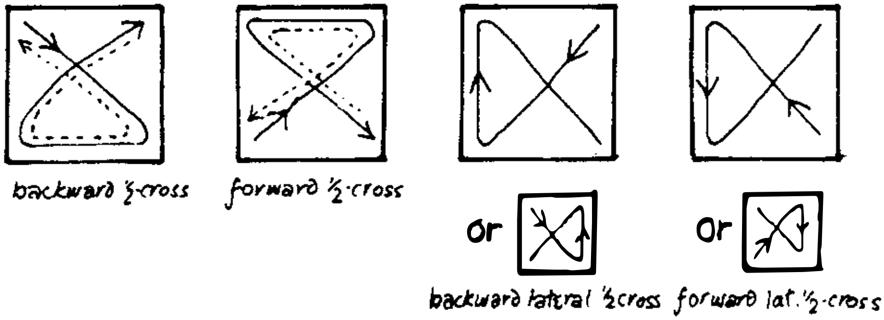


Figure 10.29 Typology of self-crossing figure-of-eight motions.

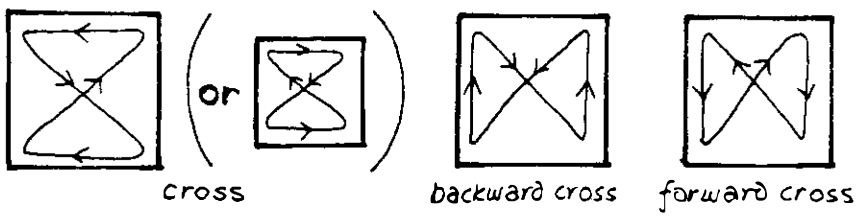


Figure 10.30 Symmetries of cyclic figure-of-eight motions.

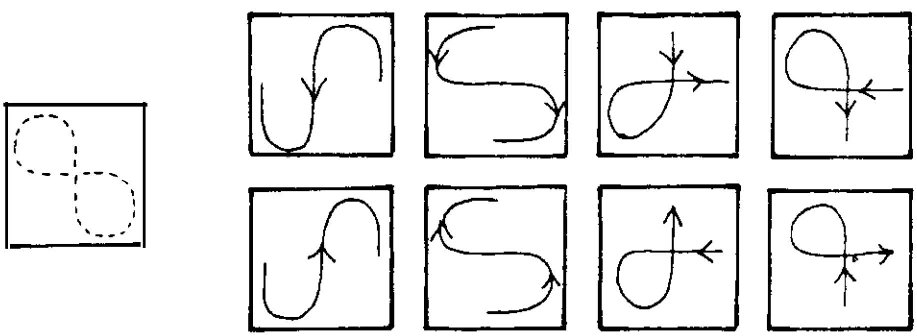


Figure 10.31 Motions along the diagonal figure-of-eight.

centre either always forwards or always backwards (Figure 10.30). Motions along the diagonal figure-of-eight are more simply asymmetric (Figure 10.31). Note also that S-shaped paths can be shaded over into arc-articulated linear paths while self-crossing paths remain quite distinct (Figure 10.32).

More extended self-crossing pathways need not be symmetrical. Figure-of-eight self-crossing motions are characterised by the reversal of

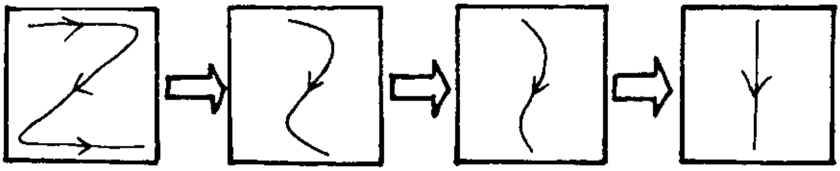


Figure 10.32 Transition of S-shape to arc-articulated linear path.

curvature of the path after each crossing of the centre. This results in a particular patterning of the directions in which the path crosses the central position. In the case of the backward (or forward) cross, this crossing is always in the same direction. In the case of the lateral cross, backward and forward crossings alternate regularly (see Figure 10.33). A quite different self-crossing motion is illustrated by the clover-leaf, in which the half-loops of the motion themselves cycle regularly around the space (Figure 10.33). This motion then carries two senses of 'circling' but lacks the 'twist' of figure-of-eight motion. This type of double motion will be discussed more fully below. Note, however, that there is a regular pattern of centre-crossings (forward, forward, backward, forward, forward etc.). We may now introduce irregular reversals and curvature into the motion to produce the irregular self-crossing motion illustrated in Figure 10.33. Here the pattern of centre-crossings is irregular (backward, forward, forward, backward etc.) and although the acoustic space is clearly articulated into centre-crossing diagonal motions and edge-hugging motions, the overall effect remains irregular or unpredictable.

Double motion

We may derive further classes of motion by combining the aesthetic qualities of motions we have already discussed. The word 'addition' used in this section does not necessarily imply that the motions can be derived by

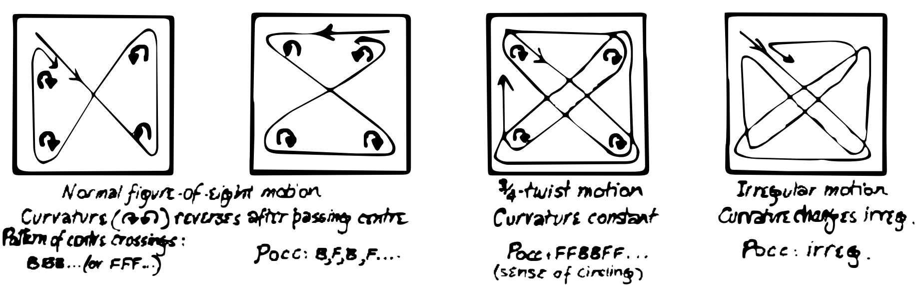


Figure 10.33 Regular and irregular paths around figure-of-eight.

mathematical addition of the two or more motions from which they aesthetically derive. As a first example, we may combine a linear oscillation with the motion perpendicular to the plane of oscillation. This gives us various types of zig-zag motion illustrated in Figure 10.34. Note that in the case of the lateral zig-zag, provided there is enough zig-zagging motion, we need not differentiate between a motion which begins at the rear and one which begins at the front as the path will spend as much time in front of us as behind us. Doubled motions, however, depend very much on the relative time-bases of the two contributory motions (more about this later) and we will find that there are limiting cases where the quality of the motion is quite different. Thus in the case of a motion which traverses a single zig-zag we must differentiate between a motion which begins at the rear and one which begins at the front (see Figure 10.35). We can also differentiate other classes of zig-zagging motion (for example Figure 10.36). These are more easily discussed in terms of the transformation of a one-dimensional frame (see below).

