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Efficient Control Mechanism Model of Robot Arm Movement In Fractal Form Based on Number of Steps and Amount of Energy Consumption

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Abstract

An interesting control mechanism model of robot arm movement can be simulated well in fractal model based on an algorithm called the partitioned-random iteration by means of the set of self-affine transformations. The fractal model is called the iterated function system (IFS) model. The combination of rotation movement of each segment of the segments in the robot arm system can be accomplished by a method called the shifting centroid method, shifting the relative local centroid to the absolute centroid. In this paper, three segments in a chain as a robot arm can represent three levels of the degree of freedom on the robot arm system. There are three simulations to show the efficient movement or not of the very end of the third segment of the robot arm to reach the target based on the number of steps and the amount of energy consumption.

Keywords

Efficient control mechanism model, IFS fractal model, partitioned-random iteration algorithm, shifting centroid method, robot arm system

1. Introduction

Modeling a control mechanism of the movement something is worth to be built as long as it can be used to predict the optimum way of controlling something such as the robot arm movement that can be planned to move in efficient way as possible. To prove that the way of control mechanism is efficient, logically it can be conducted by calculating the step number of movements which has to be in as small as possible or and the amount of energy consumed has to be in as minimum as possible. From the simulation point of view, the mathematical based model, which has a set of rigorous rules and exhibits the behavior that can be predicted such as fractal model is worth to be discussed. The result of three simulations in this paper is represented by a series of three scenarios in which scenario-1 followed by scenario-2 and scenario-2 followed by scenario-3as can be seen in the appendix.

2. Literatures review

There are many research topics related to this paper that can be grouped into four groups, the inverse problem and collage theorem, the display algorithm to generate fractal objects, the animation method and the modeling and design to solve problems. In the first group, there are at least five papers that proposed by Rinaldo, R., et.al [1], Honda, H., et.al [2], Wadstromer, N. [3], Sarafopoulos, A.,et.al [4], and Yonemoto, S.,et.al [5]. In the second group, there are at least three papers that proposed by You, F.C.,et.al [6], Xiao, H.R. [7], and Tao, X.,et.al [8].In the third group, there are at least two papers that proposed by Darmanto, T., et.al [9] and Darmanto, T. [10]. In the fourth group, there are at least three papers that proposed by Li, Y.H.,et.al [11], Xue, S.,et.al [12], and Meng, G.L.,et.al [13].

Model and implementation

Fractal Model

The fractal model can be used to simulate the movement of several fractal objects simultaneously in synchronous mode by connecting part of objects through a common point. An interesting movement to be observed is an interrelated of the rotational movements such as in degree of freedom mechanism on a robot arm that consists of a number of segments. For the sake of simplification, the segment of robot arm can be represented by the rectangle shaped fractal object with two additional points at both of the near end of a slim rectangle. The fractal model that is built by a collection of self-affine transformations relative to an absolute fixed point as a set of rules is known as the iterated function system or abbreviated as the IFSfractal model.

To have the rectangle shaped fractal object, an implementation of the inverse problem of designing a rectangle object based on the collage theorem of the IFS fractal model is needed by means of the equation (1) and (2) with description in table-1 [14]. As long as the simple rectangle has four edges, so at least four collage members in the inverse problem mechanism are located in proper places as can be seen in Figure-1. The figure-1 describes the relation between the designing model and the resulted fractal object. At the left side of figure-1 as the mechanism of a designing composition model, the four slanted rectangles form a rectangle with the two shortest edges of a slanted rectangle are connected to each shortest edge of the nearest other neighbor edges in the middle. This mechanism of a designing composition model is conducted to ensure that the resulted fractal object which has four edges are connected to each other of the nearest other edges as can be seen at the right side of figure-1.

The rectangle shaped of fractal object at the figure-1 has the identity represented by a table consists of four rows and six columns (six affine coefficients from **a** to **f**) and it is called as IFS code. To normalize the form of four slanted rectangles to be four straight lines can be done by modifying the IFS code as the representation of four collage members as can be seen in table-2 (original) and table-3 (normalized).

$$w\begin{bmatrix}x'\\y'\end{bmatrix} = \begin{bmatrix}a & b\\c & d\end{bmatrix} * \begin{bmatrix}x\\y\end{bmatrix} + \begin{bmatrix}e\\f\end{bmatrix} \quad (1)$$

$$w\begin{bmatrix}x'\\y'\end{bmatrix} = \begin{bmatrix}r*\cos t & -s*\sin u\\r*\sin t & s*\cos t\end{bmatrix} * \begin{bmatrix}x\\y\end{bmatrix} + \begin{bmatrix}e\\f\end{bmatrix} \quad (2)$$

