A Method for Analyzing Fundamental Kinesiological Motions of Human Body by Applying Interpretive Structural Modeling (ISM)

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Summary

The objective of this paper is to analyze interconnectedness of kinesiological motions by applying a well-known systems modeling approach called the Interpretive Structural Modeling (ISM). This approach is applied to the previously proposed *Somatic Balance Restoration Therapy* (SBRT), developed by one of the authors and offers a safe way in correcting imbalances and distortions that occur in the human body. The human body is a complex system composed of over 200 bones and 630 muscles that comprise the musculoskeletal system, which works not only as the frame for the human body, but as the engine of human kinetic motion as well. As a practitioner, one of the authors developed a visually identifiable diagnosis system through many years of accumulated therapy data. Although the authors attempted to find a more methodical approach to justify the SBRT by inventing the unique "Motion Diagram", a more systematic approach was required for a more efficient and homogeneous treatment. In this paper, the fundamental patterns produced by the SBRT are mapped into an n-square matrix of dimension 70, based on the Fundamental Body Motions and analyzed by the ISM. This will be followed by graphical representations and classification of the body motions into several categories based on the degree of interaction and activeness. The results has revealed a priority of the fundamental motion patterns which helps find the most effective motions to be used for identifying imbalanced or distorted parts from the larger dimension set.

Introduction

The human body is a large-scale, complex system that has evolved in order to allow humans to live with the greatest amount of ease. Through many years of research, traditional eastern medical practitioners have found that even slight imbalances and distortions of the human body are considered one of the major sources of acute and chronic musculoskeletal pain. (*Hashimoto, 1995*) The basic structure of the human frame consists of over 200 bones and 630 muscles and maintained by the integration of the four basic functions: proper breathing, a balanced diet, mental health and physical activity(*Sternburg, 2002).* Physical activity involves kinetic motions in the musculoskeletal system which are inter-linked and inter-connected when achieving a specific movement (*Floyd, 1998*). This process will continue without interruption until the motion is complete. Therefore, all bodily movements conform to this simultaneous motion, neutralization of interconnected motions, and linkages of the muscles. This is the engine of musculoskeletal motion system.

Biomechanically, this is the most effective linkage system since the combination of these kinetic motions allow the body to move in the most efficient and functional manner. To clarify the interconnectedness of all kinetic motions, one of the authors suggested dissecting all motions by the fundamental element of the human body motions. (*Kayo, 2004*) Observing each element in detail and recording them on special diagrams, the authors have established the systematic interconnecting relationship among the elements of fundamental motions. (*Kayo and Ohkami, 2007*) Furthermore, the authors have established a structure model of the human musculoskeletal system from the visual observation data in order to clarify inter-dependency among fundamental motion elements (*Kayo and Ohkami, 2008*). A system engineering method called the Interpretive Structural Modeling (*Warfield, 1973*) has been applied to this analysis.

The objective of this paper is to extract a limited number of fundamental patterns from almost countless motions of human body and to identify the interconnected relations among these motions, and thereby, to provide a practical approach to drive the kinesiology in finding and restoring imbalance and distortions of the human body. More specifically, noting that the body motions are extremely complex and multidimensional systems, the fundamental patterns produced by the SBRT are mapped into an n-square matrix of dimension 70, based on the Fundamental Body Motions and analyzed by the ISM, followed by graphical representations. This will be followed by graphical representations and classification of the body motions into four categories (based on the degree of interaction and activeness): passive, passive and active, active, and least interactive. A detailed observation of the results has revealed a priority of the fundamental motion patterns that helps to find the most effective motions to be used for identifying imbalanced or distorted parts from the larger dimension set. The approach and its applied results will turned out to be useful in finding and restoring distortion of the human body to serve as a non-invasive means to release unbearable pains.

The Data Analysis Flow with the Interpretive Structure Modeling

Fig.1 shows the data analysis flow employed in this paper. The first step is to prepare a data set to be fed to a dedicated computer program developed for this purpose of the ISM with extensive matrix manipulations. The second step is to construct an n-square matrix followed by matrix manipulations based on the Boolean Algebra. The third process is to derive a Reachability Set and an Antecedent Set according to the algorithms developed by the authors. Finally, all the results are output on a spreadsheet to view various statistical and graphical processes.

