# EW MOVEMENT NOTATION:
# SIMULTANEOUS MOVEMENT AND SPACE CHORDS

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**Abstract**

The simultaneous movements of limbs produce paths of movement which are the results of mutual interaction of the separate segments; these shapes are referred to as 'space chords'. Some of the simpler combinations of simultaneous movement are considered, and examples of space chords introduced.

## Introduction

The term 'space chord' which we apply in movement is borrowed from music, where the sounding together of single tones of differing frequencies produces a phenomenon which is other than its separate parts. A musical chord can be analysed into its components; even a single tone consists of a cluster of harmonics. Obviously by mingling, two or more tones enhance or dilute one another, giving birth to a new phenomenon. So by analogy the movement of a single part of the body with a free end always creates part of a circle, but in the movement of two adjacent limbs - each in itself producing part of a circle - the resultant path of the carried limb may become a very complex one because of the influence of the movement of the carrying limb. (See Fig.1.) We offer the first very rudimentary step in the search for a coherent and simple way of understanding the spatial paths created by the simultaneous movements of adjacent parts of the human body.

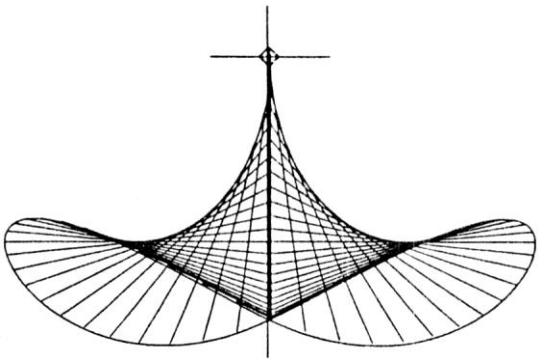


*Fig.1. Computer simulation of a space chord*

## The sphere of movement

For the purposes of the notation we regard the human body as a system of straight *rods' (limbs l connected to one another by joints. Movement of the whole body is therefore the sum of the movements of the separate limbs, just as a particular state of rest of the whole body is the aggregate of the positions of the separate limbs.

In analysing the movement of the body, we shall begin with the analysis of the movement of a single limb. Each limb moves about the joint to which it is connected. In this movement

(assuming that the limb possesses complete freedom of movement about the joint) three elements are discernible:

(a) The centre of movement (the joint).

(b) The axis of the limb (AXL).

(c) The axis of movement (AXM).

If the joint is considered as a centre of movement fixed in space, then clearly every movement of the limb about it is in fact ‘spherical’ (takes place within a sphere).

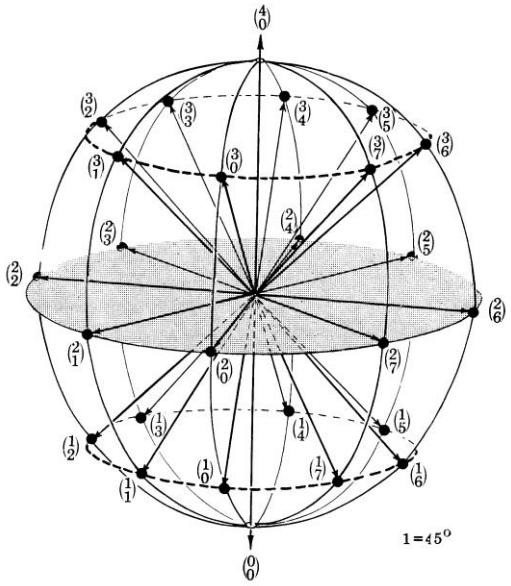



*Fig 2. The spherical system of reference*

The system of reference for positions and movements is therefore spherical 1Fî9.21. Its horizontal equatorial plane is divided by a given interval, thus establishing horizontal directions (positions(. At each of these positions a vertical plane is posited. The vertical planes are divided by the same interval as the horizontal plane. The positions are numbered, beginning from 0, which is the vertically downward direction on the vertical plane, or horizontally forward on the equatorial plane. Positions can then be identified by stating the number of the horizontal component, which indicates the vertical plane in which the position lies; and above it, the number of the vertical component, indicating the place of the position on this vertical plane. The two are enclosed in parentheses. Example: $\binom{2}{0}$

**‘Light’ and ‘Heavy’ limbs**

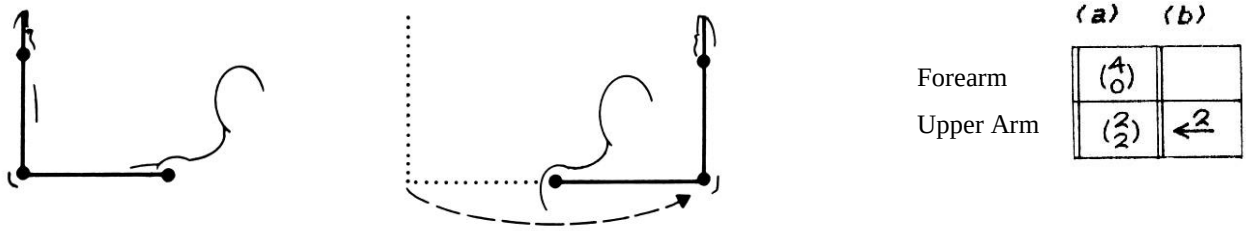
The body may be seen as an orchestra, every limb being used as a separate instrument. Although independent in some respects, these instruments are interconnected and their movements influence one another. Consider for example, the forearm – a limb which is connected at both ends to other limbs. The forearm is connected at one end to the upper arm, and at the other to the hand. When the upper arm moves, it carries with it the forearm and the hand connected to it; that is to say, it changes the relation of the forearm and hand to other members of the body. However, if the hand noves, it does not carry the forearm with it. The forearm does not carry the upper arm, but it does carry the hand.

