Modified Edge Detection based on the Theory of Universal Gravity-Implementation in MATLAB

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***Abstract*: In this paper we are going to study the modification of the original method by Genyun Sun et al. for edge detection based on the Law of Universal Gravitation. This study is based on a new approach for edge detection using gravitational search algorithm (GSA) and universal law of gravity. In the proposed approach the edges are detected using the law of universal gravity and movement of agents are computed using gravitational search algorithm. The proposed approach is able to detect the edge pixel in an image. The technique can be further extended for finding more edge pixels by modifying the gravitational search algorithm. The algorithm assumes that each image pixel is a celestial body with a mass represented by its grayscale intensity. Accordingly, each celestial body exerts forces onto its neighboring pixels and in return receives forces from the neighboring pixels. These forces can be calculated by the law of universal gravity. The vector sums of all gravitational forces along, respectively, the horizontal and the vertical directions are used to compute the magnitude and the direction of signal variations. Edges are characterized by high magnitude of gravitational forces along a particular direction and can therefore be detected.**

***Keywords* - Edge detection, Image processing, law of universal gravity, noise, gravity.**

I INTRODUCTION

Edge detection is vitally important in computer vision, image understanding, and pattern recognition. Edges correspond to sharp variations of image intensity and convey vitally important information in an image. Edges define the boundaries between regions in an image, which helps with segmentation and object recognition. They can show where shadows fall in an image or any other distinct change in the intensity of an image. Edge detection is a fundamental of low-level image processing and good edges are necessary for higher level processing. The problem is that in general edge detectors behave very poorly. While their behavior may fall within tolerances in specific situations, in general edge detectors have difficulty adapting to different situations. The quality of edge detection is highly dependent on lighting conditions, the presence of objects of similar intensities, density of edges in the scene, and noise. Detection of edges is therefore a key issue in image processing, computer vision, and pattern recognition. A variety of algorithms exists for edge characterization and detection such as the statistical methods, the difference methods and curve fitting.

II. RELATED STUDY

Among the earliest algorithms are gradient based methods such as Sobel, Prewitt, Roberts, and laplacian edge detectors. One of the most robust edge detection algorithms is perhaps the canny edge detector. Based on three criteria Canny defined an optimal filter that can be efficiently approximated by the first derivative of a Gaussian function in the one dimensional case. Canny's filter was further extended to recursive filters .Edges can also be detected using statistical methods. Huang and Tseng use a statistical analysis of the change-point problem based on the likelihood ratio test. It is however sensitive to noise and is computationally expensive. Kundu presents an edge detector which classifies pixels according to the local statistical information. Hou and Koh propose a statistical edge detection algorithm based on one-way experimental design and contrast test. However, their method is less computationally efficient than conventional detectors due to a multiple phase testing for edge detection. Lim compares quantitatively two-sample tests for edge detection in noisy images. Unlike edge detectors which suppress noise by low pass filtering, Haralick proposes to smooth noise by fitting data with a smooth function and the derivative is then obtained by differentiating the approximated function. A recursive procedure for efficiently computing cubic facet parameters has been developed recently. In, Allende introduces an effective method to extract edges for noise contaminated images. The method uses an agglomerative hierarchical cluster analysis technique to group pixels into clusters. Similarly, Kang defines an objective function to obtain both edge strength and orientation. This algorithm can eliminate double edges, thick edges, and speckles to some extent. However, it is ineffective under noisy conditions. Recently, based on the techniques that include geometry, statistics, wavelet, and neural theory, several new edge detectors have been derived. These recent methods are usually claimed to perform better than the old ones. Most of the implementations still concern the early, simple methods except for some very specific situations. Consequently, simplicity has been one of the aims when developing this method. Furthermore, it is noted that some methods mentioned above detect edges using only gray level images.

In the last decade, there have been renewed interests in the wavelet theory, and applications in filtering, classification, and compression. Wavelet and its associated multi-resolution analysis have also been applied for the characterization of image intensity variations. Mallat et al. presented their wavelet domain multi-scale edge detection approaches. In their researches, the edges are classified as the singularity points that can be detected as the local maxima of gradient moduli or the zero-crossings of wavelet coefficients. In Ref., the zero-crossings of M-band wavelet coefficients are located and viewed as the edges. These multi-scale edge detection approaches have made a significant improvement for the image edge detection. More recently, a new approach based on the discrete singular convolution (DSC) edge detection algorithm has been proposed.