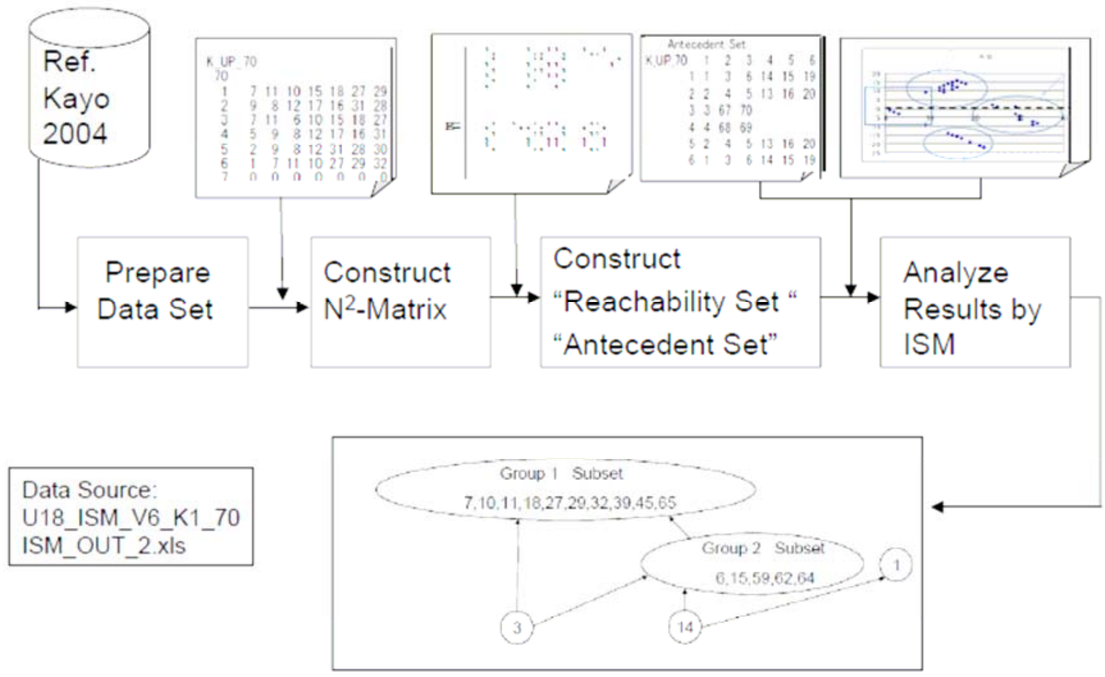

Fig.1 Data Analysis Flow with the OSM Process

Fundamental Body Motion Elements

Table 1 shows the 70 Fundamental Body Motion Elements which are identified and classified from the Observation Data. (*Kayo,2004*). The motions labeled by odd numbers are basically related to left-wise motion, while even numbers to right-wise.

Table 1 Fundamental Body Motion Elements

No	Body Motion Elements	No	Body Motion Elements
1	Turn neck towards right	36	Swing left knee (outer) - Toward left
2	Turn neck towards left Fig.5	37	Swing right knee (inner) - Toward left
3	Tilt head towards right	38	Swing left knee (inner) - Toward right
4	Tilt head towards left	39	Push right leg outwards (abduction)
5	Elevate right shoulder towards head	40	Push left leg outwards (abduction)
6	Elevate left shoulder towards head	41	Push right leg inwards (adduction)
7	De-elevate right shoulder away from head	42	Push left leg inwards (adduction)
8	De-elevate left shoulder away from head	43	Raise right knee up towards head
9	Raise right shoulder up off ground	44	Raise left knee up towards head
10	Raise left shoulder up off ground	45	Bend right knee and elevate up
11	Push right shoulder down against ground	46	Bend left knee and elevate up
12	Push left shoulder down against ground	47	Swing both lower legs toward right
13	Stretch right arm above head	48	Swing both lower legs toward left
14	Stretch left arm above head	49	Swing right lower leg towards outer
15	Extend right arm vertically	50	Swing left lower leg towards outer
16	Extend left arm vertically Fig.3	51	Swing right lower leg towards inner
17	Pull right arm towards body	52	Swing left lower leg towards inner
18	Pull left arm towards body	53	Right hip elevating upwards
19	Upward rotation of right arm	54	Elevate left hip upwards Fig.3
20	Upward rotation of left arm	55	Raise right knee
21	Downward rotation of right arm	56	Raise left knee
22	Downward rotation of left arm	57	Twist both legs to right
23	Twist both arms towards left	58	Twist both legs to left
24	Twist both arms towards right	59	Rotate right leg (outward)
25	Stretch right arm up	60	Rotate left leg (outward)
26	Stretch left arm up	61	Rotate right leg (inwards)
27	Shrink right hip bone towards head	62	Rotate left leg (inwards)
28	Shrink left hip bone towards head	63	Stretch right heel
29	Elevate right Hip bone up off ground	64	Stretch left heel
30	Elevate left hip bone up off ground	65	Shrink right heel up towards head
31	Push right hip bone down against ground	66	Shrink left heel up towards head
32	Push left hip bone down against ground	67	Stretch both right arm and right heel
33	Swing both knees toward right side	68	Stretch both left arm and left heel
34	Swing both knees toward left side	69	Raise right leg off the ground
35	Swing right knee (outer) - toward right	70	Raise left leg off the ground

Fig.2 illustrates the body motion elements of Table 1 (not exhausting). *Figures 3 and 4* show some of the more detailed body motion elements.

