ANIMATING SIMULATION OF THE FIVE SEGMENTS ROBOT ARM WITH TWO FINGERS IN IFS FRACTAL MODEL

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ABSTRAK

Gerakan dinamis lengan robot dengan dua jari yang terdiri dari beberapa segmen menjadi sesuatu yang menarik jika dapat disimulasikan dan dianimasikan secara baik dengan model fraktal versi *iterated function system*. Mekanisme *degree of freedom* pada lengan robot tersebut dapat disimulasi dan dianimasikan melalui teknik kombinasi rotasi-spin yang merupakan versi modifikasi teknik pergeseran *centroid* yang digunakan pada penelitian-penelitian terkait sebelumnya.

Kata kunci : ***iterated function system*; model fraktal; lengan robot; *degree of freedom*; teknik kombinasi rotasi-spin; teknik pergeseran *centroid***

ABSTRACT

An interesting dynamical movement of a robot arm with two fingers consisting of many segments can be simulated and animated suitably by the iterated function system version of the fractal model compared to the conventional model. The degree of freedom mechanism on robot arm movement can be simulated and animated by means of the rotation-spin combination technique which is the modified version of the shifting centroid technique previously used in other related works.

Keyword : iterated function system; fractal model; robot arms; degree of freedom; rotation-spin combination technique; shifting centroid technique

1. INTRODUCTION

A fractal model is a new way to model anything which can be used to simulate a dynamical process based on mathematical calculation since the first idea proposed by the father of fractal world, Benoit Mandelbrot (1977) and popularized by Michael Barnsley (1993) and Stephen Demko (1985) based on the concept of the Hutchinson self-similarity property of fractal attractor (Hutchinson, 1981). The most attractive fractal object is fern-like fractal build by the iterated function system (IFS) concept based on the contractive affine transformation (CAT) function and the collage theorem (Barnsley, 1993). The fractal model can be used to model the degree of freedom (DoF) mechanism of the robot arm which consists of many segments.

The elements of the IFS fractal model are the fractal object itself which is coded and the algorithm as the decoding process to build it. The IFS fractal object is represented mathematically by many CAT function, which every CAT function consists of a collection of the affine coefficients and the code of the fractal object is called as IFS code. One function represents a component of the fractal object, which depends on the other functions of other components. The decoding process is called as the random iteration algorithm because it contains the iterative process based on the collage theorem and the relative density probability of the object components randomly.

In this paper, the representation of the robot arm fractal with two fingers consists of five segments. For the sake of simplification, it can be represented by five rectangles in different size with a dot inside representing its local centroid or the local centroid of the next segment by using the non-self-similarity property, so they looked like five simple rectangles.

2. RELATED WORKS

At least there are five works to be discussed here related to this paper. Three of them are related to the natural dynamical system phenomena such as the orbital trajectory simulation on three different celestial bodies systems (Darmanto, 2013, 2015, 2018a) and the other two are related to the man-made dynamical system (Darmanto, 2014, 2018b). All of the related works are based on the shifting centroid technique which is correlating the local centroid of a fractal object to another object in a pair sequentially from the first object to others depend on the object number as a dynamical system.

The proposed rotation-spin combination technique is basically the same as the shifting centroid technique, but it has slightly differred in the location of local centroid which is in a body of the fractal object and at least coincides with a particular point in another object as a pair. In another point of view, both objects can represent as the component of a multi-object, so the last two related work which is using the shifting centroid technique and can be considered are also using the combination of rotation and spin technique, in order to differentiate with the first three works. The more detail explanation of both techniques are discussed in Method and Technique section.

3. IFS FRACTAL MODEL

Fractal Geometry

In Euclidean geometry, the dimension number is always an integer number in the sense that there is no void inside any objects that can be represented by. In fractal geometry, there is a fraction number of the dimension number, such as the dimension number in between 1.0 and 2.0, so, for example a tree object can be represented suitably by fractal geometry as long as there are many void areas inside the body of tree fractal object.

