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Study of Road Extraction Based on a Snake Model

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Abstract

The extraction of linear features like roadsides from satellite images is an important task in engineering sciences. In this paper, we aims to find the best curves which represent the roadsides visible in satellite images. An improved hybrid mathematical model based on a snake model is proposed to represents the linear features. Snake is a parametric curve which is permitted to deform from some arbitrary initial location toward the desired final location by reducing an energy function based on the internal and external energy. The model first uses the ant colony algorithm based on a proposed heuristic information parameter to find the photometric constraints in the snake model and then a cubic spline is used to interpolate "smooth curves" to the points derived from the snake model. In comparison of our model with other snake algorithms based on edge extraction, the model showed good results with improvement of about 10 percent. This success is due to the use of linear features knowledge (here roadsides) in the model.

Keywords: Linear feature, minimizing, ant colony algorithm, Snake, cubic spline, road sides.

Introduction

Satellite images have a lot of information about the different objects of terrain such as vegetation cover, buildings, roads, and soon. Extraction of the information from these objects can be used in many applications: cartography, traffic management and planning of urban. It would be a very expensive and time consuming process without satellite images, the collection and update of required information.

Atomatic extraction of roads and buildings from satellite images is a hard problem in image analysis for mapping. This paper improves a hybrid mathematical model in extraction of linear features like roadsides visible in Satellite images. Many approaches developed to deal with detecting roadsides on images[1,2]. The proposed model works based on an active contour called snake for roadsides extraction.

Snakes are Active curves, made by Kass et al[3]. Many researchers were used snakes for extracting linear features like roadsides of image[4]. The main advantage of snakes is that the geometric properties of the objects can be embedded constraints and used directly to guide the search. Geometric constraints here which are related to the roadside properties such as connectivity, low curvature and constant width, are incorporated into snakes. This cause internal forces which force the snake to satisfy defined road properties. also, the photometric constraints are used to determine relations between snakes and images. Roadside extraction is done by optimizing the position of the snake, when internal and external forces are defined. This paper proposes a modified snake model based on the ant colony optimization algorithm to detect a pheromone matrix as external energy in snake model. It also use a cubic spline model to interpolate "smooth curve" to the points derived from the snake model to extract the roadsides in Satellite images. In summary, the aims of this paper are:

Finding interest points on the linear feature of a Satellite image using ant colony optimization algorithm in a snake model.

Interpolation of derived points from the snake model with a cubic spline model to extract the feature.

Methodology

The Hybrid Mathematical Model in detection of roadsides: In the continues domain, the snake in form of a bi variant curve is defined as follows: $r(s,t) = (x(s,t), y(s,t))$, Which [$s$] is proportional to arc length,[t] is step time, and x and y are coordinates of the image curve. The snake reduces an energy function at time t as below[5]:

$$E_{tot}(r(s,t)) = E_{\text{int}}(r(s,t)) + E_{ext}(r(s,t)) \quad (1)$$

Where, E_{int} is the internal energy and E_{ext} is the external energy. Therefore, the optimal location of snake is where it s all energies neutralize effect of each other. For this work, the total energy should be minimized, so the optimization problem of the place of snake is equivalent to minimization of its energy. As shown in Neuenschwander (1996) if the snake minimizes the total energy, this energy should be the answer to the following equation[6]:

$$-\frac{\partial}{\partial s}(\alpha(s)\frac{\partial r(s,t)}{\partial s})+\frac{\partial^2}{\partial s^2}(\beta(s)\ (\frac{\partial^2 r(s,t)}{\partial s^2}))=-\frac{\partial q}{\partial r} \qquad (2)$$

Where $\alpha(s)$ and $\beta(s)$ are arbitrary functions that control effect of geometric properties against radiometric properties. In other words, show elasticity and hardness of snake. $q(r(s,t))$ is a external function. Equation-2 can be separated by two differential equations as below:

$$-\frac{\partial}{\partial s}(\alpha(s)\frac{\partial x(s,t)}{\partial s})+\frac{\partial^2}{\partial s^2}(\beta(s)\ \frac{\partial^2 x(s,t)}{\partial s^2})=-\frac{\partial q}{\partial x} \qquad (3)$$

$$-\frac{\partial}{\partial s}(\alpha(s)\frac{\partial y(s,t)}{\partial s})+\frac{\partial^2}{\partial s^2}(\beta(s)\ \frac{\partial^2 y(s,t)}{\partial s^2})=-\frac{\partial q}{\partial y} \qquad (4)$$

Above equations should be solved independently. Thus the equations have unique answers. Since q is a discrete function, equations (3), (4) cannot be solved analytically. To solve these equations, we need a numerical method.

