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Paper

Lost Property Detection by Template Matching using Genetic Algorithm and Random Search

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Abstract: In this paper, we propose an object search method which is adapted to transformation of an object to be searched to detect lost property. Object search is divided into two types; global and local searches. We used a template matching using Genetic Algorithm (GA) in the global search. Moreover we use a random search in the local search. According to experimental results, this system can detect rough position of the object to be searched. The search accuracy obtained using the present method is 83.6%, and that of a comparative experiment using only GA is 42.1%. We have verified that our proposed method is effective for lost property detection. In the future, we need to increase search accuracy to search objects more stably. In particular, we need to improve local search.

Keywords: Template matching, Genetic Algorithm, Random search, Lost property detection

1. Introduction

Recently many public facilities, namely airport and station are equipped with security cameras to administer persons that exhibit suspicious behavior and doubtful objects which are left. However in current administering systems, the security cameras are usually administered by humans. Therefore the administrators can make mistakes such as careless oversight. In addition, it might take a long time to search a lost property. A simple and efficient system is then required, such that it automatically operates and alerts.

In the public facilities, an object to be searched can be divided broadly into two types: a person that is suspicious behavior and a doubtful object to be left. The detection of a person is researched frequently. Accordingly we put a focus on an object (especially a lost property). A system that automatically searches a lost property is thought that is effective to reduce the burden of administering security cameras. Therefore the objective in this paper is to provide an auxiliary measure of searching a lost property by the proposed method.

In general, background subtraction and template matching are often used to search objects. Background subtraction needs to prepare a background image. Such an approach cannot be adapted to varying background and lighting environment. When remote function cameras such as a pan-tilt camera are used, it causes a change in the background. On the other hand, template matching is not influenced by change of background because it performs the matching between a template image and an input image. Therefore we use template matching in this paper. However in case of searching a lost property, an object to be searched has a lot of kinds and has infinitely various size and orientation to be different from the template image's object to be searched. When an object shape is changed, search accuracy by a simple template matching is therefore low. It needs to prepare template images of various sizes and orientations to be adapted to transformation of the object. Thus in matching, a large amount of processing is needed. In order to overcome this drawback, our proposed system has to be adapted automatically to change of size and orientation using few template images. In this paper, the objective is therefore to find a lost property by a template matching using Genetic Algorithm (GA) [1] [2]. GA is stochastic optimization algorithm that imitates evolution process of creatures. GA can find an optimal solution from an enormous amount of solution space. The proposed method optimizes the combination of 4 parameters, namely coordinate values that match a template image in a target image, scaling rate and rotation angle to transform the template image. However GA is not necessarily suitable to find an optimal solution in local domain. In such a case, it is necessary to use a technique that is specialized in the local search. The present system optimizes the object's location and size in the global search using GA and optimizes the object's size and orientation in the local search using random search.

As described above, we propose the system that the objective is to provide an auxiliary measure of searching a lost property in this paper. We define an owner of the lost property as a user and define an image of the security camera as a target image. An object to be searched is defined as a thing that can be lost, namely bag, shopping bag, or glove. We obtained an image of an object to be searched

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X	Y	Scaling rate	Rotation angle

Figure 1: Structure of chromosome.

from user's smartphone or digital camera as a template image. The proposed method determines the multiple candidate regions including the object to be searched from the combination of 4 parameters, and an optimal candidate is selected from among candidate regions by a user. Moreover we carry out experiments using static images as basic research that automatically searches a lost property.

2. Proposed Method

Our proposed method searches an object using template matching. As described above, we use GA because it is necessary to be adapted to transformation of the object to be searched. GA is a technique to imitate an evolution of creatures for solving an optimization problem. GA's features are as follows; it can be applied to many areas, and is suitable for global search problems. However GA is not necessarily suitable to find an optimal solution in local domain. Therefore object search is divided into two parts; global and local searches. Global search is to find an object location and size using GA. Local search is to find an object size and orientation using random search. A detail of proposed method is shown below.

2.1 Chromosome in Each Individual In GA, each individual that is the candidate of a solution has a chromosome with real numbers. Each chromosome is composed of 4 elements; coordinate values that match a template image in a target image, scaling rate and rotation angle to transform a template image. The chromosome structure is shown in Fig. 1.

