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Study on the Self-Location Estimate by the Evolutional Triangle Similarity Matching Using Artificial Bee Colony Algorithm

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***Abstract*—**In previous study, technique to estimate a self-location by using a lunar image is proposed. We consider the improvement of the conventional method in consideration of FPGA implementation in this paper. Specifically, we introduce Artificial Bee Colony algorithm for reduction of search time. In addition, we use fixed point arithmetic to enable high-speed operation on FPGA.

***Keywords*—**SLIM, Artificial Bee Colony Algorithm, Location Estimate.

I. Introduction

CURRENTLY, JAXA/ISAS (Japan Aerospace Exploration Agency/Institute Space and Astronautical Science) plans SLIM (Smart Lander for Investigating Moon) [1] and they are proceeding with the development study of the small lunar probe. A purpose of the SLIM is to land exactly at the lunar destination to perform scientific exploration. Therefore it is necessary to estimate a self-location exactly by collating the crater map which is made beforehand with the crater information of the lunar image which a space probe photographed.

It is difficult to guide a space probe by radio from the base on the earth and so it is necessary to do independence aviation by space probe oneself. In addition, we cannot equip space probe with a high-performance general-purpose PC when considering the weight saving of the space probe, a temperature change in the space and the influence of the radiation. Therefore it is necessary to realize the highly precise crater detection and self-location estimates by a small operation amount.

In previous study, ETSM (Evolutional Triangle Similarity Matching) is proposed as technique to estimate a self-location [2]–[4]. ETSM is Algorithm that estimates the self-location by searching for the triangle which resembles triangle that is formed from the crater in the photography image from a crater map by using GA (Genetic Algorithm). We consider the improvement of the conventional method in consideration of FPGA implementation in this study. Specifically, we confirmed similarity relation by the interior angle of each triangle in the previous study, but try confirmation by the ratio of the length of the sides of each triangle to shorten calculation time in this study. In addition, we shorten the search time by adopting ABC (Artificial Bee Colony) Algorithm and improve the precision.

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II. Evolutional Triangle Similarity Matching

A. Summary

In this study, we propose ETSM using ABC Algorithm. ETSM to propose is Algorithm that estimates the self-location by searching for the triangle which resembles triangle that is formed from the crater in the photography image from a crater map by using ABC Algorithm. The ESTM to propose is different from conventional ESTM in optimization algorithm to use. In addition, similarity relation is confirmed by the ratio of the length of the sides of the each triangle. Therefore fixed point arithmetic becomes possible, and calculation time is shortened.

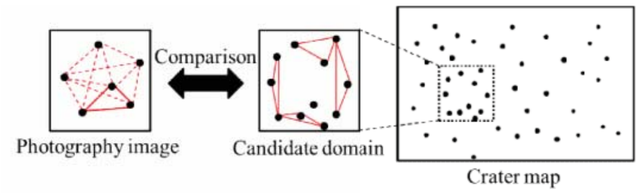

Fig. 1 Diagrammatical view of the ESTM

B. Algorithm

Fig. 1 shows a diagrammatical view of the ESTM. Where, the left image is a photography image, the right image is a crater map; the center image is candidate domain that is searched. Flows of the matching are as follows.

1) All triangles consisting of the craters in the photography image are memorized. A triangle to contain other craters are excluded from there, the ratio of the length of the side of each triangle are calculated.
2) Plural initial positions becoming the candidate domain in the crater map are decided at random.
3) Three-points that is large x-coordinate, small x-coordinate, large y-coordinate and small y-coordinate are chosen from crater in the candidate domain. Then, the ratio of length of the side of four triangles in total that are formed by each point is calculated. And the difference with the ratio of the length of the side of all triangles of the photography image

is calculated. The value that a difference is the smallest is defined as resemblance degree. And the total of four resemblance degree becomes an evaluated value of the domain.

