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Fractal batik pattern based on catastrophe theory

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Abstract
In this paper I will present the use of fractal geometry to design Indonesian batik patterns. Fractals are geometric shapes consisting of several different characteristics whose parts have the same overall shape, are fragmented, and are created by iteration. This paper aims to provide a method for making fractal geometric patterns with an iteration basis in the form of fold catastrophe and cusp catastrophe formulas. Generator algorithm consists of basis, iteration, coloring, and duplication. To help discuss further about the algorithm, I will present a script program using Matlab. Using this algorithm, we can generate thousands of aesthetically beautiful variations of batik patterns, of which we present some examples.

Keywords: batik, patterns, fractals, catastroph theory

Introduction

Identity is something that is inherent and reflects a person in a small or large scope. National identity is also a necessity that must be owned. The identity of a nation is manifested in various forms such as the national flag, national anthem, state symbol and culture. The observable aspects of culture include food, clothing, religion, language, buildings and other works. The focus of the study in this research is self-identity which is manifested in batik clothes. Batik has been designated as Indonesian Cultural Heritage by the United Nations Educational, Scientific and Cultural Organization (UNESCO)

Batik is the art of drawing on cloth for clothing [1]. This drawing art is not just drawing, but what motifs are drawn also has a philosophical meaning. The creativity of this batik art does not only dwell on local culture, but also meets foreign cultures along with cultural and business relations between countries. Local culture that is in contact with other cultures such as China, India and the Middle East gives its own color in a variety of motifs. The creativity of batik art also develops along with the development of science and technology. In this research we try to develop batik art based on fractal geometry and catastrophe theory.

The term fractal was introduced in mathematics by Mandelbrot, who defines what is called fractal geometry [2-3]. This geometry is able to describe the irregular but beautiful shapes found by nature. Fractal geometry is based on the use of the principle of repetition of geometric shapes, so that an object can reproduce itself when experiencing magnification. With fractal geometry, art can discover new creativity. Even with fractals, we can find new patterns that were previously unimaginable. With fractals, we don't need to create shapes, we just need to do shape selection, because fractals will provide an infinite variety of shapes.

In addition to the design of batik patterns [4-6], fields connected by fractal geometry are medical imaging [7-10]. Fractal geometry has also been used for data compression and modeling complex geological and organic systems, such as tree growth and river valley development. From these facts I have done research on how to make tile motifs using fractal theory.

The catastroph theory, created by Rene Thom in his book Structural Stability and Morphogenesis [11], has generated great interest among mathematicians and mathematicians alike. The theory is considered to be able to explain how continuous parameter changes can cause discontinuous phenomena. This theory is also needed to study qualitative problems in biology and social sciences [12]. Some people try to apply this theory in the field of architecture. This theory has the potential to describe the evolution of form in all aspects of nature, and thus embody the theory of real generality; which can be applied in situations where a gradually changing force causes a sudden change in behavior. For this reason, the term catastrophic theory was chosen. Many events in physics are now known examples of mathematical catastrophs. Catastroph theory can thus provide a mathematical language for the so-called uncertain sciences.

This theory comes from topology, the branch of mathematics that deals with the properties of surfaces in many dimensions [13-15]. The topology involved due to the forces present in nature can be explained by the smooth surface balance. When the balance is broken then catastroph occurs. Therefore, the problem of catastroph theory is to describe the shape of all possible equilibrium surfaces. Thom has solved this problem in several archetypal forms, which he calls the basic catastrophe. For processes controlled by no more than four factors, Thom has shown that there are only seven basic catastrophs. The basic catastrophs themselves can be reached and applied to problems in science. The seven basic catastrophs are fold, cusp, swallowtail, butterfly, hyperbolic, elliptic, parabolic. In this study, a fractal pattern based on the fold catastroph and cusp catastroph models will be made for batik designs. The mathematical formula for the fold catastroph is $y = 1/3\, x^3 - ax$ and for the cusp catastroph is $y = \frac{1}{4} x^4 - \frac{1}{2} bx^2 - ax$.

Algorithm

In making a fractal catastrophe batik pattern, the matrix base is first formed. Base in the form of a two-dimensional matrix with continuous values that can be linear, sine, quadratic and others. To get a symmetrical pattern, the base matrix value must also be symmetrical. This is an example of a symmetrical basis in matlab code:

```
x = linspace (-1,1,200);
y = linspace (-1,1,200);
[X, Y] = meshgrid (x, y);
```

After the base is formed, the iteration function is performed. The two iteration functions that worked well in my research were the 'cusp' function and the 'fold' function described in the introduction. This function has had beautiful results since the first iteration. If the number of iterations and constants are assigned random values, then each execution will produce a different image. This is an iteration of ‘fold’ function in matlab code.

```
C = 0.5+ rand;
Z = X+i*Y+eps;
for k = 1:col;
Z = Z.^3/3-Z.*c;
W = exp(-abs(Z));
end;
```

