Identification of Change Detection for Satellite Images using Ant Colony Optimization

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Abstract- Supervision of Earth surface with the help of satellite images helps in land use land cover, resource planning & management, change detection and agricultural development areas. Satellites images are great repository of information and extraction of information from these unclear images is a challenging task. In order to identify the objects and boundaries in satellite images, various digital image based processing techniques like Sobel, Canny and Prewitt have been explored in this paper. Further, Ant Colony Optimization has been used to obtain the optimized images. Hybrid techniques viz.- ACO-Sobel, ACO-Canny and ACO-Prewitt are implemented and the results are quantitatively validated with the help of entropy and PIQE values of output optimized images. The results indicates that ACO-Canny hybrid technique yields better quality satellite images as compared to ACO-Sobel, ACO-Prewitt, Sobel, Canny and Prewitt edge detection techniques.

Keywords: Ant Colony Optimization, Artificial Intelligence, Change detection, Edge Detection, Remote sensing

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1. Introduction

The data provided by satellite images is highly crucial to analyse the microscopic land details of areas being covered. For the same location, multiple satellite images are taken at different times and being compared to detect regions of changes. This change detection has widespread applications in various areas such as underwater sensing, surveillance, agricultural management, flood control, climate prediction and civil infrastructure, Radke et al [1]. For two images; same location; different times, the pixel sets are significantly different, giving rise to change detection. Change detection accuracy is affected by quality of satellite images. In general, the satellite images are unable to provide the precise details due to large land size and dense areas covered. Thus, the satellite images with weak boundaries and varying intensities are highly complex to interpret. This severely affects the decision accuracy to provide exact information regarding change detection in covered land areas. Thus, there is a need for a suitable edge detection segmentation-based image processing technique to reveal the precise image boundaries and more accurate information from the satellite images. In edge detection techniques, the discontinuities in an image are accurately identified to extract the relevant edges. In an image, vital role is played by the detection of edges. Edges assist in providing important clues which help in separating regions of an object or for identification of illumination changes. For region separation or image segmentation, the pre-processing stage includes edge detection with respect to feature extraction, Ali and Clausi [2]. The initial applications in image segmentation for remote sensing images included homogenous objects extraction and classification, Kettig and Landgrebe [3].

consideration of supervised MLC and post classification change detection methods. Mittal et al. [12] used DWT for two medical image fusion. El-Kawy et al. [13] considered western Nile delta for understanding land use land cover conditions by applying a supervised classification method on Landsat images. Lunetta et al. [14] applied a supervised classification method on understanding land use land cover conditions by Kawy et al. [12] used DWT for two medical image fusion. El-daw and Yamaguchi [15] presented an integrated study of urbanization trends by considering remote sensing and GIS. Kaur and Garg [17] did the enhancement and edge detection on remote sensing images by the use of mathematical morphology and compared the result with standard edge detection techniques. The conventional edge detection techniques are very sensitive to noise and take large computational time as number of operations are carried out for each pixel of image. Artificial intelligence technique optimized edge detection may reduce the computation time with greater visibility properties. Dhruv et al. [18] presented a comparative analysis of edge detection techniques.

In literature, various artificial intelligence techniques have been presented by researchers to improve the quality of remotely sensed images. Jayanth et al. [19] worked for remote sensed data classification by putting in the algorithm based on artificial bee colony (ABC). The classification of Satellite Images by using Genetic Algorithm (GA) has been presented by Varma and Rao [20]. Hoseini and Shayesteh [21] presented a hybrid algorithm for increasing the image contrast by including GA, ACO and SA. Particle Swarm Optimization (PSO) has been used on VHSR satellite images by Naeini et al. [22] for object-based feature selection. The GA technique is inspired by theory of evolution takes large computation time and cannot guarantee the optimal solution. Beg and Islam [23]. The heuristic Particle Swarm Optimization (PSO) technique symbolizes the social behaviour of school of fish or flock of bird in search of food. However, this algorithm experiences disadvantages such as partial optimism with respect to various factors used for analysis triggering incomplete information, feasible solutions are not provided for scattering problems. Further, for non-coordinate systems, the implementation fails. Ant Colony Optimization (ACO) is a heuristic positive feedback algorithm utilizing ant’s behaviour in search of food, Liu et al. [24]. The ACO advantages include great ability to adapt to new changes, simultaneous and rapid searching capability in a large population. In order to reveal weak edges in a set of 12 satellite images acquired from Google Earth, this study proposes implementation of computer aided conventional edge detection approaches viz.-Sobel, Canny and Prewitt and artificial intelligence technique enhanced hybrid edge detection techniques i.e ACO-Sobel, ACO-Canny and ACO-Prewitt. The efficacy of all methodologies has been evaluated by comparing entropy and piqe performance evaluation criterion. This research has not been funded by any agency.