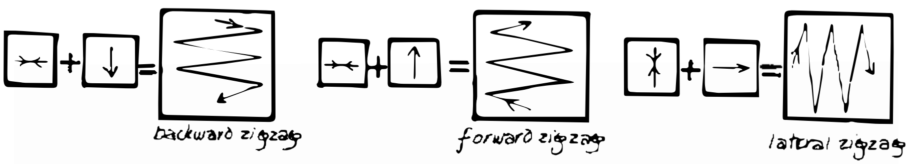


Figure 10.34 Zig-zag motions.

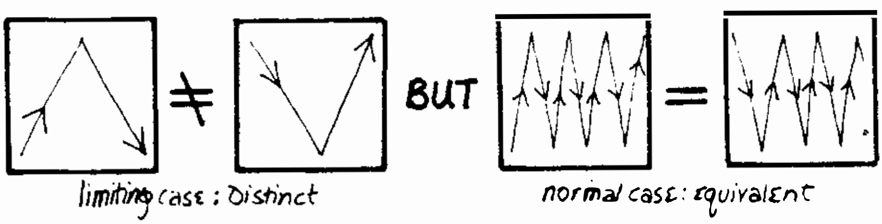


Figure 10.35 Zig-zag front/back symmetry/asymmetry.

Figure 10.36 Other possible zig-zag type.

If we now combine a back-front and a lateral zig-zag motion, where the time-bases of each contributory zig-zag are quite different, we will produce merely an oscillation between backward and forward zig-zagging (or leftward and rightward zig-zagging). Where the time-bases are almost but not exactly equal we will set up an oscillating pattern in the space (see Figure 10.37). Different patterns of fluctuation between the two senses of 'diagonality' may be set up by relative fluctuations in the time-bases of the two zig-zag motions[4].

Combining circular and direct motion we produce looping motion which proceeds in a particular direction in space whilst continually looping back on itself (see Figure 10.38). If we now allow the linear motion to oscillate back and forth across the space the looping motion will do likewise. In this situation the limiting case is equivalent to the self-crossing

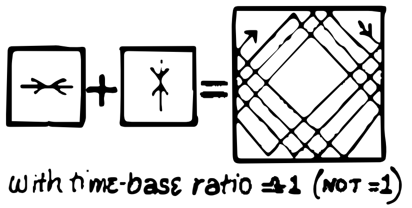


Figure 10.37 Oscillation from two zig-zag motions.

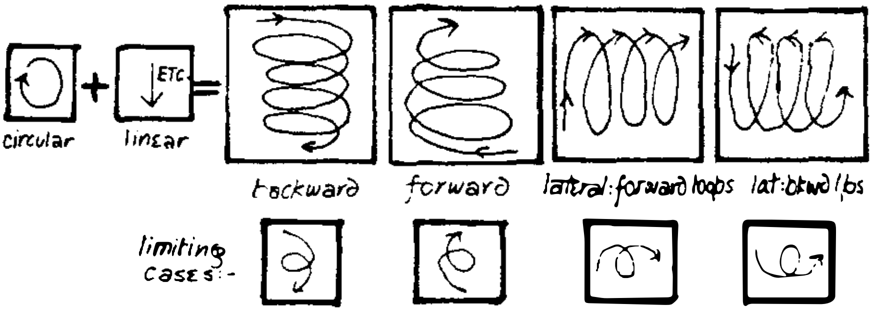


Figure 10.38 Looping motions.

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[4] Note that the precessing ellipse motion discussed below may be mathematically described in terms of a front-back and a lateral oscillation with appropriate time bases. It is, however, discussed in a different context here because it is perceptually related to circular and elliptic motion and not to linear oscillations.

motions discussed earlier. Applying linear motion to an inward-outward spiral we obtain a pulsating looping motion (see Figure 10.39).

If we now expand the linear oscillation into a narrow ellipse we may differentiate between two distinct senses of the 'addition' of the qualities of motion. If we apply the circular motion to every point along the path of the ellipse we obtain the path illustrated in Figure 10.40(a). If, however, we apply this circular motion to a particular defining parameter of the ellipse — in this case the position of one focus of the ellipse — we obtain the precessing ellipse illustrated in Figure 10.40(b). Both of these motions have the quality of circling and of elliptic motion but they are combined in a qualitatively quite different sense. The first I will refer to as *internal* addition (of the circle to the ellipse) and the latter as *external* addition. Note that we can look on this addition the other way round and regard the first motion as imposing an elliptic motion on a defining parameter of the circle (the position of its centre point) and the latter motion as the internal addition of elliptic motion to all points on the path of the circle.

Similarly we may add zig-zag motion internally or externally to circular motion (see Figure 10.41). The process of addition of motion in this

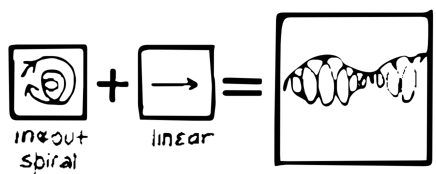

Figure 10.39 Pulsating loop motion.

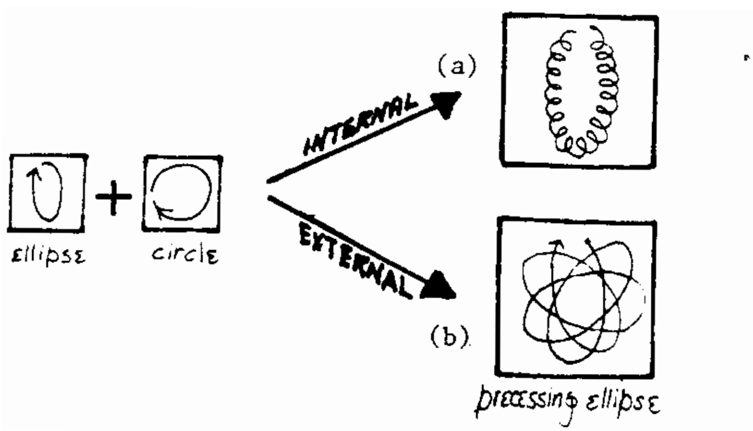

Figure 10.40 Internal and external additions of circle and ellipse motions.

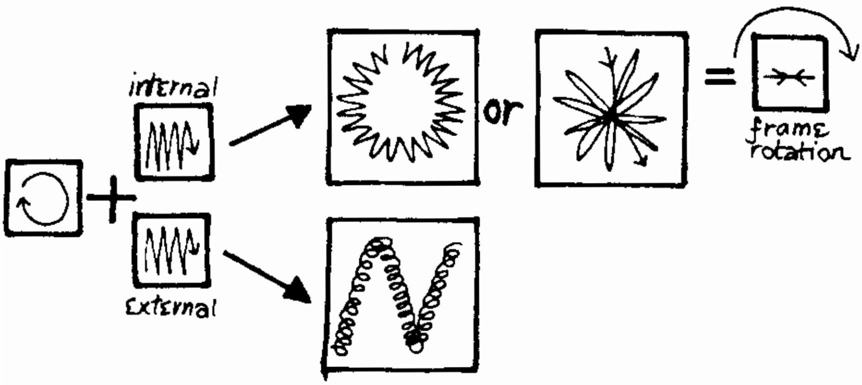

Figure 10.41 Internal and external additions of circle and zig-zag motions.