For the purposes of the present analysis, the degree of interdependence of the limbs will be described by using figuratively the terms ‘light’ and ‘heavy’. Thus a limb which carries another will be referred to as heavier than the lighter limb, which it carries. The limbs are thus divided into relative classes: heavy and light. Every limb is heavy in relation to any limb which it carries while moving, and light in relation to any limb by which it is being carried. The terms light and heavy may therefore be used of any limb, and they indicate whether the limb is moving actively or passively.

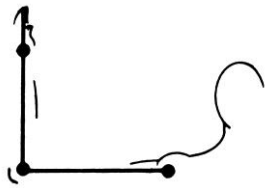
The lighter limbs change their relation to the system of reference passively, as a result of the movement of the heavier limbs. Nevertheless, a lighter limb can, at the same time that it is being carried by a heavier limb, also move independently, and this does not contradict the rule; the path which that limb creates while moving is then the result of a double movement. (See example illustrated in Fig.3.) In fact, it may be the result of three or four simultaneous movements, as for example when the hand moves independently while being carried by a separate movement of the forearm, which is at the same time carried by the upper arm, also moving independently but which is again carried by a movement of the upper body. Usually, in writing EW movement notation, the movement of each part is analysed and written as if the heavier limb were at rest.

It should be remembered that any limb may be at the same instant both heavy and light; or it may change during a sequence of movement, being at one moment heavy and then becoming light, or vice versa.

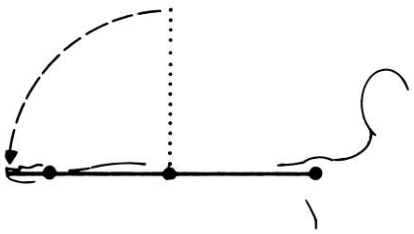
*Fig. 3. Simultaneous movement*




*(a)* *(b)*



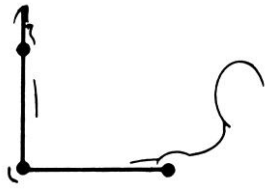
*(a)*



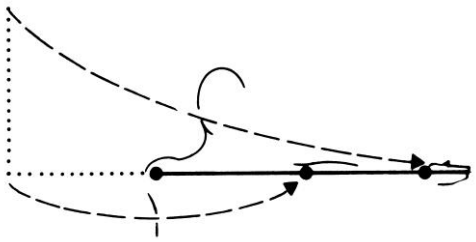
*(c)*

(c)

| | |
|---|---|
| Forearm | $\binom{4}{0}$ (2)↓2 |
| Upper Arm | $\binom{2}{2}$ |



*(a)*



*(d)*

(d)

| | |
|---|---|
| Forearm | $\binom{4}{0}$ (2)↓2 |
| Upper Arm | $\binom{2}{2}$ ←2 |

*(a) Initial position of forearm and upper arm.*

*(b) Fron position (a), Horizontal – plane movement in the upper arm alone.*

*(c) Fron position (a), plane movement in the forearm alone.*

*(d) Fron position (a), the two movements performed simultaneously.*

In this paper we deal only with two limbs, one heavy and the other light, and with the lowest degree of simultaneous movement: the heavy limb moves in rotatory, plane and conical movement; the light limb has no independent movement, but its angular relation to the heavy nevertheless determines its position and location, creating a distinct separate path in its transition through space as the heavy limb moves. Note that if a limb group is extended and maintained in a straight line, each segment being at an angle of 180 degrees to its neighbour, only movements and positions of the heavy segment are written, as the whole group then behaves as a single limb.

**Individual systems of reference**

The positions and movements of each individual part of the body are related to a system of reference centred upon the joint about which the part moves. Thus the body is regarded as a polyspherical structure. The position of a limb is defined by identifying the line (coordinate) in the system of reference to which the axis of the limb corresponds. The centre of the individual system of reference is made to coincide with the articulation of the limb and its heavy neighbour, so that the position is established as the line from the joint ‘outward’.

When a limb is being carried - eg. the lower arm by movement of the upper arm - it necessarily changes its location in space. Its individual system of reference will also be carried by the heavy limb, the upper arm, because the joint between the two limbs is the centre of the individual system of reference of the passive limb. However, the orientation of the system of reference does not change: the horizontal plane remains horizontal, the vertical planes vertical. Furthermore, the direction zero remains parallel to the direction selected as ‘absolute zero’ at the outset (Fig.4). All of this applies even when there has been a rotation of the whole body around the vertical axis, thus changing its front in relation to the system of reference.

