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Image Segementation On Satelite Images of Nusajaya With Numerical Modification Using Jacobi And Gauss Siedel

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Abstract
The purpose of this study is to investigate the application of Geographical Information System (GIS) towards the ground changes in the development of Nusajaya. The focus of this research study is situated at Nusajaya or also known as Iskandar Puteri. The objective of this research is to investigate image processing with GIS and mainly focused on the GAC-AOS model. The images of Nusajaya since 1985 to 2020 has been obtained from Google Satellite and then the image is analysed using MATLAB software of version R2021b. In addition, numerical methods specifically, Gauss Siedel (GS) and Jacobi (JB) method is used in this research to iterate the images in order to obtain the final contour. From the study, GS method has been proven produced more accurate result compared to JB method. This study reviews the method and to improve accuracy in analysing the ground changes of Nusajaya throughout the years. In future work, investigating and exploring more methods will be beneficial in order to obtain the most accurate results and able to implement for future research on ground changes.

Keywords: GIS, Nusajaya GAC-AOS, Jacobi, Gauss Siedel

1. Introduction

Image segmentation has been widely used to calculate segmentations of image from CT scans, x-rays, maps and various different kind of images including 2D and 3D images. Previous studies have identified various methods of image segmentations such as fuzzy theory-based segmentation, edge-based segmentation, ANN based segmentation and many more. This research specifically focused on edge based segmentation with PDE. Many methods can be beneficial for image segmentations for the whole image since most of them are using selective segmentations. Complications occurred when it comes to images that have many objects and more likely harder with images containing objects of small sizes with similar features (Yu et. al., 2014). GAC was originally introduced by Caselles et al. but however for land changes, this method is not suitable and lack of accuracy due to its non-linearity (Alias et. al., 2011). AOS has been applied together with GAC to linearize the mathematical model. In this research, I proposed the usage of numerical implementations in the GAC-AOS model in order to improve the edge detection analysis. Usage of numerical method will improvise the GAC-AOS model and widen the scope of research for image segmentation.

2. Materials and methods

GAC-AOS Model

GAC model which is also known as the the edge-based model helps in making contour towards the object boundaries by its edge indicator properties (Alias et al, 2019). In 1988, the first active contour model was made by Kass et. al. which is known as the Snake Model. However, the Snake Model has its drawback. This GAC model solved the partial differential equations of the image segmentation by using level set and only depends on parameterization. The image segmentation based on the level set is categorised as an active contour model (Ding et. al., 2018). It is analysed based on its boundary informations. Based on previous studies, it is identified that geodesic active contour model is very helpful for image segmentation. In 1997, Caselles et. al. has suggested another improved model which is known as geodesic active contour. This model is also an energy minimisation function which had the same accuracy as the Snake model but with less parameters. The equation of this model is as shown below.

$$\frac{\partial u}{\partial t} = |\nabla u| div\left(g(x)\frac{\nabla u}{|\nabla u|}\right) + v|\nabla u|g(x) \qquad [1]$$

on $[0, \infty]xR^2$.

However, this model also has its drawback which is it’s non linearity. This will cause a bad execution. Linearisation is important in many ways in image processing such able to improve accuracy in detecting object edges, reducing noise and able to deal with less quality images. The additive operator splitting (AOS) scheme is then applied to linearise the GAC model which is based on the previous study by Weickert et al. (1998) and the formula is as shown below:

$$u^{k+1} = \frac{1}{m}\sum_{l=1}^{m}(I - m\tau\, A_l(u^k))^{-1}u^k \qquad [2]$$

where
k refers to the number of iterations, m is the dimension, I is the image function and τ is the time step. A_l refers to the derivative along coordinate where $A_l = \left(a_{ijl}\right)_{ij}$. This is unrestrictedly stable for image processing problem.

<u>Numerical Implementation</u>

Numerical iterative methods can solve many kinds of modelling problems. This paper will focus on two iterative types of sequential programming which is the Gauss Siedel (GS) and the Jacobi (JB). The proposed methods will be an alternative formula and the modification will be done in the GAC stopping function. As mentioned, the numerical implementation will improvise the edge detections and image performance. The differences of the JB method and GS method is the way of calculating. The JB method is calculated using the values that is obtained from previous step meanwhile the GS method is calculated using the latest value during the iteration. The result of this research will be evaluated in terms of number of iterations, maximum error, time taken to execute and the root mean square error.

GS method is also known as the successive displacement method. This method which was named after the inventor of this method, Carl Friedrich Gauss and Phillip Ludwig von Siedel is an improved form of JB method. GS method is chosen due to its well-known linearity characteristic, accuracy within few iterations and less space requirements. The formula of GS is as follows:

$$x_1^{(k+1)} = \frac{1}{a_{11}}(b_1 - a_{12}x_2^{(k)} - \cdots - a_{1n}x_n^{(k)},$$
$$x_2^{(k+1)} = \frac{1}{a_{22}}(b_2 - a_{21}x_1^{(k+1)} - \cdots - a_{2n}x_n^{(k)},$$
$$\vdots$$
$$x_n^{(k+1)} = \frac{1}{a_{mn}}(b_n - a_{n1}x_1^{(k+1)} - \cdots - a_{n(n-1)}x_{n-1}^{(k+1)}$$

This simplify equation for this GS method is as shown below

$$u_i^{(k+1)} = \frac{1}{a_{ii}}\left(b_i - \sum_{j=1}^{i-1} a_{ij}u_j^{(k+1)} - \sum_{j=i+1}^{n} a_{ij}u_j^{(k)}\right) \quad [3]$$

where i = 1,2,3, …, N. This method will be executed until it converges.