Table 1. Parameters of equation (2)

Parameter	Description
r	Horizontal dimension of collage member
s	Vertical dimension of collage member
t	Deviation angle in horizontal dimension
u	Deviation angle in vertical dimension

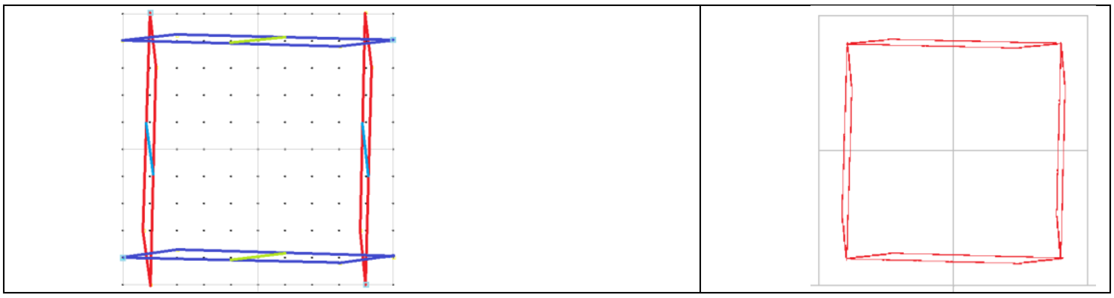

Figure 1. The collage design (left) and fractal model (right) of rectangle object in fractal form.

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Table 2.The 4 affine coefficients in columns of 6 elements in rows of rectangle as its IFS code

a	b	c	d	e	f
0.804	−0.2	0.022	0.026	−0.09	−0.08
−0.02	−0.02	0.803	−0.2	−0.4	−0.6
−0.8	0.197	−0.01	−0.02	0.103	−0.9
0.02	0.02	−0.8	0.2	0.412	−0.39

Table 3.The IFS code of the normalized rectangle of the rectangle in table-2

a	b	c	d	e	f
0.8	−0.2	0.0	0.0	−0.1	−0.1
0.0	0.0	0.8	−0.2	−0.4	−0.6
−0.8	0.2	0.0	0.0	0.1	−0.9
0.0	0.0	−0.8	0.2	0.4	−0.4

Implementation Model

The figure-2 describes the implementation of the fractal model as a robot arm model as a collection of three slim rectangles in a chain. Actually, there are four segments, but as long as the fourth segment is used just for marking the very end of robot arm with sticky mode to the third segment, it can be ignored. To make sure the rotational movement of each segment interrelated to their neighbor segments, there are two additional dots at the near ends of each segment, which have the common position of points for every two segments in pair. The left side of figure-2 displays the first segment of robot arm without dots at the both very ends as the modification form of the normalized form of rectangle object at the right side of figure-1. The right side of figure-2 displays the first segment with two additional dots connected to the second segment in which the second dot of the first segment coincide with the first dot of the second segment. The right side of figure-2 also displays thesecond segment with two additional dots connected to the third segment in which the second dot of the second segment coincide with the first dot of the third segment.

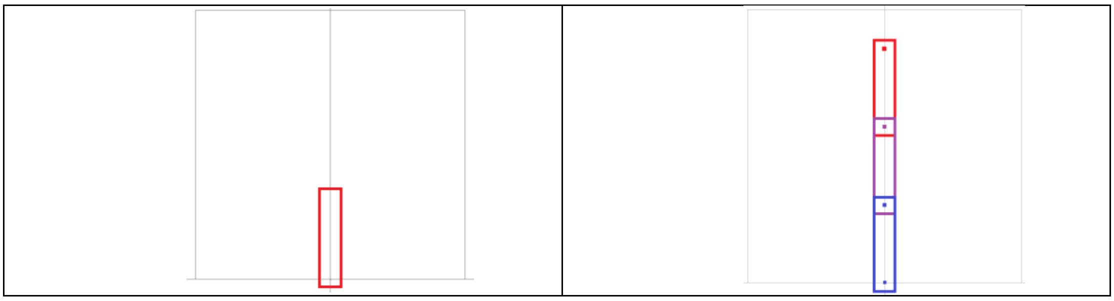

Figure2. The first segment of robot arm model (left) and three segments of robot arm (right) in a chain.