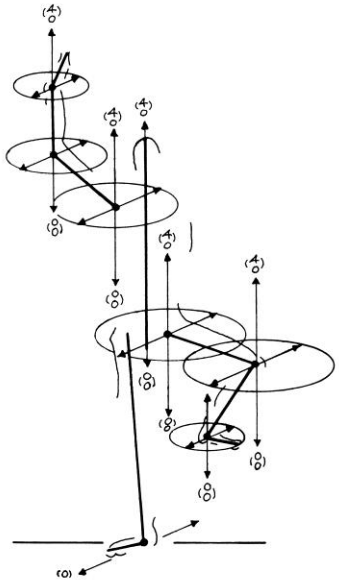


*Fig. 4: Individual systems of reference*

**Simultaneous Movement**

In the examples which follow, two adjacent limbs are represented.

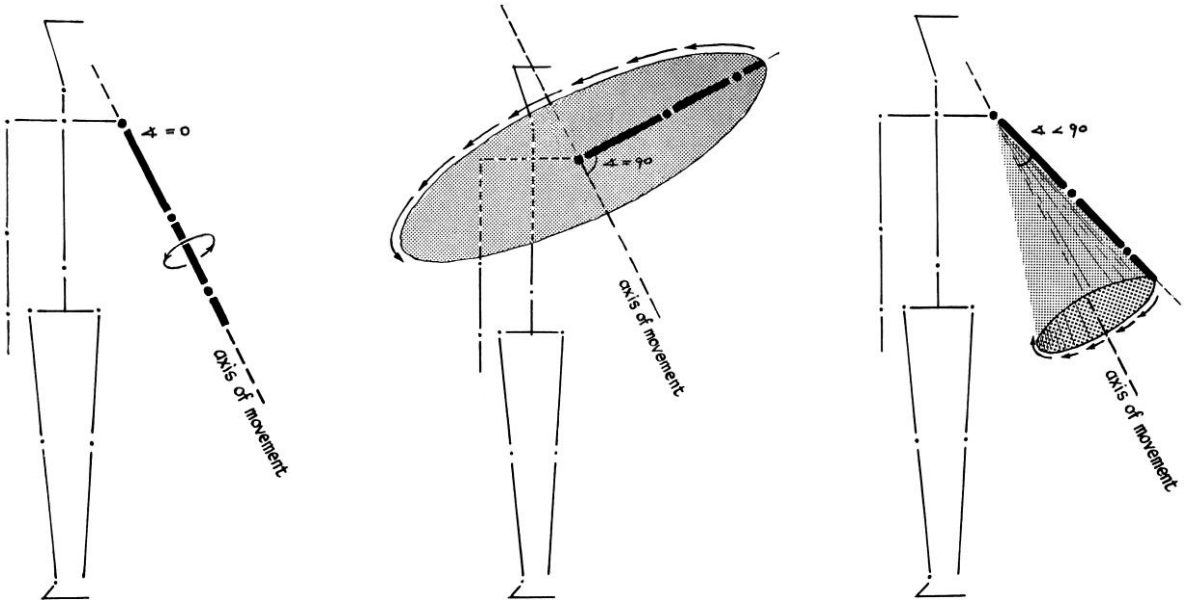
The axis of the heavy limb moves in the three types of movement:

(a) rotatory movement, in which the axis of the limb is in the same position as the axis of movement, and the limb revolves about the latter without changing its location in spare;

(b) plane movement, in which the axis of the limb moves at a constant angle of 90 degrees to its axis of movement; and

(c) conical movement, in which the angle between the axis of the limb and the axis of movement is any angle other than 90 degrees and zero.

The axis of the light limb segment is maintained statically at various angular relationships to the axis of the heavy limb. Its location in space changes passively, as a result of the movement of the heavy limb.




*Rotatory movement* *Plane movement* *Conical movement*

*Fig. 5. The types of movement*

The following examples are illustrated by computer plots of the movements of the axes of the two limbs. They consist of views from different angles: Either

(a) from the front, ie. looking from zero on the horizontal plane, towards direction (4); or

(b) from the side, looking from (6) on the horizontal plane, in direction (2); or

(c) from above, looking down on the horizontal plane; or

(d) from a forward diagonal, looking towards (3) from (7) ( See Fig. 6).

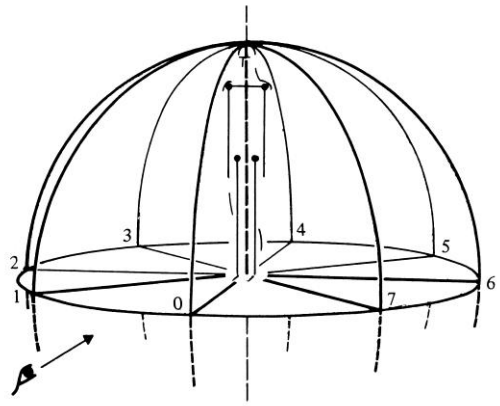



*Fig. 6. Directions on horizobtal plane*

A. Heavy limb – rotatory movement (axis of limb coincides with axis of movement)

1) Light segment is at 90 degrees to heavy.