Representation of IFS Fractal

One function of the CAT consists of six affine coefficients as described in (1). The affine coefficient-***a*** and ***d*** inside the two dimensional vector of (1) are representing the iterative correlation factor of points inside the object body from its previous ***x***-direction and ***y***-direction respectively, but the affine coefficient-***b*** and ***c*** inside the two dimensional vector are representing the iterative cross-correlation factor of points inside the object body from its previous ***y*** to ***x***-direction and ***x*** to ***y***-direction respectively. The two other coefficients, ***e*** and ***f*** inside the one dimensional vector of (1) are representing the relative position factor of points inside the object body from a fixed point as the absolute centroid.

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

Collage Theorem in Action

The best way to explain what is the collage theorem is by explaining how to compose the example collage members into a composition. There are four collage members in the Acacia-like tree fractal composition as an example illustrated in Fig.1 below. All collage member are in clockwise fashion in a different size, position and orientation except the last collage member-4 is in anti-clockwise one as illustrated in the left side of Fig.1. The corresponding Acacia-like tree fractal object is displayed in the right side of Fig.1.

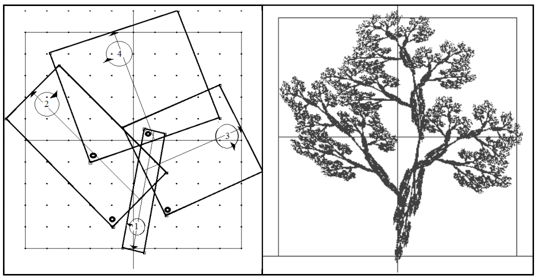

Figure 1. “Acacia-like” tree fractal design (left) and its construction (right)

The collection of the affine coefficients as the fractal object representation itself is called the iterated function system code (IFS code) as represented in (2.a) to (2.f) (Barnsley,1993). Variable description of the equations is described in Table-1. As an example of IFS code as the representation of the fractal object in Fig.1, with probability factor $\boldsymbol{p}$ is showed in Table-2.

$$a = r * \cos(theta) \quad (2.a)$$
$$b = - s .* sin\ (phi) \quad (2.b)$$
$$c = r * sin\ (theta) \quad (2.c)$$
$$d = s * cos\ (phi) \quad (2.d)$$
$$e = h \quad (2.e)$$
$$f = k \quad (2.f)$$

Table 1. Variable of Dimension, Deviation Angle and Translation of Collage Member

Variable	Description
r	Horizontal dimension of collage member
s	Vertical dimension of collage member
$theta$	Horizontal deviation angle of collage member
phi	Vertical deviation angle of collage member
h	Horizontal translation of collage member from centroid
k	Vertical translation of collage member from centroid

Table 2. IFS code of the Acacia tree object in Fig.1

a	b	c	d	e	f	p
0.088	0.108	0.018	-0.54	0.103	-0.53	0,08
0.251	0.498	-0.25	0.502	0.03	-0.22	0.30
-0.20	-0.45	-0.4	0.199	0.048	-0.34	0.28
0.6	0.186	-0.19	0.506	0.098	-0.49	0.34

Multi-object in IFS Fractal Model

A multi-object in IFS fractal model can be constructed by means of partitioned-random iteration algorithm (Darmanto, 2016) as the extension of the random iteration algorithm which is used to construct a single fractal object. In this paper, a robot arm fractal is used as a multi-object which consists of five rectangles with a dot inside in different size, position, and orientation but are connected to each other as illustrated in Fig.3, 4, and 5. The IFS code of the first two rectangles are shown in Table-4 at the APPENDIX-A.

