UNIVERSITY OF WATERLOO COMPUTER SCIENCE DEPARTMENT
UNIVERSITY OF WATERLOO COMPUTER SCIENCE DEPARTMENT
UNIVERSITY OF WATERLOO COMPUTER SCIENCE DEPARTMENT
UNIVERSITY OF WATERLOO COMPUTER SCIENCE DEPARTMENT

Rotations and Benesh Movement Notation Research Report

Don Herbison-Evans

CS-86-64

December, 1986

Rotations
and
Benesh Movement Notation

Don Herbison-Evans

Department of Computer Science

University of Waterloo

Presented at the Meeting of
Canadian Benesh Community
December 3, 1986

Summary

An arbitrary orientation of a body part in space needs up to three angles to specify it. The paper illustrates the results of combining two and three successive rotations in a variety of ways.

There are twelve choices of combinations of successive axes for three angles. The BMN choice is YZX if unmoving axes are used, or XZY if new axes are used at each sub-stage.

Some conclusions about the teaching of BMN are drawn from the investigation.

Rotations and Benesh Movement Notation

Introduction

As an antecedent to discussing the theory of projections (3) in Benesh Movement Notation (BMN), it is necessary to clarify some ambiguities in the representation of simple rotations. Consider a simple part of the body such as the head. Let us define three perpendicular axes for possible primitive rotations (see figure 1):

X : parallel to a line through the ears, giving a movement in the sagittal plane (nod)

Y : parallel to the cervical spline, giving a movement from side to side in the horizontal plane (twist)

Z : parallel to a line joining the nose to the back of the head, giving a movement from side to side in the coronal plane (tilt)

Double Rotations

Two rotations in succession give a different orientation of the head depending on :

(a) which rotations are chosen
(b) the order in which they are chosen

This is illustrated in figure 2 where equal angles of 45^o have been applied to all combinations of choices of two axes. Note that there are three possible first axes, and then four possible second axes, making twelve possible choices. The suffix 0 on an axis means that it is an axis of the head before any rotations were applied; the suffix 1 on an axis means that it is an axis of the head after a rotation has been applied. Note that the rotations are described in left to right order, so that $X_0\,Y_1$ means rotate about the initital X axis, and then about the new Y axis.

In figure 2, each head has the approximate Benesh symbol representing its rotation written above it.

It may be observed that there are only six differing orientations of the head produced by the twelve choices, each orientation occurring twice. This is because the result of applying two rotations, each about the initial axes (sub 0), is the same as applying the same rotations in the opposite order, with the new second one being about the appropriate new axis (e.g.$X_0Y_0{=}Y_0X_1$). Note that the simplest orientations from this figure to notate in BMN are Y_0X_0, Z_0X_0 and Y_0Z_0.

Triple Rotations

It may be shown that any orientation in space of a rigid object (e.g., the head) may be specified as the result of at most three successive rotations about perpendicular predefined axes (1). Figure 3 shows examples of the result of three successive rotations of 45° about each combination of choices of three fixed axes.

The three angles in the BMN head sign are indicated by the left-right tilt angle of the sign axis, the left-right asymmetry of the sign cross piece, and the vertical position of the sign cross piece (2).

Note that in figure 3, all the orientations of the head are different. Only one of them conforms to the application of three successive rotations as defined in BMN, namely $Y_0 Z_0 X_0$. This may have some application in teaching BMN, for the distinction between this choice and the other eleven possible choices must be clarified in the mind of a student before that choice may be said to be understood.

If the rotations are defined about the new axis at each stage in the succession, a different set of orientations are obtained (see figure 4). Note that one of them ($X_0 Z_1 Y_2$) is identical to the BMN choice from figure 3.

If the second rotation is defined to be about the new axis, but the third is about an original unshifted axis, yet another set of choices is obtained with a new set of orientations (see figure 5). Again, one of these ($Z_0 Y_1 X_0$) is identical to the BMN choice.

If the first two rotations are performed about initial axes, and the third one about a new axis, another set of choices is obtained (see figure 6). Again, of these is identical to the BMN choice $Z_0 X_0 Y_2$. It is possible to show that there are an infinite number of ways of combining three primitive rotations. The simplest four examples of these have been presented in figures 3, 4, 5 and 6.

Conclusion

The way that BMN notates arbitrary orientations of some part of the body may be described equivalently as:

	$Y_0 Z_0 X_0$:	twist, then tilt, then nod about unmoving axes
or	$X_0 Z_1 , Y_2$:	nod, then tilt, then twist, each about the new axis each time
or	$Z_0 Y_1 X_0$:	tilt, then twist about the new Y axis, then nod about the original X axis
or	$Z_0 X_0 Y_2$:	tilt, then nod about the original X axis, the twist about the new Y axis.