In this paper, a new edge detection algorithm is presented. The method is based on the law of universal gravity. Every image point may be assumed as a celestial body, which has relationships with other neighboring image points. The proposed edge detector algorithm includes three steps. At first, the gravitational forces of a pixel exert on every other pixels around it are computed using the law of universal gravity. Secondly, the vector sum of all gravitational forces is calculated. At last, the magnitude and direction of the vector are used to detect image edges. Experiments indicate that the new approach is effective for edge detection especially under noisy conditions.

III. LAW OF UNIVERSAL GRAVITY

Newton's law of universal gravitation states that every point mass in the universe attracts every other point mass with a force that is directly proportional to the product of their masses and inversely proportional to the square of the distance between them. Between any two objects that have mass, there exist attractive gravitational forces acting on each object separately.

Newton's law of universal gravitation can be written as a vector equation to account for the direction of the gravitational force as well as its magnitude.

$$F = G\frac{m_1 m_2}{r^2}, \quad (1)$$

Where:
F is the force between the masses,
G is the gravitational constant,
m1 is the first mass,
m2 is the second mass, and
r is the distance between the centers of the masses.

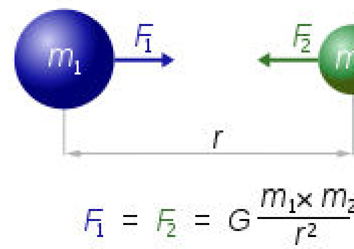

Fig 1 Law of Gravity

IV. GRAVITATIONAL SEARCH ALGORITHM

We apply Newton law of Gravity to find the optimum solution among all the set of masses, In GSA, each mass (agent) has four characteristics namely;

1) Position, and three kinds of masses

2) Active gravitational mass is a measure of the strength of the gravitational field due to a particular object.

3) **Gravitational field** of an object with small active gravitational mass is weaker than the object with more active gravitational mass.

4) **Passive gravitational mass** is a measure of the strength of an object's interaction with the gravitational field. Within the same gravitational field, an object with a smaller passive gravitational mass experiences a smaller force than an object with a larger passive gravitational mass. The position of the mass corresponds to a solution of the problem, and the fitness function is used to determine the gravitational and inertial masses.

The GSA algorithm is mainly comprises of the following steps:

1. Initialization of starting position
2. Evaluate the fitness of each agent (mass)
3. Update G agent, best agent, and worst agent among the population
4. Calculate the acceleration and velocity and thus calculate the total force on agents in all the possible directions
5. Update the position of the agents
6. Repeat steps 2 to 5 until best criterion is reached.
7. Got the best solution