According to[7] with substitution of $\alpha(s)$ and $\beta(s)$ instead of μ in (2) results in equation-5:

$$\mu(-\frac{\partial^2 r(s,t)}{\partial s^2}+\frac{\partial^4 r(s,t)}{\partial s^4})=-\frac{\partial q}{\partial r} \qquad (5)$$

For the numerical solution we use discretization methods. Discreization of the equation is to provide derivations and place of snake. This discretization of snake to regular intervals on the curve is performed follows:

$$r^{[t]}=\left\{r_i^{[t]}\right\}=\left\{(x_i^{[t]},y_i^{[t]})\right\}, \qquad for\, i=0,\ldots,n-1 \qquad (6)$$

Equation (5) can be written again as follows:

$$\mu(-(r_i^{[t]})_{ss}+(r_i^{[t]})_{ssss})=-q_{r_i^{[t-1]}} \qquad (7)$$

where $(r_i^{[t]})_{ss}$ and $(r_i^{[t]})_{ssss}$ denote the second and forth order derivatives of $r_i^{[t]}$ with respect to s. Using central differences to approximate the derivatives $(r_i^{[t]})_{ss}$ and $(r_i^{[t]})_{ssss}$, the left hand side of (7) for vertices $r_i^{[t]}$, (i = 2,. .., n − 3) can be written as: [8]

$$\begin{aligned}&\mu(-(r_i^{[t]})_{ss}+(r_i^{[t]})_{ssss})\approx-\mu(r_{i-1}^{[t]}-2r_i^{[t]}+\\&r_{i+1}^{[t]})+\mu(r_{i-2}^{[t]}-4r_{i-1}^{[t]}+6r_i^{[t]}-4r_{i+1}^{[t]}+r_{i+2}^{[t]})=\\&\mu(r_{i-2}^{[t]}-5r_{i-1}^{[t]}+8r_i^{[t]}-5r_{i+1}^{[t]}+r_{i+2}^{[t]})\end{aligned} \qquad (8)$$

Since the central differences are symmetric, they cannot be computed for the head vertices $(i=0,1)$ and the tail vertices $(i=n-2,n-1)$. Instead the forward and backward differences have to be used.

Using forward differences to approximate the derivatives $(r_i^{[t]})_{ss}$ and $(r_i^{[t]})_{ssss}$, the left hand side of (7) for vertices $r_i^{[t]}$, $(i=0,1)$ can be written as:

$$\begin{aligned}&\mu(-(r_i^{[t]})_{ss}+(r_i^{[t]})_{ssss})\approx-\mu(-(r_{i+2}^{[t]}-2r_{i+1}^{[t]}+r_i^{[t]}))\\&+\mu(r_{i+4}^{[t]}-4r_{i+3}^{[t]}+6r_{i+2}^{[t]}-4r_{i+1}^{[t]}+r_i^{[t]})=\\&\mu(-2r_{i+1}^{[t]}+5r_{i+2}^{[t]}+8r_i^{[t]}-4r_{i+3}^{[t]}+r_{i+4}^{[t]})\end{aligned} \qquad (9)$$

Using backward differences to approximate the derivatives $(r_i^{[t]})_{ss}$ and $(r_i^{[t]})_{ssss}$, the left hand side of (7) for vertices $r_i^{[t]}$, $(i=n-2\,,n-1)$ can be written as:

$$\begin{aligned}&\mu(-(r_i^{[t]})_{ss}+(r_i^{[t]})_{ssss})\approx-\mu(-(r_i^{[t]}-2r_{i-1}^{[t]}+r_{i-2}^{[t]}))\\&+\mu(r_i^{[t]}-4r_{i-1}^{[t]}+6r_{i-2}^{[t]}-4r_{i-3}^{[t]}+r_{i-4}^{[t]})=\\&\mu(-2r_{i-1}^{[t]}+5r_{i-2}^{[t]}+8r_i^{[t]}-4r_{i-3}^{[t]}+r_{i-4}^{[t]})\end{aligned} \qquad (10)$$