An infinite number of other descriptions are equally valid.

There is no unique way of choosing a combination of rotations. There is no unique way of describing one choice for combined rotations. Any axis may be the first one. The axis used at any stage may be an original unmoved one, or a new one defined in the new (incompletely rotated) position.

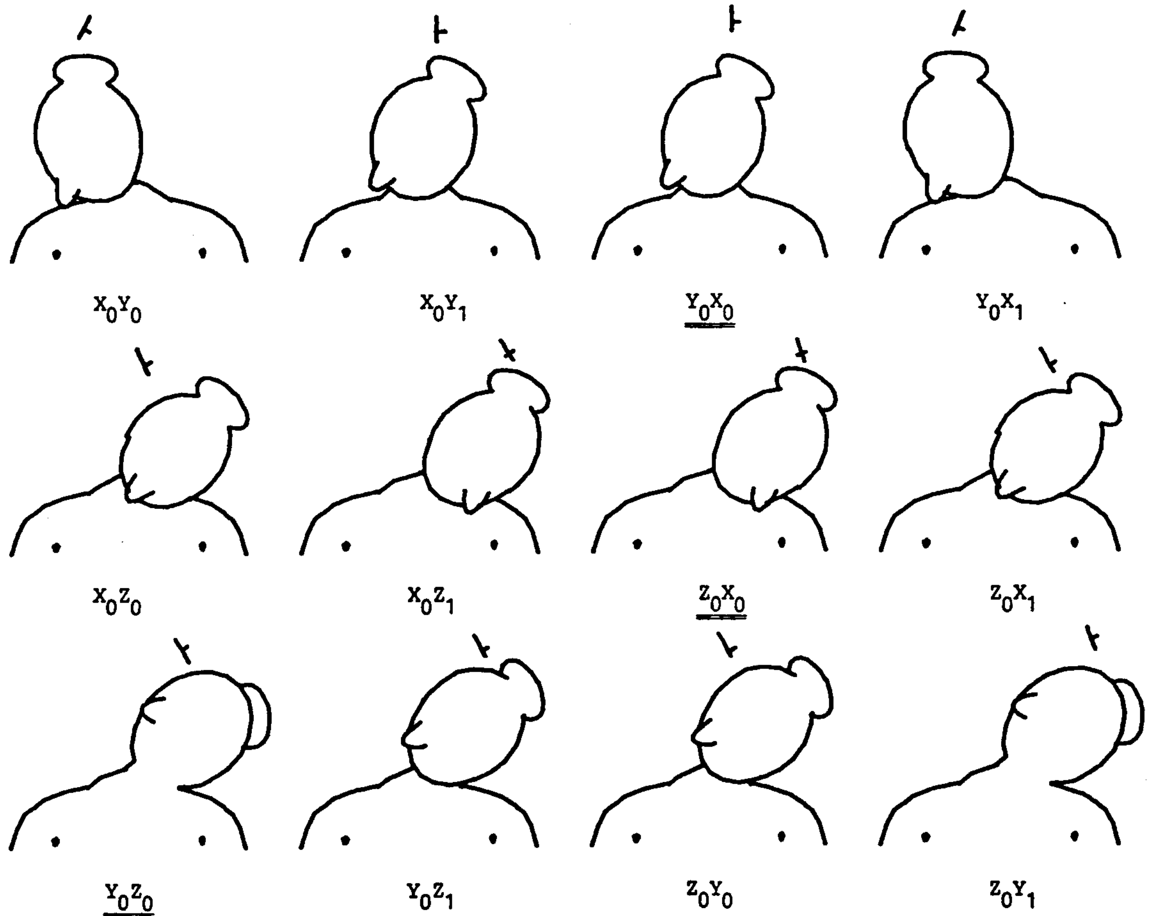
In teaching the BMN choice, teachers might bear in mind that different students may find it more natural to describe the choice in a way different to (from) that which is most natural for the teacher. It is of course important that a student's choice corresponds to the BMN choice.

References

(1) Goldstein, H., "Classical Mechanics", Addison Wesley (2nd Edn). (1980), Chapter 4 and Appendix B.

