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MATHEMATICAL MODELING FOR CONTOUR IDENTIFICATION BASED ON MEDICINAL LEAVES AND GIS IMAGES

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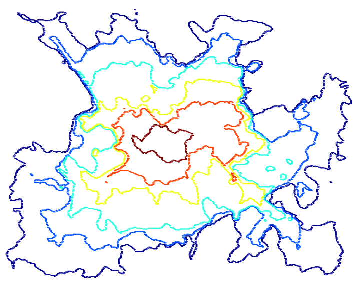
Graphical abstract



Abstract

In this paper, the identification of contour medicinal leaves and GIS images has been determined. The purposes of the Geodesic Active Contour-Additive Operating Splitting (GAC-AOS) modelling are to identify an unknown type of medicinal leaves and edge detection of our images. Besides, three iterative methods such as SOR, RBGS and Jacobi method are used to solve the linear system of equations. In the implementation of the GAC-the AOS model, the experimental result demonstrates that the SOR method gives the best performance compared to the other two methods. The computation platform is based on Intel® CoreTM Duo Processor Architecture with MATLAB version R2011a. The performance analysis is based on the iteration numbers, execution time, accuracy and RMSE.

Keywords: SOR, RBGS, JB, Geodesic Active Contour-Additive Operating Splitting (GAC-AOS) model, medicinal leaves, GIS images

1.0 INTRODUCTION

Development of the science in digital image processing technology until now has been growing very rapidly. Today, there are many applications of image processing techniques for solving science and engineering problems. For example, digital image processing can facilitate the work of man. This technique is used to process the signal image by transforming the input image into digital images for a better quality, high resolution, prediction and decision making. Image processing is very helpful to improve image quality, eliminating defects in images, identify objects, and merging with specific region of the image.

An advance of computing technology has offered an attractive and storage capability which has radically changed the lives of digital users. With the smartphone technology and high end digital camera, the signal images of medicinal plant and GIS images taken by a remote user and transmitted to an image analysis server via distributed wireless network. This is a good impact on the image analysis by integrating the mobile device and cloud computing technologies. The function of computing technology is useful to identify the herbal plants because normally users always verify the medicinal plants with similar reviews on their appearance. Only botanist can identify plant varieties based on their professional techniques. Same goes to GIS images, the computing technology makes it easier for users to detect the area of targeted places.

Thus, two-dimensional (2D) mathematical modelling of semi-implicit Addictive Operator Splitting (AOS) model [1-3] and Geodesic Active Contour (GAC) [4-7] can obtain a high resolution digital image. In this paper, contour identification of images is developed based on GAC-AOS model. GAC model is part of the active contour integrated a gradient parameter to find the edge of feature and detect the contours. GAC model was first introduced by Casellas as a segmentation framework [8], derived from energy-based snake active contours and performing contour extraction via the computation of geodesic. Many improvements of GAC model have been obtained by researchers for solving the weakness of the model discretization. The main weakness of this model is dealing with nonlinear equations and some dependent parameters [9]. This may cause inefficient algorithm implementation in terms of convergence rate and accuracy performance.

To overcome the nonlinearity of GAC model, Goldenberg adapted a numerical technique based on AOS model [9]. Then, Goldenberg has improved the mathematical model by obtaining the numerical consistency and computational efficiency of GAC model [9]. Furthermore, AOS is employed to further improve the efficiency of the flow-field smoothing. AOS schemes have been implemented by applying the recursive filtering. The separability nodes allow a straightforward implementation of AOS in multi-dimension region. Weickert proved that the AOS algorithm was ten times more efficient than explicit scheme under typical accuracy [10]. Image analysis can identify the unexplored region, providing high resolution images, integrated modeling, transmission images and reflection images.

