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SIMPLIFIED CORAL MODELING IN BATIK PATTERN GENERATION

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ABSTRACT

Coral is one of ocean organism that is beauty and various. Unfortunately, this diversity has not been explored to create artistic pattern, especially batik. Although there are lots of nature based batik patterns, most of these patterns are developed based on land plant. In the other hand, Indonesia as an archipelago country has lots of ocean biota and one of them is coral. In this research, we propose simplified computational coral model. The simplification is needed because modeling real coral growth or morphology is very complicated and resource consuming. This model then is implemented to create batik pattern computationally. This model is developed based on the stochastic approach. In this research, we propose three coral models based on the genus: Leptoseris, Gardinesoris, and Acropora. These basic coral models then have been implemented to generate batik pattern by adding artistic objects. Based on several tests, changing some controlled variables can generate different shapes or variation. In some range, the generated image still can be recognized as coral. In other range, the result image cannot be recognized as coral anymore. By ignoring complicated the environmental and biological aspects, the proposed model still can generate coral pattern and then is implemented to generate batik pattern.

Keywords: *Batik, Coral, Stochastic, Continue System*

1. INTRODUCTION

Indonesia, as an archipelago and tropical country has lots of biota in its ocean. There are lots of species in Indonesian ocean, both are animal or plant. Ocean biota is well known for its beauty and color variation. So, the ocean biota can be used as inspiration to create art product.

One of well known traditional art product in Indonesia is batik. Because of the cultural diversity, there are lots of local batik pattern in Indonesia. Floral object is commonly used as basis of pattern in batik. Floral objects that are usually used in batik pattern are flower, leaf, and branch. Although Indonesia is an archipelago state, the usage of ocean biota as inspiration or basis to create batik pattern is very limited. So, creating batik pattern that is based on ocean biota is very challenging.

One of the ocean biota that is very diverse is coral. In Indonesia, 590 coral species have been found and they are grouped into 80 genus [1]. One of the places in Indonesia that have lots of coral species is Raja Ampat, Papua [1]. In Raja Ampat, 456 coral species have been identified and they are grouped into 77 genus [1]. So, exploration in ocean biota diversity to be implemented into art product can be used as tourism promotion tool.

Besides generated manually, batik pattern also can be generated computationally. By using computational technology, batik pattern can be generated faster and more various. By using computational visualization, batik designer can evaluate batik pattern before it is applied into physical fabric.

Unfortunately, computational based batik pattern has not been popular research field yet. Lot of research in computer science that uses batik as its research object is focusing in identifying the pattern. One of popular method to generate batik pattern computationally is by using fractal method [2]. Other research used random walk [3], cellular automata [3], or L-system [4,5] to generate batik pattern.

Many scholars have studied or developed coral morphology and growth. Most of these researches are in biological field [6-15]. Merks has proposed coral growth in branching and compactification aspect [6]. Chindapol has studied water motion aspect in modeling coral growth [7]. Atkinson studied the effect of water on phosphate velocity uptake in coral communities [8]. Badgley studied the effect of nitrate concentration, water flow, and irradiance to the coral growth [9]. Sebens studied the effects of water movement on coral distribution [10]. Dennison studied the effect of water motion on coral photosynthesis and calcification [11]. Chamberlain studied the water flow aspect of branched coral [12]. Monismith studied the hydrodynamics of coral reefs [13]. Rinkevich studied the genetics effect on coral colony shape [14]. Kaandorpcoral studied the effect of nutrient on coral morphology [15].

Based on the explanation above, modeling the real coral morphology and growth is very complicated and resource consuming. It is because real coral growth model must implement biological and environmental aspects. The calculation will be complex. So, the research question is how to develop simple coral model so that the calculation will be less resource consuming but the result still can be recognized as coral. Simplification is important because as an artistic product, real model is not important in batik pattern. In the other hand, modification is more important.

The research purpose is to develop simple coral model that can be implemented to generate computational based batik pattern. The coral model is developed based on stochastic approach so that the result image that is generated each time the program is run will not be similar with the previous image result even though the controlled variables is unchanged. In this research, continuous model is used rather than discrete model.

This paper is organized as follows. In section 1, the background, research question, and research purpose are explained. In section 2, we explore the basic knowledge of the coral, especially Indonesian coral. In section 3, we explain the proposed coral model. In section 4, we explained the implementation of the coral model in generating batik pattern computationally. In section 5, we discuss the result. In section 6, we conclude the research and discuss the future research potential, especially in natural object computational batik pattern generation.

2. CORAL IN INDONESIA

Coral is ocean biota that lives in tropical and subtropical zone [1]. That is why lots of coral reef can be found easily in Indonesia, especially in Celebes. Indonesian coral is the most diverse coral in the world [1]. Beside in Indonesia, coral can be found easily in Caribbean and Indo Pacific oceans [1]. In Indonesia, coral can grow well in Celebes, Moluccas, Sorong, and Nusa Tenggara [1]. In the other side, in Sumatera, coral cannot grow well [1].

Coral reef existence has many advantages. First, coral reef becomes the place for ocean biota to live and to breed [1]. Second, coral reef can be used as medical material [1]. Third, coral reef is one of wave breaker that can avoid coast from abrasion [1].

Basically, coral is a simple animal [1]. Its body is cylindrical [1]. Its mouth becomes anus too [1]. There are tentacles surrounding its mouth [1]. Tentacle is used to catch food [1]. There is calcium skeleton that supports the coral body [1].

Coral is named based on the calcium skeleton structure [1]. All skeletons that are created from one polyp are called as corralite [1]. Based on the corralite structure, coral can be grouped into: Meandroid, Plocoid, Ceroid, Flabellate, Hydnoporoid, Phaceloid, Flabelo-meandroid, and Dendroid [1].

In scientific classification, coral is classified in Cnidaria phylum [1]. Other animals that are in the same phylum are anemone and jelly fish. Coral can be grouped into 15 families: Acroporidae, Agariciidae, Astrocoeniidae, Caryophylliidae, Dendrophylliidae, Faviidae, Fungiidae, Merulinidae, Mussidae, Oculinidae, Pectiniidae, Pocilloporidae, Poritidae, Siderastreidae, and Trachyphylliidae. The example of the coral is shown in Figure 1 [16].


Figure 1: Acropora coral

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3. PROPOSED MODEL

In this research, we propose three basic coral models based on the genus: Leptoseris, Gardinesoris, and Acropora. These genuses have different basic shape compared to each other. Therefore these basis coral models are developed in different ways.