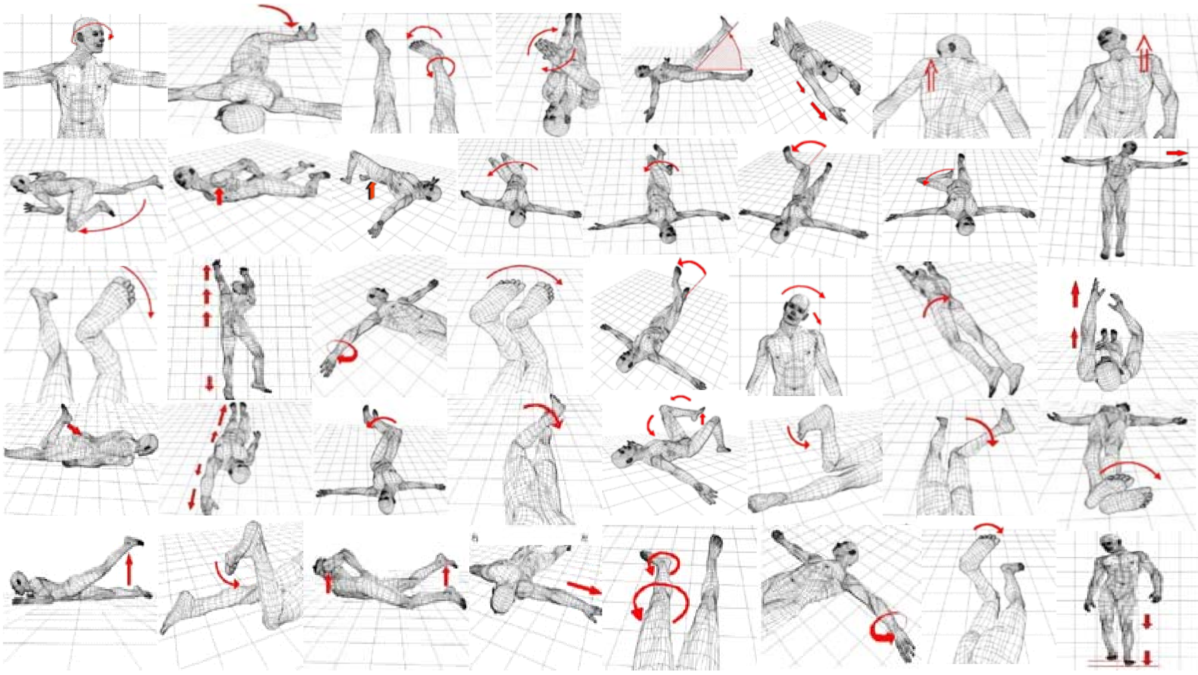

Fig.2 Fundamental Motion Elements (only 40 out of 70 patterns are shown)

Fig.3 Extend Left Arm Vertically (Motion Element No. 16)

Fig.4 Elevate Left Hip Upwards (Motion Element No. 54)

The n-square Matrix Generated by Observation Data

In most cases, any intended motion induces motions in other fundamental motions. The intended motion is called the **Active Motion** while the latter motion is called the **Associated Motion** as shown in *Fig.5*.

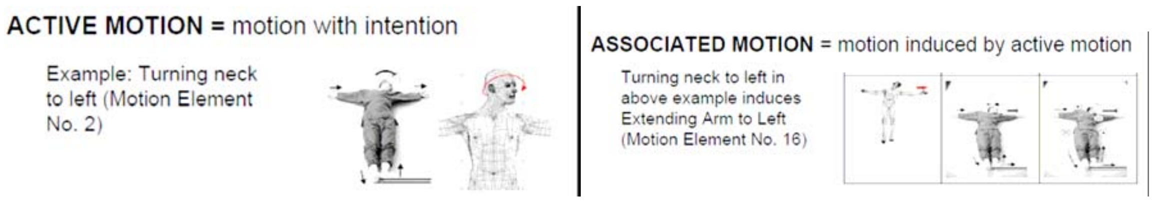

Fig.5 Active Motion and Associated Motion

All the data of *Table 1* obtained by the observations of human body motion as illustrated in *Fig. 2, 3 and 4*are integrated into a single matrix form. *Fig. 6* shows this matrix of dimension of 70 by 70. The numeric "1" in this matrix means that there exists iteration between the column and the row, while a blank space means there is no interaction. The rows correspond to the active motions, while the related columns to the associated motions induced by the active motions. This is called n-square matrix of dimension 70 by 70, which provides a basis for the Interpretive Structure Modeling (ISM).

