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An Image Recognition Method Based on Iterative Synchronization

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Abstract: *This paper proposes a method for image recognition based on the driving relationship between chaotic synchronization and initial values, using the information of the image itself directly as input. This paper first analyzes the spatial characteristics of two-dimensional data in a linearly coupled chaotic system, and designs an iterative algorithm for two-dimensional image data. It is found that the spatial characteristics of the output of different data have significant differences based on the similarity between them. Experiments using this algorithm on self built traffic data sets and JAFFE face data sets show good recognition results.*
Keywords: *Chaos,Chaotic Synchronization,Linearly Coupled Chaotic System,Image Recognition,Face Recognition.*

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I. INTRODUCTION

Since the concept of chaotic synchronization was proposed in 1990s, it has aroused the interest of a wide range of scholars in this discipline, and its theory and application have also been continuously perfected and proposed by researchers. Nowadays, this discipline has rich scientific research achievements in many fields such as physics, biology, finance, and information, especially chaotic confidential communication formed by the cross combination with information discipline has become a hot research direction. Yu et al. have presented an image recognition method based on dynamic system iteration, which takes the image as a function and constructs a dynamic system with auxiliary functions, and iteratively produces approximate chaotic attractors as image features for face recognition(Yu et al. 2015). A method based on trigonometric function to extract three-dimensional video trajectory features has been experimentally proved to have high recognition rate and less time consumption(Yu et al. 2020).

As an important direction of computer vision research, image recognition combined with chaos theory has been published a lot, but there are few works related to chaos synchronization. Florindo J proposed a chaos-based local descriptor for texture image recognition(Florindo J 2020). This is the first attempt in the literature to use chaotic mapping for image recognition, and the nonlinear characteristics of chaotic mapping enable it to capture nonlinear features that are inaccessible to local descriptors. As an important research direction in chaotic theory, it is very meaningful to study the application of chaotic synchronization theory in image recognition.

II. ASSOCIATED WORK

Because most of the dynamical systems constructed based on the existing work results are in the form of Equation (1), a simple linear coupled synchronous system is first proposed in this paper, as shown in Equation (2).

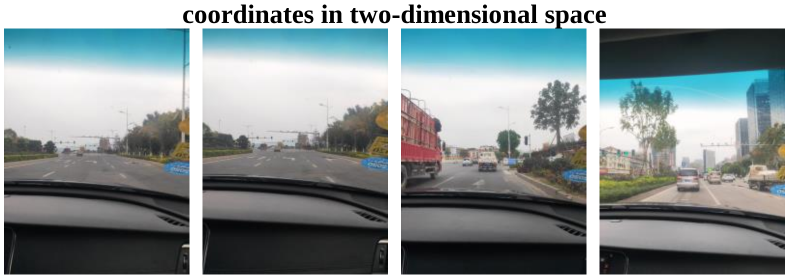
$$\begin{cases} z_1 = f(x,y) \\ z_2 = g(x,y) \end{cases} \tag{1}$$

$$\begin{cases} z_1 = f(x,y) + d(z_1 - z_2) \\ z_2 = g(x,y) + d(z_2 - z_1) \end{cases} \tag{2}$$

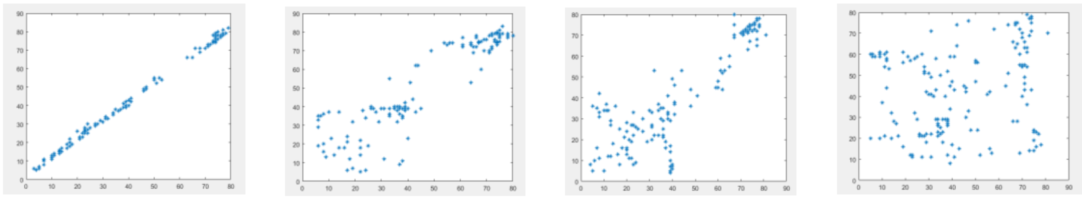
Where x, y represents the coordinates of the image, f (x, y), g (x, y) represent the gray values of the two images at the coordinate points, and d represents the coupling coefficient of the control system.

Figure 1 shows four pictures of road conditions taken in a self-built traffic dataset, using Figure 1. a as an auxiliary image, that is, f (x, y) in Equation (2), and then using a, b, c, and d as g (x, y) to participate in the iteration. Randomly select 200 points with a coefficient of d=0.2, and the following is z_1, z_2's location distribution in two-dimensional space when the iteration number i=3.