3.1 Leptoseris model

Leptoseris is coral genus that its main characteristic is like leaf sheet [17]. The coral surface consists of many radial curves. Beside the radial curve, the surface contains of centrifugal line [17]. The image of Leptoseris coral is shown in Figure 2 [17]. Based on these characteristics, then the Leptoseris model is builded.

Figure 2:Leptoseris mycetoseroides

In the proposed model, some variables are used. Variable c is the center of the coral. Variable c contains two attributes (c_x,c_y), x and y which means the horizontal position and vertical position of the coral in the canvas. Variable r_{max} is the maximum distance of the patterns that will be drawn related to the center point (c). Variable r_{seg} is the distance from the center point to the segment node. Variable d_r is the deviation of the curve. Variable l is the radial curve. Variable n_l is the number of radial curve. The curve consists of curve segments. So, L is the set of radial curves. Variable s_{cur} is used to represent the curve segment. Variable s_{cur} has 6 parameters and they can be represented in (i_l,i_s,x_1,y_1,x_2,y_2). The description of the segment attribute is in Table 1. The visualization of radial curve and curve segment is shown in Figure 3.

Table 1: Curve Segment Attributes

Attribute	Description
i_l	Curve index
i_s	Segment index
x_1	Horizontal starting position
y_1	Vertical starting position
x_2	Horizontal end position
y_2	Vertical end position

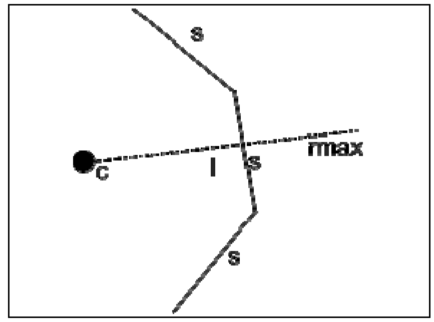

Figure 3: Visualization of Radial Curve and Curve Segment

Creating radial curves is done by iterating radial curve drawing. Each curve has starting angle (α_{start}), distance angle (α_{dist}), and segment angle (α_{seg}). Starting angle is angle from center point to the beginning of the curve. Distance angle is angle from the starting point of the curve to the end point of the curve related to the center point. Segment angle is the angle from the starting point of the segment to the end point of the segment related to the center point. The value of r_{seg}, α_{start}, α_{dist}, α_{end}, x_1, and y_1 are determined in Equation 1 to 5. The radial curve drawing algorithm is shown in Figure 4.

$$r_{seg} = rand(0, r_{\max}) \quad (1)$$

$$\alpha_{start} = rand(0,360) \quad (2)$$

$$\alpha_{dist} = rand(\alpha_{d\min}, \alpha_{d\max}) \quad (3)$$

$$x_1 = c_x + r_{seg}.\cos(\alpha_{seg}) \quad (4)$$

$$y_1 = c_y + r_{seg}.\sin(\alpha_{seg}) \quad (5)$$

```
for a := 0 to nl-1
begin
  rseg ← rand(0,rmax)
  αstart ← rand(0,360)
  αdist ← rand(αdmin, αdmax)
  αseg ← αstart
  αend ← αstart + αdist
  x1 ← cx + (rseg.cos(αseg))
  y1 ← cy + (rseg.sin(αseg))
  drawsegment()
end
```

Figure 4: Radial Curve Creation Algorithm

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In the radial curve creation algorithm, there is drawsegment procedure. Drawsegment procedure is procedure that is used to draw segments of the curve. The drawsegment algorithm is shown in Figure 5. The result is shown in Figure 6.

```
begin
  while α_seg < α_end
  begin
    α_seg ← α_seg + α_step
    r_seg ← rand(-d_r.r_seg, d_r.r_seg)
    if r_seg < 0 then
      r_seg ← 0
    x_2 ← c_x + (r_seg.cos(α_seg))
    y_2 ← c_y + (r_seg.sin(α_seg))
    drawline(x_1,y_1,x_2,y_2)
    x_1 ← x_2
    y_1 ← y_2
  end
end
```

Figure 4: Radial Curve Segment Creation Algorithm

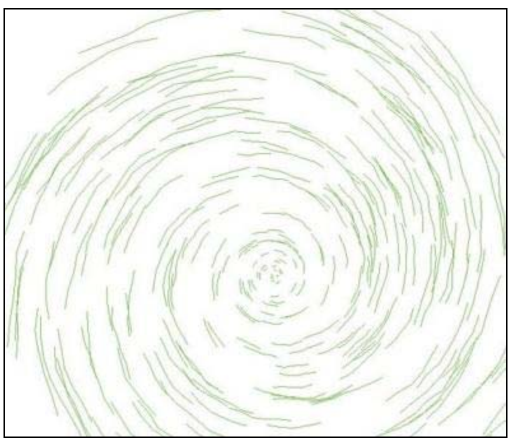

Figure 5: Radial Curve Result

After radial curve are created, the next phase is creating centrifugal segment. To create centrifugal line, some variables like c, r_{max}, r_{seg}, α_{start}, α_{seg}, x_1, y_1, x_2, and y_2 are reused. The centrifugal cegment consists of one segment only. So, x_1 and y_1 will be the starting position and x_2 and y_2 will be the end position. Variable r_{lseg} is the length of the segment. Variable n_{cseg} is the number of the centrifugal segment. The algorithm is shown in Figure 6. The final result is shown in Figure 7.

```
begin
  for a:=1 to n_cseg
  begin
    r_seg ← rand(0,r_max)
    α_start ← rand(0,360)
    x_1 ← c_x + (r_seg * cos(α_start))
    y_1 ← c_y + (r_seg * sin(α_start))
    α_seg ← α_start + rand(-α_dev, α_dev)
    r_lseg ← rand(r_lsegmin, r_lsegmax)
    x_2 ← x_1 + (r_lseg * cos(α_seg))
    y_2 ← y_1 + (r_lseg * sin(α_seg))
    drawline(x_1,y_1,x_2,y_2)
  end
end
```

Figure 6: Centrifugal Creation Algorithm

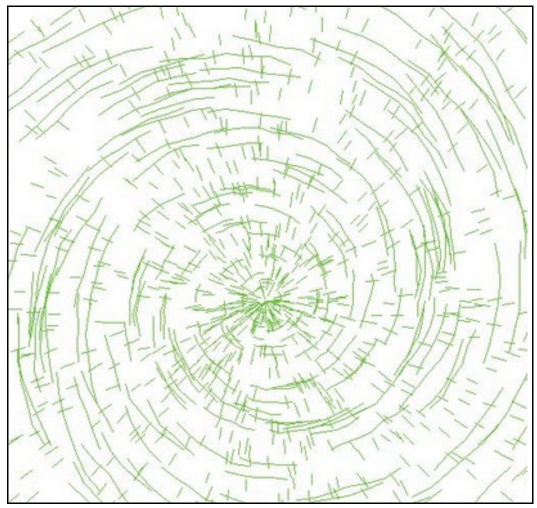

Figure 7: Leptoresis Model Result

3.2 Goniopora model

Goniopora is a coral genus which its characteristic is massive colonies and hemispherical [18]. It has irregular shape [18]. Its color is uniform blue, green, or brown [18]. Goniopora lives in sub tidal reef environment, especially in Lagoon [18]. The visualization of Goniopora coral is shown in Figure 8 [18].