The remaining paper has the following sections. Section 2 covers the various change detection techniques followed by various edge detection techniques in section 3. Section 4 covers the proposed methodology followed by result and analysis in section 5 and the last section covers the conclusion drawn.

2. Change Detection Techniques

In literature, various change detection techniques such as vegetation index differencing, principal component analysis, univariate image differencing, image regression and image rationing technique etc. have been proposed. Univariate image differencing technique, Singh [25] considers two spatially registered images and performs subtraction with respect to time \( t_1 \) and \( t_2 \), pixel by pixel and produces an image that denotes the changes in two different times. It is represented mathematically as equation (1), where for band \( k \), \( x_{ij}^k(t_2) \) represents the pixel value, \( i \) is used for defining the line numbers and \( j \) gives the pixel values in an image. First and second date are represented by \( t_1 \) and \( t_2 \) respectively and constant value \( C \) is used for producing positive digital numbers.

\[
Dx_{ij}^k = x_{ij}^k(t_2) - x_{ij}^k(t_1) + C \quad (1)
\]

Image regression, Singh [25] is the change detection regression method, the linear function with respect to pixels from time \( t_1 \) are represented by time \( t_2 \) pixels. Least square regression of \( x_{ij}^k(t_1) \) was done against \( x_{ij}^k(t_2) \) where for band \( k \), \( x \) represents the pixel value of \( (i \& j) \) line and column. The difference image is given in equation 2, if the predicted pixel value resulted from the regression line is \( x_{ij}^k(t_2) \):

\[
Dx_{ij}^k = x_{ij}^k(t_2) - x_{ij}^k(t_1) \quad (2)
\]

In Image ratioing, Singh [25], two images having different date registered are ratioed band by band. The images are with one or more bands and then the comparisons are carried out pixel by pixel and is represented by equation (3), where \( x_{ij}^k(t_2) \), represents the pixel value of band \( k \) at ith row and jth column at time \( t_2 \).
\[ R_{x_{ij}}^{k} = \frac{x_{ij}^k(t_{1})}{x_{ij}^k(t_{2})} \]  

(3)

In Vegetation index differencing, Singh [25], the enhancement of spectral differences has been established by the vegetation indices for strong vegetation absorbance and reflectance in the spectrum part of red and near-infrared. They are mathematically represented by equations (4)-(6):

- Ratio vegetation index = \( \frac{\text{band 4}}{\text{band 2}} \)  
  (4)
- Normalized vegetation Index = \( \frac{\text{band 4} - \text{band 2}}{\text{band 4} + \text{band 2}} \)  
  (5)
- Transformed vegetation index = \( \sqrt{\frac{\text{band 4} - \text{band 2}}{\text{band 4} + \text{band 2}}} + 0.5 \)  
  (6)

In principal components analysis, the count of spectral components is reduced to less principal components in the original multispectral images for the most variance. Direct multi-date classification methods are used for single analysis of two or more date data set for identification of change areas. Background subtraction method is used in removing the variations by performing subtraction of the approximated background image \( f_b \) from the original image, Singh [25]. The new image is represented by equation (7):

\[ f_n(x) = f(x) - f_b(x) \]  

(7)

In principal components analysis, the count of spectral components is reduced to less principal components in the original multispectral images for the most variance. Direct multi-date classification methods are used for single analysis of two or more date data set for identification of change areas. Background subtraction method is used in removing the variations by performing subtraction of the approximated background image \( f_b \) from the original image, Singh [25]. The new image is represented by equation (7):

\[ f_n(x) = f(x) - f_b(x) \]  

(7)

### 3. Edge Detection Methods

1. The Canny Detection: This method computes the squared gradient magnitude (Ali and Clausi [2]). For recognition of edges, the local maxima above the threshold are considered. Non-maximum suppression represents the local peak threshold detection. The main intent is to obtain an optimal operator to minimize the distance between true and reported edge, minimizes the probability of not-able to detect the edge and the probability of multiple edge detection.