B=

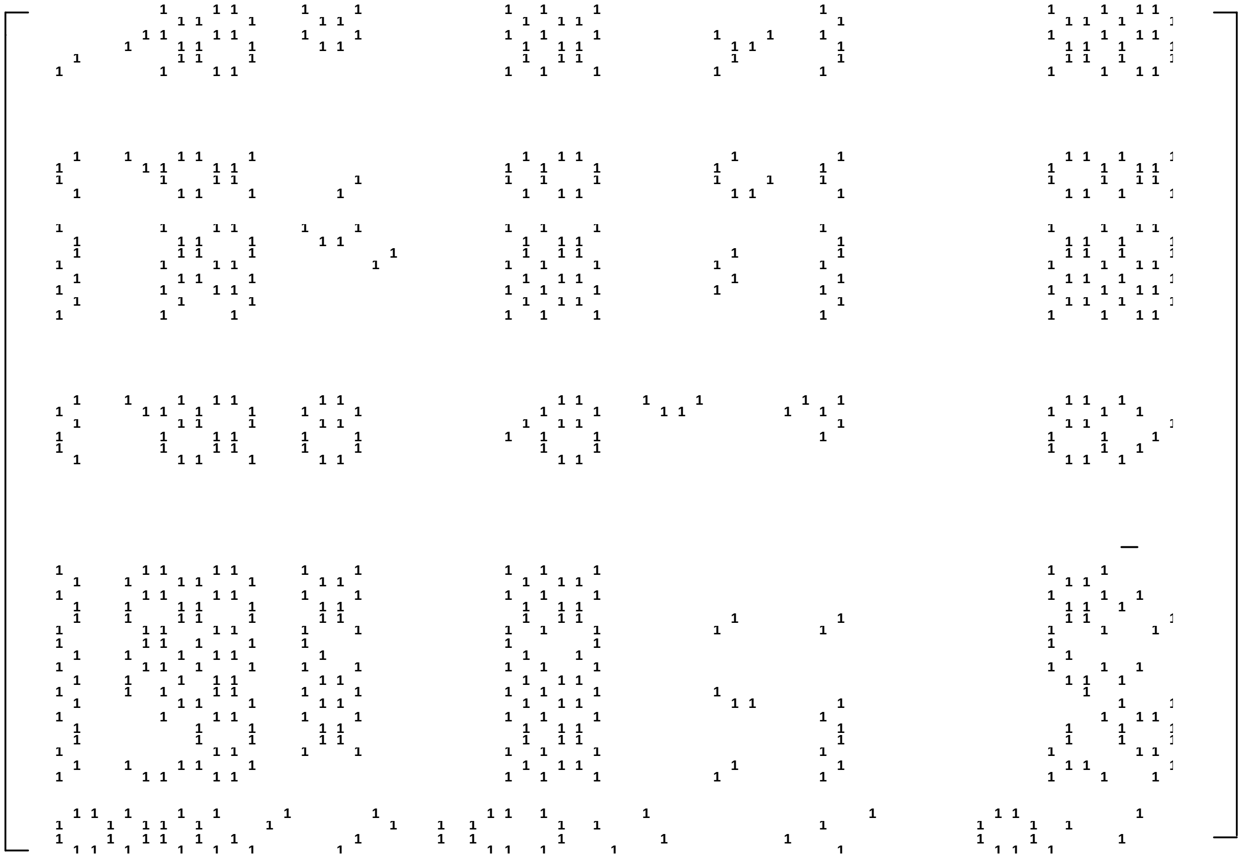

Fig.6 The n-square Matrix, B, Generated from the Observation Data

The matrix of *Fig.6* will be used in the analysis in the following sections. It should be noted that instead of using the Reachability Matrix (as defined by the multiplications of the matrix B as many times as it becomes constant), we will use the Matrix B itself for the following analysis. The implication of the n-square matrix is given in *Fig. 7* with illustrations of *Fig.6* for body motion element No.2.

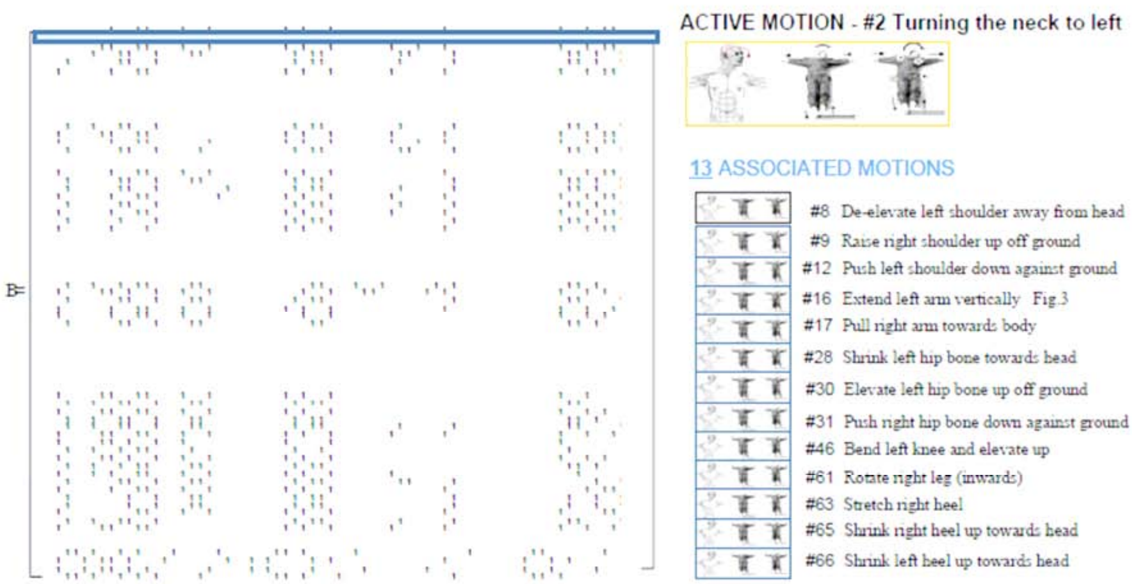

Fig.7 Relation of the Row of the n-square Matrix with Active Motion with Example of #2

Analysis of the Motions by Applying the ISM

The rows of the n-square matrix correspond to the Active Motions, while the columns correspond to the Associated (or Passive) Motions. Figure 8 shows visualized relations of the motions. The upper part of *Fig.8* is a plot of the row No.2 of the matrix B with 1 for the related motions. In other words, motion No.2 induces 13 motions such as No.8, 9, 12,16,17,28,30,31,46,60,61,63, 66. The lower part of Fig.8 is a plot of the column No.2 of the matrix B.
The motions with 1, such as No.5,13,16,20,21,23,25,33,35,38,48,50,51,54,56,58,60,61,63,67, 70 do induce the body motion No.2. *Fig. 9 and 10* illustrate other examples for the motions of No. 14 and 9.