The light (static) segment is maintained at an angle of 90 degrees to the heavy; a plane surface is passively produced by the axis of the light segment. The orientation of this plane (horizontal, vertical or oblique) is determined by the starting positions of the axes of the heavy limb segment, defined in the system of reference (SR) . The plane is necessarily also at 90 degrees to the axis of movement of the heavy segment.

(Figs. 7. 8. 9.)

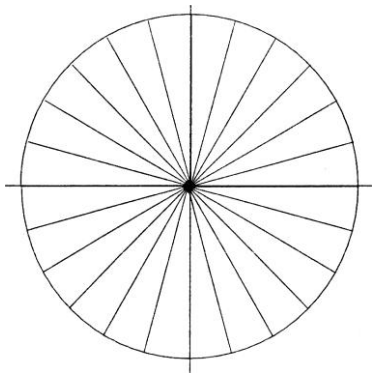


*Fig. 7. Seen from above*

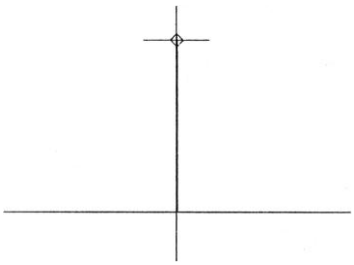


*Fig. 8. Seen from the side*

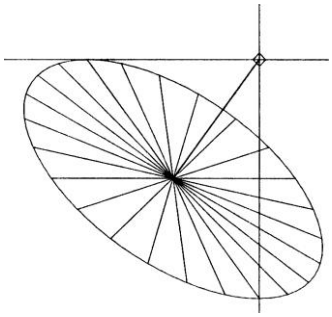


*Fig. 9. Seen from the front*

2) Light limb is at an angle other than 90 degrees.

If the angle between the axes of the segments is made greater or less than 90 degrees (so that the angle between light AXL and the AXM is correspondingly less or more than 90 degrees), the axis of the light segment will passively produce a conical path of movement. The orientation of this conical surface will be determined by the position of the heavy limb, defined in the SR, and the circular trajectory will be correspondingly horizontal, vertical or oblique (Figs .10 ,11 ,12).

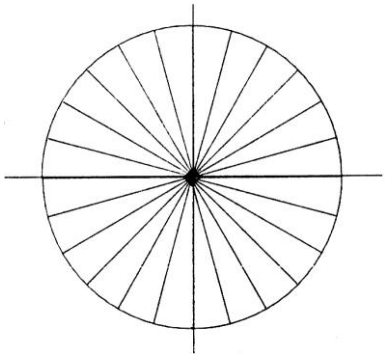


*Fig. 10. Seen from above*

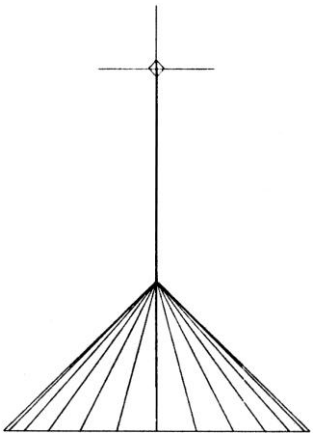


*Fig. 11. Seen from the side*

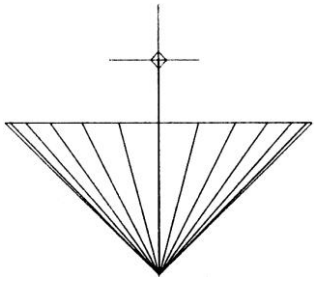


*Fig. 12. Seen from the front*

These examples offer confirmation of the validity of the classification of movement into plane, conical and rotatory, since although the light limb is here represented as moving passively, it can be seen as a simulation of active movement, so to speak 'borrowing' the AXM of the heavy limb.

B. Heavy segment - plane movement (axis of limb at 9P degrees to the axis of movement)

Note that given any series of positions of a single limb, plane movements constitute the shortest path from one to another.

We give three basic examples of cases in which the heavy limb moves in a plane, and the light limb is maintained in a fixed relation to it:

1) The position of the light limb is in the same plane as the movement of the heavy limb (which is at 90 degrees to the AXM). In this case, the path swept out by the light limb will also be planar. The change of position of the light limb will be in direct correspondence to the change of position of the heavy limb. For example: the heavy limb starts from the vertically downward position $\binom{0}{0}$ and the light limb is horizontally forward at $\binom{2}{0}$ A movement of the heavy limb through 180 degrees to upward vertical position $\binom{4}{0}$ will then carry the light limb passively through 180 degrees to position $\binom{6}{0}$. The distal extremity of the light limb traces a circle concentric to that of the heavy limb (Fig. 13).