Based on its characteristics, then Goniopora coral model is constructed. The construction is divided into two works. The first work is generating the background spot. The second work is generating the foreground object. In this model, variables c_x, c_y, and r_{max} are used. Variables c_x and c_y are used to represent the center of the coral. Variable r_{max} is used to determine the maximum distance of the object related to the center of the coral.

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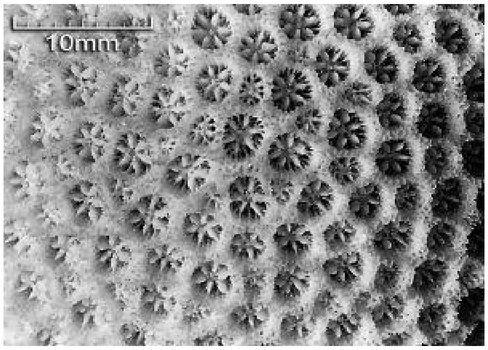

Figure 8: Goniopora tenuidens

In the first step, background object is represented by set of nodes. The node position is represented by variables x_n and y_n. Variable d is the distance between the node and the center point. Variable n_{node} represents the number of the background nodes. The nodes are placed randomly which follows uniform distribution. The value of x_n, y_n, and d are determined by Equation 6 to 8. The first step algorithm is described in Figure 9. The result is shown in Figure 10.

$$x_n = rand\left(c_x - r_{\max}, c_x + r_{\max}\right) \tag{6}$$

$$y_n = rand\left(c_y - r_{\max}, c_y + r_{\max}\right) \tag{7}$$

$$d = \sqrt{\left(x_n - c_x\right)^2 + \left(y_n - c_y\right)^2} \tag{8}$$

```
begin
  for i:=0 to n_node
  begin
    x_n ← rand(c_x-r_max, c_x+r_max)
    y_n ← rand(c_y-r_max, c_y+r_max)
    d = sqrt((x_n-c_x)^2 + (y_n-c_y)^2)
    if(d < r_max) then
      drawcircle(x_n,y_n)
  end
end
```

Figure 9: Goniopora First Step Algorithm

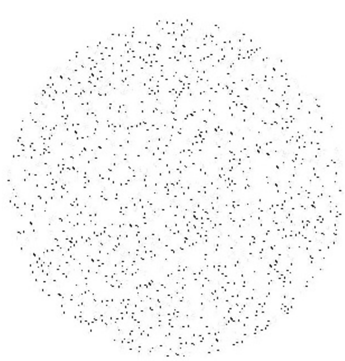

Figure 10: Goniopora First Step Result

The second step is creating the foreground object. The foreground object is a hemispheric polygon. Similar to the background object, the object position is represented by x_n and y_n as the center of the object. The object is determined randomly and follows uniform distribution.

In the foreground object, variables x_1, y_1, x_2, y_2, r_{seg}, r_{segmin}, r_{segmax}, α_{seg}, $\alpha_{stepmin}$, and $\alpha_{stepmax}$ are used. Variables x_1, y_1, x_2, and y_2 are used as the starting and end positions of the segment. Variable r_{seg} is the segmen radius related to the center of the object. Variable α_{seg} is used to determine the segment position. The foreground object algorithm is described in Figure 11. The result is shown in Figure 12.

```
begin
  α_seg ← 0
  r_seg ← rand(r_segmin, r_segmax)
  x_1 ← x_n + r_seg * cos(α_seg)
  y_1 ← y_n + r_seg * cos(α_seg)
  while (α_seg < 360)
  begin
    α_seg ← α_seg + rand(α_stepmin, α_stepmax)
    x_2 ← x_n + r_seg * cos(α_seg)
    y_2 ← y_n + r_seg * cos(α_seg)
    drawline(x_1,y_1,x_2,y_2)
    drawline(x_n,y_n,x_2,y_2)
    x_1 ← x_2
    y_1 ← y_2
  end
end
```

Figure 11: Goniopora Second Step Algorithm

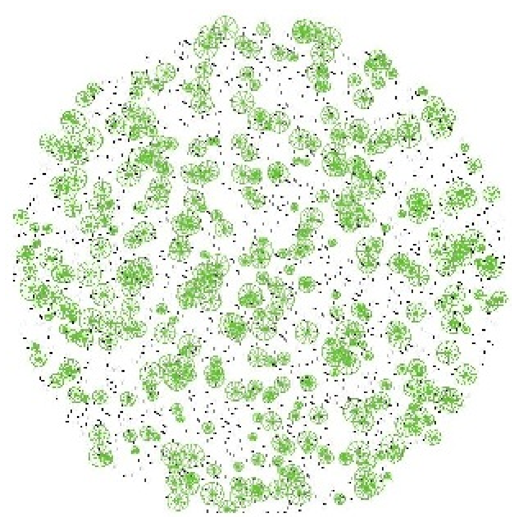

Figure 12: Goniopora Second Step Result

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3.3 Acropora model

Acropora genus is familiar with its characteristic: branching. The branching pattern is various, from korimbosa, arboresen, kapitosa, etc [19]. The other characteristic is its axial and radial corralite. In Indonesia, there are approximately 113 Acropora species [1]. The Acropora visualization is shown in Figure 13 [19].

Figure 13:Acropora carduus

Based on tree like appearance, Acropora model is constructed. There are two types of branch: main branch and sub branch. The model construction is divided into two steps. In the first step, the main branches are constructed. In the second step, the sub branches are constructed. The sub branches are nested into the main branches.