Figure 1. The output obtained by iterating with different images as g (x, y) is the distribution of coordinates in two-dimensional space



(a) (b) (c) (d)



As the similarity between the image content and the auxiliary image varies, the output results obtained by iteration also have significant differences. Preliminary observation shows that the more similar the images are, the closer the position of the output results in the two-dimensional space is to the diagonal position. The next section will provide the image recognition results and detailed recognition methods in the self built traffic dataset.

III. TARGET DETECTION FOR TRAFFIC VEHICLES

The steps for applying this method to vehicle target detection are as follows.

Algorithm 2-1 Vehicle Target Detection Algorithm Based on Linear Coupled Synchronization

Input: The template image f (x, y) serving as the detection target contains consecutive multiple frames of images of the detection target.

Output: Picture of the target vehicle marked.

Step 1: Convert the template image and the image to be recognized into a grayscale image, and the template image scale is (n, n).

Step 2: Set the grayscale value interval of the image participating in synchronization to [1, n] to avoid boundary overflow.

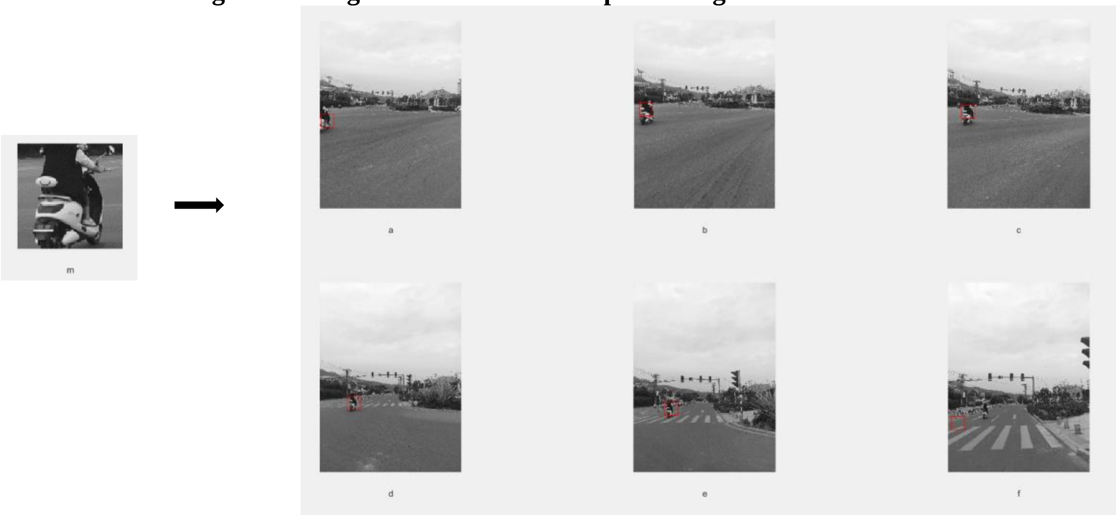
Step 3: Set a slider with the same scale as the template image and slide the intercepted area in steps of 5 from left to right and from top to bottom as g (x, y).

Step 4: Rand is used to randomly generate H points, and each point is used as the initial (x, y) coordinates for finite iterations.

Step 5: Obtain the output z_1,z_2 after each point iteration is completed, Points with $|z_1 - z_2| \le 5$ are considered to have reached synchronization, and the number of such points is taken as the score of each g (x, y).

Select 6 consecutive traffic images from the traffic dataset (Figure 2. a-Figure 2. f), and Figure 2.m is a template picture captured from Figure 2.c, which the size is 100×100. According to the above algorithm, each image and template image are put together for recognition. The recognition result is shown in Figure 2, where the parameter n=100, d=0.2, and the number of iterations per iteration is 3.

Figure 2 Recognition Results of Template Images in a Continuous Frame



Observing the detection results, it is found that in Figure 2. a-Figure 2. e, the algorithm can relatively accurately detect the template image m, while in Figure 2. f, the detection results have deviated, and the target cannot be accurately identified. After analyzing the algorithm, it is believed that the main reason for this result is that as the distance between the target and the vehicle being photographed increases, the scale of the target in the image differs greatly from the scale of the template image a. Therefore, chaotic synchronization target detection at different scales can be considered as the follow-up work of this paper. The order of magnitude range of this experiment is concentrated in [0100], so smaller iterations and random point selection are considered, which saves a lot of time. Finally, the algorithm achieves good recognition results in some images in the traffic dataset.