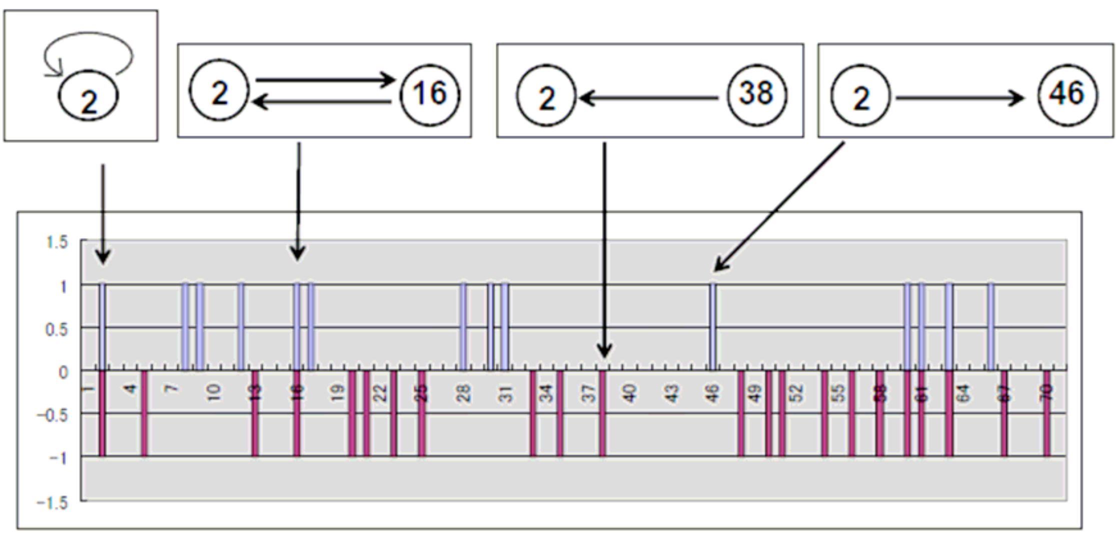

Fig.8 Active Motions and Associated Motions: Example 1: Motion No. =02

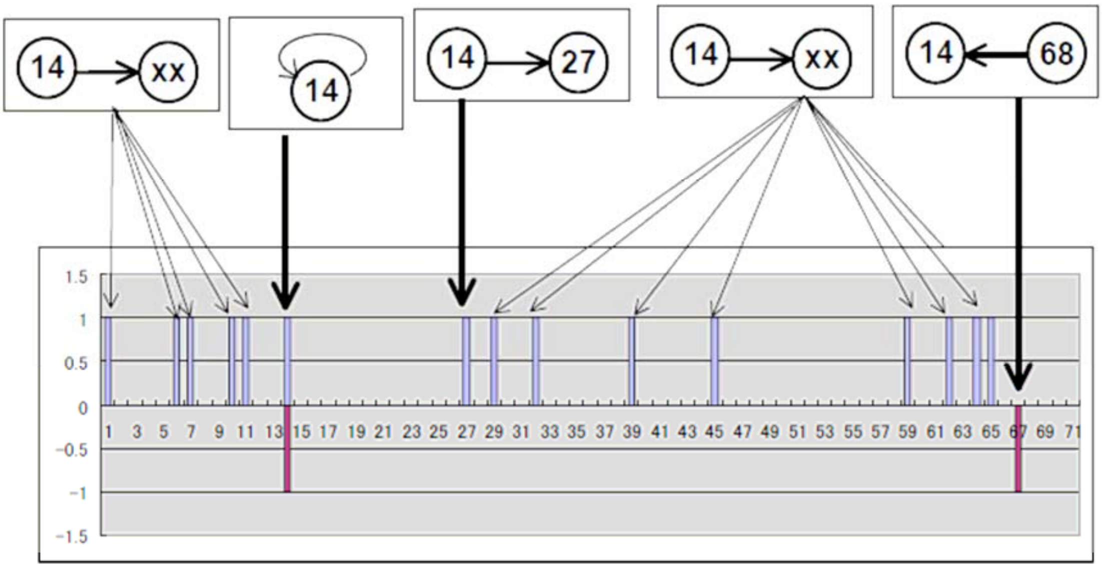

Fig.9. Active Motion Example: Motion No. =14

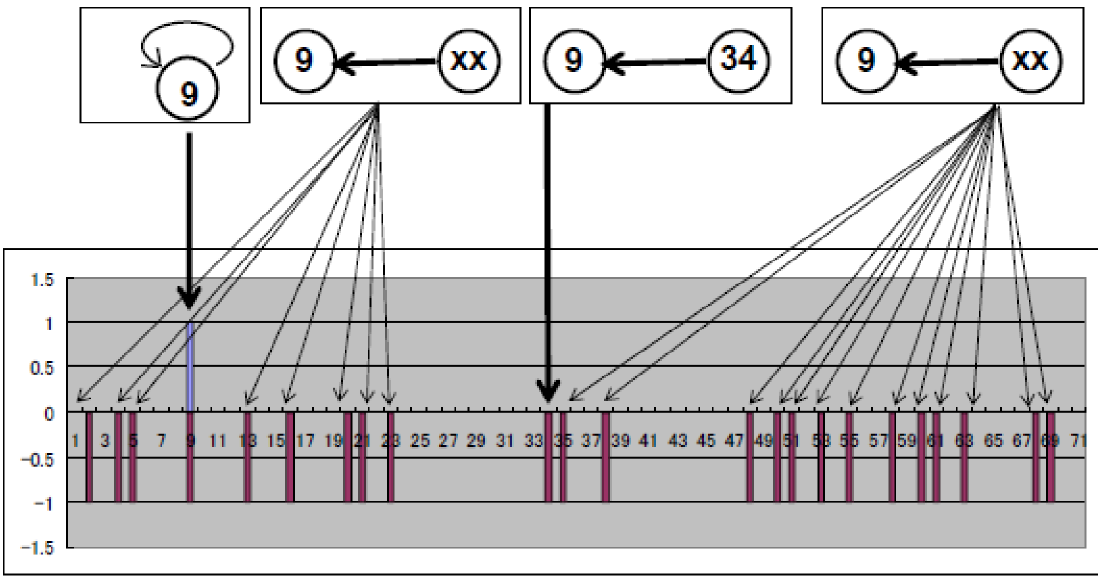

Fig.10. Passive Motion Example: Motion No. =09

Interpretations of Results of the ISM

In order to use the ISM, we define the following notations corresponding to the reachable and antecedent sets as usual approach in terms of the active and passive sets illustrated in *Fig. 8, 9 and 10*. For each of the body motions, we count the number of the associate motions to produce the dimension of the reachable set and denote it by

$$R(i), i = 1, 2...., n$$

Likewise, for each of the associated body motions, we count the number of the active motions that cause the relevant motions to produce the dimension of the antecedent set and denote it by

$$D(i), i = 1, 2, ..., n$$

Fig. 11 shows these dimensions as a function of the motion number.