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Efficient Control Mechanism

There is a generic rotation operation of affine transformation to rotate a single object combine with a generic translation operation of its local centroid that can be used as a model to mimic the movement of several segments as a robot arm in fractal form. The resultant effect of rotational movement on three segments is as the robot arm model in a chain formation in which there are a common point coincide as the connection at the near end of each segment in a pair. For the three segments of robot arm model, there are two common points as long as there are two pairs of connected segment. The first common point is connecting the first segment to the second one and the second common point is connecting the second segment to the third one.

To make sure that the control mechanism of the robot arm movement is in an efficient mode, there are two things to be concerned. The first one is the number of rotation step of the segments around their local axis. The second one is the amount of energy consumed that depends on the number of segments as a burden of the axis. For the sake of simplification, the three segments have the same weight and as the burden have the same amount of energy as one unit energy for each. For example, the rotational movement of the first segment consumed triple amount of energy as long as the second and the third segments are attached to it in a chain formation, but the rotational movement of the third segment alone consumed only a single amount of energy.

3. Simulation

There are three scenarios of simulation. The first simulation exhibits the movement of all segments rotating around their local axis in efficient way. The second simulation exhibits the movement all segments but in sticky mode as one long segment rotating around the local axis of the first segment only coincide with the origin point. The third simulation has two versions.

The third simulation version-1 exhibits the movement of the second and the third segments rotating around their local axis but in different direction, just to compensate the rotational effect of the second segment.The third segment is looked like in steady mode as the very end of segment pointing to the East while the segment moving translated to the left until the first dot of the segment coincide with the original point. In the third simulation version-2, like in version-1 except the movement of the third segments is just to compensate the rotational effect of the second segment, so the very end of the third segment is always in horizontal line. After both segments are inline horizontally, only the second segment continues rotated while the third is in the sticky mode until all segments are back to the original position as before simulations.

There is an interesting comparison of observation based on the amount of energy consumed especially between the third simulation version-1 and 2, which has the step number of rotation is the same that it can be seen in the last frame of figure-

3 and figure-4 (see appendix). To prove that a series of all movements is efficient or not, it can be shown just by calculating the step number of rotational movement that should be as small as possible with the amount of energy consumed by the movement that should be also as minimal as possible. There is a possibility two different scenarios of movement with the same number of steps but the amount of energy consumed is different. Therefore, it is interesting to determine how to model the control mechanism.

First Simulation

In the first simulation, the control mechanism model of the robot arm movement is built to show the most efficient way of moving all segments but in the most complex mode until the very end of the third segment to reach the target marked by "T" (top) from the base line. The control mechanism model in this simulation is simulated by the combination of the rotational movements of all segments of the robot arm simultaneously, but the movement mode of the second segment is in the opposite direction compared to the others.

Figure-3 (A to C) presents the first simulation that can be analyzed into three points of view. From the first segment's point of view, the contribution to make the efficient movement is by rotating the segment around the fixed point as the absolute centroid coincide with the first dot at the near end of the segment in 90 degrees anti clock wisely. The movement will stopif the second dot at the other near end of the segment reaching the vertical line connecting the fixed point to the target "T" approximately in the position one third of the distance.

From the second segment's point of view, the contribution to make the efficient movement is by rotating the segment around the second dot at the near end of the segment clock wisely.The movement will stop if the first dot at the other end of the segment reaching the vertical line connecting the fixed point to the target "T" approximately also in the position one third of the distance, while the second dot moving vertically to the position two third of the distance from the original position coincide with the origin point. From the third segment's point of view like the first segment, except the first dot of the third segment also moving vertically to the position two thirds of the distance from the original position coincide with the origin point. Finally all segments forms a vertical line with the very end of segments reaching the target "T".

The amount of energy consumed by the first segment, which has a burden of triple segments, is 90 steps multiplied by 3 units or 270 units of energy. The amount of energy consumed by the second segment, which has a burden of double segments, is 90 steps multiplied by 2 units or 180 units of energy. The amount of energy consumed by the third segment, which has a burden of a single segment, is 90 steps multiplied by 1 unit or 90 units of energy. Overall, the total energy consumed can be calculated as the sum up of all as 540 units of energy

Second Simulation

In the second simulation, the control mechanism model of the robot arm movement is built to show the most efficient way and in the most simple mode of moving all segments until the very end of the third segment to reach the target marked by "R" (right) from the "T" as the continuation of the first simulation. The control mechanism model in this simulation is simulated by the rotational movement only of the first segment of the robot arm around the original point, and the movement of the second segment and the third segment have the same direction as the first segment, so all segments is in sticky mode as one long segment. Figure-3 (C to E) presents the second simulation that can be analyzed into a single point of view that all segments rotated in 90 steps which has a burden of triple segments. Overall, the total amount of energy consumed can be calculated as the triple of 90 units or 270 units of energy (or by observation based on figure-3: 810-540).