IV. FACE IMAGE RECOGNITION

Face recognition has always been a hot topic in computer vision, and it is also an inseparable topic in the field of image recognition. Previous related work has mainly focused on using chaotic attractors generated by chaotic iteration to represent image information for image recognition, and has achieved good results in the fields of face recognition and handwritten Chinese characters. Based on the self-built traffic dataset target detection work, this paper continues to validate the proposed linear coupling synchronization system on the JAFFE (The Japanese Female Facial Expression (JAFFE) Database face dataset to determine its applicability in the direction of face recognition.

Select a total of 10 groups of 30 facial images without facial expressions in the JAFFE dataset, one image for each group for recognition, and the remaining 20 images as the collected face database. Use the average synchronization degree of the face image to be recognized with each group of images as a confidence level, and the final result shows a high degree of discrimination.

Algorithm 3-1 Face Recognition in JAFFE Datasets
Input: Face images to be recognized, a face database consisting of 10 groups of 20 face images.
Output: and the confidence level of each group of images after iteration.
Step 1: Read the face image to be recognized and read the first group of images in the face database.
Step 2: Send the chaotic synchronization program and iterate, n=100, d=0.2.
Step 3: Set the self-increasing step size to 2, uniformly select coordinate points, iterate 3 times, count the number of points that meet $|z_1 - z_2| \leq 5$ as a score, and calculate the average score of the same group of images.

Table 3-1 Confidence of different face images and groups after iteration.

GROUP	1	2	3	4	5	6	7	8	9	10
FACE 1	83.42	55.50	26.10	48.52	44.80	35.68	42.38	46.48	41.92	44.64
FACE 2	56.22	76.08	48.22	62.06	47.70	41.38	43.64	58.16	51.44	63.44
FACE 3	30.28	49.82	81.44	38.88	20.04	21.18	38.94	26.08	29.06	32.08
FACE 4	54.78	80.50	51.74	80.38	51.88	47.20	50.90	58.80	50.54	66.80
FACE 5	53.04	57.38	21.56	56.56	80.72	46.64	38.24	60.42	48.28	60.00
FACE 6	41.94	43.10	13.54	47.16	46.18	76.36	42.46	42.20	33.92	41.70
FACE 7	48.96	56.14	48.72	53.78	33.50	40.06	79.12	44.64	38.12	51.12
FACE 8	60.28	63.04	27.68	59.12	53.14	47.36	44.40	80.86	45.20	64.94
FACE 9	41.16	50.66	40.84	45.72	43.42	36.12	38.56	49.90	54.44	49.02
FACE 10	54.68	60.70	29.58	64.98	54.88	44.32	46.88	67.60	56.68	85.46

According to the results in Table 3-1, we can find that except for the fact that face 4 has two higher confidence levels at the same level and face 9 is all at a lower confidence level, the remaining face recognition results show a very high degree of discrimination, indicating that the algorithm proposed in this paper also has a certain applicability in face recognition.

Select 100 face images and 150 face images to form a sample library. The sample library consisting of 100 faces covers the five facial expressions in the dataset, and the sample library consisting of 150 faces covers all facial expressions in the dataset. The samples for recognition in the two databases are 30 and 50 face images, and the same algorithm is used for recognition. The final experimental results are shown in Table 3-2. The recognition success rates in the two databases are 77% and 82%, respectively. The experimental results show that, while the proportion of identification samples and sample library remains unchanged, expanding the number of identification samples can still maintain a stable identification rate, which indicates that the identification algorithm based on coupled control chaotic synchronization is robust; At the same time, with the increase in computational complexity, the time for single image recognition has increased from 0.453 seconds to 0.620 seconds. Compared to the method of extracting features for recognition, this method saves training time and has a lower time cost.

Table 3-2 Recognition results after increasing the sample library.

Number of sample libraries	Identification sample	succeeded	failed	identification time (s)	Success rate (%)
100	30	23	7	0.453	76.6
150	50	41	9	0.620	82

V. CONCLUSION

Currently, most of the work related to chaos theory in image recognition focuses on identifying images by iterating to obtain their characteristic information. This article considers using the image's own information directly for identification and detection. Based on the theory of chaotic synchronization state and initial value effects, it designs algorithms that demonstrate good discrimination in experiments with self-built traffic data sets and JAFFE data sets, It has high theoretical value for applying chaotic synchronization to the field of image recognition. The next step is to expand the dataset, validate and improve the method, and conduct in-depth theoretical analysis.

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