2.2 Fitness Function A fitness function in GA defines the adequacy of each individual. The quality as a solution in each individual is evaluated using the fitness function. This evaluation value called a value of fitness functon is calculated by the degree of similarity used for template matching [3]. There are some similarities such as SAD and NCC. These are calculated by Eq. (1) and Eq. (2) as follows:

$$R_{SAD} = \sum_{j=0}^{N-1} \sum_{i=0}^{M-1} |I(i,j) - T(i,j)| \tag{1}$$

$$R_{NCC} = \frac{\sum_{j=0}^{N-1} \sum_{i=0}^{M-1} \{I(i,j)T(i,j)\}}{\sqrt{\sum_{j=0}^{N-1} \sum_{i=0}^{M-1} I(i,j)^2 \times \sum_{j=0}^{N-1} \sum_{i=0}^{M-1} T(i,j)^2}} \tag{2}$$

where N and M are image's width and height, respectively. I is a pixel value of a point on coordinate (i, j) in the target image, and T is that in the template image transformed by chromosomes. We use HSV color system where a hue component is used. Moreover, we carried out comparative experiments using SAD and NCC [4]. In the global search, search accuracy of NCC has become higher than that of SAD. Therefore we define the fitness function as NCC in the global search.

2.3 Gene Operation GA has a population with many individuals in each generation. The population is usually generated by random at the first generation. The next generation is produced by GA operators; selection, crossover, and mutation. In this paper, the selection operator uses a roulette wheel selection. The selection probability is calculated by the value of a fitness function. The probability is higher when the value of the fitness function is higher. On the other hand, the individual whose value of fitness function is low can be selected in a low probability. Therefore the diversity of individuals can be kept. In the crossover, individuals selected in the selection operator generate new individuals. The crossover method used in this paper is BLX_α [5]. In this technique, new individuals are generated by random numbers within the range that is calculated by parents. At the mutation, a chromosome is renewed with a random number rarely. By these steps, the individual with the highest value of the fitness function is left in the next generation. When the all processing is finished at the last generation, the individual with the highest value of the fitness function is defined as the optimal solution. Moreover this system leaves the individual with the second highest value of the fitness function as the candidate of the solution.

2.4 Global and Local Searches In this paper, object search is divided into two parts; global and local searches. In the global search, GA manipulates coordinate values and scaling rate in chromosomes with fixed rotation angle until the start of local search. Moreover thresholds for the value of the fitness function and the number of the generations are defined. When the both values exceed the thresholds, the local search is started. However the values of the fitness function are different according to objects to be searched. It is necessary to adequately set the threshold for the value of the fitness function in every object to be searched.

2.5 Random Search in the Local Search Local search optimizes the scaling rate and rotation angle to find a better solution. These parameters are found using the coordinate values of the best individual at the current generation in the global search. The candidate of the scaling rate is selected at random within a range of plus or minus 0.4 of the scaling rate of the best individual. Moreover the rotation angle is selected by random search.

Random search is a search method using random numbers [6]. In the random search used at this system, c is the initial center point and is defined as rotation angle of the best individual in the global search. The random number that is generated within a range of plus or minus a of c is a candidate of rotation angle. Initial a is 180 degree. The candidates of scaling rate and rotation angle are evaluated by calculating the degree of similarity. The similarity is defined as SAD. The reason to use SAD is that the search accuracy of SAD is higher than that of NCC in comparative experiments. These processes are repeated by a prescribed number of times n (n=20). After these processes, the best candidate is defined as the next search center point (c). Moreover the next search range is reduced to the half (a=a/2). The random search is repeated while a is lower

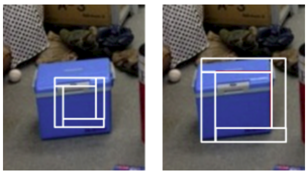

Figure 2: 4 rectangles around an individual.

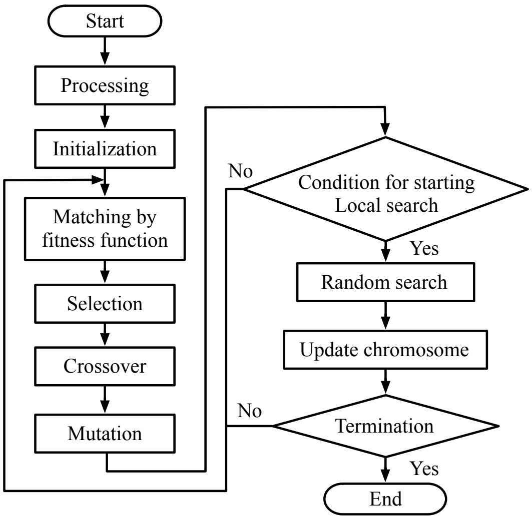

Figure 3: Flowchart of the proposed method.

than a prescribed number of times *m* (*m*=10). After the random search, when the evaluation value calculated by the present scaling rate and rotation angle improves the former best value of the fitness function, the parameters in the chromosome are updated. After the local search, its process returns to the global search and the process continues global and local searches.