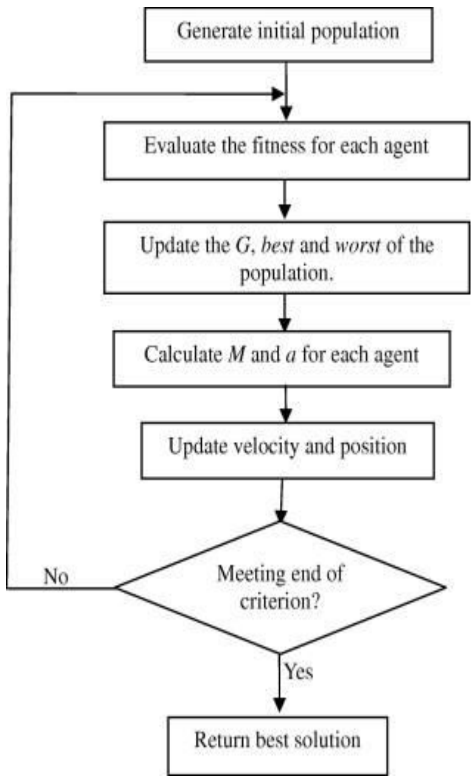

Fig 2: Flowchart of GSA

V PROPOSED IMAGE EDGE DETECTION APPROACH

A. ILLUSTRATION OF THE METHOD

The proposed approach using the gravitational search algorithm leads to a minimal set of input data to be processed. In spite of our familiarity with the concept of an edge, there is no widely accepted rigorous definition for it. Therefore, different edge detectors can produce edges in different forms of representation. One of the most common and most general definitions is the ideal step edge. To construct an edge detector, we assume that every image point is a celestial body, which has some relationship with other image points within its neighborhood through gravitational forces. For points beyond a pre-specified range, we assume all gravitational forces are zero. For each image point, the magnitude and the direction of the vector sum of all gravitational forces the point exerts on its neighborhood conveys the vitally important information about an edge structure including the magnitude and the direction.

The algorithm can be easily extended to horizontal and diagonal orientations. Edge structures in 90◦ directions are depicted in Fig 2. The magnitude of the gravitational force of the center pixel exerts on each other pixel within its neighborhood is illustrated in Fig. 2, the arrow indicates the gravitational force direction, here a=1/2 for simplification, we only consider 3X3 neighborhood of four points, of which points 1 and 4 are latent edge points whereas points 2 and 3 are non-edge points.

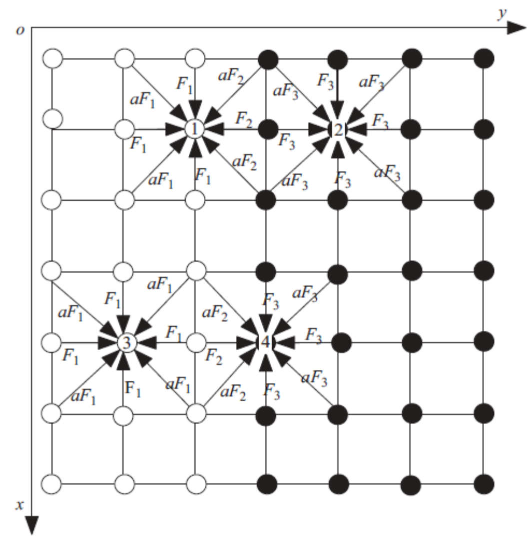

Fig 3: Basic edge structures oriented in 90◦ directions.

As can be seen from Fig. 3, all image points have four double gravitational forces. For point 1, we first compute the magnitude sum of gravitational forces in both x and y directions, respectively,

$$F_x = \left(aF_2 * \frac{\sqrt{2}}{2} + F_1 + aF1 * \frac{\sqrt{2}}{2} \right) - \left(aF_2 * \frac{\sqrt{2}}{2} + F_1 + aF1 * \frac{\sqrt{2}}{2} \right) = 0,$$

$$F_y = \left(aF_2 * \frac{\sqrt{2}}{2} + F_1 + aF1 * \frac{\sqrt{2}}{2} \right) - \left(aF_1 * \frac{\sqrt{2}}{2} + F_1 + aF_1 * \frac{\sqrt{2}}{2} \right) = \left(\frac{\sqrt{2}}{2} + 1 \right) * \left(F_2 - F_1 \right). \quad (2)$$

Then we calculate the magnitude and the direction of the vector sum of point 1 exerts on its neighborhood:

$$F^1 = \sqrt{\left(F_X{}^2\right)} + \sqrt{F_X 2 + F_y 2} = \left(\frac{\sqrt{2}}{2}+1\right)\left(F_2 - F_1\right),$$

$$\theta^1 = \arctan\left(F_x / F_y\right) = 0$$

Using exactly the same method, we obtain the response of points 2–4:

$$F^2 = F^3 = 0,$$

$$\theta^2 = \theta^3 = \arctan\left(F_x / F_y\right) = \frac{\pi}{2},$$

$$F^4 = \left(\frac{\sqrt{2}}{2}+1\right)\left(F_3 - F_2\right),$$

$$\theta^4 = \arctan\left(F_x / F_y\right) = 0.$$

According to the above, the response F is 0 for non-edge points such as points 2 and 3, but for latent edge points such as points 1 and 4, F is greater than 0. In general, $F^1 \neq F^4$, we assume $F^4 > F^1 > 0 = F^2 = F^3$. Theoretically, we can set an appropriate threshold, for example F, and let $F^4 > F > F^1$. A pixel location is declared an edge location if the value of response exceeds the threshold, here point 4 is labeled as edge point. Performing the same steps at each image point an edge map is then created. The edge direction information is given by θ.