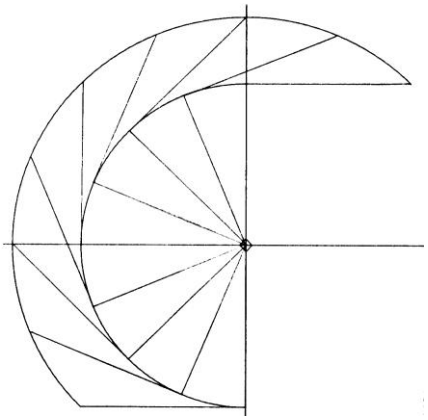


*Fig. 13.*

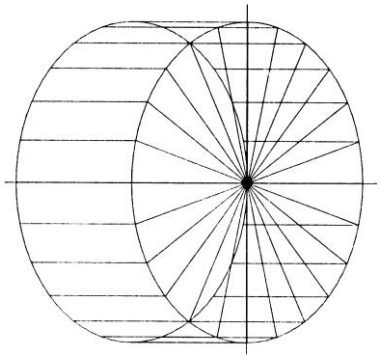


*Fig. 14.*

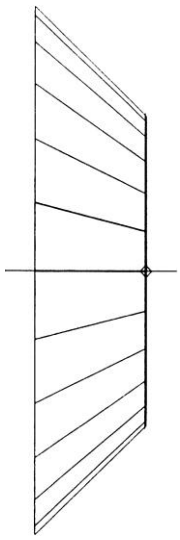


*Fig. 15.*

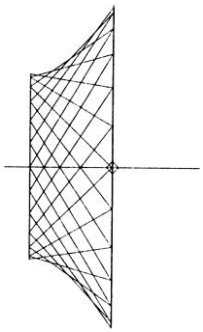


*Fig. 16.*

2) The position of the light limb is parallel to the AXM (and therefore at 90 degrees to the heavy limb).

The path of the carried light limb will have the form of a regular curved surface, which may be described as a cylinder, or part of a cylinder. The distal extremity of the limb describes a circle parallel to the plane of the movement of the heavy limb. Although its place in space changes continuously, the light limb remains in the same position relative to the coordinates of the SR, throughout the movement. This, and the fact that a continuously changing surface of the light limb is presented to the AXM, makes it analogous to rotatory movement (Fig.14.).

3) The starting position of the light limb lies in the same plane as the AXM of the heavy limb, but is neither in the same plane as the movement of the heavy limb, nor parallel to the axis of movement of the heavy limb. A curved surface is then swept out by the carried light limb; in the case of Fig.13, this surface has the shape of part of a cone, sliced (parallel to the base) by the plane of the movement of the heavy limb. The distal extremities of the light limbs trace circular paths parallel to the plane of the movement of the heavy limb (Figs. 15, 16).

C. Heavy limb – conical movement (axis of limb not at 90 or zero degrees to AXM)

We give three basic examples of cases in which the heavy limb moves in a conical movement, and the light limb is maintained in a fixed relation to it:

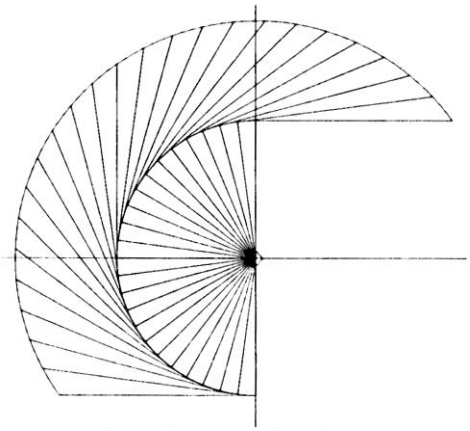


*Fig. 17.*

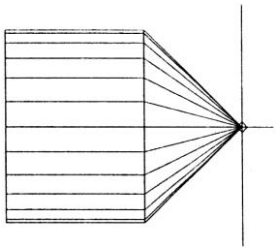


*Fig. 18.*

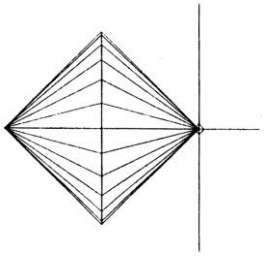


*Fig. 19.*

1) The position of the light limb is at 90 degrees to the AXM.
In this case, the path swept out by the light limb will be planar. The change of position of the light limb will be in direct correspondence to the change of position of the heavy limb. For example, a movement of 90 degrees in the heavy limb will produce a (passive) change of 90 degrees in the position of the light limb (Fig. 17).

2) The position of the light limb is parallel to the AXM.
The path of the carried light limb has the form of a cylindrical surface. The distal extremity of the limb describes a circle parallel to the base of the cone produced by the movement of the heavy limb. Although its place in space changes continuously, the light limb remains in the same position relative to the coordinates of the SR, throughout the movement (Fig. 18).

3) The starting position of the light limb lies in the same plane as the AXM
but is neither parallel, nor at 90 degrees to it.
A curved surface is then swept out by the carried light limb; this surface has the shape of a cone as in (Fig.l9), or of a truncated cone. The distal extremity of the light limb traces a circular path parallel to the base of this cone.

Comparing the cases in which the heavy limb moves in conical Movement with those in which it moves in plane movement, it is seen that there is no essential difference in the shapes of the paths of the light limb in the corresponding examples. The determining factor is found to be not the surface (cone or plane) swept out by the heavy limb in its movement, but the relation between the axis of the light limb and the axis of movement of the heavy limb.