sense may be elaborated even further (see, for example, Figure 10.42) but, at least for the moment, there are distinct limitations on our ability to perceive the characteristics of such complex types of motion. We may also add cyclical motion to itself, producing the circling loop motion illustrated in Figure 10.43. This motion has several special cases, from the rotating single loop (Figure 10.44) to circular and elliptic four-cloverleaf formations (see Figure 10.45). We may also describe three-cloverleaf formations and, even within this category, we can define two distinct types, the normal and the maximally-swung (see Figure 10.46). The latter is produced by varying the time-base of the motions appropriately. By a similar process we can produce

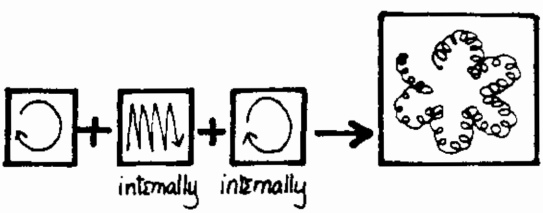

Figure 10.42 An elaboration of additions of circle and zig-zag motions.

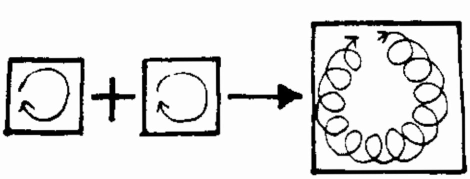

Figure 10.43 Addition of circular motions.

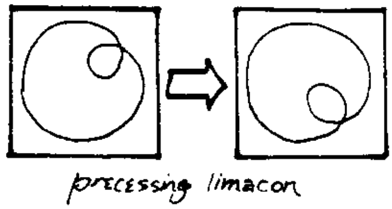

Figure 10.44 A rotating single loop.

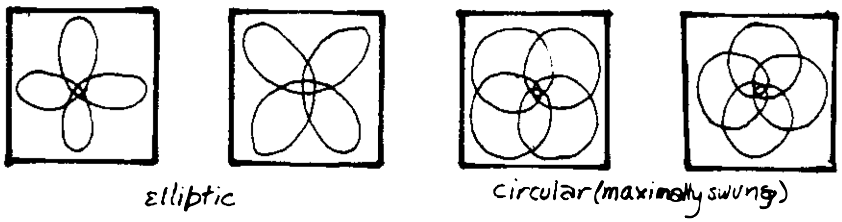

Figure 10.45 Four-cloverleaf formations.

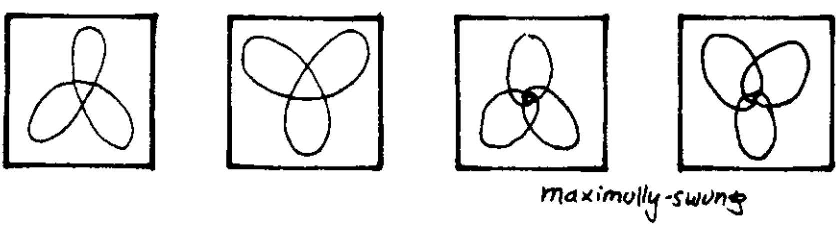

Figure 10.46 Three-cloverleaf formations.

two different kinds of four-cloverleaf pathways (see Figure 10.47) and even motions which are asymmetric with respect to the acoustic space (for example, the 'butterfly' motions illustrated in Figure 10.48). Finally we may imagine motions which loop closely around the centre, throwing out larger loops of either regular or irregular sizes at irregular intervals. These may be regarded as irregularly oscillating circular motions (Figure 10.49) and lead us into a consideration of randomness in spatial motion.

Irregular motion

We may also consider motion-types which involve irregular paths through the acoustic space. Such a path may be completely unlocalised or localised in

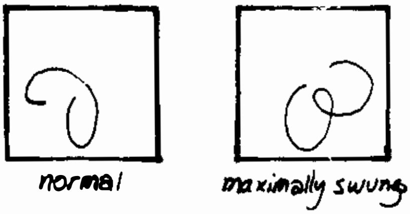

Figure 10.47 Two types of four-cloverleaf formations.

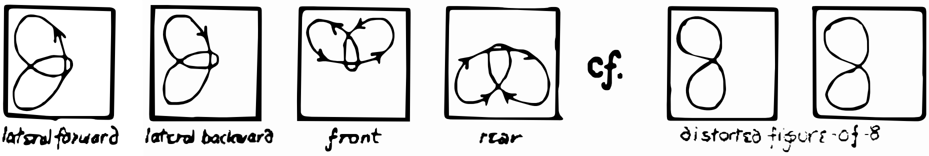

Figure 10.48 'Butterfly' pathways.

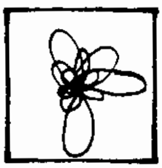

Figure 10.49 Irregular oscillating circular motion.

Figure 10.50 Localised and unlocalised irregular paths.

a particular area of the space (see Figure 10.50). Alternatively, an entirely unlocalised (or partly localised) motion may be weighted so that the sound-object spends more of its time in particular areas of the space than in others (Figure 10.51). We will leave consideration of such time-averaged properties for a later section. Clearly irregularity is a matter of degree and we can imagine a whole array of paths between completely unlocalised irregular motion and small fluctuations around a direct motion. Movements of the

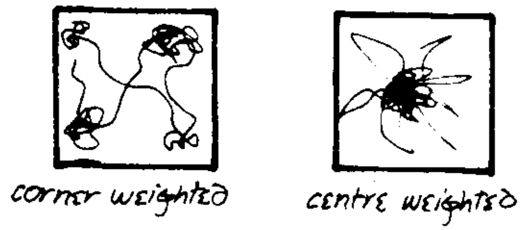

Figure 10.51 Time weighted irregular paths.

latter type are best considered as double motions, combinations of motion types we have already discussed and irregular motion. Clearly, irregular fluctuations in space can be applied to any direct motion. If, however, we apply them to double motions, we are able to do this internally or externally as before. Consider for example zig-zag motion. We may apply irregular motion internally to the zig-zag paths themselves or externally to the defining end-points or centres of the zig-zag motion (Figure 10.52). Clearly the perceived qualities of the three motions are quite different. In the first case we have an unsteadiness within the zig-zagging motion itself. In the two other cases, however, the zig-zagging motion is quite definite but its orientation is unpredictable.

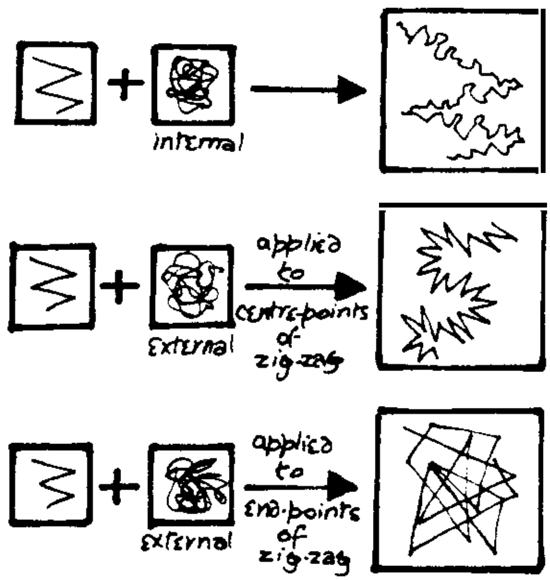

Figure 10.52 Addition of irregular and zig-zag motions.