This gives the following approximations of $\mu(-(r_i^{[t]})_{ss}+(r_i^{[t]})_{ssss})$:

$$\begin{aligned}&r_0^{[t]}:\mu(-2r_1^{[t]}+5r_2^{[t]}-4r_3^{[t]}+r_4^{[t]})\\&r_1^{[t]}:\mu(-2r_2^{[t]}+5r_3^{[t]}-4r_4^{[t]}+r_5^{[t]})\\&r_2^{[t]}:\mu(r_0^{[t]}-5r_1^{[t]}+8r_2^{[t]}-5r_3^{[t]}+r_4^{[t]})\\&r_3^{[t]}:\mu(r_1^{[t]}-5r_2^{[t]}+8r_3^{[t]}-5r_4^{[t]}+r_5^{[t]})\\&r_{n-3}^{[t]}:\mu(r_{n-1}^{[t]}-5r_{n-2}^{[t]}+8r_{n-3}^{[t]}-5r_{n-4}^{[t]}+r_{n-5}^{[t]})\\&r_{n-2}^{[t]}:\mu(-2r_{n-3}^{[t]}+5r_{n-4}^{[t]}-4r_{n-5}^{[t]}+r_{n-6}^{[t]})\\&r_{n-1}^{[t]}:\mu(-2r_{n-2}^{[t]}+5r_{n-3}^{[t]}-4r_{n-4}^{[t]}+r_{n-5}^{[t]})\end{aligned} \qquad (11)$$

In equation (11), for each $r_i^{[t]}$, it needs neighboring points in each time step[t]. So this equation can be solved in any $r_i^{[t]}$ i=0,…, n-1). This set of equations for all points of snake can be written in the form of a matrix as below:

$$K.r^{[t]}=-q_{r^{[t-1]}} \qquad (12)$$

K is a $n \times n$ matrix as:

$$K = \begin{bmatrix} 0 & -2\mu & 5\mu & -4\mu & \mu & & & & \\ 0 & 0 & -2\mu & 5\mu & -4\mu & \mu & & & \\ \mu & -5\mu & 8\mu & -5\mu & \mu & & & & \\ & & \cdot & & & & & & \\ & & \cdot & & & & & & \\ & & \cdot & & & & & & \\ 0 & & & & & & & & \\ & & & & \mu & -5\mu & 8\mu & -5\mu & \mu \\ 0 & & & \mu & -4\mu & 5\mu & -2\mu & 0 & 0 \\ 0 & & & & \mu & -4\mu & 5\mu & -2\mu & 0 \end{bmatrix} \quad (13)$$

With the help of MATLAB it is shown that the determinant of the matrix K is zero.

This matrix is singular; therefore, equation-12 cannot be solved for $r^{[t]}$ directly. To solve this problem, we enter a parameter γ called the viscosity coefficient. Viscosity coefficient of $r^{[t]}$ creates a balance between energy changes and displacements of snake. Viscosity coefficient allows the energy minimizing during high speed of snake by setting the right-hand side of equation:

$$K.r^{[t]} + q_{r^{[t-1]}} = 0 \quad (14)$$

To make of an iteration step γ . The discrete equation of snake can rewrite as below:

$$(K + \gamma I).r^{[t]} = \gamma\, r^{[t-1]} - q_{r^{[t-1]}} \quad (15)$$

Where I is an $n \times n$ identity matrix and $(K + \gamma\ I)$ is nonsingular and then it can be inverted. This indicates that $r^{[t]}$ can be achieved directly by solving (15) numerically. Therefore to find the location of the snake with minimum value of energy, the equation (15) is solved for a number of time steps. The iteration begins with the given initial location of the snake $r^{[0]}$. The viscosity γ can be obtained as:[7]

$$\gamma = \frac{\sqrt{2n}}{\Delta} \left| \frac{\partial E_{tot}(\vec{r})}{\partial \vec{r}} \right| \quad (16)$$

Δ is the built middle displacement of the snake's curves.

According to (15), $q_{r^{[t-1]}}$ is an n×1 matrix related to external energy. This paper propose ant colony algorithm to find a new solution for $q_{r^{[t-1]}}$.

The purpose of the Ant Colony algorithm is to find a good solution for q_r by building the pheromone matrix.

All of K ants go on the image I with a size of $M1 \times M2$ whose each pixel consider as a point. The initial value of each member of the pheromone matrix $\tau^{(0)}$ is τ_{init} .

