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Accurate Extraction of Go-coordinates using Genetic Algorithm for Automatic Generation of Go-record

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Abstract—We develop the system which automatically carries out Go-record from the image of the Go-game situation. For the Go-record, Go-stone has to decide its position on the 19x19 cells of the Go-board which we call Go-coordinates. In our system, the Go-board is shot in various directions with the CCD camera. In this case, it is difficult to directly extract accurate Go-coordinates in the image. However, we are able to extract accurate Go-coordinates if the area of the Go-board is recognized accurately. But, it is difficult to manually decide the four corners of a Go-board in the appropriate time and at the pixel unit. Consequently, in the first step, the contour of the Go-board has to be automatically recognized from the image which includes unrelated objects. In this paper, we propose the pattern matching algorithm for the extraction of the accurate Go-coordinates in the image using the genetic algorithm (GA) within several 10 seconds. We evaluated the proposed algorithm on the prototype using the proposed algorithm by dealing with the image which includes unrelated objects. As a result, it has been verified that the prototype generates the correct Go-record.
key words: Genetic Algorithm, pattern matching, accurate Go-coordinates, Go-record

1. Introduction

The Go-record is carried out by the third person in manual operation. It takes several hours to play Go-game. Therefore, automating the Go-record has a large advantage. Then, we develop the system which automatically carries out Go-record from the image of the Go-game situation. For the Go-record, the Go-stone has to decide its position on the 19x19 cells of the Go-board which we call Go-coordinates. It is easy to directly extract accurate Go-coordinates in the case of using the camera fixed on the top of the Go-board.

In our system, the Go-board is shot in various directions with CCD camera. Every time the Go-players play Go-game, the direction and the position of the camera are changed. Therefore, the shape of the Go-board in the image is transformed into the various shapes of the polygon with four tops. And, these shapes have no geometrical similarity one another. An example of Go-board view under these conditions is shown in Fig.1. In this case, it is difficult to directly extract accurate Go-coordinates in the image. However, we are able to extract accurate Go-coordinates if the contour of the Go-board is recognized accurately. Consequently, in the first step, the contour of the Go-board has to be recognized from the image which includes unrelated objects.

For a detection of the shape, Hough Transform [1][2][3] is commonly used. Generalizing the Hough Transform [2] is able to detect arbitrary shapes. But, in this method, the detected arbitrary shapes have to be the same geometrical similarity as a template. Therefore, we can't use this method for our system, because the shape of the Go-board in the image has no geometrical similarity. For example, in the application program [3] using the generalizing the Hough Transform, the shapes of the target objects are similar circles or similar rectangles.

Figure 1: Gray level image of Go-board. Horizontally 320 pixels, vertically 240 pixels.

Therefore, since we can't use these conventional methods for the detection of the shape, we propose new technique to accurately extract the contour of the Go-board in the image using a genetic algorithm. A genetic algorithm is a new algorithm for searching of an optimum solution. One of advantages of a genetic algorithm has characteristic as global search. Then, it is hard to be trapped at local solution. One of defects of a genetic algorithm is not suited for the real-time processing. However, its defect does not influence so much in our system, because we may detect the contour of the Go-board for once the entrance of the playing Go-game.

Many researches for image pattern recognition using a genetic algorithm are reported [4][5][6]. The method [4] is not very effective to accurately extract the shape. The method [5] is a technique combined the generalizing Hough Transform with Genetic Algorithm. The purpose using GA is to search a most heavy vote in the parameters' space of generalizing Hough Transform. In this method, the detected arbitrary shapes have to be the same geometrical similarity as a template. The method [6] is a hybrid of a Genetic Algorithm and a simulated annealing. Using this method, the shape is extracted accurately, but the target shape has to be a geometrical similarity also. Therefore, we can't use these methods.