Third Simulation Version-1

In the third simulation version-1, the control mechanism model of the robot arm movement is built to show not the most efficient way compared to the version-2 of moving all segments except the first segment until all the segment are back to the original position as before the first simulation started and as the continuation of the second simulation. The rotational movement of the third and the second segments of the robot arm around each local centroid simulate the control mechanism model in this simulation. The direction of the rotational movement of the third segment is in the opposite direction of the second segment, so the third segment is looked like in a steady mode.

Figure-3 (E to I) presents the third simulation version-1 that can be analyzed into two points of view. From the second segment's point of view, the rotational movement needed is in 180 steps and has double burden of segment. The amount of energy consumed by the second segment is 180 steps multiplied by 2 units or 360 units of energy. From the third segment's point of view, the rotational movement needed is in 360 steps and has a single burden of segment. The amount of energy consumed by the third segment is 180 steps multiplied by 1 unit or 180 units of energy. Overall, the total amount of energy consumed can be calculated as the sum up of both or 540 units of energy (or by observation based on figure-3: calculated from: 1350-810).

Third Simulation Version-2

In the third simulation version-2, the control mechanism model of the robot arm movement is built to show the most efficient way by keeping the very end of the third segment in the horizontal line connecting "R" to original point. Figure-4 presents the third simulation version-2 that can be analyzed into two points of view. From the second segment's point of view, the rotational movement needed is in 180 steps and has double burden of segment. The amount of energy consumed by the second segment is 180 steps multiplied by 2 units or 360 units of energy. From the third segment's point of view, the rotational movement needed is in 360 steps and has a single burden of segment. The amount of energy consumed by the third segment is 90 steps multiplied by 1 unit or 90 units of energy. Overall, the total amount of energy consumed can be calculated as the sum up of both or 450 units of energy (or by observation based on figure-4: calculated from: 1260 - 810).

Compared to the third simulation version-1, the total energy consumed in the third simulation version-2 is 90 units less. The efficiency can be accomplished, because there is no overhead movement of the very end of segments by keeping it always in straight line from the beginning position to the position of the target as also it is accomplished in the first simulation.

4. Conclusion

Controlling the movement mechanism of robot arm in efficient way can be modeled by fractal model by means of the partitioned-random iteration algorithm and the shifting centroid method. The control mechanism efficiency of robot arm movement can be calculated based on the smallest steps number with the minimum amount of energy consumed by the rotational movement of the segments by considering no overhead movement of the very end of segments.

References

[1] Rinaldo, R., Zakhor, A. 1994. Inverse and approximation problem for two-dimensional fractal sets, IEEE Transactions on Image Processing, 3(6), 802-820

[2] Honda, H., Haseyama, M., Kitajima, H. & Matsumoto, S. 1997. Extension of the collage theorem, International Conference on Image Processing

[3] Wadstromer, N. 2003. An automatization of Barnsley's algorithm for the inverse problem of iterated function systems, IEEE Transcations on Image Processing, 12(11),1388-1397

[4] Sarafopoulos, A., Buxton, B. 2006. Resolution of the Inverse Problem for Iterated Function Systems using Evolutionary Algorithm, In Proceedings of IEEE International Conference on Evolutionary Computation,

[5] Yonemoto, S., Okuda, T. 2016. Sketch based Picture-Collage Generation Using Evolutionary Computation, In Proceedings of International Conference Information Visualisation (IV)

[6] You, F.C., Chen, Y.J. 2011. The Programming of Snow Flower Fractal Graphics Based on Iterated Function System, Applied Mechanics and Materials, 143-144, 765-769

[7] Xiao, H.R. 2013. Application Study of Fractal Figures Based on Iterated Function System Algorithm, Advanced Materials Research, 694-697,2886-2890

[8] Tao, X., Bai, S., Liu, C., Zhu, C., Chen, H., Yan, Y. 2021. Algorithm of Controllable Fractal Image Based on IFS Code, In Proceedings of IEEE International Conference on Power Electronics, Computer Applications