At the n-th step, one ant selects from the total K ants randomly, and this ant will go on the image for L movement steps. This ant goes from the point (l, m) to its neighboring point (i, j) according to a probability which is as below:[9]

$$p^{n}_{(l,m),(i,j)} = \frac{\left(\tau^{(n-1)}_{i,j}\right)^{\alpha} \left(\eta_{i,j}\right)^{\beta}}{\sum\limits_{(i,j)\in \sum \Omega_{(l,m)}} \left(\tau^{(n-1)}_{i,j}\right)^{\alpha} \left(\eta_{i,j}\right)^{\beta}} \quad (17)$$

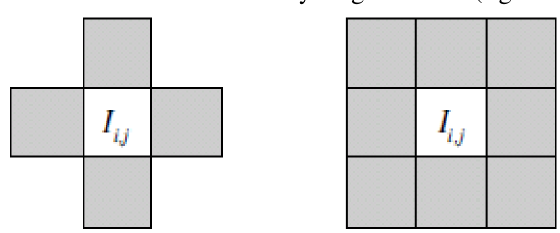
In above equation, $\tau^{n-1}_{i,j}$ is the pheromone value of the point (i, j), $\Omega_{(l,m)}$ is the neighborhood points of the point *(l, m)*, $\eta_{i,j}$ is the heuristic data at the point (i, j). The constants $\alpha\ and\ \beta$ show the effect of the pheromone matrix and the heuristic matrix.

In this process, there are two steps. The first step is to determine the heuristic information $\eta_{i,j}$ in (17). In this article, we suggest it to be determined by the pixel location *(i, j)* as below:

$$\eta_{i,j} = (I(i,j) - I_m(i,j))^2 \quad (18)$$

That $I(i,j)$ is the intensity value of the pixel at the location (i, j) of the image I. $I_m(i,j)$ is the middle value of the intensity values of a window with size of 3×3 centered on (i, j).

The second step is to select the range of the ant's movement in (17) at the location (l, m). In this paper it is 4-connectivity neighborhood or the 8-connectivity neighborhood (figure-1).



(a) (b)

Figure-1

(a) The movement in 4-connectiving **(b)** 8-connectiving

This approach has two steps to update the pheromone matrix. The first step is out after the movement of each ant with each construction-step. Each component of the pheromone matrix is updated as below:

$$\tau^{n-1}_{i,j} = \begin{cases} (1-\rho)\ \tau^{(n-1)}_{i,j} + \rho\, \Delta^{(k)}_{i,j} & if\ (i,j) \\ is\ visited\ \ by\ the\ current\ \ k-th\ ant & \\ \tau^{(n-1)}_{i,j}\ \ otherwise & \end{cases} \quad (19)$$

Where ρ is the evaporation rate, $\Delta^{(k)}_{i,j}$ is specified by the heuristic matrix that is, $\Delta_{i,j}^{(k)} = \eta_{i,j}$. The second update is performed after the movement of all ants within each construction-step as below:

$$\tau^{(n)} = (1-\psi)\,\tau^{(n-1)} + \psi\,\tau^{(0)} \tag{20}$$

Here, ψ is the pheromone reduction factor. Pheromone matrix is used in the snake model as external energy to extract roads sides of a image.

In the iterative process, the energy loss per step, compared to the previous step shows that snake is moving in the right direction of minimizing energy, otherwise, if the energy increases snake maintains his previous position and the distance decreases. This continues to be lower than the specified threshold value. A small value indicates that snake with a location corresponding to the lowest energy has been optimized.

Interpolation: We wish to interpolation "smooth curve" to the points of final location of snake to extract the geometric roadside model. One technique is splines that is usually use for interpolating of natural curve. Splines are curves that move through given points with to have weights, but they move smoothly from each interval to the next interval. The conditions for a cubic spline interpolation are to pass a set of cubics through the points, using a new cubic in each interval. In here, we need to have the slope and the curvature for the pair of cubics that join at each point.

We can to write the cubic for the ith interval, that lie between the points (x_i, y_i) and (x_{i+1}, y_{i+1}) in the form:

$$y = a_i(x-x_i)^3 + b_i(x-x_i)^2 + c_i(x-x_i) + d_i \tag{21}$$

According to Luis Osbipo, the following matrix is used for the total number of points to define interpolate spline.

$$\begin{bmatrix} h_1 & 2(h_1+h_2) & h_2 & & & \\ & h_2 & 2(h_2+h_3) & h_3 & & \\ & & h_3 & 2(h_3+h_4) & h_4 \ldots & \\ & & & & & \\ & & & h_{n-2} & 2(h_{n-2}+h_{n-1}) & h_{n-1} \end{bmatrix} \begin{bmatrix} s_1 \\ s_2 \\ s_3 \\ s_4 \\ . \\ . \\ s_{n-1} \\ s_n \end{bmatrix} = \begin{bmatrix} \frac{y_3-y_2}{h_2} - \frac{y_2-y_1}{h_1} \\ \frac{y_4-y_3}{h_3} - \frac{y_3-y_2}{h_2} \\ . \\ . \\ . \\ \frac{y_n-y_{n-1}}{h_{n-1}} - \frac{y_{n-1}-y_{n-2}}{h_{n-2}} \end{bmatrix} \tag{22}$$

In equation-22, there is only *n-2* equations, but n unknowns.