D. Heavy limb – Plane and conical movement together with rotatory movement:

Plane and conical movement cannot be performed by the same limb at the same time, since our definitions of these two types of movement make them mutually exclusive. However, both plane movement and conical movement can be combined with rotatory movement, since a limb can perform rotatory movement while also moving about an axis exterior to itself. Despite the

seeming complexity of this movement combination, it is nevertheless one which constantly recurs in the actions of the human body, to which it is more natural than pure and conical movement.

In the final part of the present paper we shall see examples in which the light limb is maintained at a constant angle to the heavy, and the latter produces either conical movement or plane movement. But because in these examples the heavy limb also rotates, the light limb does not produce circular trajectories or topologically simple curved surfaces. Since it may not be possible to refer to the latter as cones, cylinders and the like, a different terminology is called for, but that is not a subject for this introductory essay.

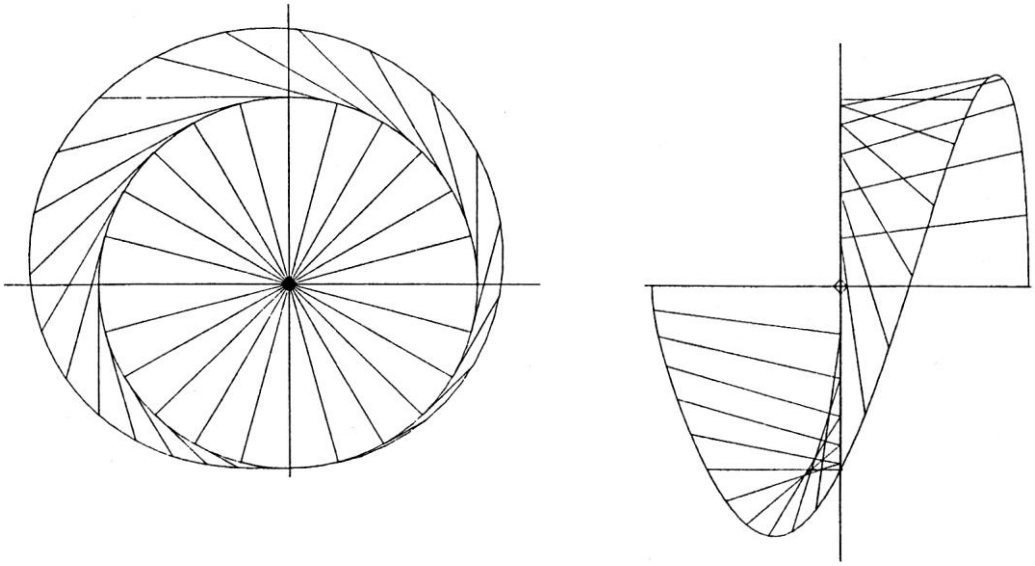


*Fig. 20a. The two projections depict the same path of two moving limbs. The heavy limb noves in a plane, at the sane time rotating through 180 degrees; the light limb is maintained at an angle of 90 degrees to the heavy.*

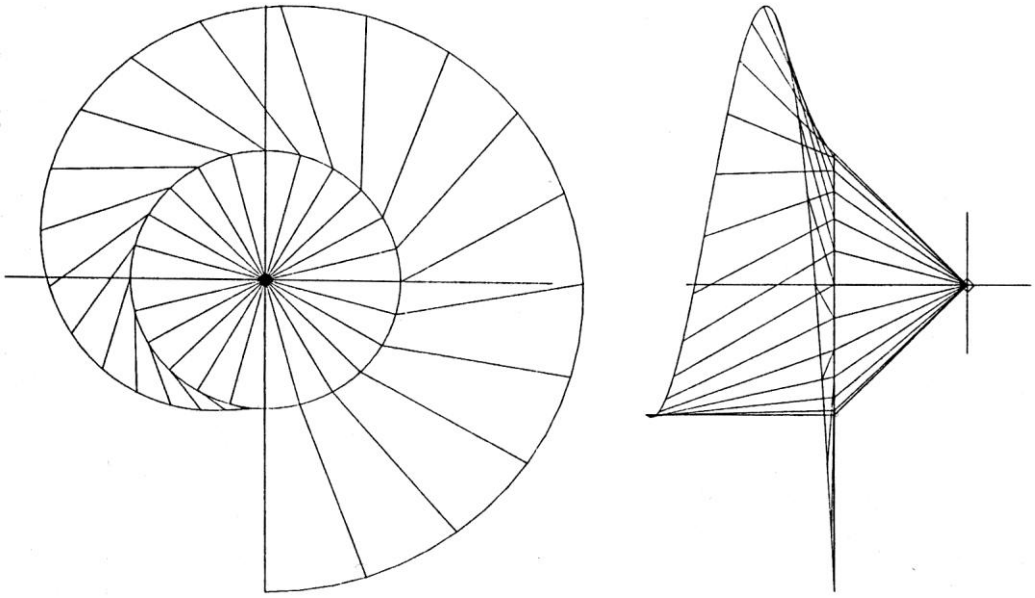


*Fig. 20b. The two projections depict the path of a heavy limb moving in a conical movement and rotating through 180 degrees, while the light limb is naintained at an angle of 45 degrees to it.*