The contour matching problem becomes popular approaches among the researchers. In this paper, a global database of image contour identification contributes by integrating the identification of medicinal plants with the characteristics of medicinal plants [11-14]. The combination of digital source data and the signal image of plant species is proposed. The outcomes will obtain by implementing the contour matching method to perform the process of matching objects in a simple approaches. The aim of this research is to develop the software using the mathematical modeling as the computation engine to identify, to define and to perform the object matching in real-time solution.

In this paper, two processes are proposed for modeling of image processing. First, the edge detection process using GAC-AOS model. Second, contour matching process using MK-RoD method. The simulation of the model and method are discretized by finite difference method and numerical method. Thus, the contour matching process using SIFT match and MK-RoD algorithm is presented. Numerical results of mathematical modeling and the high resolution of visualization are presented.

2.0 METHODOLOGY

2.1 GAC-AOS Model

GAC-AOS model is the integrating modeling between GAC model and AOS model [8]. The AOS model overcomes the weaknesses of GAC model where the AOS model derives a linear system of equations in the matrix form; $Au = f$ as stated in the equation below.

The evaluation in x-direction [15-16]:

$$\left[1 + 2\tau \sum_{j \in N(i)} \frac{2|\nabla u|_j^k}{\left(\frac{|\nabla u|}{s}\right)_i^k + \left(\frac{|\nabla u|}{s}\right)_j^k}\right] x_{i,j}^{k+1} - 2\tau \frac{2|\nabla u|_{i,j}^k}{\left(\frac{|\nabla u|}{s}\right)_{i,j-1}^k + \left(\frac{|\nabla u|}{s}\right)_{i,j}^k} x_{i,j-1}^{k+1} - 2\tau \frac{2|\nabla u|_{i,j+1}^k}{\left(\frac{|\nabla u|}{s}\right)_{i,j+1}^k + \left(\frac{|\nabla u|}{s}\right)_{i,j}^k} x_{i,j+1}^{k+1} = u_{i,j}^k + \tau|\nabla - u|_{i,j}^k vg \quad (1)$$

The evaluation in *y*-direction [15-16]:

$$\left[1 + 2\tau \sum_{j \in N(i)} \frac{2|\nabla u|_j^k}{\left(\frac{|\nabla u|}{s}\right)_i^k + \left(\frac{|\nabla u|}{s}\right)_j^k}\right] y_{i,j}^{k+1} - 2\tau \frac{2|\nabla u|_{i,j}^k}{\left(\frac{|\nabla u|}{s}\right)_{i-1,j}^k + \left(\frac{|\nabla u|}{s}\right)_{i,j}^k} y_{i-1,j}^{k+1} - 2\tau \frac{2|\nabla u|_{i,j+1}^k}{\left(\frac{|\nabla u|}{s}\right)_{i+1,j}^k + \left(\frac{|\nabla u|}{s}\right)_{i,j}^k} y_{i+1,j}^{k+1} = u_{i,j}^k + \tau|\nabla - u|_{i,j}^k vg \quad (2)$$

The simulation of linear system of equations above can be done by using some numerical methods such as: Successive-Over-Relaxation (SOR), Red Black Gauss-Seidel (RBGS) and Jacobi method (JB).

2.2 Successive-Over-Relaxation (SOR) Method

SOR method comes from the modification of Gauss-Seidel (GS) method. The convergence of SOR method is faster than GS method. The choosing of optimum value of ω will accelerate the rate of convergence of SOR. If $\omega = 1$, this method will reduce to GS method. The flow of the SOR algorithm shows in **Algorithm 1** below.

