Satellite Image Edge Detection for Population Distribution Pattern Identification using Levelset with Morphological Filtering Process

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Abstract. Population distribution pattern is directly related with economic gap of a region. Analysis of population distribution pattern is usually performed by studying statistical data on population. This study aimed to analyze population distribution pattern using image analysis concept, i.e. using satellite images. Levelset and morphological image filtering methods were used to analyze images to see distribution pattern. The research result showed that Levelset and morphological image filtering could remove a lot of noises in analysis result images and form object edge contours very clearly. The detected object contours were used as references to recognize population distribution pattern based on satellite image analysis. The pattern made based on the research result didn’t show optimal result because Levelset performed image segmentation based on the contours of the analyzed objects. Other segmentation methods should be combined with it to produce clearer population distribution pattern.

1. Introduction

Population distribution pattern should be studied considering it is relation with population density in a region, which is directly related with economic growth in the region. Moreover, population distribution pattern will form certain cluster pattern, which can be used to see the equalization and population growth of a region. It is the initiative basis of implementation strategy of MP3EI program. Dense population distribution pattern will cause economic gap compare with other regions with normal distribution pattern [1]. One of the approaches to analyze population distribution pattern is image analysis.
Discussion on image concept has been developing for a long time and is one of the important research fields in knowledge. Image isn’t only a representation of an object for documentation or art. Furthermore, image contains information which may not have been thought of before. To get the information, a technique and in-depth understanding on issue which will be raised through image media are required.

In the past several decades, image is often utilized for various things, especially related to satellite image. In agriculture, for example, it is used to identify the usage and classification of agricultural land [2], vegetation, slope, body of water and river, and able to identify humidity and soil texture to analyze the suitability of land to be planted with certain plant [3] and even monitor agricultural land and predict harvest yield [4]. Satellite image is also used to analyze river water quality [5], investigate earthquake with low magnitude [6], extract flood path and assess impact of flood [7], detect ship [8] and predict rainy season [9].

In previous studies, Levelset is used to analyze medical images [10-15]. The current study implemented Levelset method on satellite image analysis. The main purpose was to determine population distribution pattern based on satellite images using images of detected object edges. Morphological image filtering concept was used to modify the brightness of the images before segmentation using Levelset. It was expected to produce better image pattern than before the application of morphological image filtering.

The discussion of this paper consists of six parts. The first part discusses research background, the second and third sections discuss theoretical basis used in the research. The fourth part is the research stages. The fifth part is the discussion of the research. The last part is the overall conclusion of the research.

2. Levelset Method

Levelset is a numeric method, which is often used for problem defined in higher dimension. This method is used in surface evolution case and typological change of image object. This method also uses active contour curve, where a curve moves dynamically after given internal or external force, so the curve moves toward the desired object edge. Generally, levelset function is formulated as equation (1) as follows:

\[ \phi(x, y, t = 0) = \pm d \]  

where \((x, y)\) is object area which contains contour, \(z\) is distance from point \((x, y)\) to curve which is initiated to \(\phi(t=0)\). Position \((x, y)\) determines the symbol of \(d\), where \(d\) is positive if it moves away from the center of the initiated curve (outside of initialization curve), and \(d\) is negative if \((x, y)\) approaches the center of the initiated curve. Convex or concave curve formed during identification of object form will be shown in the area between positive and negative \(d\) values.

Initiation of \(\phi\) in \(t=0\) will show \(\phi\) for every \(t\) value based on motion equation \(\frac{\partial \phi}{\partial t}\), so that levelset equation (1) is as follows:

\[ \frac{\partial \phi(x(t), t)}{\partial t} = 0 \]
\[ \frac{\partial \phi}{\partial x(t)} \frac{dx(t)}{dt} + \frac{\partial \phi}{\partial t} = 0 \]
\[ \frac{\partial \phi}{\partial x(t)} x_t + \phi t = 0 \]  

Because \(\frac{\partial \phi}{\partial x} = \nabla \phi\) and speed \(x_t\) is given by force \(F\) to surface, therefore,

\[ x_t = F(x(t))n \]  

Where,
\[ n = \frac{\nabla \phi}{|\nabla \phi|} \]

So motion equation (2) above can be written as:

\[ \phi_t + \nabla \phi \cdot \nabla \phi_t = 0 \]

Because \[ x_t = F(x(t))n \]

and

\[ n = \frac{\nabla \phi}{|\nabla \phi|} \]

So equation (2) is

\[ \phi_t + \nabla \phi F n = 0 \]

\[ \phi_t + \nabla \phi |\nabla \phi| \cdot \nabla \phi = 0 \]