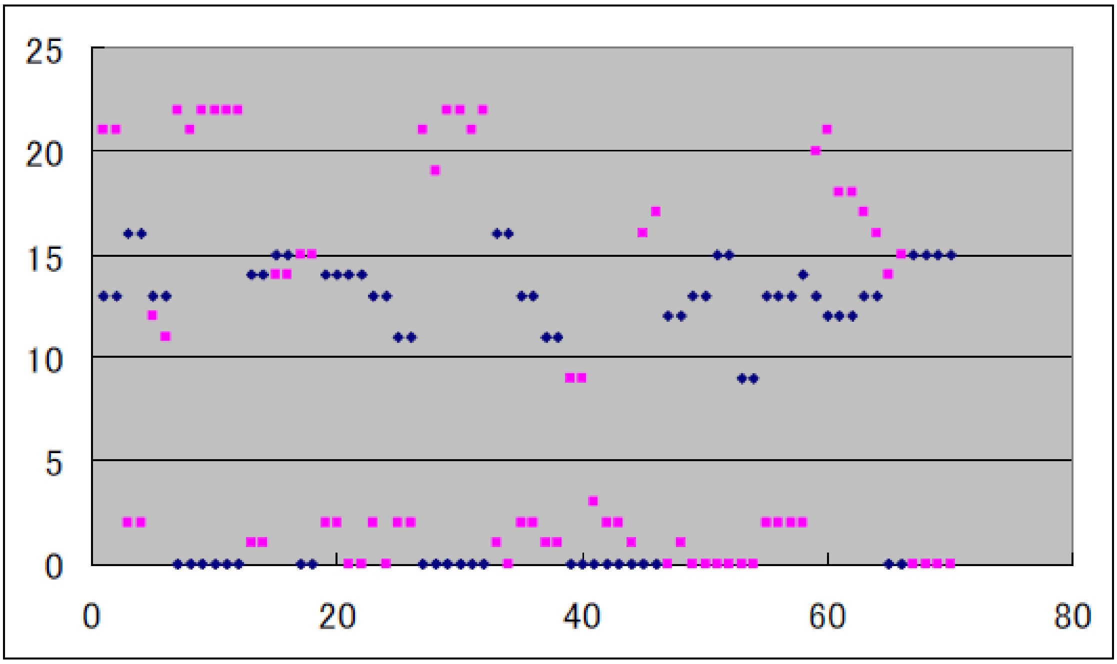

Fig. 11 Motion Number vs. Dimensions of the R(i) and D(i), i=1,…,70

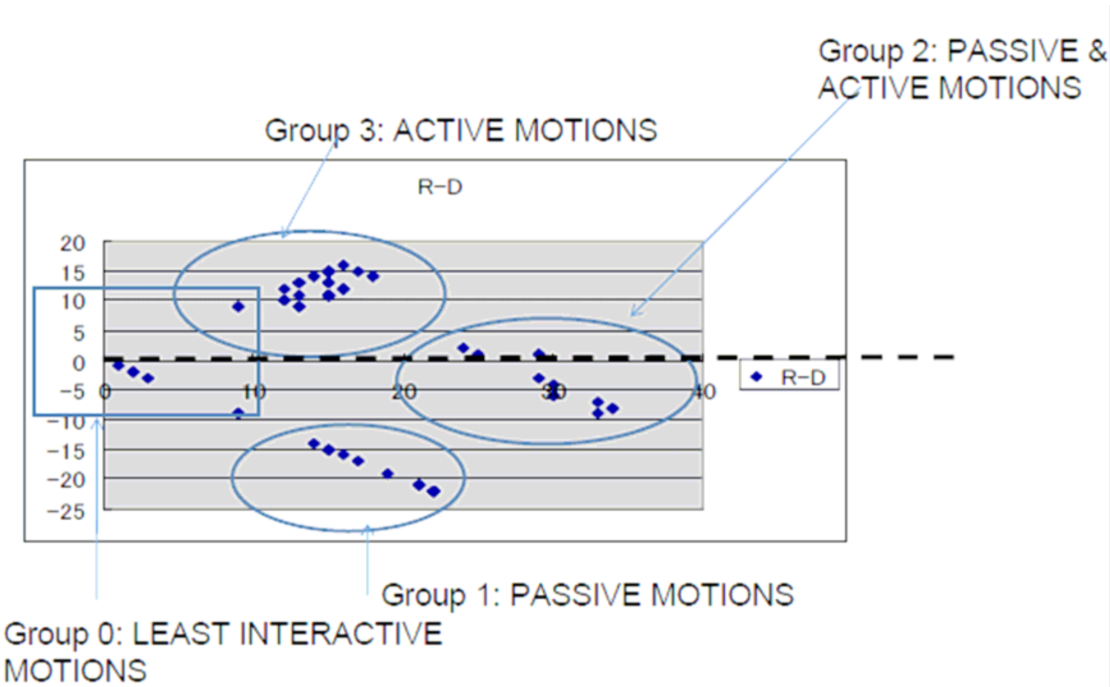

Fig. 12 Plot of (R-D) vs. (R+D) and Grouping of the Motions

From *Fig.11 and 12*, it is observed that body motions can be categorized into 4 groups:

1) Passive Group: does not cause associated motions but are affected by other motions. This may be called D(i) dominant set to record
2) Active/Passive Group: causes associated motions and are also affected by other motions.
3) Active Group: affects several or dozens of associated motions but are affected little by other motions.