4) If evaluated value is less than the threshold or the number of iterations is more than certain number, search is finished. Otherwise, new candidate domains are decided by ABC Algorithm and search is repeated back to step 3.

III. Artificial Bee Colony Algorithm

A. Summary

ABC algorithm is an optimization algorithm based on the behavior of the honey bee. In the ABC model, the colony consists of three groups of bees, namely employed bees, onlooker bees and scout bees. The food source is set of solutions, and bees update the information of food source. The best food source is determined by repeating the update. Flows of the update are as follows. In this study, we use Mersenne Twister to generate the random number.

B. Algorithm

1. Initialization Phase

The food sources are generated. Information of the food source is determined at random within set range. The fitness of each food source that was generated is calculated. The food source that fitness is the highest is memorized as an optimal solution. Fitness is given by (1):

$$fit_i = \begin{cases} \frac{1}{1+f(x_i)} & f(x_i) \geq 0 \\ 1+|f(x_i)| & otherwise \end{cases} \quad (1)$$

where, f is an evaluated value of the domain and x_i is ith food source.

2. Employed Bees Phase

Employed bees update the food source in charge, respectively. At first, generate candidate for new food source by (2).

$$v_{ij} = x_{ij} + \phi(x_{ij} + x_{kj}) \quad (2)$$

where, v_{ij} is candidate for new food source, φ is selected random within range of -1 ~ 1.

After that, the fitness of a candidate of a new food source is calculated and compared with the fitness of the current food source. Employed bee update a food source if the fitness of the candidate of a new feeding ground is higher.

3. Onlooker Bees Phase

The relative probability of fitness of each food sources is calculated. The relative probability is given by (3).

$$p_i = \frac{fit_i}{\sum_{n=0} fit_n} \quad (3)$$

The food source by roulette wheel selection that consider the relative probability is selected and Step 1 is applied. The above mentioned processing is repeated by the number of times of the number of onlooker bees.

4. Memorize Phase

We compare the fitness of each food sources and the fitness of the optimal solution that is memorized. Update the optimal solution if there is a food source with the fitness that is higher than the optimal solution.

5. Scout Bees Phase

If there is a food source that number of the time non-updated reaches a certain number, it is replaced with new food source which is generated randomly. Replace only one of them if the food source that meets the criteria exist more than one.

6. Repeat Check Phase

If the number of iterations is more than certain number, it is finished. Otherwise, it is repeated back to Step1.

In this study, we define the food source as a vector which consists of x-coordinate, y-coordinate, x-direction size of the candidate domain and y-direction size of the candidate domain. We try to estimate these optimal parameters.

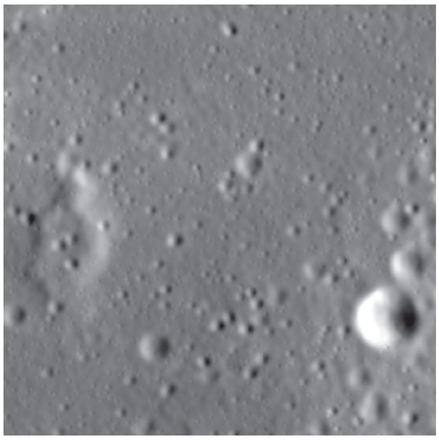

Fig. 2 Lunar image

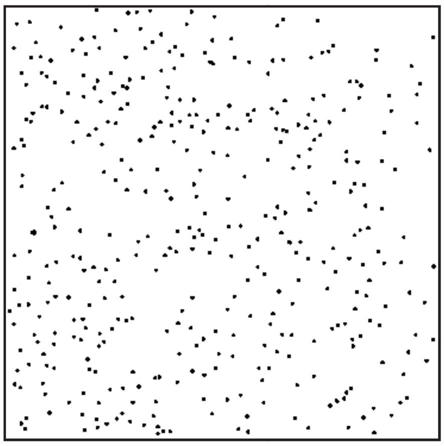

Fig. 3 Plot image

IV. Crater Detection

A. Summary

In this study, we adopt the technique by the principal component analysis to the detection of the crater [5], [6]. The central location of each crater is detected by crater detection from a lunar image such as Fig. 2. And an image such as Fig. 3 that plotted the central location of each crater is made.