4. METHOD AND TECHNIQUE

Primitive Methods

There are at least three major primitive methods, the horizontal translation, the vertical translation, and the rotation methods. The horizontal translation method is affecting two of the current affine coefficients (***e'***, ***f'***) as in (3.a, 3.b). The vertical translation method is affecting two of the current affine coefficients (***e'***, ***f'***) as in (4.a, 4.b). The rotation method is affecting all of the current affine coefficients (***a'***, ***b'***, ***c'***, ***d'***, ***e'*** and ***f'***) as in (5.a), (5.b), (5.c), (5.d), (5.e), and (5.f) (Darmanto,2016). The equations parameter description is described in Table-3.

$$e' = e + (1.0 - a * tx) \quad (3.a)$$
$$f' = f - c * tx \quad (3.b)$$

$$e' = e - b * ty \quad (4.a)$$
$$f' = f + (1.0 - d * ty) \quad (4.b)$$

$$a' = a * cos(dt) * cos(dt) - (b + c) * cos(dt) * sin(dt) + d * sin(dt) * sin(dt) \quad (5.a)$$

$$b' = (a - d) * cos(dt) * sin(dt) + b * cos(dt) * cos(dt) - c * sin(dt) * sin(dt) \quad (5.b)$$

$$c' = (a - d) * cos(dt) * sin(dt) - b * sin(dt) * sin(dt) + c * cos(dt) * cos(dt) \quad (5.c)$$

$$d' = a * sin(dt) * sin(dt) + (b + c) * cos(dt) * sin(dt) + d * cos(dt) * cos(dt) \quad (5.d)$$

$$e' = e * cos(dt) - f * sin(dt) \quad (5.e)$$
$$f' = e * sin(dt) + f * cos(dt) \quad (5.f)$$

Table 3. Parameter of Translation and Rotation Methods

Parameter	Description
tx	Translation in x-direction
ty	Translation in y-direction
dt	Deviation angle

Rotation-Spin Combination Technique

The best way to explain the rotation-spin combination technique which has two steps of the mechanism is by an illustration as can be seen in Fig.2, as the modification of the shifting centroid technique presented in (Darmanto, 2013, 2015, 2018a, 2014, 2018b). Initially to rotate the second segment of robot arm around a local centroid which coincides with the near top end of the first segment of robot arm position, the shifting operation of its centroid as the local centroid to the absolute centroid is needed, while the first segment of the robot arm is rotated around the absolute centroid to the new position as the first mechanism. After the second segment of the robot arm is rotated around the absolute centroid, the shifting operation of the centroid from the absolute centroid back to the position of local centroid as its centroid but in the new position is needed which coincides with the new position of the near top end of the first segment of the robot arm as the second mechanism.

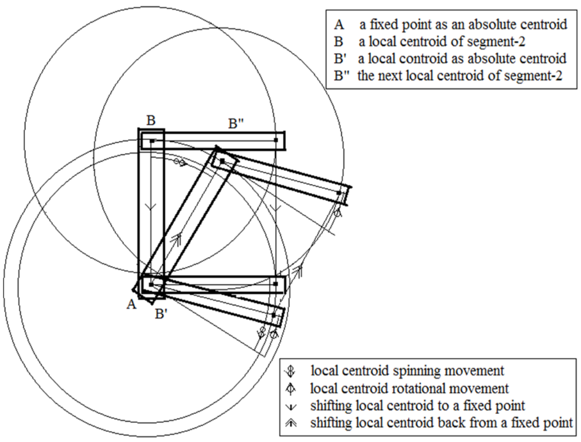

Figure 2. An illustration of the rotation-spin combination technique

5. ANIMATING ON SIMULATION

Animating Rotation or Spin of Robot Arm

To simulate the sticky situation on all segments of the robot arm, the spin rate in the rotation-spin combination procedure of all segments on each local centroid is set to zero, but the rotation rate of all segments on a fixed point as the absolute centroid is set at the same rate. The animation result of this situation is shown in Fig.3, in which all segments are rotated around a fixed point at x = 0, y = 0 clock wisely.