This may be called R(i) dominant set to record,

R (i) dominant set: {3, 4}, {13, 14}, {19, 20, 21, 22, 23, 24}, {47, 48, 49, 50, 51, 52}, {67, 68, 69, 70}

D(i) dominant set : {7, 8, 9, 10, 11,12}, {17,18}, {27, 28, 29, 30,3 1, 32}, {39, 40,41,42,43,44,45,46},{65 ,66}

4) 4th Group: least interactive, neither active nor passive, and can be deleted from the current analysis (although this is not always the case in every analysis).

Investigation on the Motion Patterns by Further Application of the ISM

Further application of the ISM produces a hierarchical representation of the whole motion elements as shown in *Fig.13*. The Passive Group is located at the top, the Active Group at the bottom, and the Intermediate Group is in between. It is obvious this grouping corresponds to that of *Fig.12*, where the motion numbers are not indicated. The arrows do not mean that all the elements are directly connected to each other between the circles. Instead, there is a clear separation as will be explained.

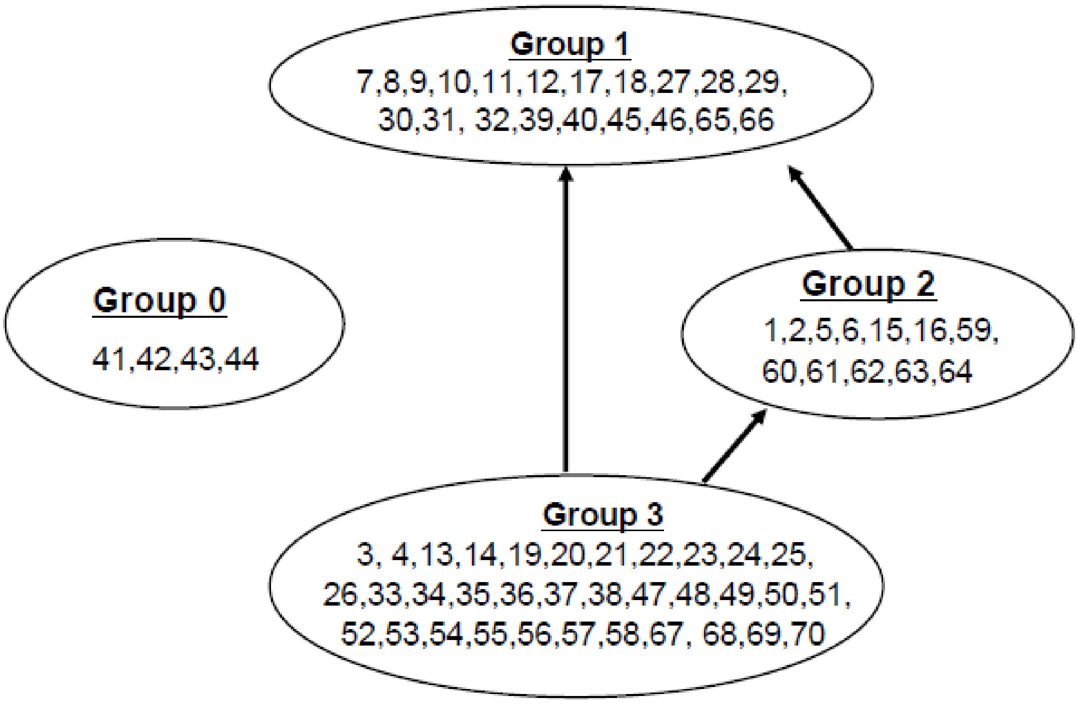

Fig. 13 Classification of Motions into Four (4) Groups

Fig. 13 can be interpreted as the following: Any of the motions in Group 3 will induce some of the motions in Group 1 directly; or it will stimulate some of the motions in Group 2, and then the induced motions of Group 2 will induce some motions of Group 1 – an indirect path. Remembering that the odd motion numbers are related to left/right motions in some way, the observation as noted above generate more specific results as explained below.

Let us start from the motion number 3 as shown in *Fig.14*. From the n-square matrix of *Fig. 6*, it will induce motions both in Group 1 and 2 as shown above. Table 2 represents a detailed relation between the corresponding motion numbers, active or associated.

Table 2 Associated Motions Induced by No.3 and its Induced Motions in Group 2

	7	10	11	18	27	29	32	39	45	65	Group 2
From 3	×	×	×	×	×	×	×	×	×	×	6, 15, 59, 62, 64
From 6	×	×	×		×	×	×	×	×	×	1, 59, 62, 64
From 15	×	×	×	×	×	×	×	×	×	×	1, 59, 62, 64
From 59	×	×	×	×	×	×	×		×	×	1, 15, 62, 64
From 62		×	×	×	×	×	×		×	×	1, 15, 59, 64
From 64	×	×	×		×	×	×	×	×	×	1, 6, 59, 64