Algorithm 1: SOR method

for xi = 1: time steps
    for i =1: n

$$u_i^{(k+1)} = \frac{\omega}{a_{ii}}\left(f_i - \sum_{j=1}^{i-1} a_{ij} u_j^{(k)}\right) + (1-\omega)u^k$$

$$i = 1,2 \ldots n \quad where \quad \omega > 1$$

End
$err = |u^{k+1} - u^k|$
If $err = tol$
break

end
end

2.3 Red Black Gauss-Seidel (RBGS) Method

RBGS method is an iterative numerical scheme that contains two-subdomain which are Ω^R and Ω^B. Thus, there is the communication cost between these two sub-domains to send and receive the neighborhood data [18-19]. The algorithm of this method is shown in **Algorithm 2** as follows:

Algorithm 2: RBGS method

$for\ xi = 1: \mathrm{TIMESTEP}$
for i =1: n (Grid Calculation Ω^R)

$$u_i^{(k+1)} = \frac{1}{a_{ii}}\left(f_i - \sum_{j=1}^{i-1} a_{ij} u_j^{(k)}\right) \quad i = 1,3,5 \ldots, n$$

end
for i =2: n (Grid Calculation Ω^B)

$$u_i^{(k+1)} = \frac{1}{a_{ii}}\left(f_i - \sum_{j=1}^{i-1} a_{ij} u_j^{(k+1)}\right) \quad i = 2,4,6 \ldots, n$$

End

$$err = |u^{k+1} - u^k|$$

If $err = tol$
break
end
end

2.4 Jacobi Method

JB is a classical iterative method and was proposed by Carl Jacobi. The new time step depends on all values at the previous time steps. The calculation of this method is shown in **Algorithm 3** below:

Algorithm 3: Jacobi method

$for\ xi = 1: \mathrm{TIMESTEP}$
for i =1: n (Grid Calculation Ω^R)

$$u_i^{(k+1)} = \frac{1}{a_{ii}}\left(f_i - \sum_{j=1}^{i-1} a_{ij} u_j^{(k)}\right) \quad i = 1,3,5 \ldots, n$$

end
for i =2: n (Grid Calculation Ω^B)

$$u_i^{(k+1)} = \frac{1}{a_{ii}}\left(f_i - \sum_{j=1}^{i-1} a_{ij} u_j^{(k+1)}\right) i = 2,4,6 \ldots, n$$

end

$$err = |u^{k+1} - u^k|$$

If $err = tol$
break
end
end

2.5 Contour Matching Process

The contour matching is the process to match an object or a sample that has been converted from digital image into another sample without knowing its types and characteristics. This research used point pattern matching based on SIFT match algorithm. Thus, the aim of SIFT is to find the key-points of the specific region of the images and to reduce the error estimation. Then, the MK-RoD algorithm is used to obtain the validity ratio [17]. The flow of contour matching process is shown in **Algorithm 4** below.

Algorithm 4: Contour Matching Process

```
start
 Configure database
  Insert Image
    Do:
      Run SIFT Match Algorithm
      Get the validity ratio
    end
  if Match<1
 Print OUTPUT
end
```

3.0 RESULTS AND DISCUSSION

The demonstration of GAC model based on an AOS scheme with the application of SOR, RBGS and JB methods on medicinal leaf images and GIS image processing are shown in Table 1 and Table 2 respectively. In this paper, the number of convergence tolerance (ε) is 1xe^{-5} and 1xe^{-10}. Numerical results and its performance contain the comparison of (ε), number of iterations and the maximum error. The tables below represent the movements of the initial contour line, toward the targeting edges of the input images. Thus, we can see the difference of number iterations to complete the edge detection process for both images.

The epsilon value, (ε) is inversely proportional to the number of iterations. The calculation at each point on the edge of the leaf will be more specific and accurate at the smallest value of epsilon in the program rather than the greater value of epsilon.