We can obtain two variants (s_1 and s_n) using the relation that correspond to the end-condition assumptions. It can be reduced the S vector to *n-2* vectors, and the coefficient matrix becomes square with size of *(n-2)* × *(n-2)*. Therefore, the matrix is tridiagonal, and then is solved speedily and can be stored economically.

After the values s_i are obtained, the values of a_i, b_i, c_i, d_i can be determined for each interval between points (x_i, y_i) and (x_{i+1}, y_{i+1}).

$$a_i = \frac{(s_{i+1}-s_i)}{6h_i} \qquad b_i = \frac{s_i}{2}$$
$$c_i = \frac{y_{i+1}-y_i}{h_i} - \frac{2h_i s_i + h_i s_{i+1}}{6} \qquad d_i = y_i \tag{23}$$

Thus a cubic spline interpolate to the points derived from the snake model.

Results and Discussion

The proposed model is applied on two samples of IKONOS satellite images with resolution of 1m were taken on 2000 with size of 500*500. The images belong to a part of area in city Kish from Iran. The initial snake is generated by selecting nodes $r_i^{[t]}$ at regular distance intervals manually along the road segments. The images contain roads with different widths. At some places, the roads are partially gapped due to trees and houses shadows. For those regions, we expect the snake to recover the lacking information. In the experiments, the fixed parameters are assigned values that found to produce good results. The parameters of the Ant colony algorithm set as:

$\tau_{init} = 0.9$: the initial value of each componen of the pheromone matrix
N = 200 : total number of construction steps
L = 600 : total number of ants movement steps within each construction step
K = 100 : the total number of ants
$\alpha = 2.5$: the weighting factor of the pheromone information in (17)
$\beta = 1$: the weighting factor of the heuristic information in (17)
$\psi = 0.05$: the pheromone decay coefficient in (20)
$\rho = 0.005$: the evaporation rate in (19)

However in order to perform snake's optimization according to the strategy discussed in this paper, two parameters γ, μ have to be determined in (5) and (16).

The first is the first displacement $\Delta^{[0]}$ allowed for snake's vertices during the first optimization step [$t = 0$]:

$$\Delta^{[0]} = \frac{1}{n}\sum_{i=0}^{n}\left|\left(\vec{v}_i^{[0]}\right)_t\right| \quad (24)$$

The value of $\Delta^{[0]}$ can be obtained by the width of roads. To achieve the required accuracy, this value should be smaller than the smallest road width in the image. Otherwise, the initial snake on a path moves very far from the orginal location and route and can never go back to the main road. On the other hand, very small value of $\Delta^{[0]}$ slows down the speed of the algorithm. Roads in the rural or semi-urban areas are usually between 3 and 10 meters in width. Thus for the balance between accuracy and speed of the algorithm, the initial displacement of snake can be considered as $\approx 0.5m$. The second parameter we must determine is the parameter $\Delta^{[t]}$. This parameter is related to the displacement of snake at time[t]. If the total energy increases, this parameter must be reduced. Appropriate choice of this parameter is as follows:[10]

$$\Delta^{[t]} = \frac{\Delta^{[t-1]}}{\rho} = \frac{\Delta^{[0]}}{\rho^{t}} \qquad (\rho \succ 1) \quad (25)$$

If the smallest value of ρ is reduced, the result is $\Delta^{[t]}$ and thus optimization will be longer but with this low value, the accuracy increases. On the other hand, large values ρ increase the speed and reduce accuracy of the algorithm.

The advantage of the exponential function in the above equation is that reduction of $\Delta^{[t]}$ at the beginning of the optimization occurs too fast and this decline is performed slowly at the end of the optimization. This corresponds to the fact that the location of a linear feature can be produced quickly, while many optimal steps with small changes are taken on initial snake.

The last required parameter is $\Delta_{\min}$ which the minimum of the used $\Delta^{[t]}$ provided stopping the algorithm for the optimal location of snake. Snake optimized with a small amount of $\Delta^{[t]}$ have higher accuracy. But like the previous two parameters are calculated high accuracy requires many optimal steps which in this case it will be a long-time algorithm. Since $\Delta_{\min}$ is dependent on the size of the pixels in each image, it has been shown experimentally that 0.1 pixel, is the appropriate choice for $\Delta_{\min}$.