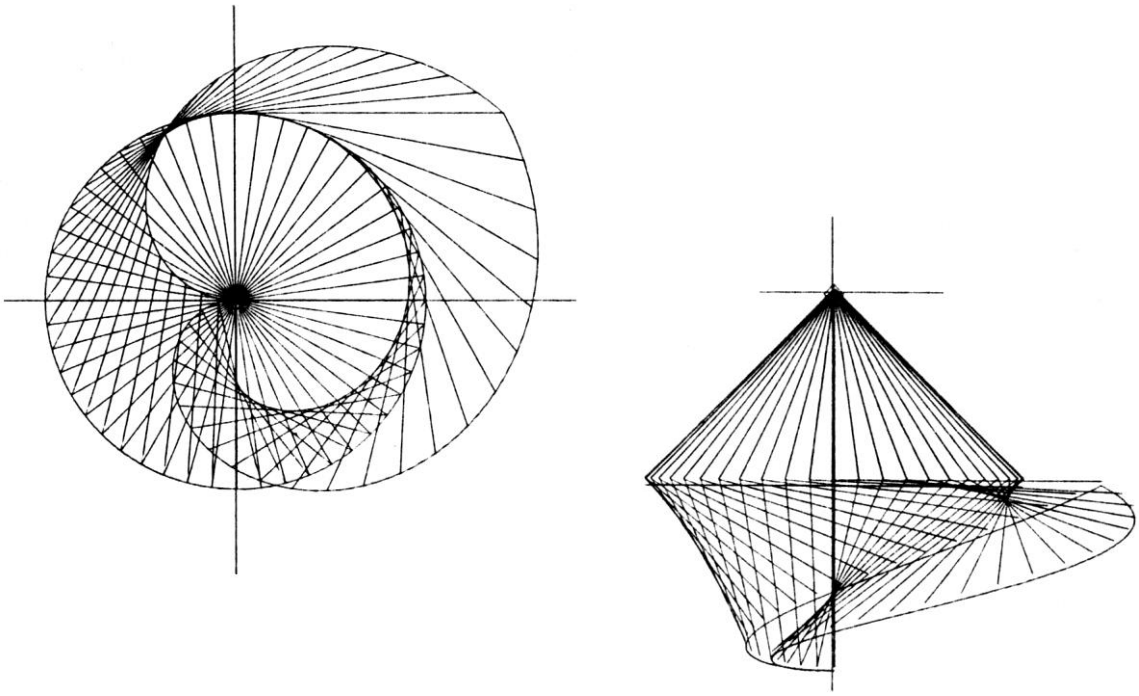


*Fig. 21a. The two projections show the path of a a heavy limb in conical movement, rotating through 90 degrees and then through 45 degrees in the opposite direction.The angle between the two is 90 degrees.*

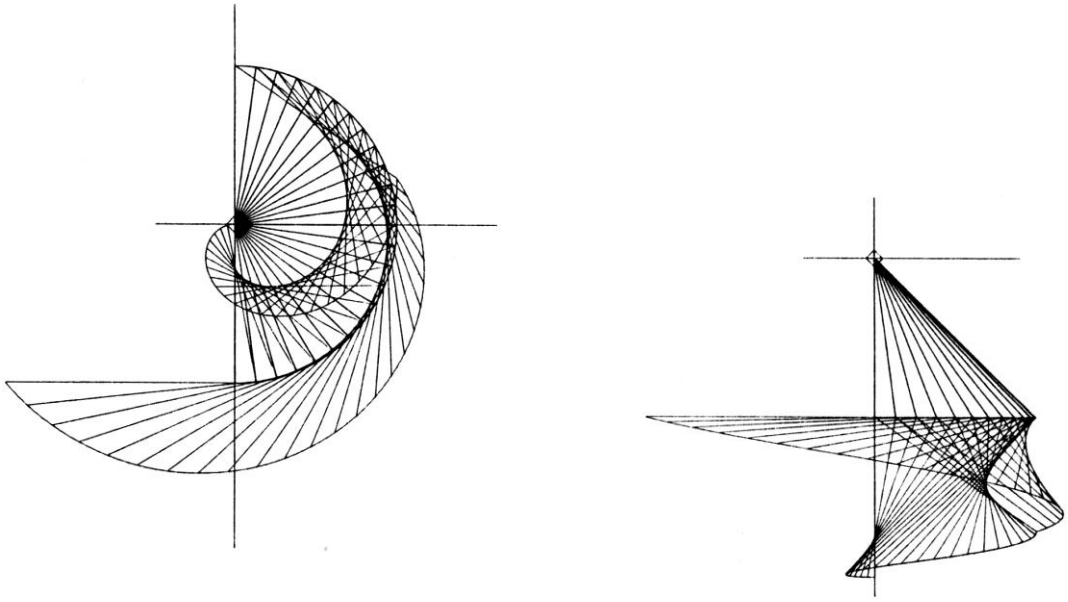


*Fig. 21b. The two projections depict the path of a heavy limb performing 180 degrees of conical the movement, followed by 180 degrees of conical movement in the contrarydirection,while continuously rotating through 90 degrees in onedirection. The light limb is maintained at 90degrees to the heavy.*