2. The Sobel Detection: This operator implements a 2-D spatial gradient measurement and stresses the high spatial frequency region of an image which in turn corresponds to the edges. When the input image is a greyscale image, it helps in finding the fairly accurate absolute gradient magnitude at each point (Senthilkumaran and Rajesh [26]). The derivative matrix used for horizontal and vertical [equation (8)-(9)] are as follows:

\[ G_x = \begin{bmatrix} -1 & 0 & +1 \\ -2 & 0 & +2 \\ -1 & 0 & +1 \end{bmatrix} \]  

(8)

\[ G_y = \begin{bmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ +1 & +2 & +1 \end{bmatrix} \]  

(9)

The gradient approximation can be combined to give gradient magnitude using:

\[ G = \sqrt{G_x^2 + G_y^2} \]  

(10)

(3). The Prewitt Detection: This helps in estimation of orientation and magnitude of an image, limited to 8 possible orientations, Senthilkumaran and Rajesh [26]. This can detect two types of edges, horizontal edge and vertical edge. For finding out the horizontal edge, the following derivative in equation (11) is used:

\[ G_x = \begin{bmatrix} +1 & +1 & +1 \\ 0 & 0 & 0 \\ -1 & -1 & -1 \end{bmatrix} \]  

(11)

The vertical edge can be obtained by the using the derivative in equation (12):

\[ G_y = \begin{bmatrix} -1 & 0 & +1 \\ -1 & 0 & +1 \\ -1 & 0 & +1 \end{bmatrix} \]  

(12)

### 4. Proposed Methodology

The main intent of this paper is to propose the Ant Colony Optimization based edge detection segmentation, which helps in change detection of remote sensing images. Edge detection techniques such as Sobel, Canny and Prewitt help in generating edge maps for initialization of ants and finally achieve the output image. The flow chart of the proposed methodology is depicted in Fig 1.

![Fig 1: Proposed Methodology Flowchart](image-url)

4.1 Ant Colony Optimization
ACO is a probabilistic technique. It focuses on the objective of locating the optimal path in the graph by considering the behaviour of real ants, which are on the lookout for a path between the food source and their colony. The algorithm, Dorigo and Birattari [27], followed is:

1. Set and initialize all parameters and pheromone trails.
2. If criteria of termination-unsatisfied. Ant solutions formation is done.
3. Employ Local Search (optional).
4. Updating of Pheromones
5. Endwhile

The ant colony optimization characteristics (Dorigo and Gambardella [28]) are: (i) It is an heuristic approach as it quickens the speed of obtaining optimization. (ii) It is robust approach as one or more failures will not affect the final solution. (iii) It is considered as a distributive approach as every ant is completely independent and works in parallel and distributed manner. (iv) It is a self-adjustable approach as even a single ant can change the situation using the pheromone. In ant colony system with edge detection, from node \((r, s)\) to node \((i, j)\), Nezamabadi-Pour et al. [29] defined the probability for displacing the \(k\)th ant is defined by equation (13):

\[
p^k_{(r,s),(i,j)} = \begin{cases} \frac{\tau_{(i,j)}^\alpha \eta_{(i,j)}^\beta}{\sum \sum \tau(u,v)^\alpha \eta(u,v)^\beta} & \text{if } (i, j) \text{ and } (u, v) \in \text{admissible nodes and } v \leq s+1, \\
0 & \text{else}
\end{cases}
\] (13)

If \((i, j)\) and \((u, v)\) \(\in\) admissible nodes and \(v \leq s+1, s-1 \leq j, u \leq r+1, r-1 \leq l\), then the probability is defined as above else it is equal to 0 and where the visibility of pixel \((i, j)\) is represented by \(\eta_{(ij)}\) and \(\tau_{(ij)}\) are the intensity of pheromone respectively, and the control parameters are defined as \(\alpha\) and \(\beta\). The pheromone (Nezamabadi-Pour et al. [29]) is updated as per equation (14) and the conventional Ant colony optimization flow chart (Kim et al. [30]) is depicted in Fig 2.

\[
\tau_{(i,j)}(\text{new}) = (1 - \rho)\tau_{(i,j)}(\text{old}) + \Delta \tau_{(i,j)}
\] (14)

In proposed technique, the ants are employed on the maps generated by the edge detection techniques i.e. Sobel, Canny and Prewitt. The difference in the pixel intensity value leads to ants movement. The technique includes the initialization process followed by pixel transition phase and pheromone update. Once all the paths and the neighbour pixel values are covered, the method stops and provides the complete edge information.