First experimental is a part of the study area that is shown in figure 2(a). The image contains roads with different curvature from straight to high. The figure-2(b) shows pheromone image derived from ant colony algorithm. Figure-2(c) shows the initialization snakes to start the algorithm. Initial snakes generated by selecting some nodes at regular distance interval manually a by the road segments.

The model of this paper can be literately given the different results. For example for 20 iterations, the result shows in figure-2(d). After 900 iterations, we can find the results in figure-2(e) and for 1300 iterations the results is shown in figure-2(f).When we continue for more iterations, the result is same. The results showed, the energy function is minimizing for the iterations 1300.

Second experimental is another part of the study area that is shown in figure 3(a). The image also contains different roads with different curvature from straight to high. The fig 3(b) shows pheromone image derived from ant colony algorithm. Figure-3(c) shows the initialization snakes to start the algorithm; The model of this paper can be literately given the different results. For example for 40 iterations, the result is shown in figure-3(d). After 500 iterations, we can find the results in Fig 3 (e) and for 1200 iterations the results is shown in figure-3(f).When we continue for more iterations, the result is same. The results showed the energy function is minimize for the iterations 1200.

Figure-4 gives the variation of the total energy of the snake during the localization process of the high curved roads in the experimental. It is see that the total energy decreases until it reaches a constant level which corresponds to the final location.

For geometric accuracy assessment of the proposed algorithm, the roadsides are extracted both manually as reference and automatically. Since the reference is known, a quantification of the localization error is available. Indeed, the obtained results are sampled and compared to the reference vectors. The validation is done with three parameters: average distance error, Completeness, and correctness.

The average distance error is the distance between the references and the obtained results define as: [11]

$$D = \frac{1}{N_{sample}}\sum_{i=1}^{N_{ample}}\sqrt{(x_i - x_i^t)^2 + (y_i - y_i^t)^2} \quad (26)$$

Where (x_i, y_i) are the coordinates of the obtained solution using the algorithm, and (x_i^t, y_i^t) are the coordinates of the references. Completeness is the percentage of the references has been extracted. The completeness is defined as:

$$\text{completness} = \frac{\text{matched}\, l_e}{l_r} \quad (27)$$

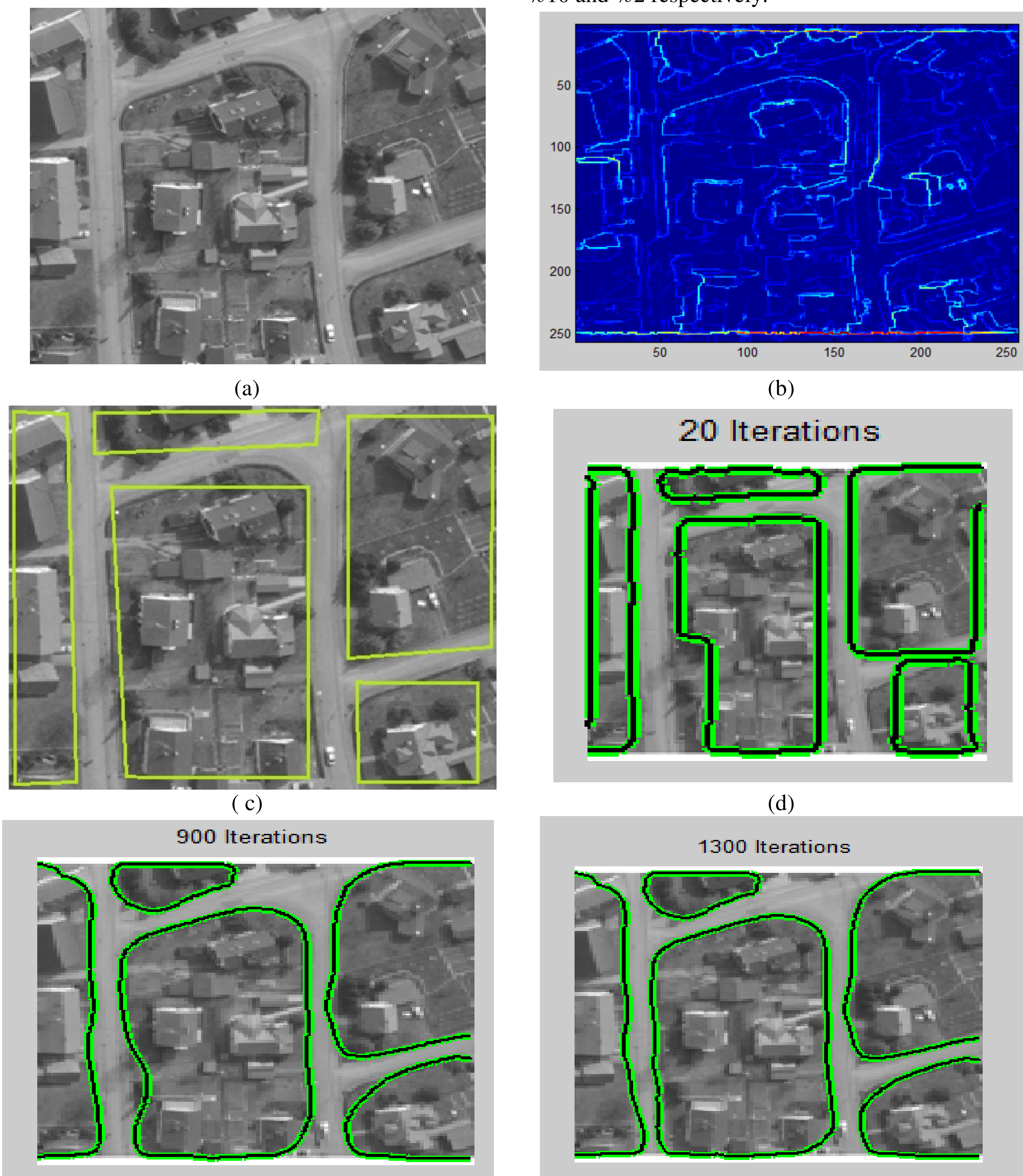
Where $\text{completeness} \in [0,1]$. l_e is defined as the length of the extracted line segment and l_r the length of the reference segment.

