A Study on Satellite Image Processing and Recognition

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Abstract— **This paper is to engage in buildings recognition of our campus using satellite images provided by the Google Earth. In the study, an image processing system based on a GUI was designed to facilitate the pre-processing of satellite images. Firstly, it converted the image taken from the Google Earth into an intermediate file suitable for on-going image processing. Secondly, a contour of a campus building was extracted from the satellite image by a colour histogram separation program. After segmentation, some features were extracted from the binary image. Thirdly, a normalization process was proceeded to normalize the extracted features and to save them along with its original satellite image into a database. Fourthly, the normalized features were passed to three recognition systems for buildings identification. Three recognition systems employing statistic, fuzzy logic, and neural network approaches respectively, were implemented for the purpose of analysis and comparison. Our preliminary results suggested that a recognition system using the neural network approach was most feasible and reliable among them for campus buildings recognition.**

***Keywords*—Satellite Image Processing, Recognition Systems, Fuzzy Logic, Histogram, Neural Networks**

1. INTRODUCTION

Since the world's first commercial satellite was launched in 1965, Satellites have been providing services to improve the quality of our lives. For example, satellite cloud images ([8],[13],[14]) make weather forecast more accurate. Satellite communication systems provide us with high-quality multimedia services for recreation and entertainment. Global position systems can provide us with road maps for vehicle navigation. Since 2005, Google Earth software has been providing location specific satellite images in a bird's eye view to let us see our surroundings. It has been raising a lot of privacy issues. This is because the Google Earth can give a close-up perspective at a specific address. Whatsoever, the Google Earth provides a lot of valuable images for us to do some researches on them. For example, on-line query systems for road maps like UrMap, Google Maps and Yahoo Maps let us find a way to reach our destination easily while driving, hiking or biking. Different images from real-time satellites were applied to landslide detection [7], Typhoon forecasting [11], forest fire monitoring [6], glacier movement estimation, objects identification and tracking, wrecked ship searching, and so on. For more information, please refer to [6]-[10]. In Taiwan, many applications of satellite images were focused on different areas [11]-[16], such as Application of Cloud Classification [13], Locating and Tracking of the Typhoon from Infrared Satellite Images [11] and Topographic map revision using high resolution satellite imagery [12].

The purpose of this paper is to use the satellite images of our college campus for the identification of campus buildings. It covered the recognition of eight buildings on our campus as shown in Fig. 1. The eight buildings were Spiritual Fort (Fort for short), Experiment Building (abbreviated as Experi.), Administration Building, International Conference Centre, a student dormitory, a swimming pool (pool for short), and two teaching buildings (Gin-Ye Building and Le-Chun Building). Because the satellite images are not clear and sharp in contrast, most edge detection methods are not applicable to them. Instead, a colour separation method was used to separate campus buildings from the satellite images. Three recognition methods, statistical method, fussy logic method and neural network method, were implemented for the purposes of analysis and comparison with an aim at finding the most feasible recognition system among them.

Fig. 1 Satellite image of Taipei College of Marine Technology (abbreviated as TCMT)
(Source: Google Earth)

2. SATELLITE IMAGE PROCESSING

In this study, VB programming language was used as a tool for developing a satellite image processing system. A GUI based image processing system was designed to facilitate the pre-processing of satellite images. In the main menu of the GUI, there were many useful tools for image pre-processing. For example, it converted an image provided by Google Earth into an intermediate file, which was suitable for on-going image processing such as a colour separation program, a conversion program changing colour into gray level, and a histogram program. A contour of a campus building was extracted from a satellite image using a colour separation method, which used two valleys of the peak in the colour histogram as two thresholds. From Fig. 2, we can see that the satellite image is of low contrast and illumination. In the histogram, the distribution of gray level is from 50 to 220 and the peak value of the histogram is around 130. The contrast of gray level is only 170, and it is obviously low. In addition, the gray level of the satellite image is not evenly distributed over the range from 0 to 255. Instead, there are only ten or more discrete levels. A labeling method was also included in the satellite image processing system. Labeling an image is to assign different numbers to the objects and to identify objects in the image. By counting the area of an object, we can remove small objects in the image.