Fig 2: Flow Chart of Ant Colony Optimization

5. Result & Analysis

In this work, 12 remote sensed images covering New Delhi, India area from Google earth are considered and are displayed in table 1. For every remote sensed image, three conventional edge detection algorithms (Sobel, Canny and Prewitt) are applied in MATLAB environment. In order to improve the quality and reveal more edges, three hybrid edge detection techniques (ACO-Sobel, ACO-Canny and ACO-Prewitt) optimized by ACO artificial intelligence are implemented. The output images after implementation of conventional Sobel, Canny and Prewitt edge detection segmentation techniques are shown in table 2. The hybrid artificial intelligence (ACO-Sobel, ACO-Canny and ACO-Prewitt Edge Detection) optimized satellite images are depicted in table 3.

<table>
<thead>
<tr>
<th>Name of Image</th>
<th>Satellite Image</th>
<th>Name of Image</th>
<th>Satellite Image</th>
<th>Name of Image</th>
<th>Satellite Image</th>
</tr>
</thead>
</table>
Table 2: Satellite Images obtained by Conventional Edge Detection Techniques (Sobel, Canny and Prewitt)

<table>
<thead>
<tr>
<th>Name of Images</th>
<th>Satellite Images from Conventional Edge Detection Segmentation Techniques</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SOBEL</td>
</tr>
<tr>
<td>(A)</td>
<td>![A]</td>
</tr>
<tr>
<td>(B)</td>
<td>![C]</td>
</tr>
<tr>
<td>(C)</td>
<td>![E]</td>
</tr>
<tr>
<td>(D)</td>
<td>![G]</td>
</tr>
<tr>
<td>Name of Images</td>
<td>Satellite Images from Hybrid Artificial Intelligence Optimized Edge Detection Segmentation Techniques</td>
</tr>
<tr>
<td>---------------</td>
<td>---------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>(A)</td>
<td><img src="image_url" alt="Image" /> <img src="image_url" alt="Image" /> <img src="image_url" alt="Image" /></td>
</tr>
</tbody>
</table>

Table 3: Hybrid Artificial Intelligence (ACO-Sobel, ACO-Canny and ACO-Prewitt Edge Detection) Optimized Satellite Images
To quantitatively evaluate the results, entropy value and perception based image quality evaluator (piqe) for every image are computed and compared. The entropy value is an indication of quality of a satellite image; higher value of entropy ensures better quality of an image. Perception based image quality evaluator is used to assess the quality of an image, smaller score is the indicator of better image perception quality. The entropy value can be calculated as per equation (16). Here, total grey area is given by $L$ and $p_i$ is the probability distribution at each level:

$$E = - \sum_{i=0}^{L} p_i \log_2 p_i \quad (16)$$

The comparison of entropy values of satellite images for conventional and ACO optimized edge detection techniques is shown in table 4. From table 4, it has been observed that for satellite image A, the entropy values for Sobel, Canny and Prewitt are 0.2235, 0.5792 and 0.2228 respectively, whereas the improved entropy values for ACO-Sobel, ACO-Canny and ACO-Prewitt are 0.277, 0.6047 and 0.2760 respectively. Similarly, for image B, the entropy values are 0.2148, 0.6423 and 0.2142 respectively. The entropy values obtained from satellite images after ACO implementation are 0.2640, 0.6649 and 0.2650 respectively. Similarly, the entropy values for satellite images C, D,... K, L are summarized in table 4. Thus, highest entropy values from output satellite images are obtained from hybrid ACO-Canny edge detection segmentation technique. The comparative results are also depicted in fig 3 by column charts.

The comparison of piqe factor is presented in table 5. From the table, it has been observed that for image A, the values for sobel, canny and prewitt are 78.0338, 75.1839 and 80.7228, whereas for ACO-sobel, ACO-canny and ACO-prewitt, the values are 77.7611, 74.7690 and 75.5853. Similarly, for image B, the values are sobel-76.6260, canny- 74.0497, prewitt-81.5241, ACO-sobel-76.1649, ACO-canny- 74.0497 and ACO-prewitt- 75.7519. The piqe values for images C, D,...K, L are presented in table 5. It has been observed that for images A, B, C, E, F, I, J and L, the piqe value for ACO-canny is smallest as compared to other parameters. Smaller the piqe value, better is the perception quality of an image.