Table 1 The comparison of different epsilons (ε), 1e-5 and 1e-10 based on SOR, RBGS and JB for medicinal plan leaf (Mengkudu)

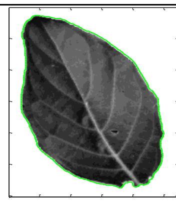
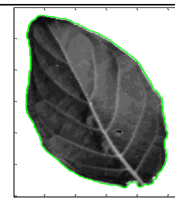
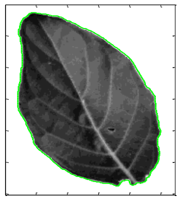
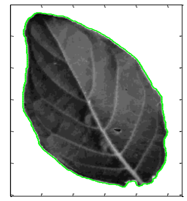
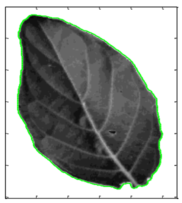
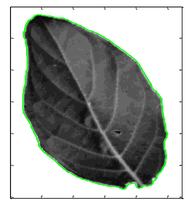
Method	Epsilon (ε) $1e^{-5}$	$1e^{-10}$
SOR	 48 iterations	 88 iterations
RBGS	 117 iterations	 235 iterations
JB	 218 iterations	 453 ierations

Table 2 The comparison of the different epsilons (ε), 1xe-5 and 1xe-10 based on SOR, RBGS and JB for GIS image

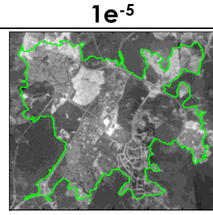
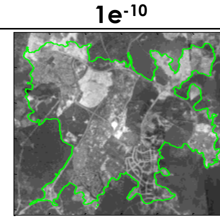
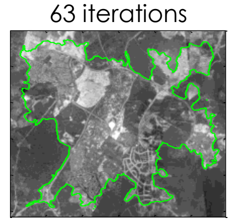
Method	Epsilon (ε) $1e^{-5}$	$1e^{-10}$
SOR	 39 iterations	 63 iterations
RBGS	 110 iterations	 220 iterations
JB	 205 iterations	 424 iterations

Table 3 Analysis results of SOR, RBGS and JB for medicinal plan leaf image (Mengkudu)

Tolerence, ε		SOR	RBGS	JB	$\left\|\frac{SOR-JB}{JB}\right\|\times 100\%$
	iteration	48	117	218	77.98%
	execution time	862.98864	2689.57857	3607.57263	76.08%
1e-5	convergence rate	0.22	0.54	1	78.00%
	MSE	9.36861e-006	9.78085e-006	9.92112e-006	5.57%
	RMSE	8.62653e-007	4.55343e-006	4.77888e-006	81.95%
	iteration	88	235	453	80.57%
	execution time	1988.91161	5422.61983	9763.65842	79.63%
1e-10	convergence rate	0.19	0.52	1	81.00%
	MSE	8.69926e-011	9.67795e-011	9.81561e-011	11.37%
	RMSE	7.55069e-012	3.94508e-011	4.12902e-011	81.71%

Table 4 Analysis results of SOR, RBGS and JB for GIS image

Tolerance, ε		SOR	RBGS	JB	$\left\|\frac{SOR-JB}{JB}\right\|\times 100\%$
	iteration	39	110	205	80.98%
	execution time	4601.52353	16393.09354	28223.30816	83.70%
1e-5	convergence rate	0.19	0.54	1	81.00%
	MSE	7.44953e-006	9.58997e-006	9.74479e-006	23.55%
	RMSE	7.72515e-008	1.94649e-007	2.07020e-007	62.68%
	iteration	63	220	424	85.14%
	execution time	9681.32946	31680.80752	44778.74731	78.38%
1e-10	convergence rate	0.15	0.52	1	85.00%
	MSE	8.59979e-011	9.11697e-011	9.89715e-011	13.11%
	RMSE	9.03218e-013	1.57245e-012	1.73824e-012	48.04%

3.1 Analysis of Results

The convergence rate of SOR, RBGS and JB is depend on the number of iterations and execution time. Table 3 and Table 4 show that the SOR method performs faster than RBGS and JB. The SOR method performs the lowest number of iterations for convergence process. The results from each table show that SOR method completes the edge detection process faster than RBGS and JB. Table 3 represents the SOR method is 78% and 81% faster than JB for $\varepsilon = 1e-5$ and $\varepsilon = 1e-10$ respectively. In terms of number of iterations, Table 4 stated that SOR method is 80.98% faster than JB and 64.55% faster than RBGS. SOR method is considered as an accurate method because in each table, the SOR method gives the lowest value of the root mean square error (RMSE) as well as absolute error (MSE). Thus, SOR method is the alternative iterative method for solving the GAC-AOS modeling for image processing and contributes to the lowest number of iterations as well as the fastest execution time, highest convergence rate and lowest value of RMSE.