In the main branch construction, variables c_x and c_y are used to determine the seed position or the center of the coral. The main branches grow from the seed. The number of the main branch is determined by the starting angle (α_{start}), end angle (α_{end}), and the step (α_{step}). Variable r_{max} is used to determine the main branch length. Variable r_{curmax} is the maximum length of the current main branch. Variable ω is the length factor of the maximum main branch with the value is from 0 to 1. Variable r_{seg} is the length of the main branch segment. Variable α_{seg} is the direction of the main branch segment. Variable α_{dev} is the deviation of the segment direction. Variables x_1 and y_1 are the starting point of the main branch segment. Variables x_2 and y_2 are the end point of the main branch segment. The value of r_{curmax}, r_{seg}, α_{seg}, and α_{step} is determined by Equation 9 to 12. The main branch construction algorithm is shown in Figure 14. The result is shown in Figure 15.

$$r_{cur\max} = rand(\omega.r_{\max}, r_{\max}) \tag{9}$$

$$r_{seg} = rand(r_{seg\min}, r_{seg\max}) \tag{10}$$

$$\alpha_{seg} = \alpha_{seg-1} + rand(-\alpha_{dev}, \alpha_{dev}) \tag{11}$$

$$\alpha_{step} = rand(\alpha_{step\min}, \alpha_{step\max}) \tag{12}$$

In the main branch construction algorithm, random process is used in some instructions. This random process follows uniform distribution. As uniform distribution, the random number that is produced is limited in the range of the minimum and the maximum values.

```
begin
  αdir ← αstart
  while(αdir < αend)
  begin
    x1 ← cx
    y1 ← cy
    rmain ← 0
    αseg ← αdir
    rcurmax ← rand(ω * rmax, rmax)
    while(rmain < rmax)
    begin
      rseg ← rand(rsegmin,rsegmax)
      x2 ← x1 + rseg * cos(αseg)
      y2 ← y1 + rseg * sin(αseg)
      drawline(x1,y1,x2,y2)
      drawsubbranch()
      x1 ← x2
      y1 ← y2
      rmain ← rmain + rseg
      αseg ← αseg + rand(-αdev, αdev)
    end
    αstep ← rand(αstepmin,αstepmax)
    αdir ← αdir + αstep
  end
end
```

Figure 14:Acropora Main Branch Algorithm

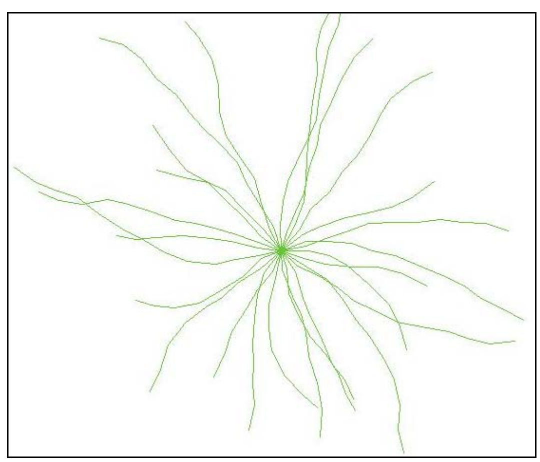

Figure 15: Main Branch Result

As it is shown in Figure 14, the sub branch construction is executed in drawsubbranch function. In this process, some variables are used. Variable p_{split} is the probability of the sub branch that is created within segment. Variable r_{sub} is the length of the sub branch. Variable p_{dir} is used to determine the direction of the sub branch, on the left or on the right of the main branch segment. Variable α_{sub} is the angle of the sub branch. Variable α_{subdev} is the deviation of the sub branch angle. Variables x_1 and x_2 are the starting point of the sub branch. Their value is determined in main branch algorithm. Variables x_3 and y_3 are the end point of the sub branch. The sub branch algorithm is shown in Figure 16. The result is shown in Figure 17.

```
begin
  if(rand(0,100)/100 < p_split)
  begin
    r_sub ← rand(r_minsub,r_maxsub)
    if(rand(0,100) > 50)
      p_dir ← -1
    else
    begin
      p_dir ← 1
      α_sub ← α_seg + (α_subdev * p_dir)
      x_3 ← x_1 + r_sub * cos(α_sub)
      y_3 ← y_1 + r_sub * sin(α_sub)
      drawline(x_1,y_1,x_2,y_2)
    end
  end
end
```

Figure 16:Acropora Sub Branch Algorithm

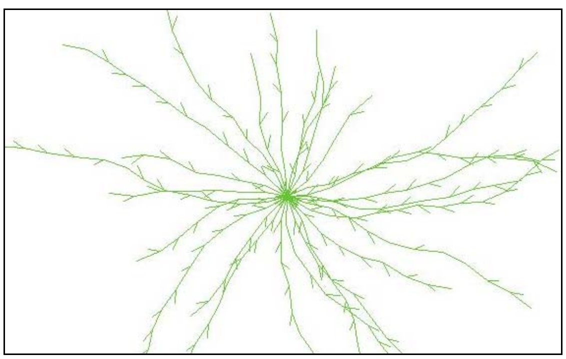

Figure 17:Acropora Sub Branch Result

4. IMPLEMENTATION

The proposed models then are implemented to generate batik pattern. The main characteristic of batik is array of dots. Other art object may be added into the image. In this research, some artistic objects are added into these three basic coral models.

In the Leptoresis model, array of dots are added both in the radial curve and the centrifugal line. The dot then replaces the line. Flower like object is also added into the end of every radial curve. The result is shown in Figure 18. In Figure 18, it can be seen that the distance between dots for radial curve that is closer to the coral center is tighter than the radial curve that is farther from the coral center. It is often seen in the radial curve that is close to the coral center because the distance between dots is too tight so that the array of dots is looked like bold curve.

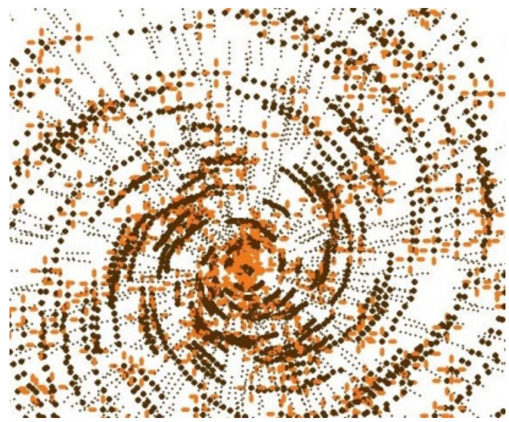

Figure 17:Leptoseris Based Batik Pattern

In Goniopora model, some modifications can be implemented both in the background object and or in the foreground object. In the first modification, in the basic Goniopora model, the size of the circle is static. So, more dynamic circle size can be used to replace the static size circle. The result of the first modification is shown in Figure 18.