2.6 Checking the Histogram of Hue Values around Each Individual The downside of this system is to cause a fact where the value of a fitness function of individuals with small scaling rates are higher than that of individuals with large scaling rates. To improve this downside, this system checks the histograms of hue values (color value) in 4 rectangles around each individual. Fig. 2 shows 4 rectangles around an individual. First, this system counts the number of the rectangles which have the hue value that is similar to the template image's one. When the number of the rectangles is over 1, the scaling rate of the individual is increased by 0.2. Moreover when the number of the rectangles is over 3, the fitness function value of the individual is decreased by 0.1.

2.7 Process of the Proposed Method The process of the proposed method is described below. Fig. 3 shows a flowchart of the proposed method.

Step 1: Preprocessing. To reduce processing area we compress sizes of a target and a template images. It can reduce a processing time in GA. A compressed value of each pixel in a source image is calculated by using the Gaussian filter. The number of pixels of the target image is reduced to the one-sixteenth. The template image is reduced to the one-64th.

Step 2: Initialization. A chromosome of each individual is generated by random numbers. However the chromosome has the rotation angle of 0 degree and this parameter is fixed.

Step 3: Matching by fitness function. The fitness function is calculated by expression (2) in the global search.

Step 4: Checking the histogram of hue value around each individual. This process is carried out every 10 generations.

Step 5: Selection, crossover, and mutation. The selection operator uses the roulette wheel selection. In the crossover, selected individuals are used by BLX_α to generate new individuals. At mutation, the coordinate values and scaling rate of a chromosome are renewed with values which are generated by random number according to mutation probability.

Step 6: Condition for starting local search. When a global search result exceeds thresholds, search process advances to Step7. Otherwise the process returns to Step3.

Step 7: Local search. Local search evaluates selected scaling rate and rotation angle using expression (1). A chromosome of the best individual is updated when the evaluation value improves the former best value of the fitness function. After the local search, the process returns to Step3.

Step 8: Condition for termination of search. When the number of the generations reaches the preset value that is the maximum number of generations, the object search is finished. Moreover after the local search started, when the same elite individual is maintained without change for 200 generations, the object search is finished. Otherwise it returns to Step3.

3. Experiments

We try to construct and evaluate the system of helping to search an object. Our proposed method determines the multiple candidate regions including the object to be searched from the combination of 4 parameters, and an optimal candidate is selected from among candidate regions by a user. At experiments, our proposed method tries to find two candidate regions, and we confirm whether an optimal candidate is included.

3.1 Experimental Conditions In this section, experiments for static images are described to demonstrate the effectiveness of the proposed method. We use the images that were taken by iPhone5, and these file format is JPEG. The target images used in this paper are shown in Fig. 4. The size of the images is 612 $\times$ 816 pixels. Moreover we

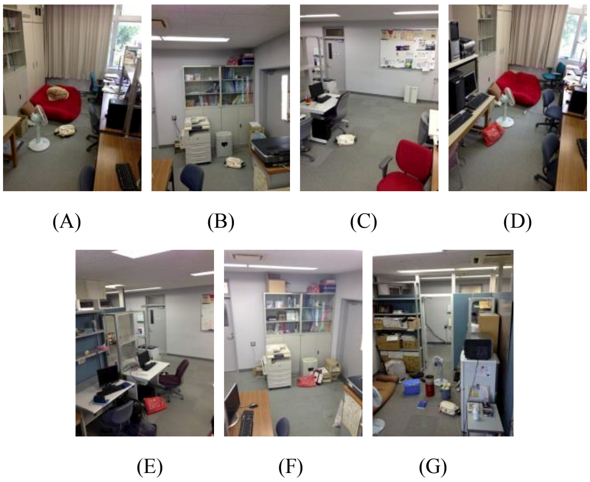

Figure 4: Target images.

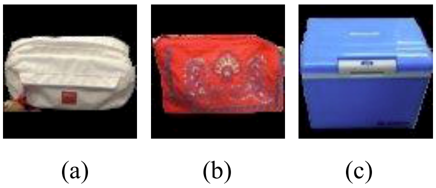

Figure 5: Template images.

Table 1: Pairs of target images and template images.

Experiment	Target image	Template image
1	(A)	(a)
2	(B)	(a)
3	(C)	(a)
4	(D)	(b)
5	(E)	(b)
6	(F)	(b)
7	(G)	(c)

Table 2: Parameters in GA.

Maximum number of generations	600
Population size	60
Chromosome length	4
Scaling rate	$0.5 \sim 3.0$
Rotation angle	$-180 \sim 180$
Crossover probability	0.8
Mutation probability	0.1
Threshold of the generations	400

cut off the object to be searched from images whose photography condition is different from target images, to provide template images. The template images are painted black over a background, and are shown in Fig. 5. The size of the images is 80×80 pixels.

Table 1 shows the pairs of a target image and a template image in each experiment. We try 20 times run in each experiment. The parameters of GA used in this experiment are shown in Table 2.

Table 3: Results obtained by calculating the regional area that an object overlaps in a target image and a template image.