[9] Darmanto, T., Suwardi, I.S., Munir, R. 2014. Hybrid Rorational and Revolving Simulation of Propeller in Aircraft with Two Propellers by Fractal Animation Model based on Shifting Centroid Method in Double Mode From a Fixed Point, In Proceedings of International Conference on Computer, Control, Informatics and Its Applications

[10] Darmanto, T. 2018. Simulation of Rotating a Robot Arm by Non-Metamorphic Animation Method in IFS Fractal Model Based on Shifting Centroid Technique, In Proceedings of International Conference on Information and Communication Technology

[11] Li, Y.H., Feng, J.C., Wang, Y.H. 2008. Stochastic Fractal Modeling and Process Planning for Machining Using Two-Dimensional Iterated Function System, Key Engineering Materials, 392-394,575-579

[12] Xu, S., Yang, J., Wang, T., Liu, H., Gao, J. 2009. Application of fractal art for package decoration design, In Proceedings of IEEE International Conference on Computer-Aided Industrial Design & Conceptual Design

[13] Meng, G.L., Yang, X.H., Li, D.X. 2012. Textile Pattern Design Based on IFS, Applied Mechanics and Materials, 251, 239-243

[14] Darmanto, T. 2016.Animating Fractal of Things: Based on IFS Fractal Model, ISBN: 978-3-659-86851-1, Lambert Academic Publishing (OmniScriptum GmbH & Co. KG)

APPENDIX

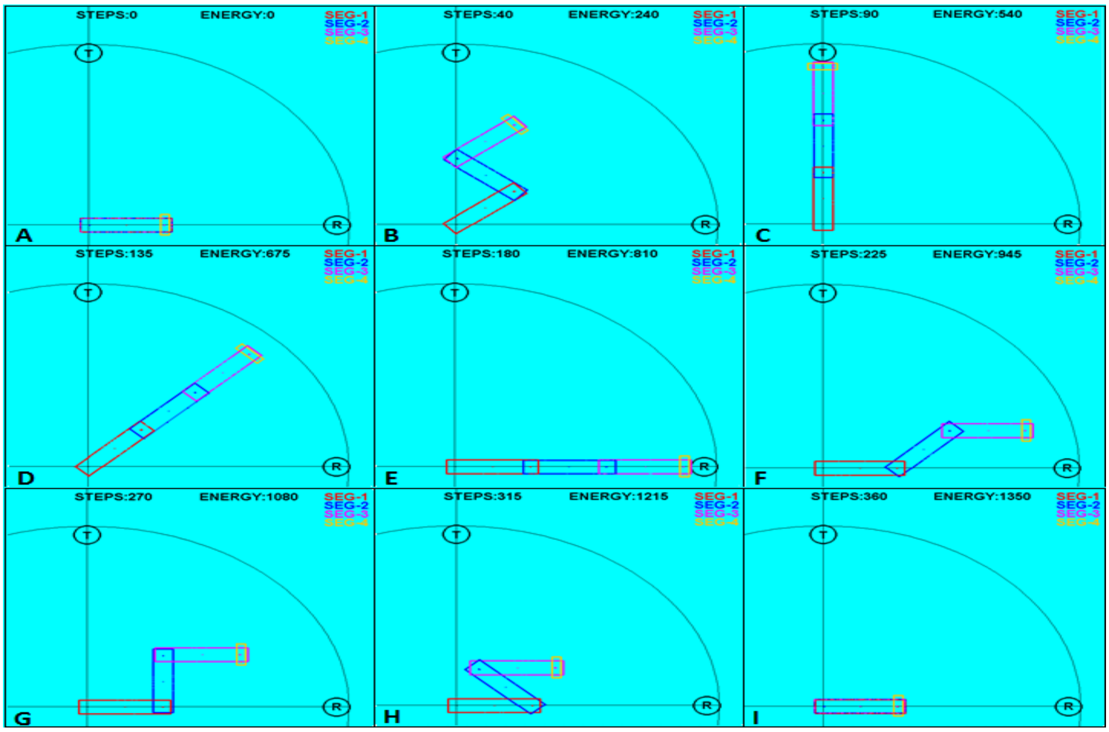

Figure3. Simulation-1 (A to C), simulation-2 (D to E), simulation-3 version-1(E to I)