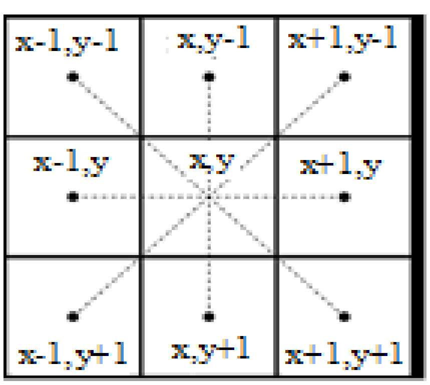

Fig 4 Local configuration for computing the intensity variation at (*x*,*y*).

B EXPERIMENTAL RESULTS

Conventional approaches to edge detection are computationally expensive because each set of operations is conducted for each pixel. The proposed approach is more focused on the optimization of the edge detection problem. To demonstrate the efficiency of the proposed approach, we carried out computer experiments on gray-level images. We have selected the Taj image Fig(5). This image is a natural and non-textured image. The settings of these images vary from in-door scenes to out-door views. The resolution of the image is 8-bit per pixel and of the size of 256 × 256 pixels. Most edge detection techniques utilize a post processing thresholding immediately after feature extraction to thin and extend edge contours. There are many well-established thresholding methods and edge thinning techniques. In the present work, the edge detection consists of two steps: edge magnitude calculation and threshold (fig 6). For magnitude result, we first get the contrast stretched image with brightness ranging from 0 to 255 by linear stretch method, then utilizes Otsu method to generate a threshold and (fig 7) shows Detected edge map.

Fig 5 Original Edge image

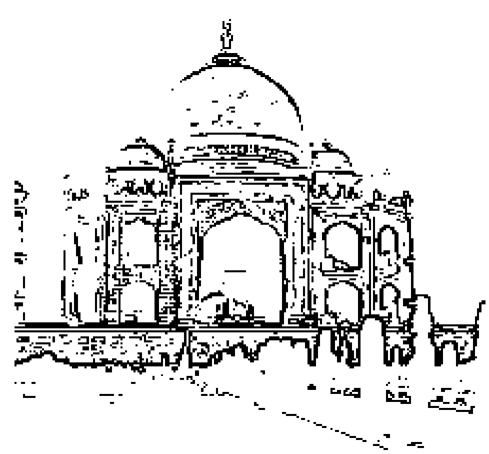

Fig 6 Using Adaptive thresholding

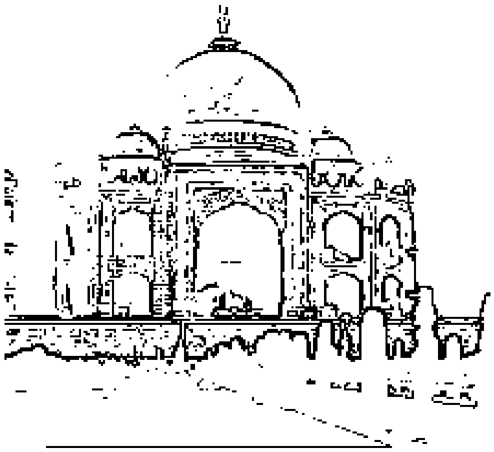

Fig 7 Detected Edge map

VI. CONCLUSION

In this paper a new algorithm which is efficient for edge detection based on the law of universal gravity has been successfully developed. The proposed approach uses local variations of image intensity in-order to detect edges. Experiment on a image is shown that the algorithm is consistent and reliable even when image quality is significantly degraded. The proposed approach leads to a minimal set of input data to be processed thus making the process much faster and memory-efficient then the edge detection algorithm.

VI. REFERENCES

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