The most important phase is color filling. In principle, in Matlab, we can create a color map matrix randomly by assigning random values to the red, green and blue components. Black color can be obtained by combining RGB = 0,0,0. Brown color is obtained by combining RGB = 0.5,0.5,0. The yellow color is obtained by combining RGB = 1,1,0. And white with a combination of RGb = 1,1,1. The green color is obtained by combining RGB = 0.1,0. The combination of random numbers RGB = (random, random, 0) can produce a reddish, brownish or greenish color. In matlab, for this purpose an algorithm can be made as follows:

```
Makskolor = 256;
for i = 1:makskolor;
kolor(i,1)=rand;
kolor(i,2)=rand;
kolor(i,3)=rand;
end;
```

The resulting pattern from the previous phase is called a single cell. If you want a repeating batik pattern, one cell is duplicated into one column consisting of 2 symmetrical cells arranged downwards. Then for the row, just double it if it's symmetrical. If it's not symmetrical, multiply it by flipping it vertically. How to duplicate can be with the program or manually using an image editor. The full algorithm in the Matlab code is presented below

```
% fractal fold catastrophe
clear;
col=5+rand*5;
disp (col);
m=700;
n=500;
cx=0;
cy=0;
l=1;
disp(l);
x=linspace(cx-l,cx+l,m);
y=linspace(cy-l,cy+l,n);
[X,Y]=meshgrid(x,y);
c=0.5+ rand;
Z=X+i*Y+eps;
for k=1:col;
Z=Z.^3/3-Z.*c;
W=exp(-abs(Z));
end
makskolor=256;
for i=1:makskolor;
kolor(i,1)=rand;
kolor(i,2)=rand;
kolor(i,3)=rand;
end;
colormap (kolor)
pcolor(W);
shading flat;
axis('square','equal','off');
%fractal cusp catastrophe
clear;
col=rand*5;
disp (col);
m=1000;
n=500;
cx=0;
cy=0;
l=1;
disp(l);
x=linspace(cx-l,cx+l,m);
y=linspace(cy-l,cy+l,n);
[X,Y]=meshgrid(x,y);
c=-1;
b=-1;
Z=X+i*Y;
for k=1:col;
Z=Z.^4-Z.^2/2*b-Z.*c;
W=exp(-abs(Z));
end
makskolor=64;
for i=1:makskolor;
kolor(i,1)=rand;
kolor(i,2)=rand;
kolor(i,3)=rand;
end;
colormap (kolor)
pcolor(W);
shading flat;
axis('square','equal','off');
```

Results

In this research, two programs have been executed, namely the c fold catastroph and the cusp catastroph based. Because it uses random values, each execution produces a different pattern. From this computer program, we can produce thousands of different batik motifs. We just need to choose a motif that we think is subjectively beautiful. Examples of batik motifs that I have produced can be seen in Figure 1, Figure 2, Figure 3, Figure 4, Figure 5, and Figure 6. Figures 1, 2 and 3 are examples of fractal patterns on the basis of iteration using the fold catastrophe formula. Figures 1 and 2 are the results of one pattern cell from the first algorithm. If one cell of the pattern in Figure 2 is duplicated, it will get a batik pattern as shown in Figure 3. As in the previous images, Figures 4, 5 and 6 are examples of fractal patterns on the basis of iteration using the cusp catastrophe formula. Figures 4 and 5 are the results of one pattern cell from the second algorithm. If one pattern cell in Figure 5 is duplicated, a batik pattern will be obtained as shown in Figure 6. Because this algorithm involves random numbers, each execution will produce a different pattern. Therefore, the presented algorithm can generate thousands of fractal patterns.