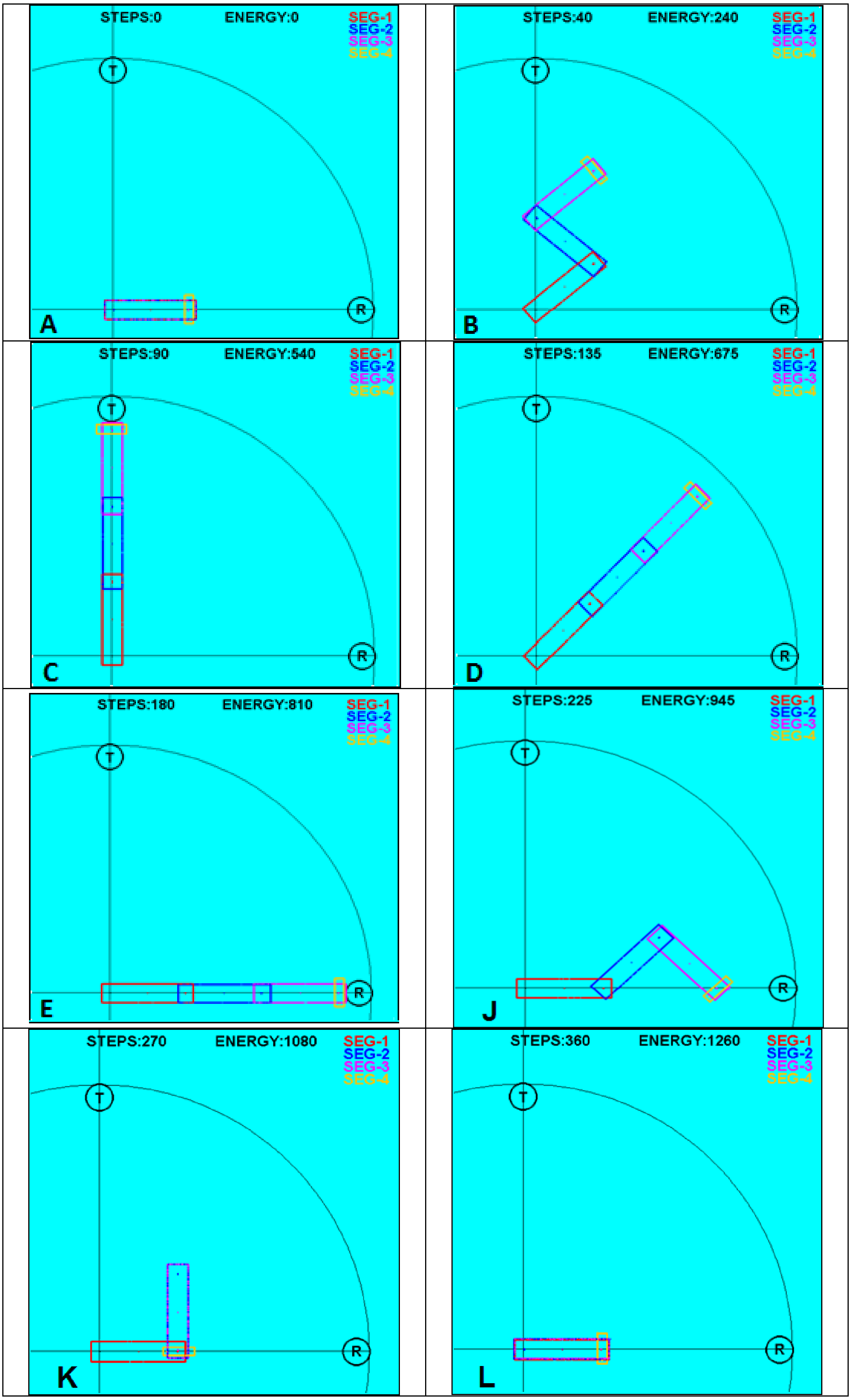
STEPS:0 ENERGY:0
SEG-1
SEG-2
SEG-3
SEG-4
T
R
A
STEPS:40 ENERGY:240
B
STEPS:90 ENERGY:540
C
STEPS:135 ENERGY:675
D
STEPS:180 ENERGY:810
E
STEPS:225 ENERGY:945
J
STEPS:270 ENERGY:1080
K
STEPS:360 ENERGY:1260
L

Figure4. Simulation-3 version-2 (frame-J, K, and L replace frame-F, G, H and I of simulation version-1 in figure-3)