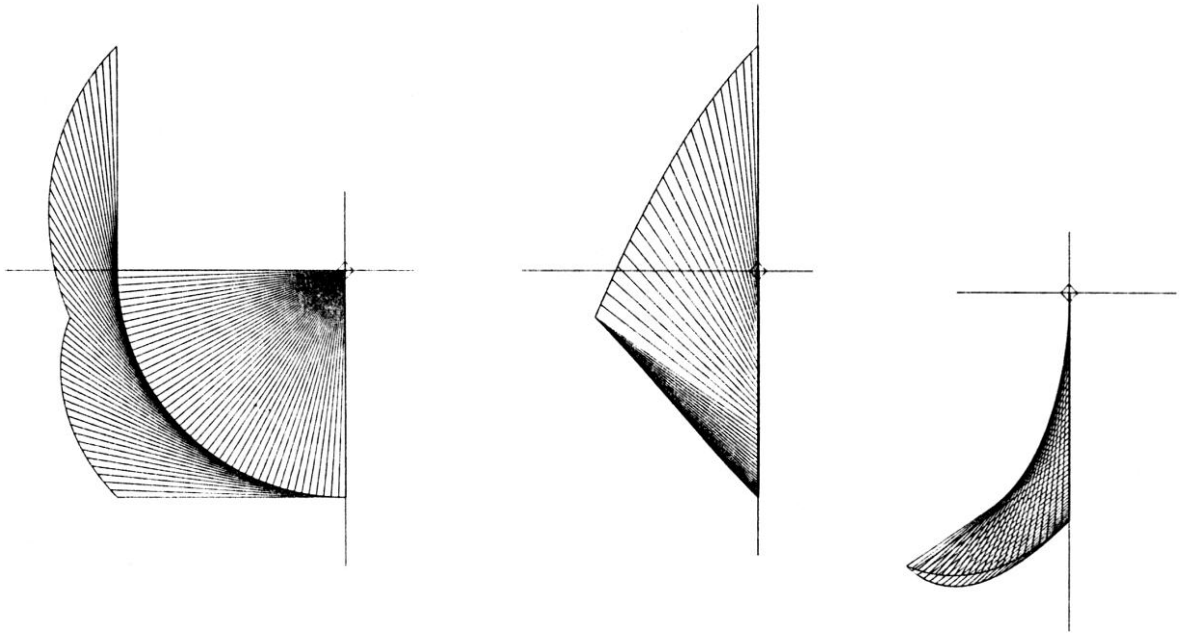


*Fig. 22. Three projections (on planes at 90 degrees to one another) of the path of a heavy limb moving in a plane, while rotating through 45 degrees and then through 45 degrees in the contrary direction, while the light limb is maintained at 90 degrees to the heavy. This is close to the physical reality of the human body, because the intervals are feasible for many adjacent limbs, such as the upper arm and forear.*

**Conclusion**

We have presented an introduction to a study of movements producing unfamiliar curves and surfaces. We may ask what practical applications such a stud, – can have beyond its own aesthetic interest. It might be of use in the field of robotics now much in vogue, but its most immediate value lies in the contribution to visual awareness of the nature of movement, and in improving the understanding of unfamiliar modes of movement.

The psychophysical needs which movement notation attempts to meet, involve the analysis and re-analysis of the movement of the body limb by limb. It may appear that this procedure is taken to exaggerated lengths if judged by comparison with the motor behaviour of human beings in daily life. The development of motor accomplishments usually tends towards a state in which analysis of the movement of the limbs is not conscious but such as to allow the rapid, fluent and unthinking skill of goal-oriented movement which best serves both routine and artistic requirements.

The breaking down of movement into components through which it is possible to see what each part of the body does, constitutes something of a revolution. This can be undertaken only by a willing adult.

This essay is an attempt to capture the fugitive element of movement . The examples are ideal models; they are not representations of anything ‘real’ to be seen, although they do exist as classes of possible syntheses in the capacity of movement of the body. They may seem only distantly connected with anything that happens in real life, but are nevertheless illustrative of an idea which is realisable when interpreted by the moving body. This suggests the possibility of a meta-notation, based upon knowledge of the detailed data encompassed in the basic notation.

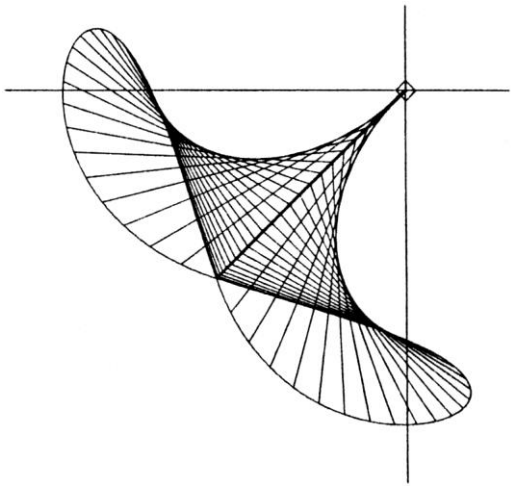


*Fig. 23. Another view of the plot shown in figure 1. It shows the heavy limb moving through 90 degrees in a vertical plane and then back through 90 degrees, the light limb in the meantime rotating through 360 degrees. The angle between the limbs is 90 degrees.*