We may similarly combine irregular motion with circular motion, or looped circular motion (see Figure 10.53) or to pulsating looped motion (Figure 10.54). In the case of these circular motions, the external addition causes the circle centre to wander about in a random manner. With the

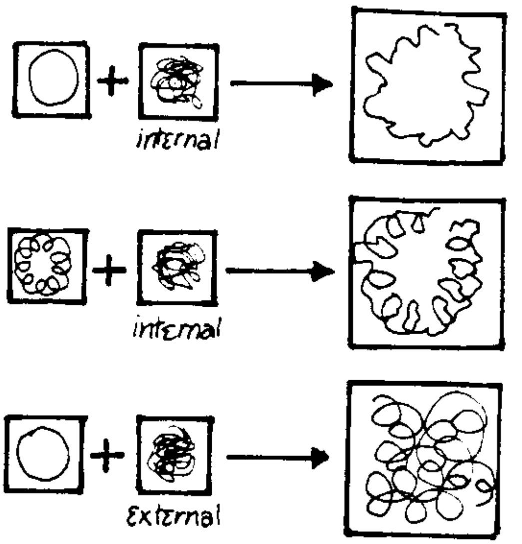

Figure 10.53 Addition of irregular and circular motions.

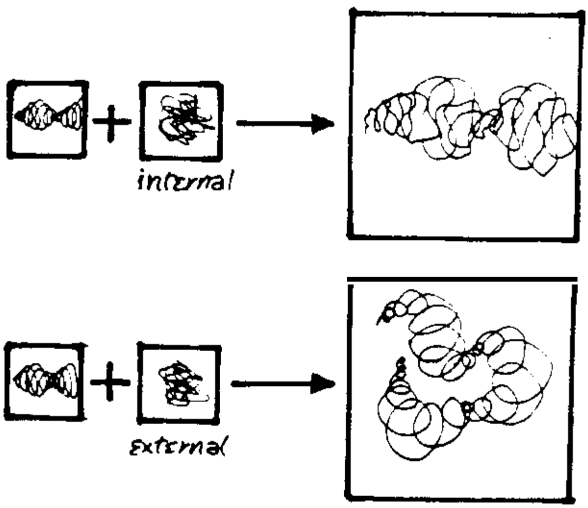

Figure 10.54 Addition of irregular and pulsating looped motions.

pulsating loop motion, however, there is another external parameter, the rate of oscillation of the pulsation. This, too, may be made to fluctuate randomly. These variables combine to produce a motion with one degree of order (looping) and two degrees of disorder (random circle centre and random pulsation rate (time-base randomness) (Figure 10.55)).

Clearly, when a motion becomes too complex we cease to perceive any pattern in it at all. Thus internal addition of irregularity will be perceived as a 'jitteriness' of the motion only where it is a small component of the motion. Beyond a certain point the motion will appear quite random. External addition of irregularity is in fact more interesting because the zig-zagginess, or loopiness of the motion is preserved. These qualities should differentiate one kind of randomly wandering motion from another.

Time

A motion is characterised not only by its path in space but also by its behaviour in time. We may distinguish the first order time properties (different speeds of motion) and second order properties (the way in which the speed changes through time, the acceleration or deceleration of the motion). We might even consider in some cases third order properties of the motion (the way in which the acceleration or deceleration changes through time) but for the moment we will assume that this degree of precision is not generally audible.

The absolute speed of the motion will determine its perceived aesthetic character. A very slow motion will be experienced as a mere relocation of position or even as 'drift' rather than a movement with some definiteness or 'intention'. As the speed of the motion increases the apparent energy associated with that motion is increased. Motion at

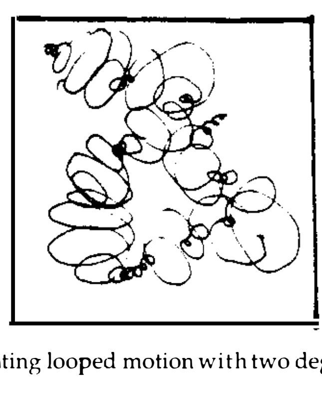

Figure 10.55 Pulsating looped motion with two degrees of randomness.

intermediate speeds has a feeling of definiteness or 'purposefulness', an intention to get from one location to another. Fast motions carry a feeling of urgency or energy. Where fast motion is introduced suddenly into a relatively static frame, there is a sense of sudden surprise. The similar introduction of a very slow motion into a static frame may induce a sense of gentle disorientation. Very fast motion in a circle may even induce a sense of head-spinning dizziness.

Considering now different categories of speed change we may broadly differentiate six classes of motion (see Figure 10.56). Accelerating motions, with their sense of rushing towards a final position, thus increase in spatial 'definiteness' or 'intention' and point to the significance of their target point. They are a kind of spatial 'anacrusis'. Decelerating motions, on the other hand, have exactly the opposite effect, a definiteness in leaving their point of origin and a sense of coming to rest at their target, a calming or spatial 'resolution'.

Accelerating-and-decelerating or decelerating-and-accelerating motions allow us to define some new types of linear motion. Figure 10.57 defines a whole class of there-and-back linear (or narrow elliptical) motions. Where these have a decelerating-accelerating time-contour they are perceived as 'thrown' elastic motions. It is as if the sound-object is thrown out from its point of origin on an elastic thread whose tension slows down its motion and then causes it to accelerate back towards the source. Simple constant speed motion along any of these paths would usually break down in our perception into two separate motions, one in the outward and the other in the inward direction. The time-contour, however, gives the whole motion a special kind of unity. Conversely, the accelerating-decelerating time-contour gives the feeling of 'bounced' elastic motion, the motion gathering energy and then being forcibly repelled by the edge of the space it defines, losing energy as it returns. Again, the overall there-and-back motion is unified by the time-contour.

Where a motion cyclically accelerates and decelerates, our aesthetic interpretation may depend on our position in relation to the motion. Consider the maximally-swung elliptic four-cloverleaf motion of Figure 10.47. We may apply a synchronised pattern of accelerating and

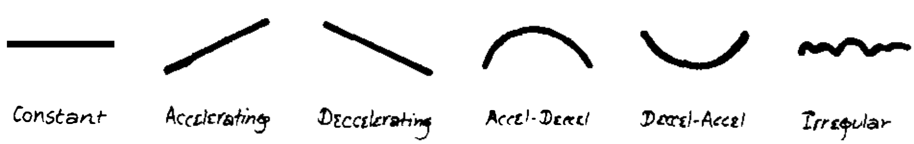

Figure 10.56 Time contours (classes of motion).