<table>
<thead>
<tr>
<th>Name of Images</th>
<th>Conventional Sobel</th>
<th>ACO-Sobel</th>
<th>Conventional Canny</th>
<th>ACO-Canny</th>
<th>Conventional Prewitt</th>
<th>ACO-Prewitt</th>
</tr>
</thead>
<tbody>
<tr>
<td>(A)</td>
<td>0.2235</td>
<td>0.2770</td>
<td>0.5792</td>
<td>0.6047</td>
<td>0.2228</td>
<td>0.2760</td>
</tr>
<tr>
<td>(B)</td>
<td>0.2148</td>
<td>0.2640</td>
<td>0.6423</td>
<td>0.6649</td>
<td>0.2142</td>
<td>0.2650</td>
</tr>
<tr>
<td>(C)</td>
<td>0.2194</td>
<td>0.2635</td>
<td>0.6660</td>
<td>0.6886</td>
<td>0.2192</td>
<td>0.2628</td>
</tr>
<tr>
<td>(D)</td>
<td>0.1908</td>
<td>0.2266</td>
<td>0.7303</td>
<td>0.7372</td>
<td>0.1899</td>
<td>0.2237</td>
</tr>
<tr>
<td>(E)</td>
<td>0.1754</td>
<td>0.2095</td>
<td>0.6627</td>
<td>0.6721</td>
<td>0.1726</td>
<td>0.2051</td>
</tr>
<tr>
<td>(F)</td>
<td>0.2025</td>
<td>0.2336</td>
<td>0.6307</td>
<td>0.6389</td>
<td>0.2007</td>
<td>0.2311</td>
</tr>
<tr>
<td>(G)</td>
<td>0.1872</td>
<td>0.2237</td>
<td>0.7077</td>
<td>0.7185</td>
<td>0.1841</td>
<td>0.2200</td>
</tr>
<tr>
<td>(H)</td>
<td>0.2116</td>
<td>0.2655</td>
<td>0.6523</td>
<td>0.6782</td>
<td>0.2091</td>
<td>0.2631</td>
</tr>
<tr>
<td>(I)</td>
<td>0.2257</td>
<td>0.2708</td>
<td>0.6686</td>
<td>0.6896</td>
<td>0.2240</td>
<td>0.2689</td>
</tr>
<tr>
<td>(J)</td>
<td>0.2192</td>
<td>0.2397</td>
<td>0.6736</td>
<td>0.6785</td>
<td>0.2186</td>
<td>0.2395</td>
</tr>
<tr>
<td>(K)</td>
<td>0.1869</td>
<td>0.2160</td>
<td>0.7124</td>
<td>0.7208</td>
<td>0.1842</td>
<td>0.2136</td>
</tr>
<tr>
<td>(L)</td>
<td>0.1849</td>
<td>0.2074</td>
<td>0.7119</td>
<td>0.7186</td>
<td>0.1834</td>
<td>0.2065</td>
</tr>
</tbody>
</table>
6. Conclusion

The change detection helps in monitoring the local, regional and global levels changes with respect to land use land cover, agricultural monitoring, resource planning, climate change and natural disaster assessment. This change detection in huge areas is usually carried out by processing the remotely sensed satellite images for better understanding and comparisons. The change detection process is degraded by drawbacks of weak boundaries and noises in satellite images covering large areas. In proposed methodology, three edge detection segmentation techniques viz.- Sobel, Canny and Prewitt are applied to precisely detect the image boundaries and visual perception of satellite images. The hybrid artificial intelligence optimized ACO-Sobel, ACO-Canny and ACO-Prewitt techniques are used to improve the quality of satellite images in minimum computation time. The performance of output satellite images is quantitatively compared by using entropy values and perception based image quality evaluator. In comparison with conventional edge detection techniques (Sobel, Canny and Prewitt) and hybrid artificial intelligence optimized ACO-Sobel and ACO-Prewitt techniques, ACO-Canny hybrid edge detection yields the highest entropy values for all the images and smallest piqe value for 8 images. This confirms much better image quality of processed images. These superior quality output satellite images may help in better & accurate change detection.

References