In this paper, we propose the pattern matching algorithm for accurate extraction of the Go-coordinates in the image, which is shot from the various directions, using the genetic algorithm (GA). And, in our experimental results, we show that our proposed algorithm is effective for accurate extraction of Go-coordinates. We evaluated the proposed algorithm on the prototype by dealing with the image which includes unrelated objects. As a result, it has been verified that the prototype generates the correct Go-record.

2. Methods and Procedures

The algorithm for the recognition of Go-board countor consists as following. Repeated steps between **repeat** and **until** are named Genetic Algorithm. In the last step, the template, which is the best approximate Go-board contour, is formed.

1. Input a gray level image which includes a Go-board and unrelated objects, and then it is binarized.
2. Create the initial population.
3. **repeat**
4. Compute fitness value for each individual.
5. Elite saving, crossover, and mutation.
6. **until** the elite individual fitness is not improved during ten generations.
7. Output the last elite individual.

We describe the details of our proposed genetic algorithm in the following.

2.1. Chromosome

We utilize the template for the recognition of the Go-board contour. The shape of the template is the polygon with four tops. We describe this template with T_i which is shown in equation (1). The suffix "$_i$" shows the individual number in each generation.

$$T_i \stackrel{\text{def}}{=} (Ax_i, Ay_i, Bx_i, By_i, Cx_i, Cy_i, Dx_i, Dy_i) \qquad (1)$$

We use this template(T_i) as a chromosome in GA. And, this one chromosome is correspondent to one individual in GA. Eight coordinate values of T_i are respectively correspondent to eight genes in GA. T_i is expressed as a string of the one dimension in the computer data format. X coordinate value of a gene is 9 bits, and Y coordinate value of a gene is 8 bits.

The initial value of chromosome is generated randomly as follows. At first, point O shown in Fig.2 is decided randomly in the image. At second, poing A in Fig.2 is decided randomly in the left side and upper side of point O. Equally, point B, point C, and point D are decided. When new chromosomes whose coordinates (Ax_i, Ay_i), (Bx_i, By_i), (Cx_i, Cy_i), and (Dx_i, Dy_i) are generated in each operation of elite saving,clossover, and mutation, these coordinates are checked by the similar conditions in the case of Fig.2. For example, point A is checked as $Ax_i < Bx_i$, $Ax_i < Cx_i$, $Ay_i < Cy_i$, and $Ay_i < Dy_i$. Therefore, the order of the four tops of polygon is fixed.

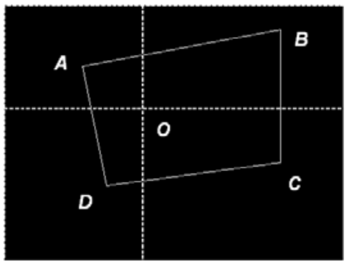

Figure 2: Generation of initial template.

2.2. Fitness Measure

For the fitness measure, we propose the function in which the fitness is improved with the template approaching to the contour of the figure which resembles the approach polygon with four tops in the binary image. The function, f_i, is shown in the equation (2). The suffix "$_i$" shows the individual number.

$$f_i = (Ms_i/Ts_i) \times (Ms_i/Gs) \qquad (2)$$

In the equation (2), Gs is a set of white pixels in the binary image. Ts_i is a set of pixels inside template. Ms_i is a set of pixels of $Gs \cap Ts_i$. First term of equation (2) means a degree of similarity between a region surrounded with a template and a white region in the binary image. Second term of equation (2) means a degree the size of a white region surrounded with a template. Therefore, first term becomes larger value, if there is a white region which is similar to a template region than any other. Second term becomes larger value, if there is a larger white region overlapped with a template than any other. Then, the product of first term and second term selects the largest polygon with four tops estimated as a Go-board. Though this function is simple, the region of a Go-board can be precisely detected, even if the noise exists in circumference and inside in the region (e.g.Fig.6).