Equation (5) described the curve movement of \( \phi \). The most interesting main feature of \( \phi \) is the possibility of surface curve obtained by the following equation:

\[ k = \frac{\nabla \phi}{|\nabla \phi|} \]

\[ k = \frac{\varphi_{xx} \varphi^2 - 2 \varphi_{xy} \varphi_x \varphi_y + \varphi_{yy} \varphi^2}{(\varphi_x^2 + \varphi_y^2)^{1/2}} \]  ...(6)

In image processing, when image has pixel and function to be discretized, \( \phi_t \) will be evaluation for every pixel \((i,j)\) with

\[ \frac{\phi(i, j, t + \Delta t) - \phi(i, j, t)}{\Delta t} \]

where curve gradient will be evaluated based on the following finite difference equation:

\[ \nabla^{+x}(i, j) = \max[0, \Delta^{-x}\phi(i, j)]^2 + \min[0, \Delta^{+x}\phi(i, j)]^2 \text{ untuk } F > 0 \]  ...(8)

\[ \nabla^{-x}(i, j) = \max[0, \Delta^{-x}\phi(i, j)]^2 + \min[0, \Delta^{+x}\phi(i, j)]^2 \text{ untuk } F < 0 \]  ...(9)

Where \( \Delta^{-x}\phi \) or \( \Delta^{+x}\phi \) is finite difference position left or right of image pixel point. Therefore, equation (5) becomes,

\[ \frac{\phi(i, j, t + \Delta t) - \phi(i, j, t)}{\Delta t} + \max[F, 0] \nabla^{+x}(i, j) + \min[F, 0] \nabla^{-x}(i, j) = 0 \]  ...(10)

From equation (10) surface \( \phi(i, j) \) can be updated using equation:

\[ \phi(i, j, t + \Delta t) = \phi(i, j, t) - \Delta t \left[ \max[F, 0] \nabla^{+x}(i, j) + \min[F, 0] \nabla^{-x}(i, j) \right] \]  ...(11)

Calculation of surface curve depends on \( \phi \), so central difference equation below can be used:

\[ \varphi_{xx}(i, j) = \frac{\varphi(i + 1, j) - \varphi(i - 1, j) - \varphi(i + 1, j) - \varphi(i - 1, j)}{\Delta t} \]  ...(12)

\[ \varphi_{yy}(i, j) = \frac{\varphi(i, j + 1) - \varphi(i, j - 1) - \varphi(i, j + 1) - \varphi(i, j - 1)}{\Delta t} \]  ...(13)

\[ \varphi_{xy}(i, j) = \frac{1}{4} \left[ (\varphi(i + 1, j + 1) - \varphi(i - 1, j + 1) - \varphi(i + 1, j - 1) - \varphi(i - 1, j - 1)) \right] \]  ...(14)

\[ \varphi_x = \frac{1}{2}(\varphi(i + 1, j) - \varphi(i - 1, j)) \]
∅_y = \frac{1}{2}(∅(i, j + 1) - ∅(i, j - 1)) \quad \ldots(16)

So curve calculation equation is as follows:

\[ k(i, j) = \frac{∅_{xx} ∅_y^2 - 2∅_{xy} ∅_x ∅_y + ∅_{yy} ∅_x^2}{(∅_x^2 + ∅_y^2)^{3/2}} \quad \ldots(17) \]

\[ k(i, j)|\nabla ∅(i, j)| = \frac{∅_{xx} ∅_y^2 - 2∅_{xy} ∅_x ∅_y + ∅_{yy} ∅_x^2}{∅_x^2 + ∅_y^2} \quad \ldots(18) \]

To keep the curve area flat, high curvature value should be set. It means lowering ∅ value will only make zero levelset grow, while high curvature value will do the opposite. Therefore, changes of ∅(i, j) on curvature can be performed with the following equation:

\[ ∅(i, j, t + ∆t) = ∅(i, j, t) - ∆t [\max[F, 0] \nabla^+(+x) (i, j) + \min[F, 0] \nabla^-(−x) (i, j)] + ∆ \quad \ldots(19) \]

3. Morphological Image Filtering

Morphologic filtering (MF) is an image form analysis technique which works based on translation and dilation concepts. Dilation is a process of adding pixel to object limit in image, while erosion is the opposite. Dilation and erosion are usually used in digital image processing. Erosion followed by dilation is called morphological opening. Conversely, dilation followed by erosion is called morphological closing. This is then called morphological filtering [15]. MF has several methods, including top-hat and bot-hat filtering. Top-hat works by filtering image object by reducing the result of morphological opening, while bot-hat works by filtering object to display morphological opening by reducing pixel from the original image. Mathematically, top-hat filtering is defined as:

For example f : E \rightarrow R \quad \ldots(20)

It is assumed as a grayscale image and maps a number of points based on Euclidean distance or discreet space E (e.g. R2 or Z2) into more real line. So, top-hat transformation is given equation (21) if given b(x) as a grayscale element structure.

\[ Tw(f) = f - f \circ b, \quad \ldots(21) \]

The operation in equation (21) is called white top-hat, where o is morphological opening. Black top-hat operation is defined as in equation (22).

\[ Tb(f) = f \bullet b - f, \quad \ldots(22) \]

Where • is morphological closing.