And correctness serves as a measure of the precision of the extracted road. In fact, it is the percentage of the extracted road which is covered by the references. The correctness is defined as:

$$\text{correctness} = \frac{\text{matched}\, l_e}{l_e} \quad (28)$$

Table-1 gives the obtained values of above parameters for the experimental. The result shows the proposed method is efficient in automatic linear feature extraction of digital images. The completeness and correctness improved in comparison of our method with respect of other methods of road extraction based on the edge[12]

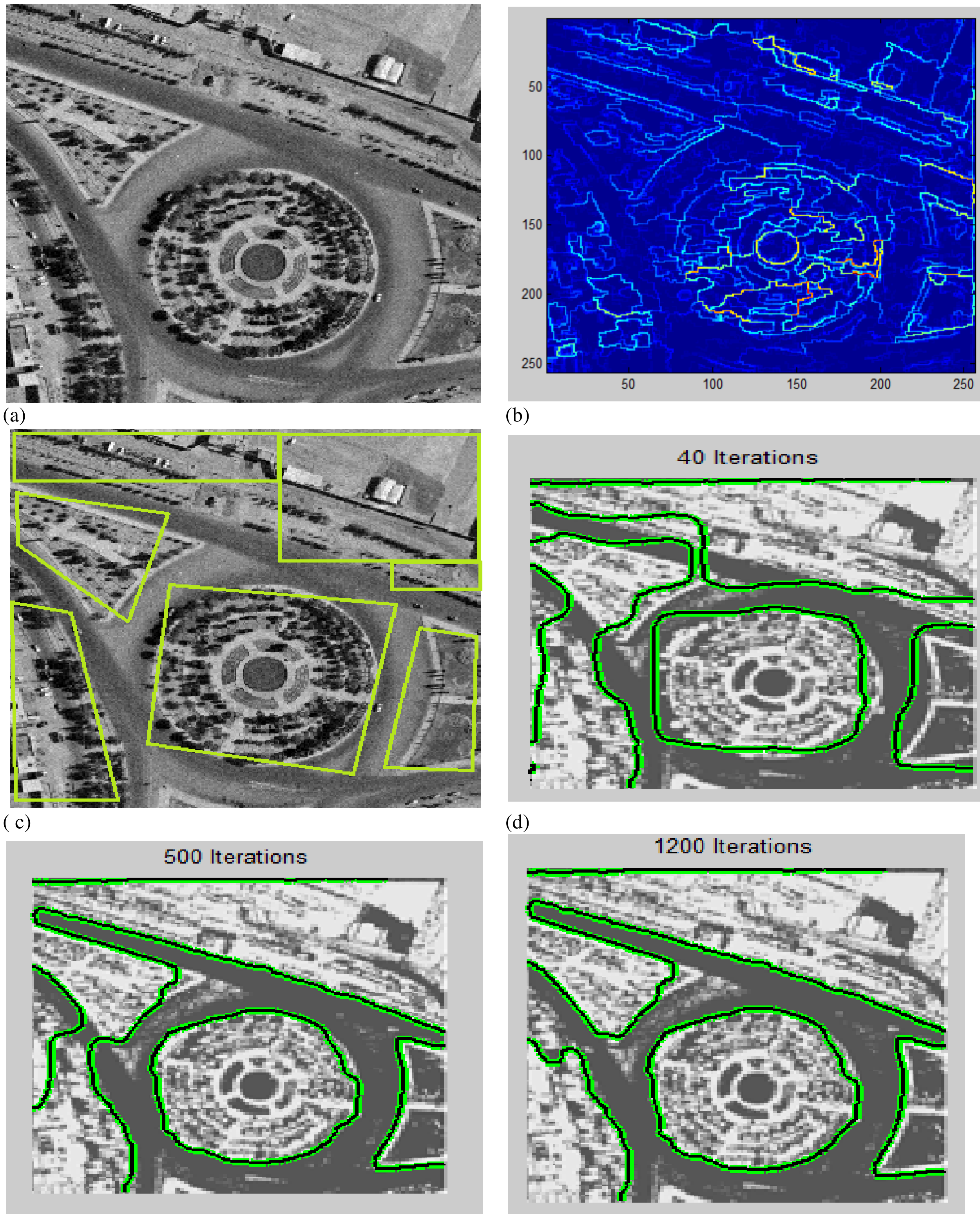
The method increased the completeness and correctness about %10 and %2 respectively.