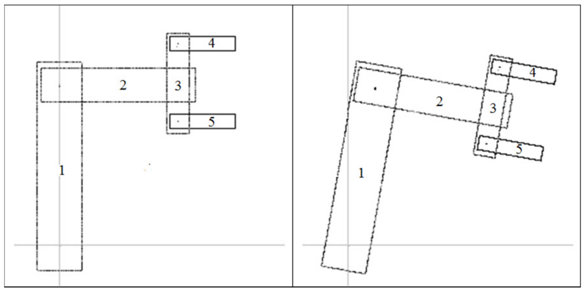

Figure 3. Animating DoF mechanism in one degree (with all sticky segments)

Animating DoF Mechanism

To simulate the DoF mechanism animation in two degrees on one segment of the robot arm, the spin rate in the rotation-spin combination procedure of the segment can be set to any values. In Fig.4 the spin rate of segment-2 is set in the same rate with the rotation rate but in the opposite direction, so the segment-2 and also the other segments except the first segment are looked like in the steady state pointing horizontally to the left, while the first segment rotated around a fixed point at x = 0, y = 0

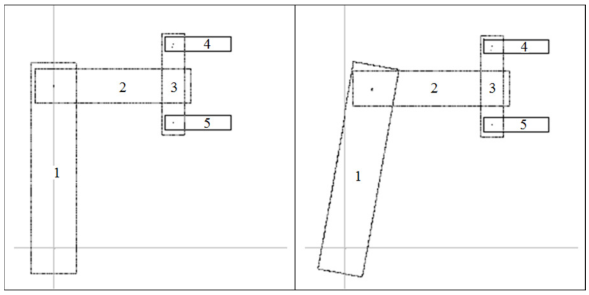

Figure 4. Animating DoF mechanism in two degrees (segment-2)

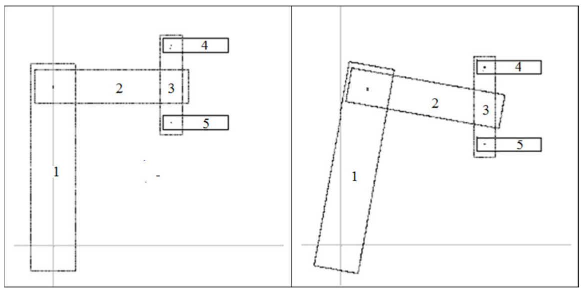

Figure 5. Animating DoF mechanism in two degrees (segment-3)

Animating DoF Mechanism in More than Two Degrees

The simulation of animating DoF mechanism on a robot arm is always rotating in purpose clock wisely. There are four phases, which in the phase-1 and 3 the first segment is looked like rotated 90 degrees while the other segments are spinning around their local centroid, but in phase-2 and 4, the first segment is looked like in steady state while the other segments are spinning around their local centroid to the same position as the initial position relative to the first segment except the direction is changed to be 90 degrees rotated clock wisely.

By applying the rotation-spin combination technique in phase-1 and 3, the simulation exhibits the combined effect between the effect of rotation around a fixed point and the effect of spin around each local centroid on all segments. The combination effect of the rotation and spin resulted from applying the above technique is as the reason that the name of this technique is taken from.

In this simulation, the rotation rate of all segments around a fixed point at $x = 0$, $y = 0$ is set in the same value clock wisely. By applying this technique on the two fingers of a robot arm, the DoF mechanism in four degrees with double modes can be exhibited in every phase.

In the phase-1, the spin rate of the first and second segments are set at the same rate but in the opposite direction, the first segment is spin clock wisely around its local centroid which coincides with the fixed point at $x = 0$, $y = 0$, but the second segment is spin anti clock wisely around its local centroid. The spin rate of the last three segments is set in a half spin rate of the first two segments in anti-clockwise fashion, except the last two segments is set in the opposite direction and closing to each other, in order to show the pinch in effect. The image sequence of this animation can be seen in Fig.6 at APPENDIX-B.

In the phase-2, the spin rate of all segments is in reverse direction, so the first segment is looked like in the steady state because it's rotation and it's spin rate are the same but in the opposite direction, and the other segments are spin around their local centroid in reverse direction compared to their spin direction in the phase-1. At the end of phase-2, all segments are back like in the initial position at phase-1, but rotated 90 degrees clock wisely. The image sequence of this animation can be seen in Fig.7 at APPENDIX-B.

In the phase-3, the spin rate of the first and second segments are set at the same rate but in the opposite direction as the rate in the phase-1, but for the sake of accelerating the simulation, the spin rate of the last three segments is set in the same rate as the spin rate of the first two segments in anti-clockwise fashion, except the last two segments, is in the opposite direction and separated away to each other, in order to show the pinch out effect. The image sequence of this animation can be seen in Fig.8 at APPENDIX-B.