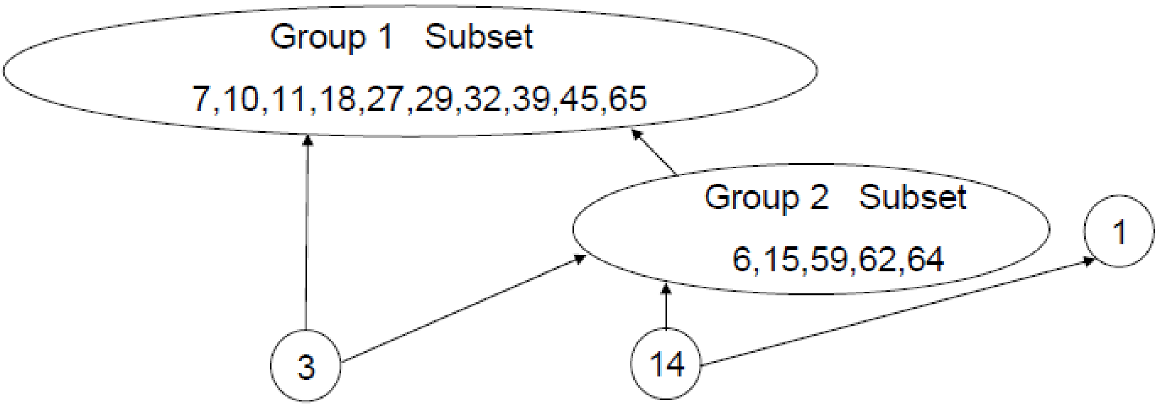

Fig. 14 Subset of the Motion Patters Associated with No.3 and No.14

Table 3 Associated Motions Induced by No.4 and its Induced Motions in Group 2

	8	9	12	17	28	30	31	40	46	66	Group 2
From 4	×	×	×	×	×	×	×	×	×	×	5, 60, 61
From 5	×	×	×		×	×	×	×	×	×	2, 61, 63
From 60		×	×	×	×	×			×	×	2, 16, 60, 63
From 61		×	×	×	×	×			×	×	2, 16, 60, 63

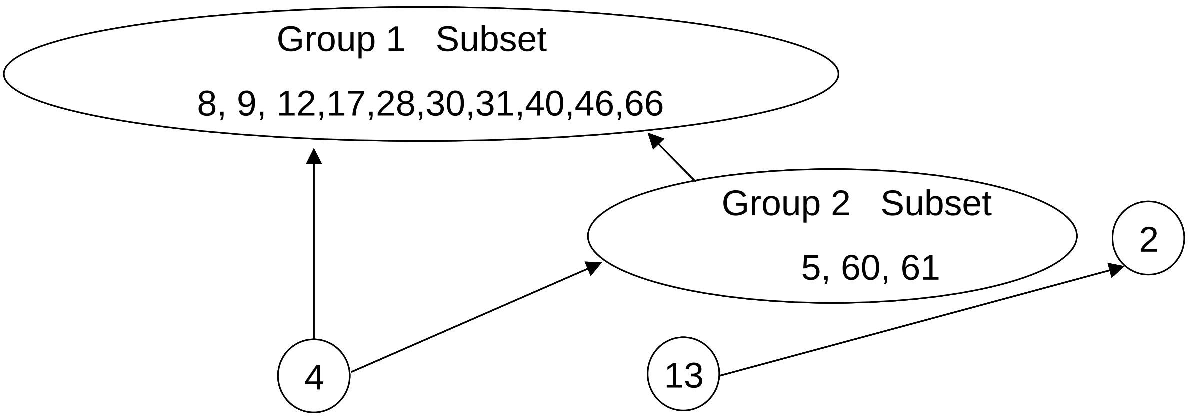

Fig. 15 Subset of the Motion Patters Associated with No.4 and 13

From the results shown in *Tables 2* and 3, and *Fig.14 and 15*, we can conclude:

A. Motion No.3 **Tilt Head Towards Right** and Motion No.4 **Tilt Head Towards Left** are complementary as expected a priori. However, it is remarkable that these two motions induce all the motion elements of Group 1 in a direct manner.

B. Motion No.14 **Stretch Left Arm Above Head** has almost the same effects on Group 1 as Motion No.3. Likewise, Motion No.13 **Stretch Right Arm Above Head** has almost the same effect on Group 1 as Motion No.4.

C. Motion No.3 has effect on the Group 1 through some motions of Group 2, but such effects are very similar to those of the directly induced motions by Motion No.1 as seen from *Table 2*.

D. Motion No.4 has effect on Group 1 through some motions of Group 2, but such effects are very similar to those of the directly induced motions by Motion No.1 as seen from *Table 2*.

E. Other Motion Elements of Group 3 can be categorized either in Motion No.3 or 4.

From the investigations noted above, we have identified the most important body motion elements, and this will be helpful in choosing the body motion elements for inspection or therapy.

Concluding Remarks

In this paper, the authors have identified 70 body motion elements by analyzing the observation data for actual human movements. Then, these elements are transformed into an n-square matrix form and then used in the Interpretive Structure Analysis (ISM). Each row of this matrix turns out to be the Active Motion to induce the Associated Motions, to yield a set of the row called reachable set R (i). Likewise, each column yields an antecedent set D (i). Based on these sets, the motion elements have been categorized into four groups: the first one is R (i) dominant, the second D (i) dominant and the third is nearly balanced, and the fourth is least active. In addition, the application of the standard ISM procedure has revealed that one motion (such as No.3 and No.4) can cover most of the important motion elements directly or indirectly through the motions of Group 2. The results are expected to clarify the association mechanism and to develop a therapy method without accompanying pain or unpleasant exercises. It is concluded that the approach developed and its herein results will be useful by providing a striding step to identify and restore distortion of the human body that may cause unbearable pains unless removed somehow.

For future study, the authors are now developing a Mechanical Engineering Approach using Multi-Body Dynamics and an optimization technique based on a Non-linear Programming (*Ohkami and Kayo, 2008).* In addition, we are investigating the usefulness of a sensor system to detect small electric current caused by muscle movements. This will reveal complex associated motions from three independent approaches: the theory, visual observations and accurate measurement. This will lead to a more systematic therapy methodology in the near future

Acknowledgement

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Biography

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