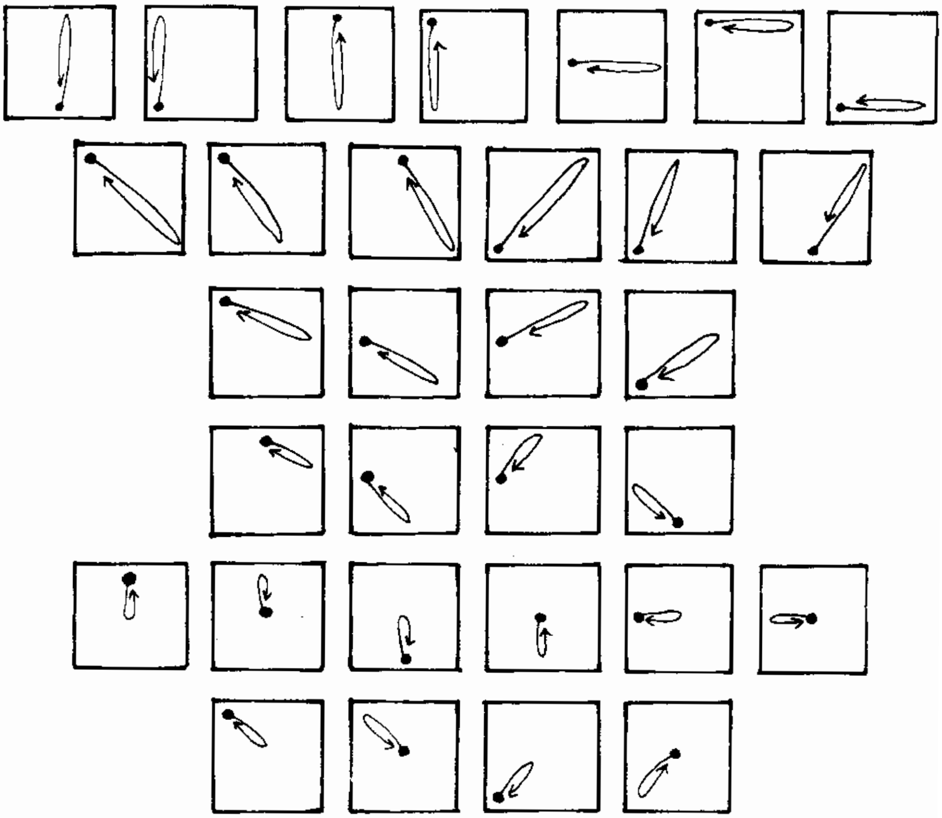

Figure 10.57 Elastic or bounced motions.

decelerating motion to this path in one of two ways. In the first case the movement on the elliptic outer loops will accelerate whilst the motion close to the observer will be slow. As the sound-object will therefore spend most of its time circling slowly around the observer's head, the motion will appear rooted in the centre but making dramatic swings out into the distant space. The motion will thence appear 'bounced' elastic. In the opposite case, however, the motion along the outer ellipses will be slow, accelerating towards the centre and moving very quickly around the observer's head. Here the sound-object will spend most of its time on the outer edges of the space, making sudden (and perhaps disturbing) close loops around the listener. The motion will then appear 'bounced' elastic but in the opposite direction (inwards) to the first case (see Figure 10.58). We can imagine a third situation in which the motion around the listener's head is at a medium pace, suddenly accelerating before it moves off along

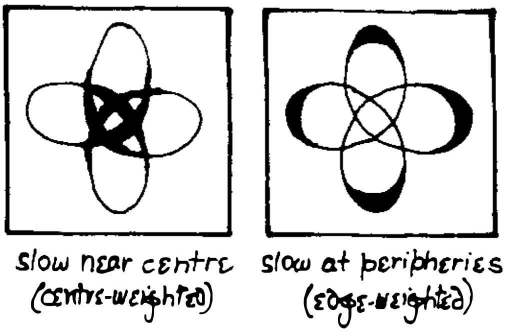

Figure 10.58 Bounced elastic four-cloverleaf motions.

the outer ellipses where it decelerates. In this particular case the motion at the centre has a stable phase (where it is moving at a medium rate) and the listener may thus feel that the sound is rooted in the centre of the space but ejected to the edges by 'thrown' elastic motion. This example illustrates the way in which subtle interactions between motion contour and spatial path may influence the aesthetic impact of a particular spatial motion. As another example, consider the inward spiral (see Figure 10.21). Where this motion accelerates towards the centre we have a sense of the sound-object rushing towards, or being sucked into, the centre of the vortex. Conversely where the motion decelerates there is a feeling of the sound-object coming to rest at the centre of motion.

In the case of cyclical and oscillatory motions, changes in the motion contour may synchronise with the rate of oscillation. In this way, a cyclical or oscillatory motion may be given an entirely new character. For example, a circular motion may start slowly at the front and accelerate as it moves towards the back of the space, decelerating as it moves back to the front. The circle thus no longer defines all directions as equivalent. It becomes oriented as with most other motions in acoustic space. In the case of double motions, the relationship between the time-cycles of the contributory motions will determine the type of spatial pattern traced out by the path of the sound-object. Aesthetically, however, it is more profitable to analyse the paths of the resulting patterns and this we have done in a number of cases in the previous section.

There is, however, another sense in which temporal considerations enter into our perception of spatial motion. Returning to Figure 10.51 we may remember that random motion may be weighted in the sense that the sound-object may spend more of its time in particular areas of the space than others. The otherwise random motion does have certain time-averaged characteristics which allow us to distinguish it from other random motions. There is an interesting parallel here with our perception and analysis of noise-based signals. Taking a time-average of a white noise signal would show it to contain all possible frequencies with equal probability. We may, however, filter the noise such that the occurrence of certain frequencies becomes more probable, and we then obtain a different sound, a noise with a distinctive 'colour'. The weighting of an unlocalised random motion corresponds exactly to this concept of filtering.

We may go even further. Even more patterned motions such as circling-looping motion may be time-weighted so that the sound-object spends more of its time in a particular part of the space (see Figure 10.59). This is equivalent to stressing a particular 'formant' (or quadrant) of the motion; as the analogy with filtering time-averaged sounds still stands but we are dealing with a regular pattern. This analogy with filtering procedures gives us a powerful tool for analysing our perception of complex types of motion. We might, for example, apply it to discontinuous motions (where a sound appears and disappears in various locations in the space without passing through the intervening positions).