In the phase-4, the simulation begin from the position like the initial position at phase-1 but rotated 180 degrees or in upside down position. The spin rate of all segments is set in reverse direction, so the first segment is looked like in the steady state, because its rotation and its spin rate are the same but in the opposite direction, and the other segments are spin around their local centroid in reverse direction compared to their spin direction in the phase-3. At the end of phase-4, all segments are back to the initial position as at the beginning of phase-1 but rotated 270 degrees clock wisely. The image sequence of this animation can be seen in Fig.9 at Appendix-B

6. CONCLUSION

By composing five rectangle fractals connecting one to another like a robot arm with two fingers and applying the rotation-spin combination technique according to the local centroid position of each segment relative to a fixed point as the absolute centroid, the moving animation of a robot arm rotated around a point can be simulated. The simulation exhibits the DoF mechanism of a robot arm with two fingers in four degrees that can be used to pinch in by grasping something and to pinch out by releasing it somewhere by two fingers, while the robot arm rotating around a point as a reference.

REFERENCES

Mandelbrot, B.B. (1977). *Fractals, Form, Chance, and Dimension*. San Francisco: Freeman.

Barnsley, M.F., Demko, S. (1985). *Iterated Function Systems and the Global Construction of Fractals*. A. Mathematical and Physical Sciences, Vol-399, Issue-1817, pp.243–275, Royal Society Publishing.

Barnsley, M.F. (1993). *Fractals Everywhere*. Morgan Kaufmann, 2nd edition.

Hutchinson, J.E. (1981). *Fractals Self-similarity*. Indiana University Mathematics Journal 30, pp.713 – 747.

Darmanto T., Suwardi I.S., Munir R. (2013). *Orbital Trajectory Simulation of Satellite around Space Object by Fractal Animation Model based on Shifting Centroid from a Fixed Point*. Konferensi Nasional Informatika (KNIF), STEI, ITB.

Darmanto T., Suwardi I.S., Munir R. (2015). *Orbital Trajectory Simulation on Twin Stars System In IFS Fractal Model Based On Hybrid Animation Method*. Journal of Computer Science and Information, Vol-8, Issue-2, Juli 2015, pp.71 – 78.

Darmanto, T. (2018a). *Animating DoF Mechanism on Simulation of a Satellite Trajectory around a Planet in Three Celestial Bodies System by IFS Fractal Model*. International Conference on Computer, Control, Informatics and Its Applications (IC3INA); ISBN: 978-1-5386-5740-9

Darmanto T., Suwardi I.S., Munir R. (2014). *Hybrid Rotational 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*. International Conference on Computer, Control, Informatics and Its Applications (IC3INA)

Darmanto T. (2018b). *Simulation of Rotating a Robot Arm by Non-Metamorphic Animation Method in IFS Fractal Model Based on Shifting Centroid Technique*. 6th International Conference on Information and Communication Technology (ICoICT), Telkom University Indonesia - Multimedia University Malaysia, © IEEE (Indonesia Section) ISBN: 978-1-5386-4572-7

Darmanto T. (2016), *Animating Fractal of Things based on IFS Fractal Model*. Lambert Academic Publishing, copyright © 2016, OmniScriptum GmbH & Co. KG, ISBN 978-3-659-86851-1

APPENDIX-A

Table-4. Initial IFS code of two rectangles (first 4 rows) with a dot (row-5) of segment-1 (left) and segment-2 (right) in Fig.3, 4, 5

a	b	c	d	e	f	p	a	b	c	d	e	f	p
0.0	0.0	-0.914	0.8	-0.055	-0.038	0.24	0.8	0.914	0.0	0.0	0.382	-0.429	0.24
-0.2	0.173	0.0	0.0	0.033	0.063	0.24	0.0	0.0	-0.173	-0.2	-0.047	-0.440	0.24
0.0	0.0	0.914	-0.8	0.055	-0.342	0.24	-0.8	-0.914	0.0	0.0	-0.099	-0.346	0.24
0.2	-0.173	0.0	0.0	-0.033	-0.443	0.24	0.0	0.0	0.173	0.2	0.330	-0.335	0.24
0.01	0.0	0.0	0.01	0.0	-0.384	0.04	0.01	0.0	0.0	0.01	0.284	-0.384	0.04