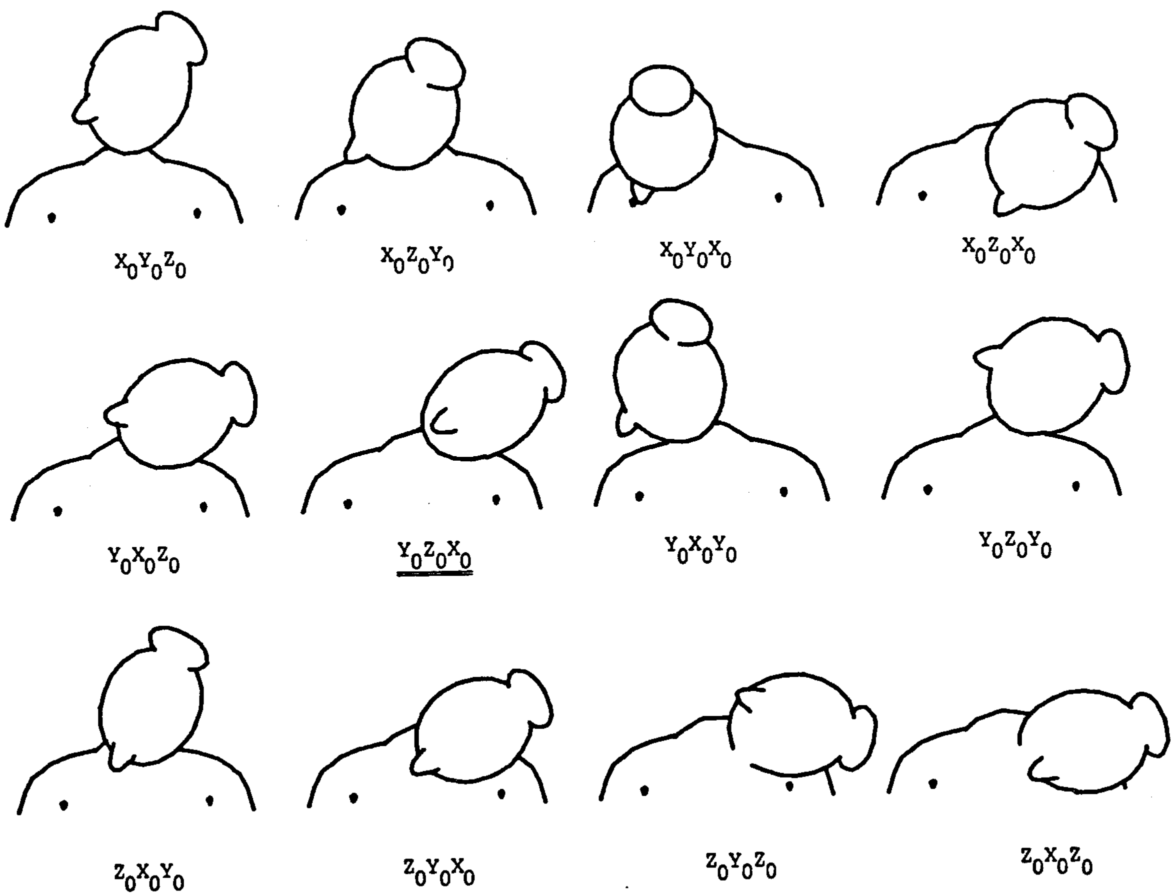
(2) McGuinness-Scott, J., "Movement Study and Benesh Movement Notation", Oxford University Press (1983) p.24.

(3) Russell, K., "Projection, Part 1: How the Notation Represents 3 Dimensional Movement on a Two Dimenstional Stave", The Technical Journal, Benesh Institute (London) (1980).