Frame motions

In certain situations a group of sound-objects, or a single oscillating sound-object, may define a line (which need not be straight) in the space. This may be regarded as a one-dimensional frame and we may investigate motions of the total frame (as opposed to motions of the individual objects). In a sense, a frame motion could be seen as merely a set of simultaneous motions of independent objects. If, however, certain types of symmetry are preserved between the objects (or in the nature of the oscillation) we will perceive the group of objects to move as a whole. As well as the fairly straight-forward

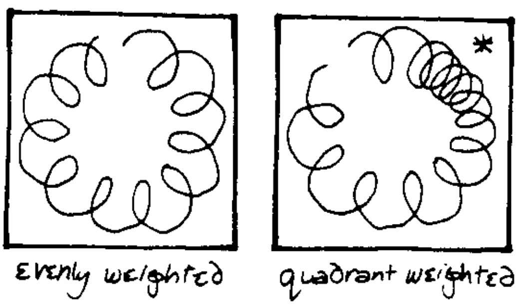

Figure 10.59 Time-weighted circling-looping motion.

motions we will consider here, a frame may be considered to 'writhe' in all sorts of strange ways if the objects defining it move in elaborate relative motion. There is no clear dividing line between a complex frame motion and a sense of independent motion of the sound-objects.

We may consider frame translation, swing, twist, flip and rotate. These are illustrated in Figure 10.60, together with their application to a one-dimensional linear oscillation. Note that a frame twist is only effective with an asymmetric one-dimensional sound-image. Otherwise it will be read merely as a frame translation which contracts towards the centre and then expands outwards again to beyond the centre (a three-dimensional twist would be different). The frame may also be contracted or expanded and these operations may be combined with the previous class of movements (see Figure 10.61).

We may also consider motions of a two-dimensional frame. The frame defined by the entire acoustic space may rotate, contract or expand

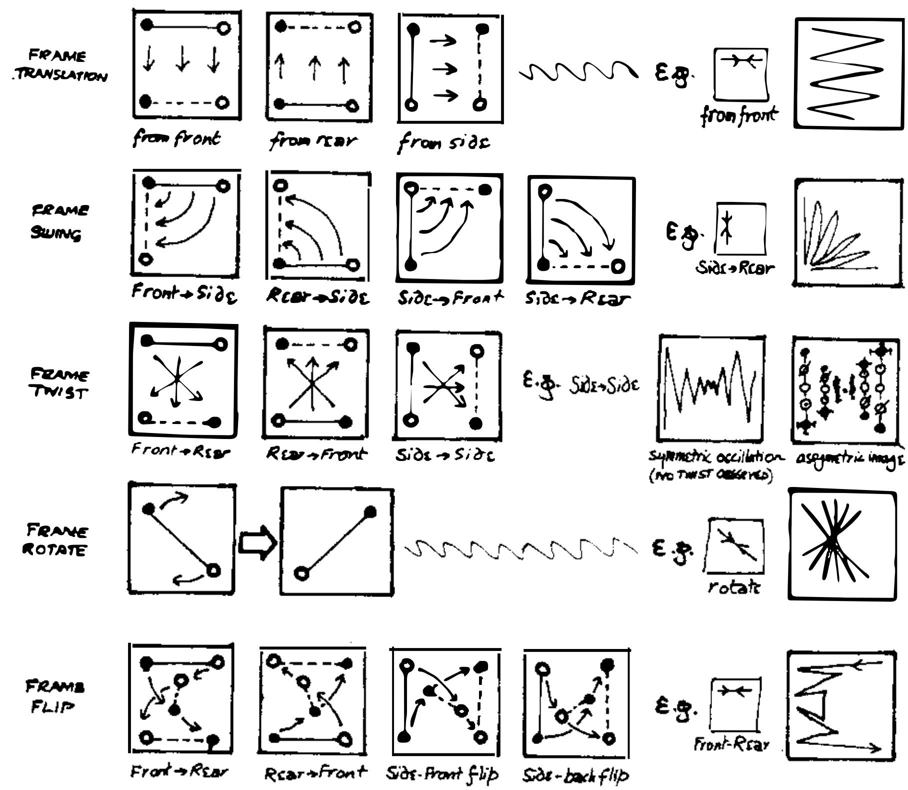

Figure 10.60 One-dimensional frame motions.

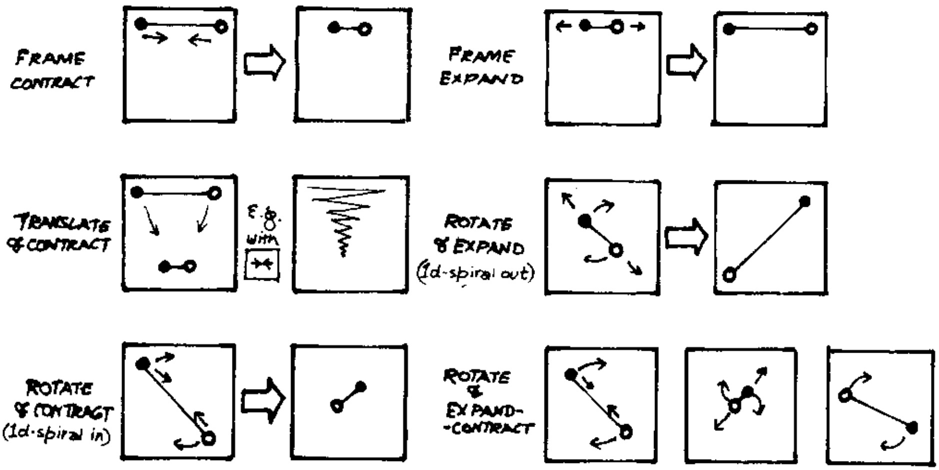

Figure 10.61 Further one-dimensional frame motions.

(see Figure 10.62). By combining these types of motion the frame itself may spiral inwards or outwards (Figure 10.63). We might also consider translations of an entire two-dimensional frame (Figure 10.64(a)). The change in the listener's perspective implied by this motion, however, would be better suggested by a corresponding expansion and contraction

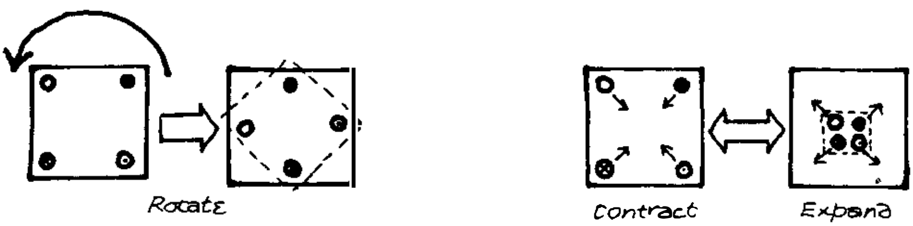

Figure 10.62 Two-dimensional frame motions.

Figure 10.63 Further two-dimensional frame motions (spiral forms).

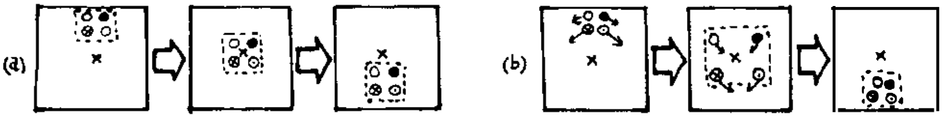

Figure 10.64 Further two-dimensional frame motions (translations).