B. The False Detection of the Detection Crater

Many errors occur between result of the crater detection and crater map made beforehand. These are called the false detection of the crater.

The false detection of the crater is following three:

1. Increase

There is not the central location of a crater detected with a photography image in a crater map.

2. Delete

There is the central location of a crater not detected with a photography image in a crater map.

3. Shift

There is a slight error between the coordinate of the crater map and the coordinate detected with a photography image.

Fig. 4 shows a kind of the false detection of the crater detection.

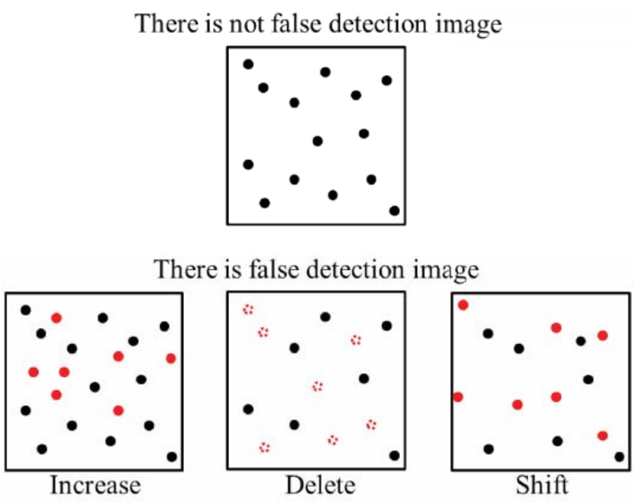

Fig. 4 Kind of the false detection of the crater detection

V. Simulation

We make a crater map from the photography image of the "Kaguya" which is moon surroundings satellite. In addition, we make five photography images which are photographed from different coordinates by cutting off different five places from the same image. Then, we detect the crater of each image and make an image to use for a self-location estimate. Fig. 5 shows the procedure of preparation. The size of the crater map is 1024×1024. The size of the photography image is 256×256.

Table I shows the initial parameters of Genetic algorithm in this study. Table II shows the initial parameters of ABC algorithm in this study.

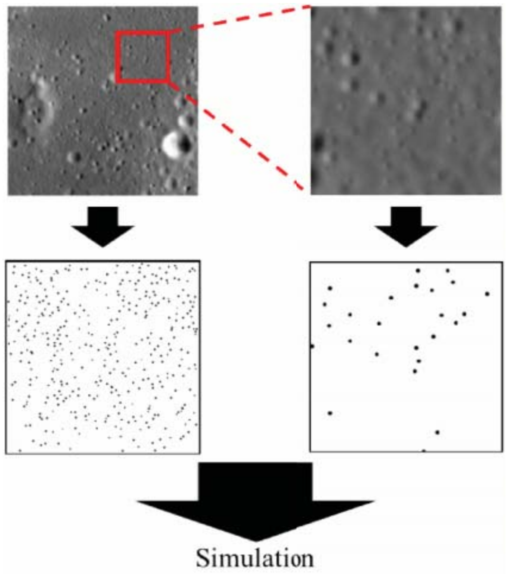

Fig. 5 Preparation procedure

TABLE I
INITIAL PARAMETERS OF GENETIC ALGORITHM

	Meaning	Value
PopulationSize	Number of the individual in a population	25
MaxGenerations	Number of the generations	1000
CrossoverRate	Rate of the crossover	0.9
MutationRate	Rate of the mutation	0.05

TABLE II
INITIAL PARAMETERS OF ABC ALGORITHM

	Meaning	Value
FoodNum	Number of the food sources	25
Limit	Limit of the number of the non-updated	100
MaxCycle	Number of the repeat	1000

A. Simulation1

We estimate each self-location from five images which we made. We try estimates 100 times and determine success probability and average time. We compare result of the Genetic algorithm with result of the ABC algorithm.