2.3. Selection

For the clossover, we adopt the model which can leave the child at the probability in proportion to the fitness of each individual.

$$P_i = \frac{f_i}{\sum_{j=0}^{\text{Total}-1} f_j} \qquad (3)$$

P_i in the equation (3) gives the probability which selects chromosome. "Total" in the equation (3) is a number of population. For the crossover, each chromosome is selected in proportion to the f_i.

2.4. Crossover

Every gene of two chromosomes selected on f_i has a crossover point. Then, one bit of each gene is exchanged each other at random. This situation is shown in Fig.3. Each gene value in the selected chromosome is decided at random.

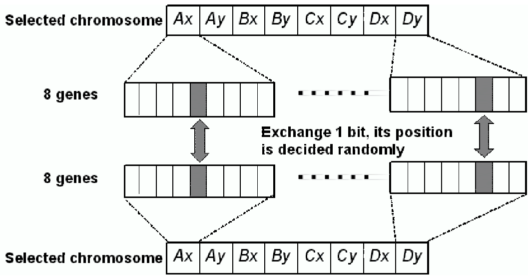

Figure 3: Situation of crossover.

2.5. Elite Saving Strategy

We used two elite saving strategy modes for the simulation. The first mode which we call mode A, the elite chromosome is selected, and it is copied to new chromosome. The new chromosome is inserted into the next generation. Mode A is a standard technique in genetic algorithm. We propose the second mode which we call mode B. Mode B is the elite strategy mode for combining a global search with a local search. At mode B, seventeen new chromosomes are generated from the elite chromosome. One new chromosome is a duplicate chromosome of the elite chromosome. By increment or decrement the value of each gene with one bit, sixteen new chromosomes are generated for a local search. These seventeen new chromosomes are inserted into next generation. The Mode B is the technique which supplements the defect of a global search. Mode B is shown in Fig.4.

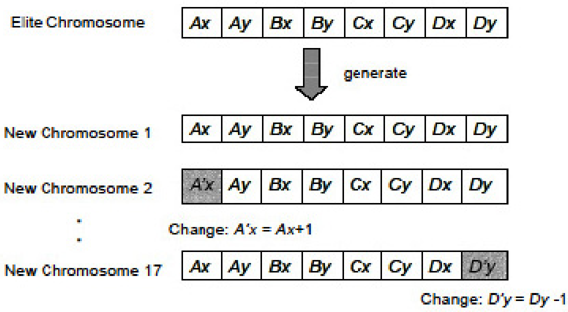

Figure 4: Elite saving strategy -Mode B- .

2.6. Mutation

In a mutation, new chromosomes are generated according to mutation-rate from the elite chromosome in each generation. One of four tops in a chromosome is selected randomly, and its value is changed at random.

3. Results

We evaluated the proposed algorithm. We show experimental parameters of GA at Table 1.

We did experiment on the binarized Go-board image. The elite fitness in Fig.5 is saturated under 81 percents, because the image includes many unrelated objects. The last elite template in Fig.6 matches sufficiently with the contour of the binarized Go-board image.

Table 1: Parameters of GA in experiments.

Population size	200
Crossover rate	1.0
Mutation rate	0.08
Elite saving	Mode B
End condition	until elite fitness is not improved during 10 generations

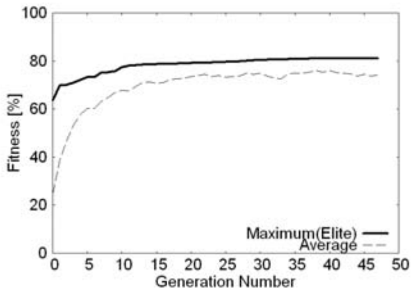

Figure 5: Fitness value in binarized image using Mode B. The processing of GA is terminated in 48 generations, as the elite individual fitness is not improved during last ten generations.

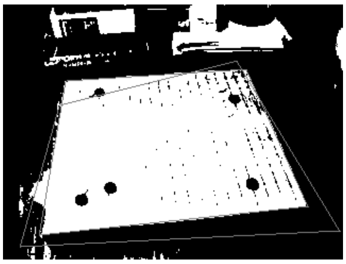

Figure 6: Initial elite template and last elite template in binarized image using elite saving strategy Mode B.