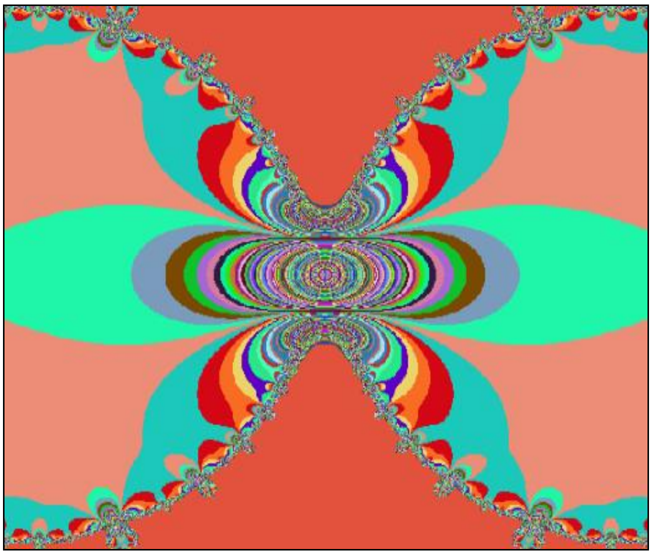

Fig 1: Fractal catastrophe batik motif 1

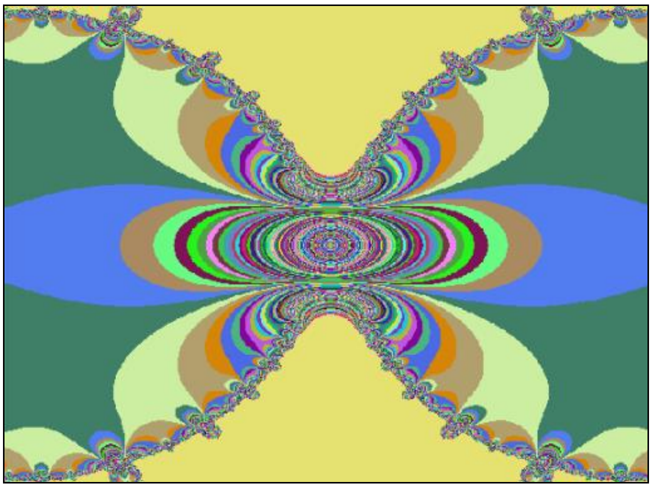

Fig 2: Fractal catastrophe batik motif 2

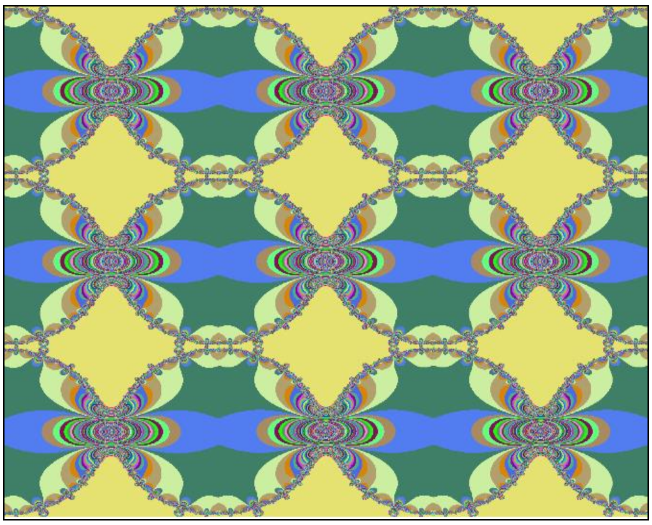

Fig 3: Fractal catastrophe batik motif 3

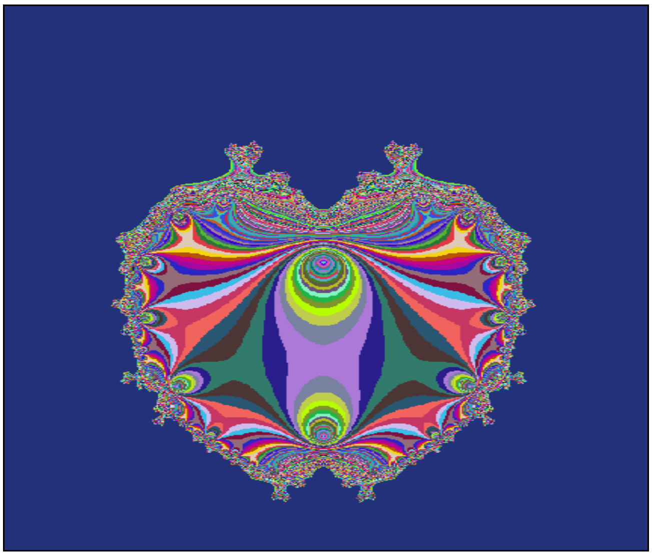

Fig 4: Fractal catastrophe batik motif 4

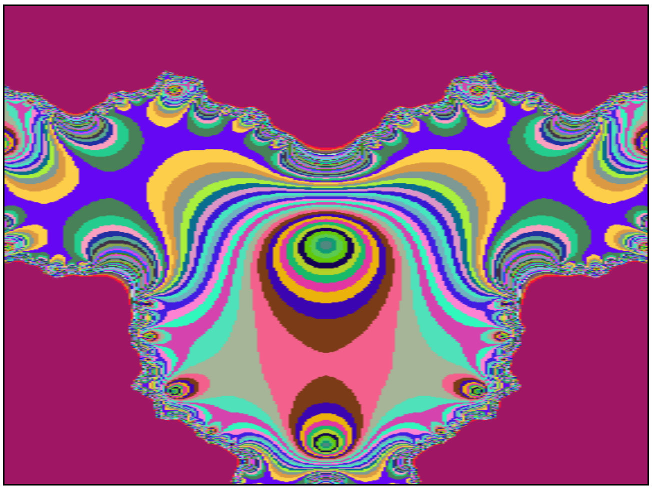

Fig 5: Fractal catastrophe batik motif 5

Fig 6: Fractal catastrophe batik motif 6

Conclusion

The discovery of Fractal Geometry has made it possible to find thousands of beautiful batik motifs automatically so that it is very pleasant. Fractals make it possible to better understand geometric figures with regular structures. By using Fractal geometry, we can play with large simulations without limits through digital systems. Thus, we can gradually involve science in art and culture.

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