B. Simulation2

We make the false detection images which increased or deleted or shifted randomly the points of the image. The number of points to change is 10, 20, 30, 40, 50 % of all points in image. And we estimate each self-location from each image which we made. We try estimates 100 times and determine success probability and average time. We compare result of the Genetic algorithm with result of the ABC algorithm.

VI. Results

Tables III and IV show result of simulation I.

TABLE III
RESULT OF SIMULATION I USING GENETIC ALGORITHM

Image number	Number of points	Success probability [%]	Average time [msec]
1	27	100	864.78
2	28	44	4886.93
3	34	100	1953.42
4	23	77	2189.4
5	22	95	708.37

TABLE IV
RESULT OF SIMULATION I USING ABC ALGORITHM

Image number	Number of points	Success probability [%]	Average time [msec]
1	27	100	899.96
2	28	100	1120.66
3	34	100	1998.68
4	23	100	478.31
5	22	100	392.89

Table III proves that conventional technique can't completely estimate. Moreover, estimate time is uneven. Table IV proves that proposed technique is possible to completely estimate. In addition, estimate time is proportional to the number of points.

Tables V and VI show results of simulation II.

TABLE V
RESULT OF SIMULATION II USING GENETIC ALGORITHM

A kind of the false detection	Scale factor of the number of points to change [%]	Number of points	Success probability [%]	Average time [msec]
Not false detection (original image)	0	27	100	864.78
Increase	10	29	100	1109.3
	20	32	100	1615.76
	30	35	100	2247.02
	40	37	100	2839.98
	50	40	99	3820.51
Delete	10	25	100	682.03
	20	22	100	498.25
	30	19	100	432.1
	40	17	99	1394.23
	50	14	100	953.53
Shift	10	27	100	873.88
	20	27	100	898.73
	30	27	100	1306.19
	40	27	100	2207.45
	50	27	95	3195.66

Table V proves that conventional technique can't completely estimate. Moreover, estimate time is uneven in the case of delete and shift. Table VI proves that proposed technique is possible to completely estimate. In addition, estimate time is proportional to the number of points in most cases.

TABLE VI
RESULT OF SIMULATION II USING ABC ALGORITHM

A kind of the false detection	Scale factor of the number of points to change [%]	Number of points	Success probability [%]	Averag e time [msec]
Not false detection (original image)	0	27	100	899.96
Increase	10	29	100	1126.19
	20	32	100	1637.91
	30	35	100	2425.19
	40	37	100	2750.05
	50	40	100	3910.13
Delete	10	25	100	686.57
	20	22	100	470.51
	30	19	100	401.28
	40	17	100	371.22
	50	14	100	781.43
Shift	10	27	100	876.55
	20	27	100	906.51
	30	27	100	1038.61
	40	27	100	993.99
	50	27	100	1154.5

VII. CONCLUSION

In this research, we examined improvement proposal of ETSM using the ABC algorithm. As a result, proposed method estimated self-location completely. In addition, estimate time is proportional to the number of points in most cases. In contrast, in the case of the conventional method, estimate time is uneven, and the estimated success probability was inferior to the proposed method, too. Therefore, we consider that the proposed method is superior to a conventional method.

In future, we aim at completely estimating a self-position against the image that the position of all points was changed. At present, estimated success probability decreases. However, there are two probable causes regarding this problem. The first is that the quantity of the triangle fluctuates by fluctuation of the quantity of the point. The second is that operation precision decreases by using fixed point arithmetic. By these factors, the triangle that an error is extremely small is judged similar triangle. Therefore, we will consider reconsideration of the operation precision, and comparison method that can tolerate decrease of the operation precision. About the search time, we were able to obtain sufficient results on the general-purpose PC. We implement this on FPGA and will aim at the achievement of the target time.

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