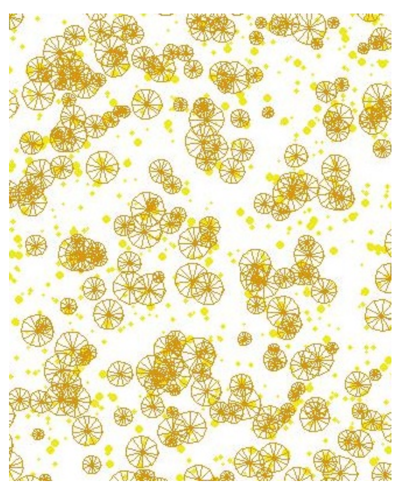

Figure 18:Goniopora Based Batik Pattern (First Modification)

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In the second modification, the background object can be replaced with some background objects. It means that there are some background objects that are generated stochastically rather than single size circle object which is in the basic Goniopora model. The objects selection follows basic discrete distribution. The algorithm is shown in Figure 19. In this research, we propose two types of objects, small circle and flower like object. The result is shown in Figure 20.

```
begin
  x ← rand(0,100)
  if(x < m1)
    draw(object1)
  else if(x < m2)
    draw(object2)
  else if(x < m3)
    draw(object3)
  …
  else
    draw(objectn)
end
```

Figure 19: Background Object Selection Algorithm

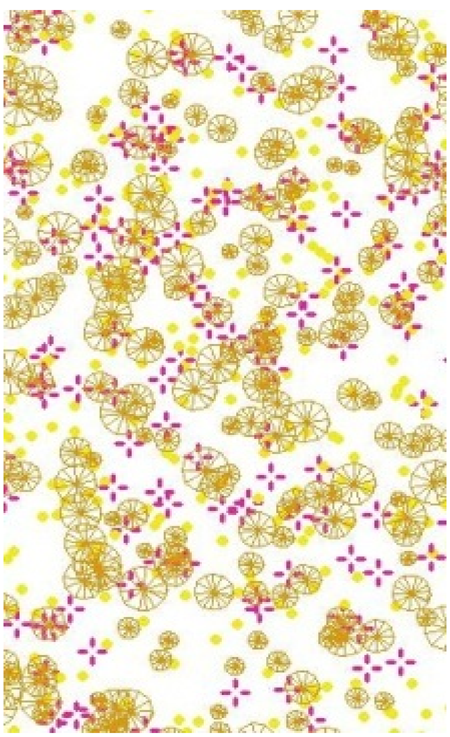


Figure 20: Goniopora Based Batik Pattern (Second Modification)

In the third modification, the foreground object can be replaced with new foreground object. Even there are modification, the new foreground object must represent the basic Goniopora model. In this research we add some dots in the foreground object. The result is shown in Figure 21.

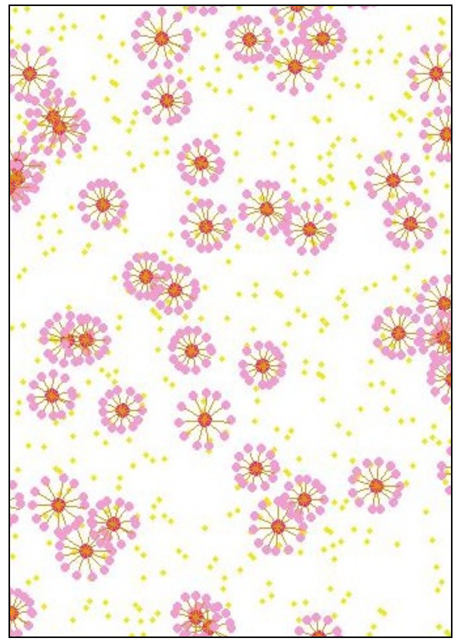


Figure 21: Goniopora Based Batik Pattern (Foreground Modification)

In the Acropora model, modification can be implemented by adding background object, modifying main branch, and or modifying sub branch. In this research, we propose the modification in these three aspects: background, main branch, and sub branch. In the end of each sub branch, we add flower like object. The result is shown in Figure 22.

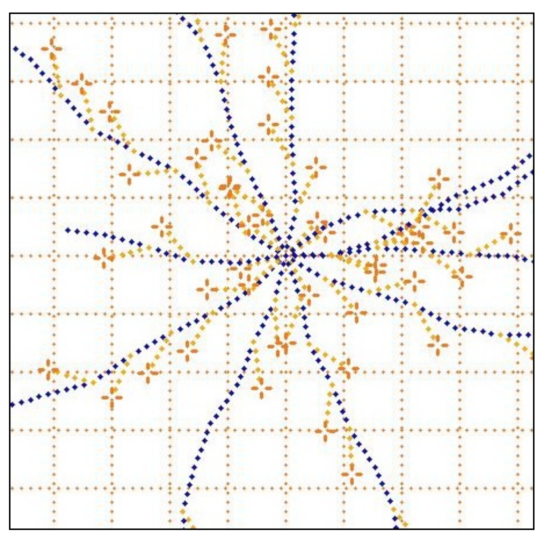
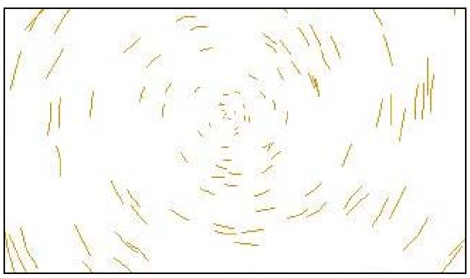


Figure 22: Acropora Based Batik Pattern

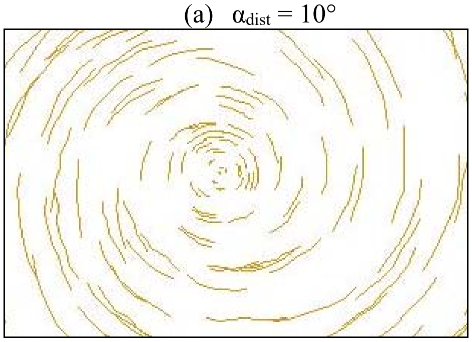
5. DISCUSSION

After the proposed model is implemented into batik pattern generator, there are several tests to observe the relation between the controlled parameters with the observed result. The observation is done visually or numerically. The controlled and observed result that are tested are depended on the coral model.