(a) (b) (c) (d) (e) (f)

Figure-2

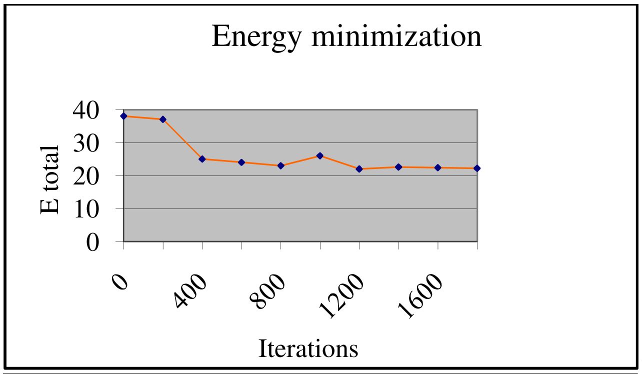
(a) image, (b) extracted pheromone matrix as external energy in snake model, (c) initialization snakes, (d) snakes in 20 iteration, (e) snakes in 900 iteration , (f) extracted road sides



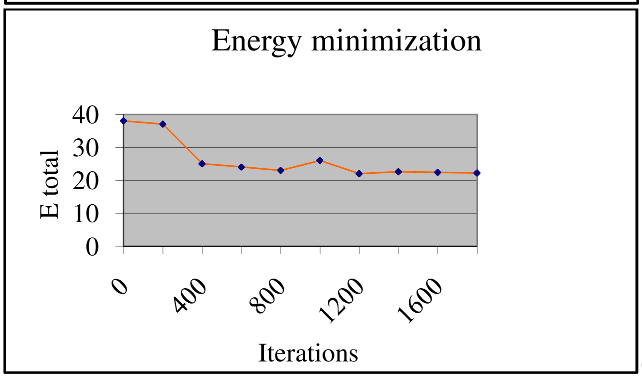
(a) (b) (c) (d) (e) (f)

Figure-3

(a) image, (b) extracted pheromone matrix as external energy in snake model, (c) initialization snakes, (d) snakes in 40 iteration, (e) snakes in 500 iteration, (f) extracted road sides



(a)



(b)

Figure-4
Variation of the total energy of the snake attracted by the high curved roads for (a) experimental 1 and (b) experimental 2

Table-1
The accuracy assessment of the proposed algorithm

Parameter	**Experimental 1**	**Experimental 2**
Number of reference points	120	150
Number of extracted points	110	120
Completeness	95%	80%
correctness	94%	86%
average distance error (D)	0.2	0.5

Conclusion

This paper developed an algorithm for extracting linear features like roads from satellite images. The algorithm was based on the improved ant colony model combined with the snake model to identifying and extracting the linear features from satellite images. The ant colony approach can establish a pheromone matrix that gives the pheromone information at each pixel position of the image. The pheromone matrix was used as the external energy in the snake model to extract the roads from images. The precision of the model was examined visually and quantitatively. Visually, the extracted roadsides were closed to the roads on the original image, and quantitatively, the statistical results verified that the proposed approach has also effective.

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