(Figure 10.64(b)); the observer passes through the acoustic landscape (or vice versa). We might also consider various distortions of the two-dimensional frame as illustrated in Figure 10.65. We cannot go too far along this road, however, without the sense of 'frame' being lost and the sound-objects appearing to move independently of one another. There is a sense in which any mutual movement of the sound-objects in the space which preserves certain symmetries can be considered a frame motion or distortion, but how we actually perceive this will depend upon the particular circumstances.

Two types of frame motion are of particular interest: the first (see Figure 10.66) involves the expansion of sound-objects from the centre into the surrounding space. If this is accompanied by an accelerated motion it

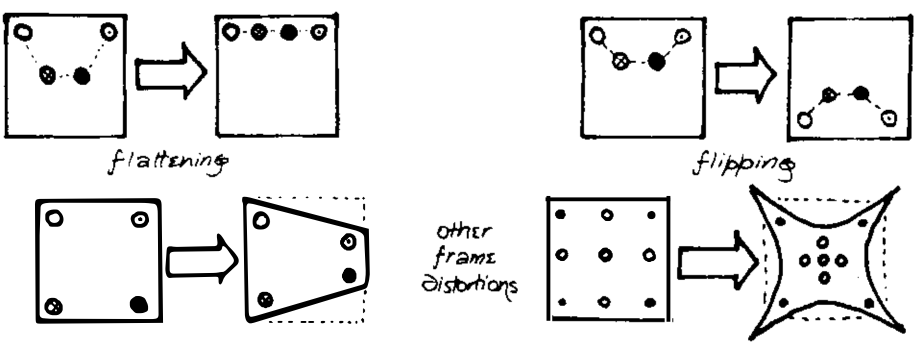

Figure 10.65 Two-dimensional frame distortions.

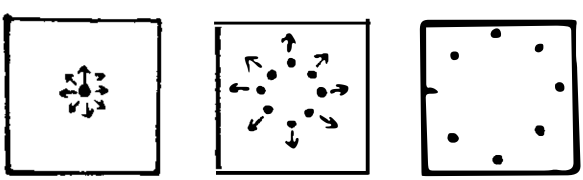

Figure 10.66 Frame motion (expansion).

should give a sense of growth, whereas if accompanied by a decelerating motion which is initially quite fast, a sense of exploding will be conveyed. Conversely (see Figure 10.67) all the elements in a space may collapse into the central position and, if this is achieved with an accelerating motion, a sense of imploding will be created. In more complex situations we may imagine most of the objects in the acoustic space undergoing a symmetrical rotation whilst a single object pursues an independent course. How we perceptually group the objects in these situations will depend partly on the various relative motions of the objects and partly on various landscape aspects of our perception (for example, recognition or sonic relatedness of the sound-objects).

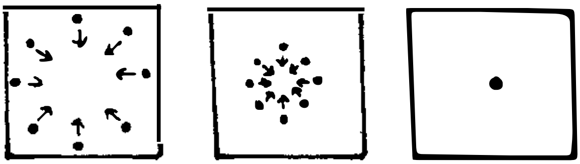

Figure 10.67 Frame motion (contraction).

Some principles

We may draw the following set of conclusions to this part of our discussion:

(1) acoustic space is an oriented space: in particular, front and back are to be clearly distinguished from one another;
(2) individual motions in the space may be direct or cyclical/oscillatory;
(3) motions may have more than one characteristic;
(4) a degree of irregularity may be imposed internally or externally on any basic pattern of movement;
(5) the temporal characteristics of a motion will significantly affect its character: with direct motion (or cyclical motions which have directed characteristics such as the cloverleaf) the motion contour will determine the 'gestural' feel of the motion, while with cyclical double and random motions the motion contour will contribute to the spatial structure of the path;
(6) in certain cases we may consider a one-dimensional or the entire two-dimensional frame of reference to move.

The counterpoint of spatial motions

Having now established an enormous potential vocabulary of spatial motion, we may consider how the motion of distinct sound-objects in the acoustic space may be counterpointed with one another. Direct motions (or directed aspects of motions, either spatial or temporal) may in this respect be distinguished from cyclical or oscillatory motions. This distinction, we will discover, is akin to that between sounds of dynamic morphology and sounds of stable mass or tessitura in that the former motions may be organised gesturally whilst the latter may be organised in a sense 'harmonically'. Any directed aspect of a motion may be considered as a spatial gesture, These gestures may then be made to move independently, to interact, or to trigger one another just as with sonic gestures.

For example, we may have three sound-objects in the acoustic space: sound A wanders slowly around the edges of the space, sounds B and C, however, dart about rapidly in the space always avoiding each other. In this situation we would tend to hear the movement of A as a separate and independent spatial layer, not interacting with B and C. B and C, however, would form an interactive contrapuntal system because their spatial motions clearly interact with one another. In Figure 10.68, various motions of the sound-objects B and C are plotted. These motions might be independent, interactive, or triggering. In the latter case, for example, the arrival of sound B at a particular location will suddenly cause sound C to move off (the two locations in question need not be the same). Just as with sonic gestures, gestural interaction relies on the relative temporal coordination of the gestures in time and their intrinsic qualities. We may for example make gestures which have similar temporal structures but different spatial qualities, for example, motions which are accelerating in a synchronised way but which move differently in direction and spatial contour (see Figure 10.69). Similarly, the spatial interrelatedness (or lack of it) between two gestures may be established in many ways, particularly with reference to the symmetry of the space (see Figure 10.70). In this way we may establish a subtle interplay between the relative timing and the spatial characteristics of various spatial gestures which is akin to the counterpoint of gesture and transformation. This was discussed in Chapter 6.

Gesture and transformation in space may underline or counterpoint other (possibly gestural) properties of the sound-objects themselves. Clearly

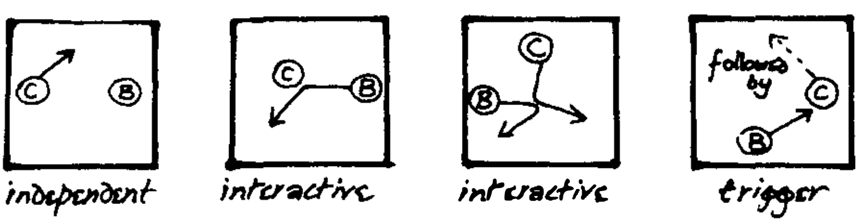

Figure 10.68 Gestural interactions of spatial motions.

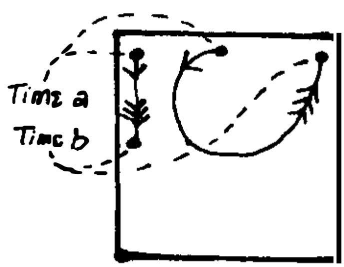

Figure 10.69 Synchronised motions with different spatial contour.