The Jacobi (JB) method was named after Carl Gustav Jakob Jacobi and is also known as the simultaneous displacement method. The JB method is mainly created for parallel computation if it is compared in terms of computation efficiency. This method is one of the common methods used nowadays due to its uncomplicated and easy implementation compared to GS method. The JB formula is shown as below:

$$u_i^{(k+1)} = \frac{1}{a_{ii}}\left(b_i - \sum_{j=1}^{i-1} a_{ij}u_j^{(k)} - \sum_{j=i+1}^{n} a_{ij}u_j^{(k)}\right) \quad [4]$$

3. Results and discussion

In this thesis, a GAC-AOS model has been implemented and modification has been made on its stopping function. In order to make sure its better performance, this research have decided several ways of analysing the proposed model. The first one would be the execution time. Next, the number of iterations needed is also one of the important factors to compare. The number of iterations should be lesser at a given time for either method until it converges. A measurement of numerical error is also important by checking the root mean square error (RMSE) or maximum error (ME).

As from previous research by Alias et al (2019), the proposed model of using modified GAC model as shown Figure 4.3.1. Improvement were made by using GAC- AOS as the method proposed to indicate the edge detection from the GIS images. Numerical methods specifically, GS and JB method is used in this research to iterate the images in order to obtain the final contour. Figure below is one of the process to obtain the expected result for this research.

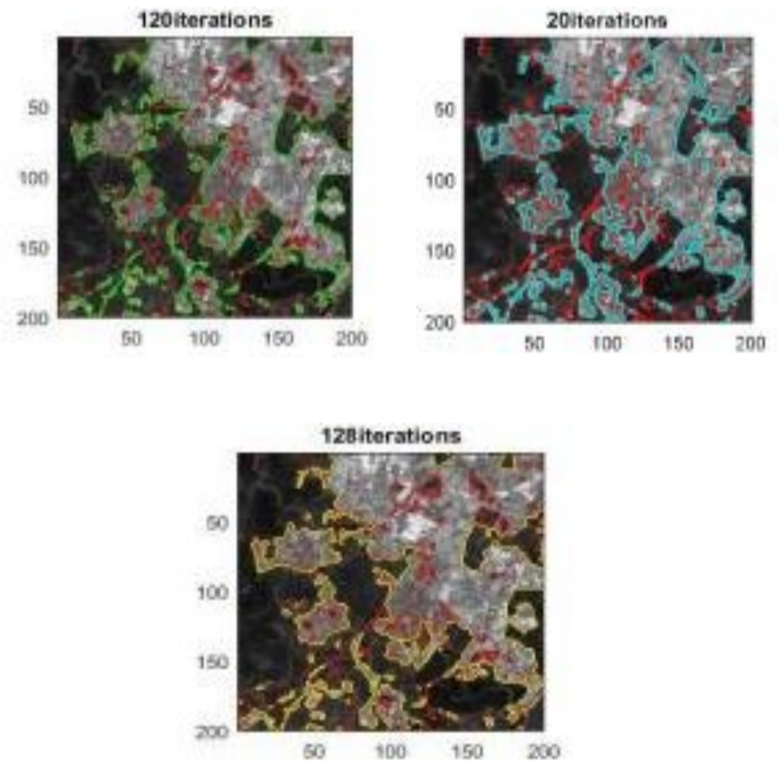

Figure 1 : Successful Edge-Region Segmentation from High-Resolution Satellite Images of Nusajaya

The GAC-AOS model with modification of GS and JB has been applied to the images. The image of 257x257 pixel is analysed and the result is as shown in table below.

Table 1: Result Comparison of JB and GS through GAC-AOS Model

Parameters	**Method**		
	GS	**JB**	$\left\|\frac{GS-JB}{JB}\right\| \times 100\%$
τ	5	5	0
v	-0.3	-0.3	0
σ	0.5	0.5	0
Size of pixel	257x257	257x257	0
Δx	1	1	0
Δy	1	1	0
Iteration	470	550	14.55 %
ME	4.66279e-004	1.48378e-003	68.57 %
RMSE	1.68772e-006	5.37063e-006	68.57 %
ε	1.0e-5	1.0e-5	0

From the table, the parameters measured was τ, the time of execution, v is the positive constant, σ as the domain, ε is the tolerance and Δx and Δy is the grid spacings of each direction. From Table 4.1, we concluded that GS is more effective then JB method since GS has lesser iterations than JB at the same amount of time taken which is 470 and 550 respectively. It is 14.55% better when using GS compared to JB. The RMSE and ME also shows that GS method has higher results than JB. GS is 68.57% more accurate than JB method. Therefore, as shown in the table, it is proven GS method is better than JB method.

Conclusion

This study is about the land changes in Nusajaya and image processing, GAC-AOS has been applied and modification has been made by using the GS and JB method. From this research, it is proven that the current method of GAC-AOS model can be modified to obtain values with higher accuracy. The result has proved that GS method provides better accuracy and consistency compared to the JB method. Higher accuracy can be seen from the images where with the correct iterative method, the model can detect the boundaries of each object better compared to without the aid of GIS.

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