The points around the digital edge of the medicinal plant leaves and GIS are calculated until matched with its original contour. Figure 1 represents the final contour of medicinal leaves at epsilon (ε) $1xe^{-5}$. As the epsilon (ε) is smaller, point around the edge of medicinal leaves become more accurate. The strategies are well suited to be implemented on other medicinal plant species such as pegaga, mas cotek, keembung, mengkudu, misai kucing and hempedu bumi. The colour of each contour represents the depth of the contour leaves. Furthermore, The dark color of contour line shows a center of the leaves, while for the light color of contour line shows a slightly far from the center of the leaves. Figure 2 represents the contour of GIS images. Each color of contour represents the density of area. The outer layer (dark blue) shows less developed area and the center (of GIS images (maroon) shows the rapid urban developed area.

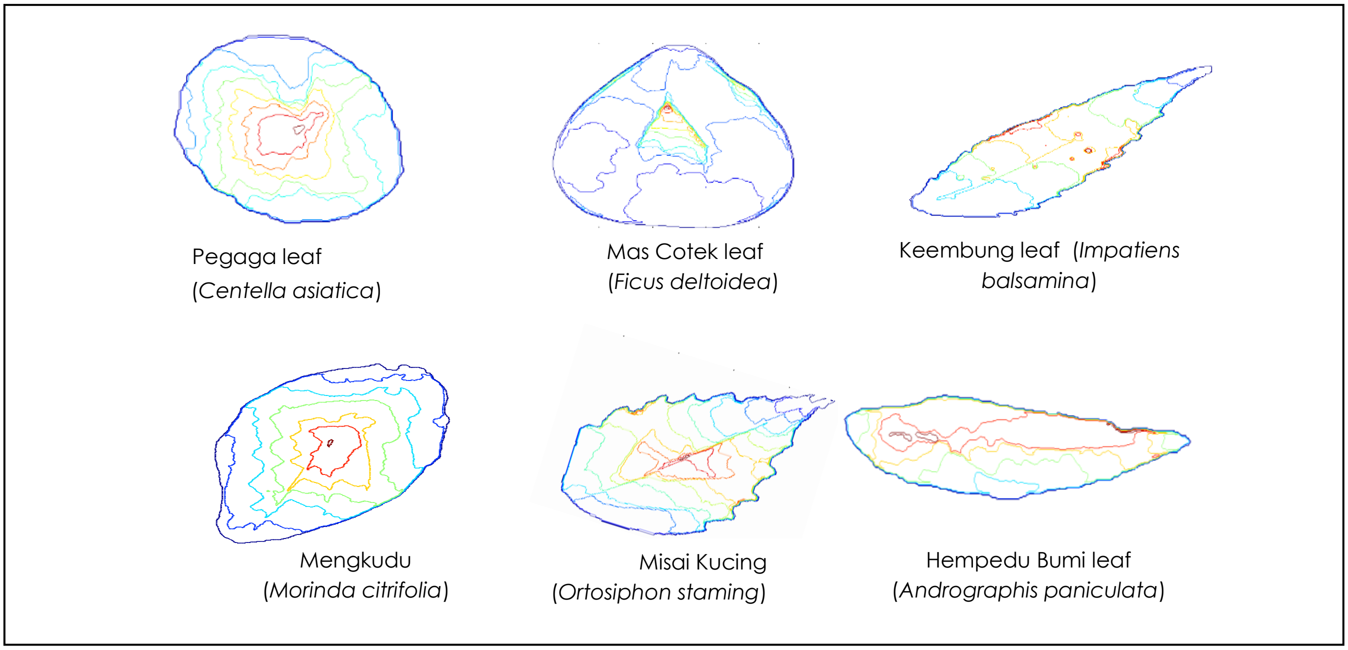


Figure 1 The final contour of medicinal leaves

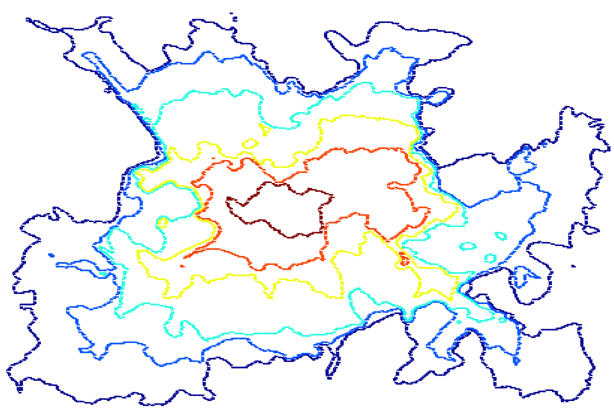


Figure 2 The final contour of GIS images

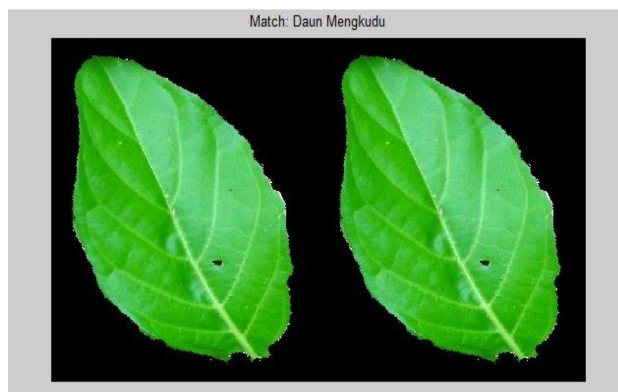


Figure 3 Final result of MATLAB program from the contour matching process

3.2 Analysis of Matching Process

Contour matching process on GIS images based on size and shape indicators are considered as less efficient compared to the matching process on leaf pattern. It is due to the image quality of the raw source of the test samples. The disadvantage of contour matching process focuses on its measurement and shape without considering other indicators. As the both of the samples have a sample measurement and shape on Figure 3, it will automatically detect fully percentage 100%.

4.0 CONCLUSION