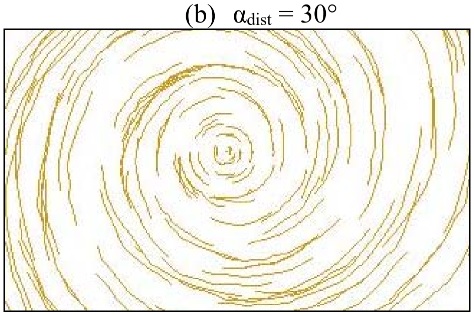
In Leptoseris model, the test is to observe the radial curve result and the centrifugal segment result. In radial curve result, the controlled variables are α_{dist}, $\alpha_{step,}$ and d_r. The result is observed visually. The relation between α_{dist} and the result image is shown in Figure 23. In this test, the α_{step} is set 5°.



(a) $\alpha_{dist} = 10°$



(b) $\alpha_{dist} = 30°$

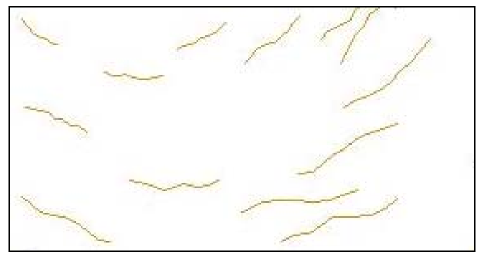


(c) $\alpha_{dist} = 50°$

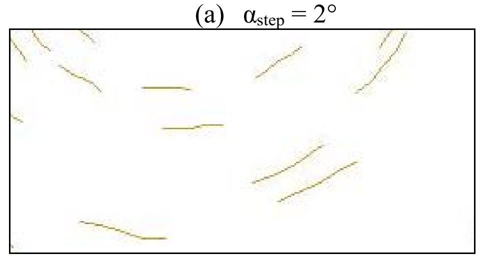
Figure 23: Relation Between α_{dist} and Radial Curve Result

Based on the result image in Figure 23, it can be seen that the α_{dist} variable gives significant impact in radial curve result. Higher value of α_{dist} makes the radial curve result is like high speed whirlpool. When α_{dist} is 10°, it is shown that the radial curve is common with short segment. When the α_{dist} is higher, the segment is like whirlpool and the segment is longer. In the end, when the α_{dist} is set 50°, the radial curve result is like high speed whirlpool.

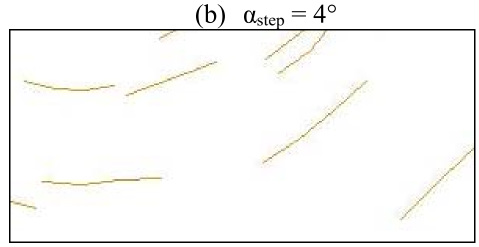
The next test is to observe the relation between α_{step} and the radial curve result. The α_{dist} is set 15°. The α_{step} is set 2°, 4°, and 6°. The result is shown in Figure 24.



(a) $\alpha_{step} = 2°$



(b) $\alpha_{step} = 4°$



(c) $\alpha_{step} = 6°$

Figure 24: Relation Between α_{step} and Radial Curve Result

Based on the result in Figure 24, it is shown that the lower value of α_{step} makes the the curve wavier. In the other hand, higher value of α_{step} makes the curve straighter. When the α_{step} is 2 degree, the curve is looked wavy. When the α_{step} is 6 degree, the curve is looked almost straight.

The next test is to observe the relation between d_r and the radial curve result. The α_{dist} is set 30°. The α_{step} is set 6°. The d_r is set 0.1, 0.3, and 0.5. The result is shown in Figure 25.

Based on the result in Figure 25, it is shown that the different value of d_r makes different

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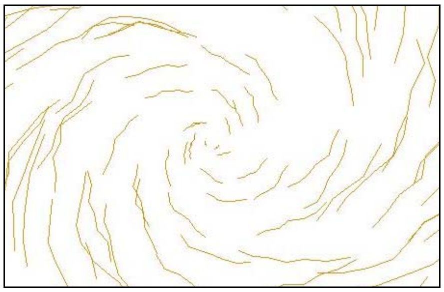
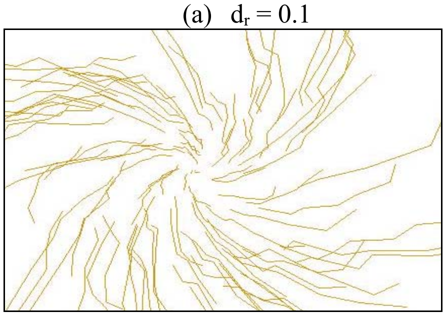
radial curve pattern. Lower value of d_r makes the curve more radial that it is seen in Figure 25(a). When the value of d_r is higher, as it is seen in Figure 25(b), the curve is tended to be centrifugal. In Figure 25(c), when the d_r is set 0.5, the curve is more centrifugal than in Figure 25(b) and the curve starting position is closer to the coral center point.


(a) $d_r = 0.1$


(b) $d_r = 0.3$

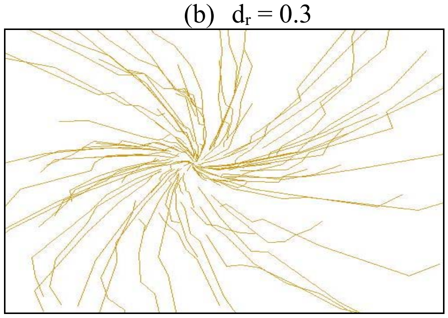
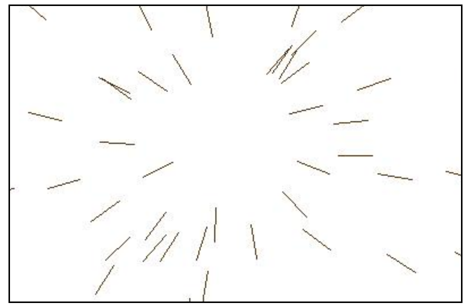
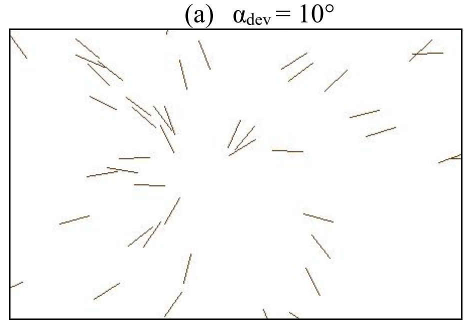

(c) $d_r = 0.5$

Figure 25: Relation Between d_r and Radial Curve Result

The next test is to observe the centrifugal segment. The controlled variable is the α_{dev} variable. The value of α_{dev} is set 10°, 30°, and 50°. The result is shown in Figure 26.