APPENDIX-B

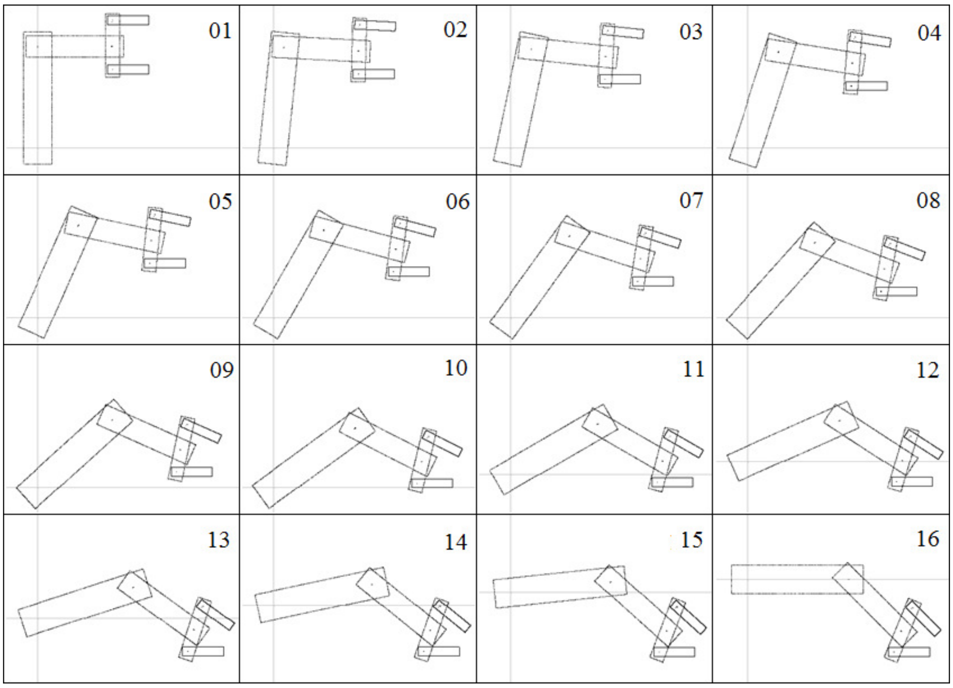

Figure 6. Fractal image sequence of animating DoF mechanism in four degrees in phase-1