Experiment	Success	Failure	Success rate[%]	processing time[sec]
1	20	0	100	1.51
2	20	0	100	1.46
3	20	0	100	1.39
4	12	8	60	1.51
5	16	4	80	1.18
6	10	10	50	1.26
7	19	1	95	1.18
Total	117	23	83.6	1.36

Table 4: Results of 20 times run in the global search.

Experiment	Success	Failure	Success rate[%]	processing time[sec]
1	20	0	100	0.67
2	20	0	100	0.62
3	20	0	100	0.62
4	16	4	80	0.62
5	20	0	100	0.56
6	20	0	100	0.56
7	20	0	100	0.62
Total	136	4	97.1	0.61

3.2 Experimental Results In order to evaluate the degree of success in object search we calculate the regional area in which an object in a target image and the candidate region overlap. The rate of overlapping region is calculated by the percentage of the candidate region in the object of the target image. We define the condition of success as the case such that the rate of the overlapping region is more than 50%. Table 3 shows the experimental results. The average of the search accuracy is 83.6%. It is considered that this system can detect rough position of the object to be searched. However the search accuracy is relatively bad at experiments 4 and 6. We try to find the cause of those results with global and local searches. Table 4 shows the results obtained by the global search. In the global search, the condition of success is defined as the case such that the rate of the overlapping region is over than 0%. According to the results, it is considered that this system has enabled to detect the position of the object to be searched. However at experiment 4, the search accuracy obtained by the rate of the overlapping region is low. The number of the failures is 4 in the global search. Next Table 5 shows the results obtained by the local search. The condition of success in the local search is defined as the case such that the scaling rate is found within a range of plus or minus 0.2, and rotation angle is found within a range of plus or minus 30 degree compared to the solution. The average of the search accuracy is 48.5%. The results in the local search fell short of our expectations, especially the success rate is very low at experiments 4-7. The scaling rates of the results become smaller than the actual values in many cases. A possible fac-

Table 5: Results of 20 times run in the local search.

Experiment	Success	Failure	Success rate[%]	processing time[sec]
1	20	0	100	0.84
2	16	4	80	0.84
3	17	3	85	0.76
4	7	9	44	0.89
5	0	20	0	0.63
6	0	20	0	0.70
7	6	14	30	0.59
Total	66	70	48.5	0.75

Table 6: Results of the comparative experiments of 20 times run.

Experiment	Success	Failure	Success rate[%]	processing time[sec]
1	13	7	65	1.01
2	2	18	10	1.11
3	9	11	45	1.11
4	2	18	10	1.11
5	0	20	0	1.10
6	1	19	5	1.11
7	12	8	60	1.11
Total	59	81	42.1	1.11

tor is that the color value (elements of HSV color system; hue, saturation and lightness) of the pixel of the object to be searched in the target image is different from template image's one. Therefore if the region that calculates the value of the fitness function is smaller in size, the value of the fitness function becomes higher, because the difference between the color pixel value of the pixel same position in the target image and the template image's one is smaller. To improve the search accuracy, we have to improve how to check the histogram of hue values around each individual as shown in Fig. 2. Moreover we need to improve the way of evaluation in the local search.

3.3 Comparative Experiments In this paper, object search is divided into two parts; global and local searches. We carry out another experiment to verify the effectiveness of our proposed method. At comparative experiments, we use a comparative system using template matching only by GA. The comparative system optimizes all chromosome elements; coordinate values that match a template image in a target image, scaling rate and rotation angle to transform a template image. Moreover there is no change from the previous experimental conditions (Table 2). The success condition is defined as the case such that the rate of the overlapping region is more than 50%. Table 6 shows the results of the comparative experiments. The average of the search accuracy is 42.1%. The comparative experiment gives a lower success rate than the experiments using our proposed method. According to the results, it is thought that the global and local searches of our proposed method are effective for lost property detection.

4. Conclusion

In this paper, the objective is to provide an auxiliary measure of searching a lost property by the proposed method. We use template matching to search an object. Moreover object search is divided into two parts; global search using GA and local search using random search. The proposed method determines the multiple candidate regions including an object to be searched from the chromosome that is the combination of 4 parameters, and an optimal candidate is selected from among candidate regions by a user. The average of the search accuracy using our proposed method is 83.6%, and that of the comparative experiment using only GA is 42.1%. We have verified that our proposed method is effectiveness for lost property detection. Moreover this system can detect rough position of the object to be searched in the global search. In the future, we need to increase the search accuracy to search an object more stably. Therefore we need to improve local search. We try to improve the way of its evaluation and the way of checking the histogram of hue values around each individual. Moreover it is necessary that we carry out experiments using images of security cameras.

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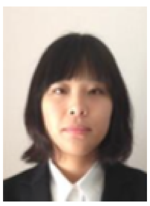

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