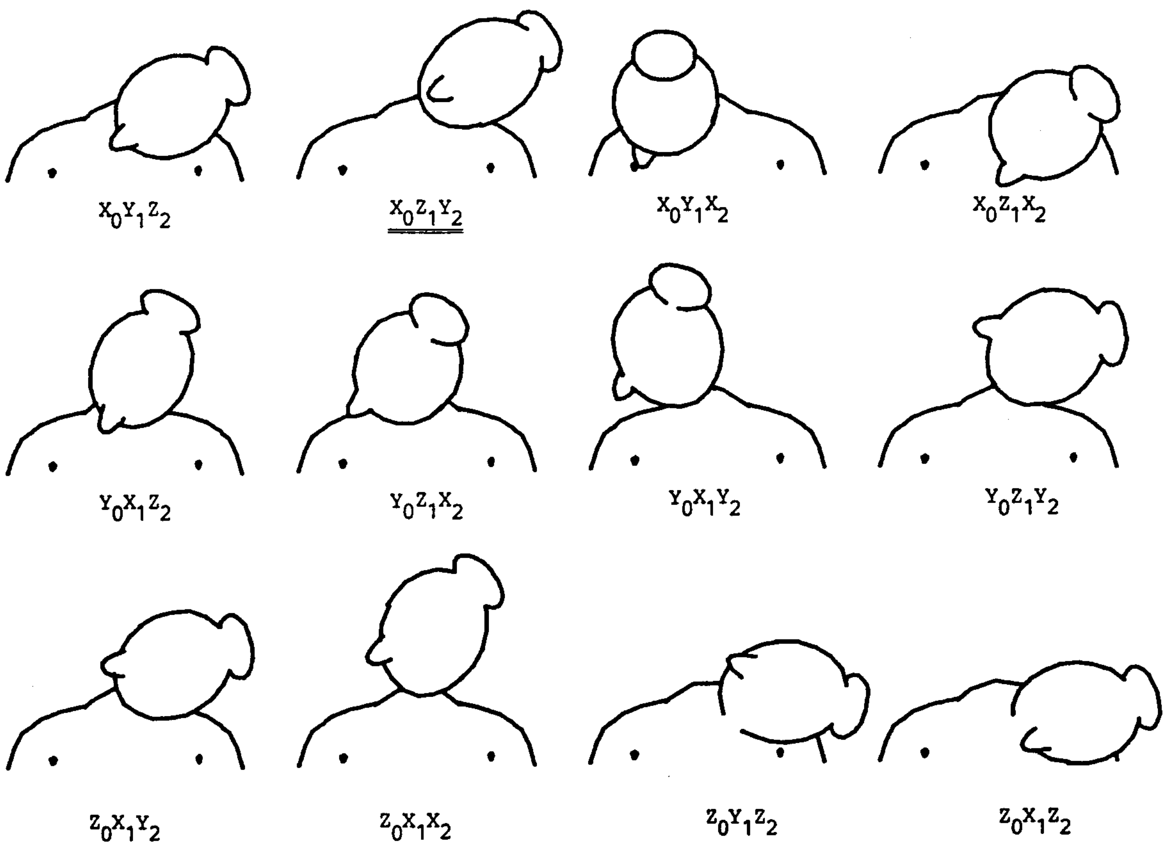
The application of two successive rotations
of 45° about different sequences of axes,
the axes being figures in space.

Figure 2



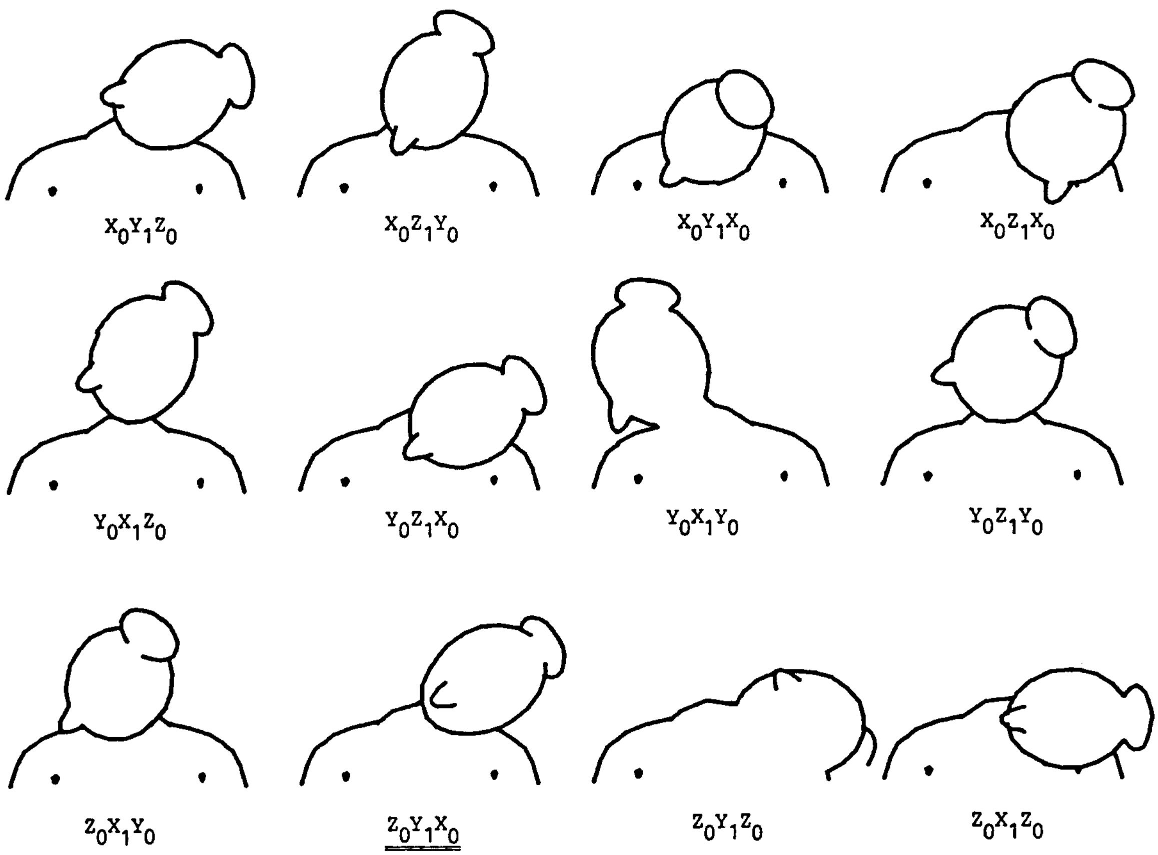
The application of 3 successive rotations of 45° about different sequences of axes fixed in space.