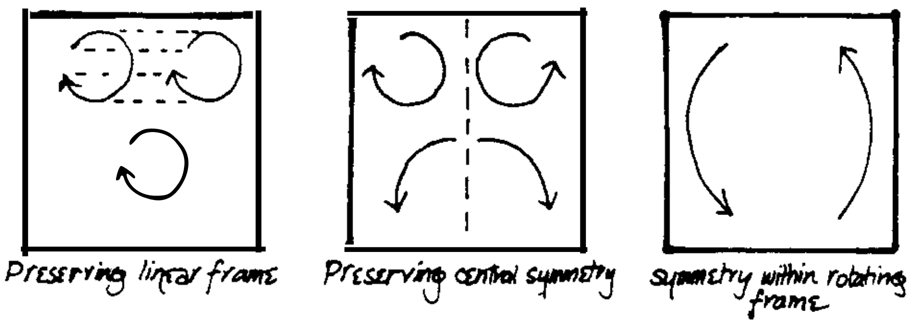

Figure 10.70 Multiple motions symmetry considerations.

a motion accelerating towards a point through a crescendo has a quite different feel from a similar motion accelerating through a diminuendo. In cases such as the merging and divergence of sonic streams, the coordination of spatial motion and timbral transformation is obviously of the utmost importance. Conversely, it is not possible to conceive of a collision between two sound-objects having identical sonic structures. We would perceive at worst a mono image as our ears located the sound-object between the two (hypothetically) moving sources or we would achieve a merge; a sense of collision could only be created between two objects of quite distinct sonic properties.

The symmetries (or lack of them) established between the relative spatial positions of the sound-objects simultaneously help to define the total space itself. Once all objects in the space are in motion — particularly if these motions are asymmetric — a sense of disorientation can be created as there is nothing left to define the limits or orientation of the space (this is where closing the eyes becomes important as we can always establish a visual reference grid). Conversely, if such motions are set against a background of distant but static sound-objects, a sense of energetic activity within the frame may be achieved. A cyclic motion on the other hand may be regarded as a kind of spatial 'resonance', mapping out as it does a particular way of dividing up, and in many cases orienting, the space (see Figure 10.71). Various motions may then be spatially or temporally coordinated in order to create various degrees of 'consonance' or 'dissonance'.

The harmonic analogy is not so far fetched as it may at first sound. Consider for example the motions in Figure 10.72(a). Here two motions follow the same circular pattern, the same direction. Clearly when the two objects start from the same point at the same time we hear the rotation of a single image. Alternatively, if the objects are placed exactly at opposite sides of the space (Figure 10.72(b)) they are symmetrically oriented with respect to the head and we hear what amounts to a one-dimensional frame rotation. These may be regarded as harmonically related states of the rotation of the system. If we now make the two objects rotate at slightly different speeds (Figure 10.72(c)) they will continually pass through the states of parallel rotation and anti-parallel rotation (Figures 10.72(a) and (b)). We are producing a kind of portamento between two harmonic states of the system.

We can discover not only spatial 'harmonics' but temporal 'harmonics' in a rotating system. Let us imagine two objects rotating along the same circular path but in opposite directions. If they rotate at the same speed, they will always cross at the same points on the circle (at 0° and 180°) (Figure 10.73(a)). Similarly if one rotates twice as fast as the other they will always cross at the same four points of the circle (0°, 90°, 180°, 270°)

Figure 10.71 Spatial division and orientation from cyclic motion.

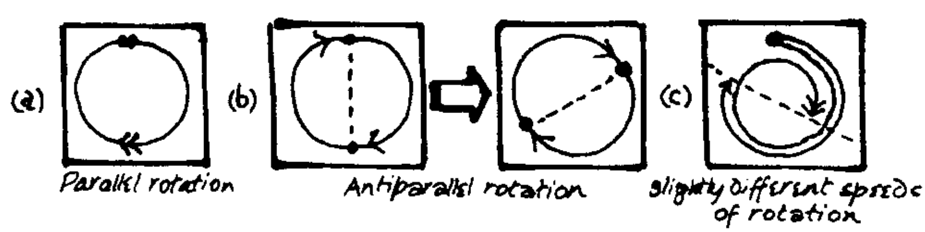

Figure 10.72 Spatial 'harmonics'.

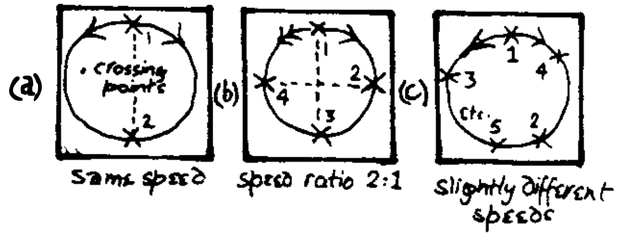

Figure 10.73 Temporal 'harmonics'.

(Figure 10.73(b)). All of these may be regarded as temporal harmonics of the system. Again, we may make one of the sound-objects move slightly faster than the other and we may observe the motion pass through these various harmonic states (Figure 10.73(c)). A temporal portamento of motion has been created.

In Figure 10.74 the two objects move on different paths. The two paths, however circulate around the space in the same direction (always anticlockwise). They are therefore in some kind of spatial 'harmony' with one another. If at the same time the cycle times are coordinated so that, for example, they are both at the centre rear of the acoustic space at the same time a further temporal 'harmony' is achieved between the two motions. In Figure 10.75 a group of sound-objects rotates around the centre of the space. If they all preserve the same angular velocity we hear merely a rotation of a one-dimensional frame around the centre. If, however, they all have the same linear velocity the outer objects will gradually lag behind the inner objects. The motions of the various objects are however spatially 'harmonised' with each other or at least they set up a particular feeling or structuring to the space which is more vaguely akin to an inharmonic resonance. Examples of this type may be multiplied *ad libitum*. Furthermore, gestural motions may be superimposed on these situations, either through the movement of other objects through gestural articulation of the cyclic

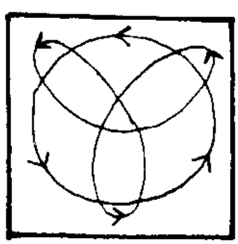

Figure 10.74 Spatial coordination of two motions.

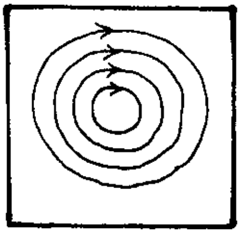

Figure 10.75 Coordination of rotations.

motions, or through the consecutive use of gestural and 'harmonic' modes of organisation. The counterpoint of spatial motions is thus in itself an extremely rich field for the sonic artist to explore.

Conclusion

There is clearly even more we can say about spatial motion. We have not yet considered the up-down dimension; we have not considered oscillating motions which are so fast as to produce amplitude modulation of the signal (the timbral effects of spatial motion); we have not considered analogies with the sphere of dance.

As the technology is further developed which permits us to analyse and control the various parameters which enable us to accurately locate sounds in space and, as reproduction facilities and acoustics are improved, we can expect this analysis to be expanded and refined; certainly at this stage it cannot claim to be complete. The organisation of spatial motion is undoubtedly a growth area in sonic art.