In Fig.7, we superimposed the Go-coordinates on the gray level Go-board image in Fig.1. The Go-coordinates are generated by projective transformation according to the last elite template in Fig.6. Since the last elite template in Fig.6 matches very well with the Go-board contour, the Go-coordinates in Fig.7 correspond very well with the position of Go-stone.

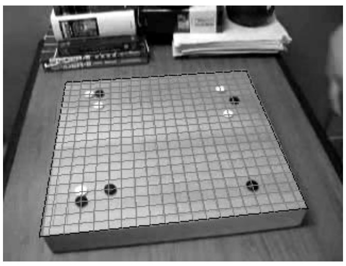

Figure 7: Superimpose the Go-coordinates on Fig.1. The Go-coordinates are generated by projective transformation according to the last elite template in Fig.6.

4. Prototype System

We implemented the prototype system using our proposed algorithm. This system automatically generates the Go-record from the images shot with CCD camera. And, it is composed of three units only. These units are one 1.10GHz note PC, one digital camera, and one pair of switches which tells the system to set the Go-stone on the Go-board. The overview of the prototype is shown in Fig.8. The outline of the prototype is described below.

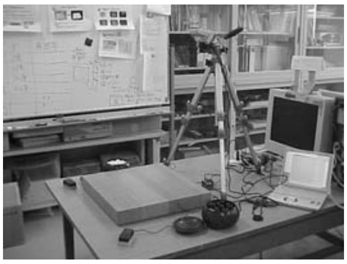

Figure 8: Prototype system for automatic generation of Go-record.

4.1. Procedure of Generation of Go-record

The procedure of generation of Go-record by the prototype system is composed of following five stages. Our proposed algorithm is used in third stage.

1. Image is got at switch pushed point in time.
2. Image is binarized using Ohtsu method.
3. Go-coordinates is extracted using our proposed algorithm.
4. The position of Go-stone is decided according to Go-coordinates, and the Go-record is generated.
5. Go-record is displayed on the viewer.

4.2. Results using Prototype

We evaluated the prototype system under stable lighting in the room. We reproduced the conditions of the Go-game played by the professional Go-player. We can play a Go-game after processing the above stage 1, 2, and 3 in about 30 seconds to 60 seconds. The situation of the Go-game from Go-stone number 1 to Go-stone number 130 is shown in Fig.9, and its correct Go-record, which is automatically genatated by the prototype system, is shown in Fig.10.

5. Conclusions

We proposed the pattern matching algorithm for the automatic extraction of the accurate Go-coordinates in the image using the genetic algorithm within several 10 seconds, as it is difficult to manually decide the four corners of a Go-board in the appropriate time and at the pixel unit. We evaluated the proposed algorithm on the prototype using the proposed algorithm by dealing with the image of the Go-game situation. As a result, it has been verified that the prototype generates the correct Go-record. In future, we will verify our proposed algorithm in various cases, and improve our proposed algorithm and the system for automatic generation of Go-record.

Figure 9: Overview of Go-game.

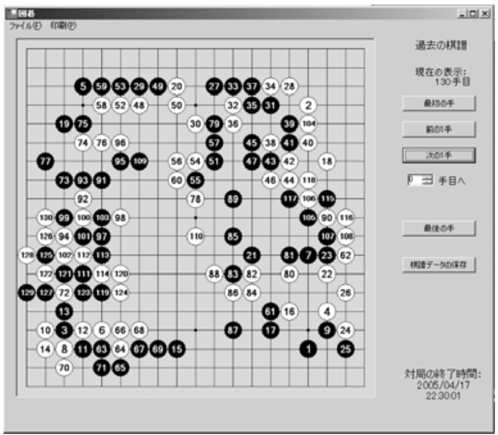

Figure 10: Go-record from Fig.9.

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