A contour identification and edge detection based on the GAC-AOS model are presented. Three iterative methods such as SOR, RBGS and JB are studied. In this paper, the GAC is employed to detect the edges of images. The GAC model is well suited model for image segmentation and numerical analysis. Besides, AOS scheme is employed in the GAC model in order to perform the fastest implementation of the image processing. Table 3 and Table 4 are proving that SOR method is the superior method to solve the mathematical modeling followed by RBGS and JB. The numerical results such as execution time, number of iterations, accuracy and RMSE were proved that GAC-AOS model are capable to detect the edge of different application and images integrated with the implementation of some numerical methods. For medicinal leave, the edges and contour are successfully detected using the GAC-AOS model. The objective is to identify the medicinal plant to perform the raw materials in making high quality and useful herbal product. Therefore, GIS images need to be updated and reliable information and maps in contemplation of land use changes. The contribution of this paper is the successful to apply the GAC-AOS model on medicinal leaves and GIS images. However, the image segmentation will involve a huge data. So for the future contribution, parallel algorithm will be used on the GAC-AOS model in order to support the huge data and gives the better and clear visualization. Institute Bioproduct Development, UTM was implemented the integration of mathematical modeling and contour matching process as the computation engine of software development for detecting the specific species of Malaysia medicinal plant.

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