Figure 3



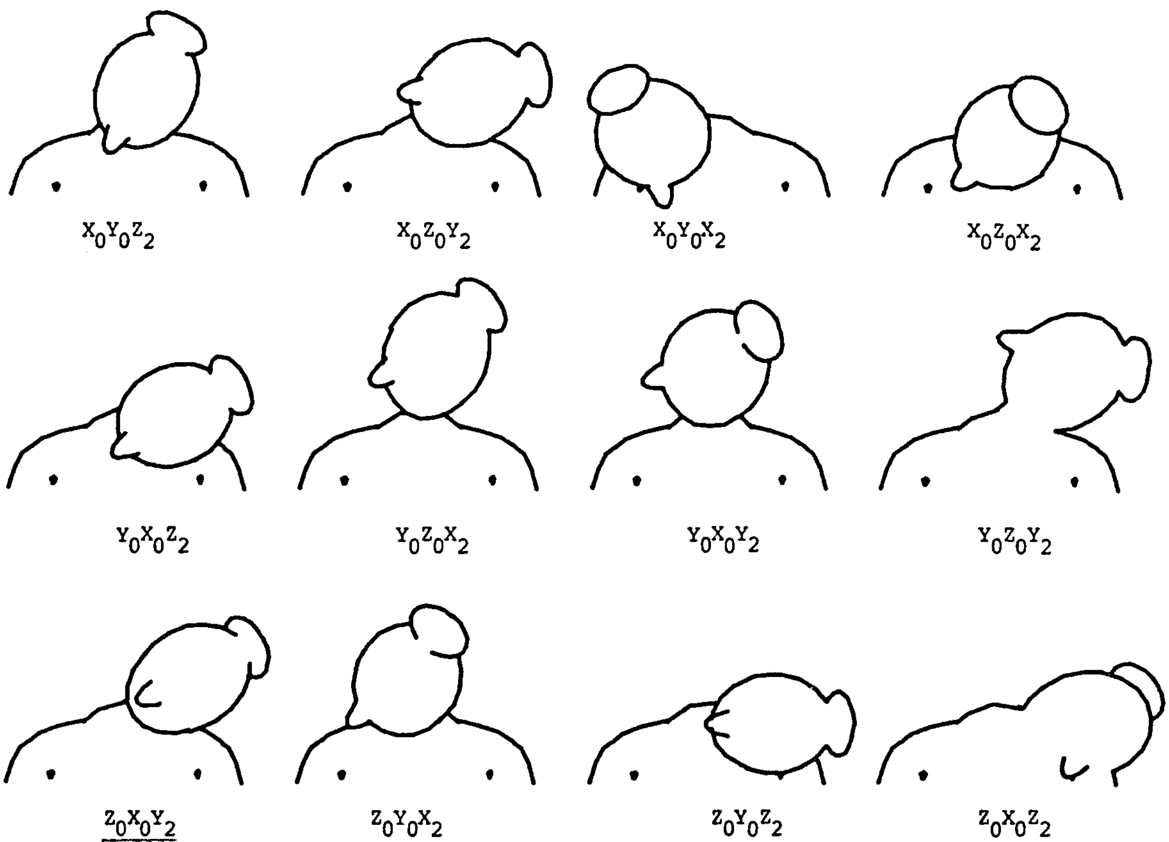
Three successive rotations, each about an axis of the head.

Figure 4



Three successive rotations, with the second about a new axis in the head, and the third about one of the original axes.

Figure 5



Three successive rotations: the first two about fixed axes in space, the third about an axis in the head.

Figure 6