Based on the result in Figure 26, it is seen that the value of α_{dev} has significant impact to the centrifugal segment. When α_{dev} is low as it is seen in Figure 26(a), the segment is fully centrifugal and the coral center point is clear. During the increasing of the α_{dev} value, the segment direction is more random but the coral center point still can be predicted as it is seen in Figure 26(b). When the α_{dev} is high, the segment direction is very random and the coral center point cannot be predicted anymore.


(a) $\alpha_{dev} = 10°$


(b) $\alpha_{dev} = 30°$

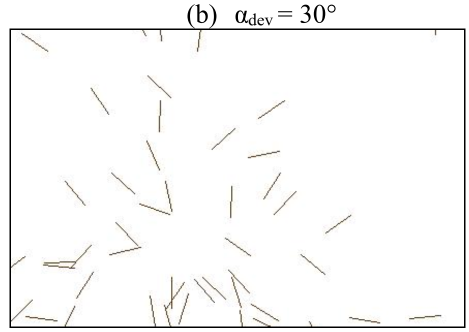

(c) $\alpha_{dev} = 50°$

Figure 26: Relation Between α_{dev} and Centrifugal Segment Result

The next test is for Goniopora based coral model. The test is to observe the foreground object. The controlled variable is α_{step} where in this test, the $\alpha_{stepmin}$ and the $\alpha_{stepmax}$ is set equal. The image result is observed for the value of α_{step} is set 10°, 50°, and 90°. The result is shown in Figure 27.

Based on the result in Figure 27, it is seen that the value of α_{step} has impact to the foreground object shape. When the α_{step} is low as it is seen in Figure 27(a), the foreground object is seen circle. When the value of α_{step} is higher, foreground object is more polygonal as it is seen in Figure 27(b) and Figure 27(c).

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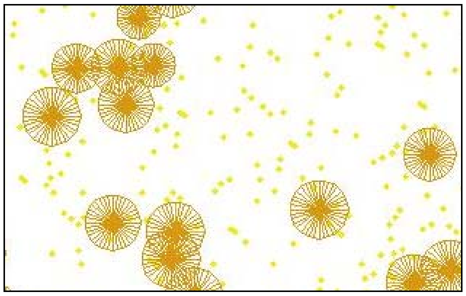
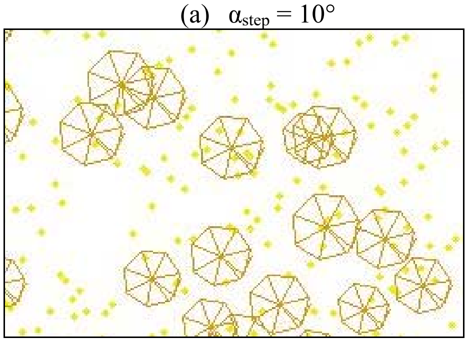
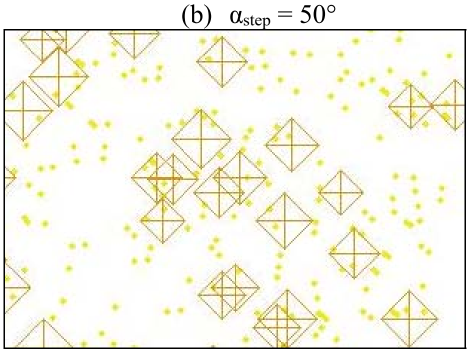


(a) α_{step} = 10°



(b) α_{step} = 50°



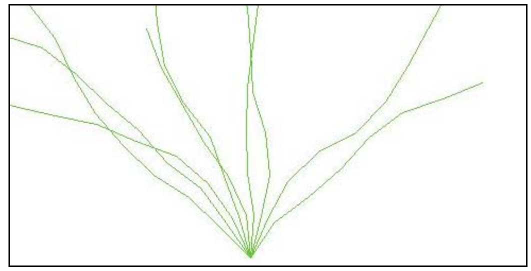
(c) α_{step} = 90°

Figure 27: Relation Between α_{step} and Foreground Object in Goniopora Model

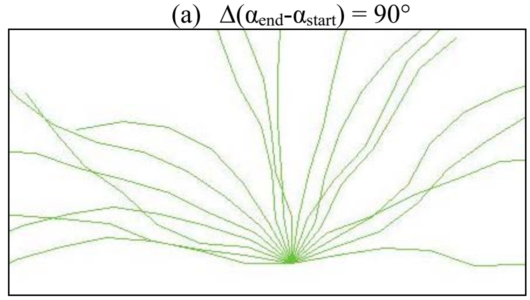
The next test is to observe Acropora based coral model. There are two tests for Acropora based coral model. The first test is for the main branch. The second test is for the sub branch.

Observation the main branch is done by observing the relation between the angle difference between the α_{start} and α_{end} and the shape of the main branch. The value of the angle difference is set 90°, 180°, and 360°. The result is shown in Figure 28.

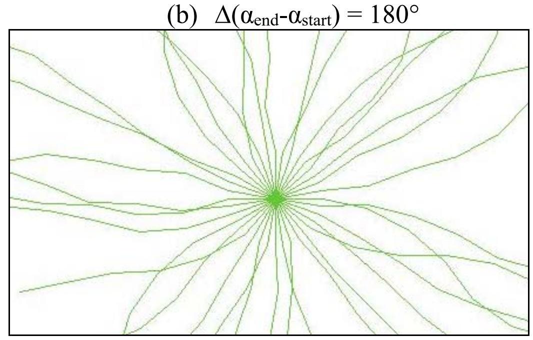
Based on result in Figure 28, it is seen that higher value of the angle difference between α_{end} and α_{start} makes significant impact to the main branch shape. When the angle difference is small, the coral main branch spread narrowly as it is seen in Figure 28(a). When the angle difference grows high, the coral main branch spreads wider as they are seen in Figure 28(b) and Figure 28(c).



(a) $\Delta(\alpha_{end}\text{-}\alpha_{start})$ = 90°



(b) $\Delta(\alpha_{end}\text{-}\alpha_{start})$ = 180°



(c) $\Delta(\alpha_{end}\text{-}\alpha_{start})$ = 360°

Figure 28: Relation Between $\Delta(\alpha_{end}\text{-}\alpha_{start})$ and Main Branch Shape

The next test is to observe the relation between split probability (p_{split}) and the number of sub branches. In this test, α_{start} is 0°, α_{end} is 360°, and $\alpha_{startstep}$ is 10. The controlled variable is probability of split (p_{split}). The observed variable is the number of sub branches (n_{sub}). There are five running sessions for every value of p_{split}. The result is shown in Table 2 and Figure 29.