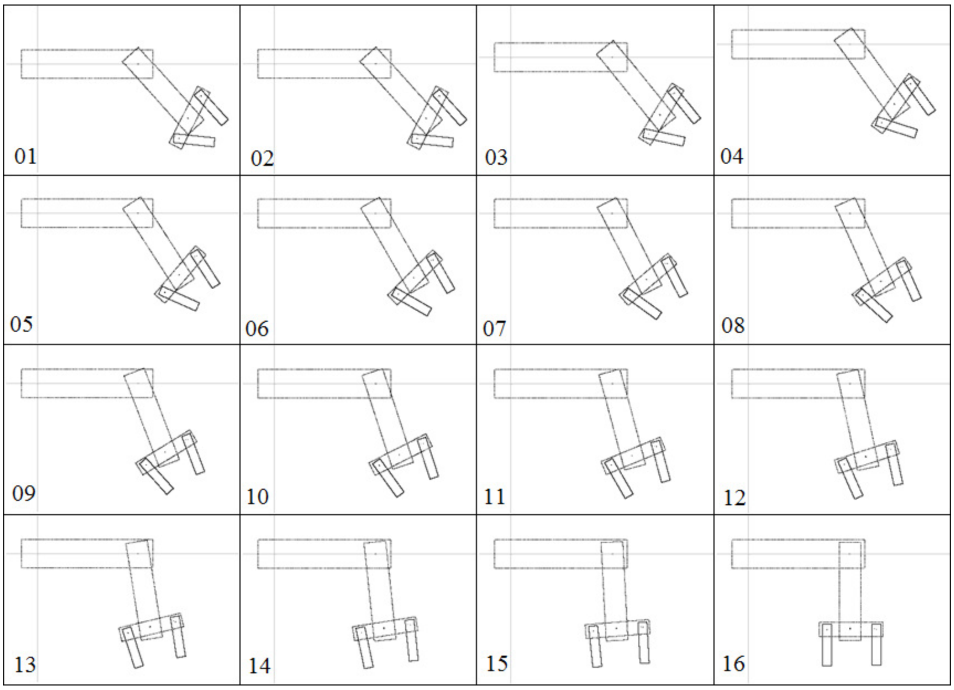

Figure 7. Fractal image sequence of animating DoF mechanism in four degrees in phase-2

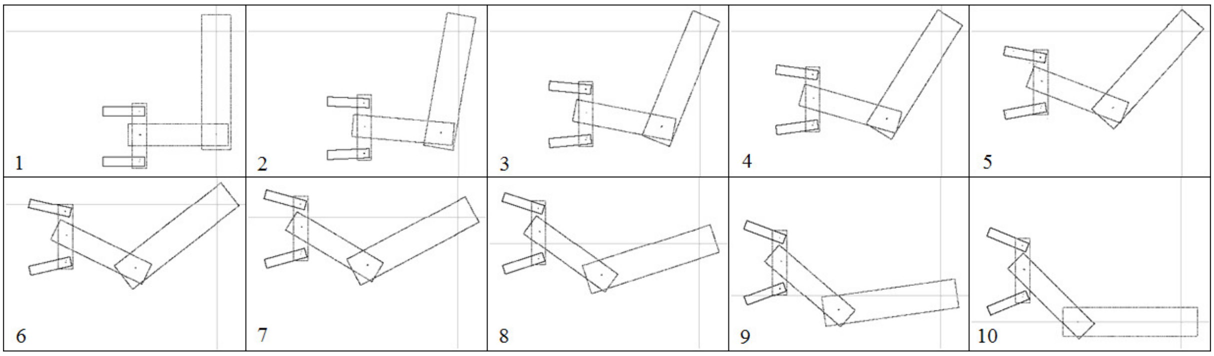

Figure 8. Fractal image sequence of animating DoF mechanism in four degrees with double modes by means of the rotation-spin combination technique phase-3

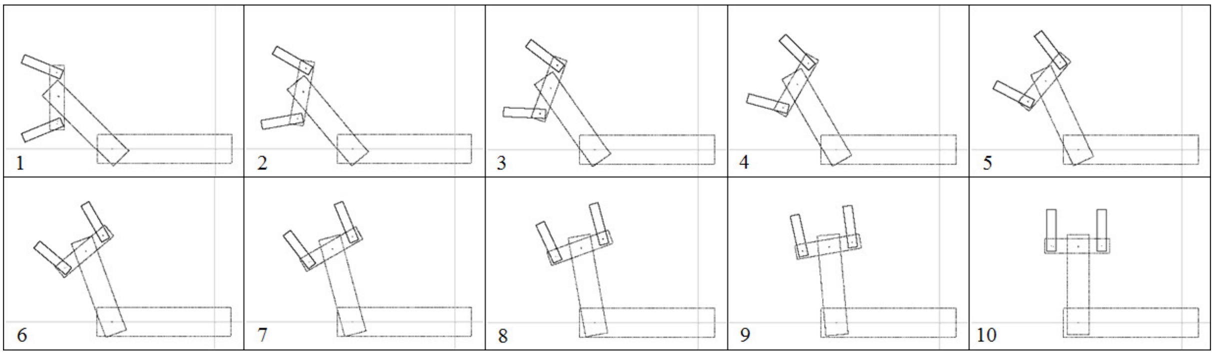

Figure 9. Fractal image sequence of animating DoF mechanism in four degrees with double modes by means of the rotation-spin combination technique phase-4