4. Research Methodology

The research started with collecting data of satellite images using Google Map Satellite Downloader. Five sub-districts were tested using levelset to see population distribution pattern based on the result of satellite image segmentation. In this research, the levelset method used to help satellite image analysis was based on the levelset method developed by Baris Sumengen. Before satellite images were analyzed, several parameters had to be determined, i.e. phi value as the input of levelset function, alpha value as a constant to calculate euler’s transformation (\( \partial t \)), where the value to be input is between 0 and 1. Iteration determination is also performed to determine the number of repeat on performed on levelset function when segmenting a satellite image. Other parameters, such as normal evolve, vector evolve and kappa evolve, were given in a range between 0 and 1. The value indicates...
whether there is any force or not in levelset function. The parameter value determination is related with force parameter value (pressure) given in normal condition \((V_n)\), vector component \(x\) (u), vector component \(y\) (v) and curve curvature weight \((b)\), where \(b\) must always be positive. It means that if one of parameters normal evolve, vector evolve and kappa evolve is 1, parameters \(V_n\), u, v and \(b\) can’t be empty matrix array \([\ ]\), so the accuracy parameter values of levelset function has to be determined.

5. Results and Discussion

The result of analysis of satellite images of every sub-district showed that the contour shapes of object edges were identified clearly. The contour shape of object edges which weren’t residential buildings were clearly indicated in blue. Meanwhile, red in test result images was the contour of analyzed object edges, meaning it showed the contour of residential buildings and its surrounding facilities.

Every satellite image of each sub-district was tested three times with different numbers of iteration but the same parameters. The result of the test on satellite images of Pandeglang sub-district showed that in the 50th iteration, the edge contour of nearly every object, whether building or forest, was identified. In the 100th iteration, the identified contours were grouped by dominant color attached to the object. Forest objects with darker base color than building objects showed clearer differences of color of object edge contour and area contour in the 150th iteration. The result of the test of satellite images also showed that the more iteration was used, the better the image segmentation result. This was evident in the segmentation pattern of the edge contour which showed silhouette of the main objects, where blue contour line indicate edge contour of forest objects (dark base color) and red indicated edge contour of building and road objects (light base color). The result of the test of satellite images using Levelset is shown in Table 1.

| Iter. | Image Input | Levelset Segmentation Result |
|-------|-------------|-----------------------------|
| 50    | ![Image](image1.png) | ![Segmentation](segmentation1.png) |
| 100   | ![Image](image2.png) | ![Segmentation](segmentation2.png) |

Table 1. The result of image test for Pandeglang Sub-district (Ciekek area)
| Iter | Image Input | Levelset-Morphological Image Filtering Segmentation Result |
|------|-------------|----------------------------------------------------------|
| 50   | ![Image 1](image1.png) | ![Segmentation Result 1](segmentation_result1.png) |
| 100  | ![Image 2](image2.png) | ![Segmentation Result 2](segmentation_result2.png) |
| 150  | ![Image 3](image3.png) | ![Segmentation Result 3](segmentation_result3.png) |

**Table 1.** Cont.

**Table 2.** The result of image test for Pandeglang Sub-district (Ciekek area) Levelset-Morphological Image Filtering
In the next test, Levelset method was combined with morphological image filtering technique. The result of the combination of both methods could remove unnecessary noises from object edge contours, so the detected object contours made image objects clearer. The resulted image segmentation showed better result because objects in satellite images, such as buildings, forest, and other constructions, could be clearly differentiated using the formed contours. The result of the test on satellite images using Levelset and morphological image filtering combination is shown in Table 2.

6. Conclusions

The usage of Levelset method for satellite image segmentation, especially after being combined with morphological image filtering, could remove many noises in analysis result images and form very clear object edge contours. The detected object contours could be used as reference to recognize population distribution pattern based on satellite image analysis. However, the resulted patterns were optimal because Levelset performed image segmentation based on the contour of the analyzed objects. Other segmentation method should be combined with it to produce clearer population distribution pattern.

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