Table 2. Relation Between p_{split} and n_{sub}

p_{split}	n_{sub}		
	Average	Minimal	Maximal
0.1	3.2	0	7
0.2	5.2	2	7
0.3	6.8	3	9
0.4	16.2	8	21
0.5	43	36	51
0.6	68.8	52	83
0.7	163.8	79	227
0.8	223.6	211	236
0.9	249.6	240	261

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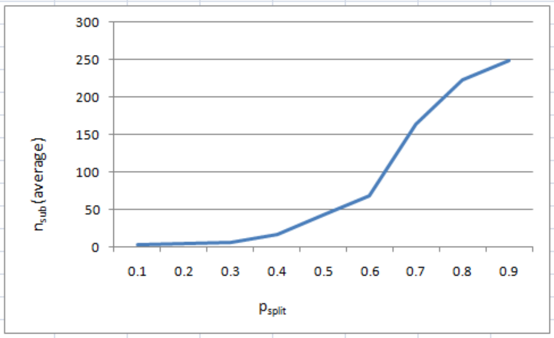

Figure 29: Relation Between p_{split} and n_{sub}

Based on the result in Table 2 and Figure 29, it can be seen that higher probability of split makes the number of sub branches increases. Based on trend in Figure 29, it is seen that the increasing of the number of sub branches follows sigmoid curve. High slope occurs when the probability of split is from 0.4 to 0.8. After that, the increasing of the number of sub branch is slow.

Based on the test result, especially in visual observation, general coral like patterns have been developed. The result pattern also represents Leptoseris, Goniopora, and Acropora models. Unfortunately, if we look deeper, there are several problems and limitations between coral pattern that is generated by these proposed models and the coral pattern in the real world.

In Leptoseris model, there are limitations comparing with the real coral pattern. In the reality, a radial curve is connected with some radial curves near it. In this proposed model result, a radial curve is separated to each other. In the real world, the centrifugal segments are branches that are connected to the radial curve. In this proposed model, the centrifugal segments are generated separately from the radial curve.

In Goniopora model, in the real world, the there are not any star like objects that overlap the other star-like object. There is specified distance between star-like objects. In our proposed model, because the position of the star-like objects are generated randomly and the position of the other star-like objects is not concerned, so that there is possibility that there are several star-like objects that overlap the other star-like objects. In the real world, the small circles position is between star-like objects so that basically the small circles fill the empty space between the star-like objects. Unfortunately, in this proposed model, the small circles are generated randomly and the random process follows uniform distribution. The star-like position is not concerned in this model. So there is possibility that there are small circles that is covered by the star-like object.

In Acropora model, in the real world, even branching process is limited, it is possible. Another main branch can exist from another main branch. This condition is different to the proposed model. In this proposed model, even there are more than main branch that spreads from single seed, the main branch cannot be split to produce another main branch. In this proposed model, branching process occurs only when the main branch creates sub branch.

This proposed model, especially in Acropora model can be compared with the previous works [4,5]. In the fibrous root model, the branch can be split into another branch and the branching process is controlled by branching ratio variable [4]. So, in the previous work, there are not any specific main branch and sub branch terms [4]. In this proposed model, there are two specific branch types: main branch and sub branch. The sub branch is generated from main branch. Main branch cannot produce another main branch. In the other hand, there are not any branches from sub branch. The similarity with the previous work [4] is that there are many branches that are spread out from a seed.

By comparing this proposed model with the previous work [5], there are some differences. In the previous work, crack is generated from one stress node [5]. The initial stress node is similar with the seed. In the crack model, there is only one segment that exists from one initial stress node [5]. So, if we assume that the stress node is the seed, there will only one main branch from a seed and it is not realistic. Another problem is branching process. Similar to the fibrous root model [4], in the crack model, the branching process is limitless. So, the simplified crack model [5] must be modified if it will used to create coral pattern, especially Acropora model. The other difference is the branching angle. In this proposed model, the angle between the main branch direction and the sub branch direction is low. In crack modeling, the angle between the split branch is high [5].

6. CONCLUSION AND FUTURE WORK

Based on the explanation above, the stochastic coral model has been developed and the model has been implemented to generate batik pattern successfully. In this paper, three coral models have been developed. They are Leptoseris, Goniopora, and Acropora based models.

In this research, even we ignored the environmental and biological aspect as these aspects are the major concern in developing real coral model in natural science field, the coral patterns still can be generated. By ignoring the environmental and biological aspects, developing coral model becomes simpler and easier. Nevertheless, the result image still can be recognized as coral shape. Additional artistic objects have been added to change node and line in the basic coral model to convert it into batik pattern.

Some parameters affect the shape of the coral model. In Leptoseris mode, lower step angle makes the radial curve wavier. Otherwise higher step angle makes the radial curve straighter. Higher α_{dist} makes the radial curve is like high speed whirlpool. Lower d_r makes the radial curve tends to be radial. Otherwise, higher d_r makes the radial curve tends to centrifugal. Lower α_{dev} makes the centrifugal segment tend to spread centrifugally and the coral center point still can be recognized. Higher α_{dev} makes the centrifugal segment tend to spread randomly and the coral center point cannot be recognized. In Goniopora model, lower α_{step} makes the foreground object is like circle. On the other hand, higher α_{step} makes the foreground objects is like polygon. In Acropora model, higher $\Delta(\alpha_{end}-\alpha_{start})$ makes the main branch spreads wider. The increasing of probability of split makes the number of sub branches grows and follows sigmoid curve.

Comparing with the real coral shape, there still are limitations and differences between the coral pattern in the real world and in the result from the proposed model. In Leptoseris model, the radial curve is separated with other radial curves. The centrifugal segment is also separated with the radial curve. In Goniopora model, a star-like object can overlap the other star-like objects. In Acropora model, the main branch cannot produce other main branch.

There are still many research potentials in nature object model development as basis for generating batik pattern. There are lots of coral model that has not been explored. So, exploring more coral models is still possible. Beside coral, there is lots of ocean biota that can be explored, such as: turtle shell, fish skin, and ocean alga. Exploring new pattern will makes richer batik patterns rather than the classic patterns.

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