Converting a gray-level image into a binary image, we can reduce many complex details of the image because it facilitates the abstraction of features from a campus building. Features like area, height, weight, perimeter, and gravity centre were extracted from the campus building. Because Google Earth provides us with the images of our earth, which are available in a bird's-eye view and in different angles, positions, and sizes, we therefore need to reduce the differences of features between these images. To reduce their differences, it is necessary to normalize the features abstracted from these images to make them independent from their size, position, and angle. After the features were extracted from the bi-valued image, a normalization process was proceeded to normalize the extracted features and then save them along with its original satellite image into an image database. In summary, we implemented a GUI based image processing system to facilitate the pre-processing of the satellite images. The system was composed of 9 programs, including a file conversion program, a colour separation program, a colour-to-gray level program, a gray level-to-binary program, a histogram program, an image labelling program, an azimuth adjustment program, a features abstraction program, and a normalization program.

The image database was so designed to facilitate the retrieval of images and their normalized features. It provided many maintenance functions such as insertion, deletion, update, and searching a record. In addition, it also provided the functions of finding a previous record, finding a next record as well as positioning the first or last record.

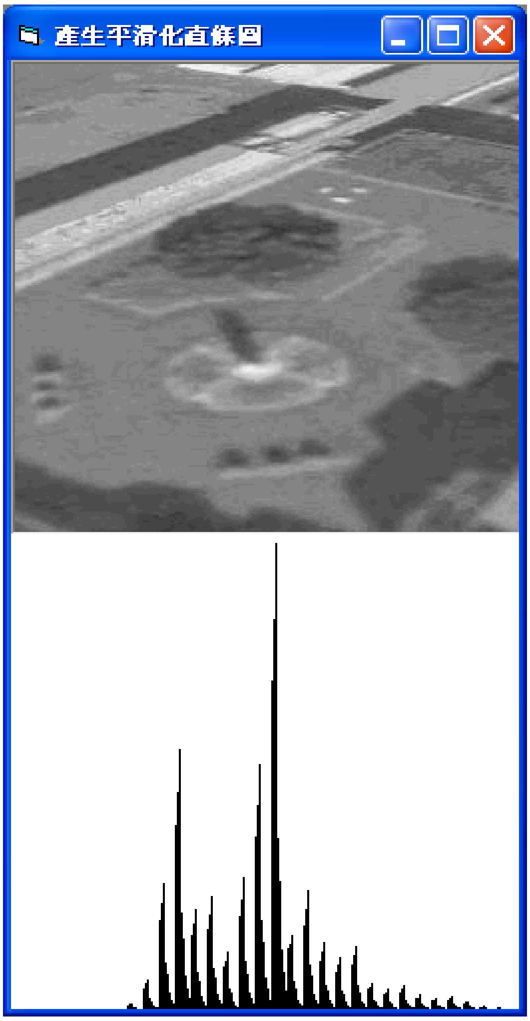

Fig. 2 A histogram of the satellite image of TCMT (Source: Google Earth)

Fig.3 Gray level image and binary edge diagram of TCMT (Source: Google Earth)

In the beginning of this research, we were supposed to use the Prewitt's edge detection method [1]-[2] to find a contour of the campus building. However, we found that the edge contour contained many high-frequency components, as shown in Fig. 3 and that they were hard to be removed from the campus building in the process of feature abstraction.

As shown in Fig. 4, red colour was used to separate the Gin-Ye Building from the satellite image. First, a colour histogram based on red colour was created. Then, two valleys around the peak in the histogram were selected as two thresholds for building separation. The pixels in the satellite image are kept if they lie within the two thresholds. Otherwise, pixels are removed. For example, the red color histograms can be used to separate Gin-Ye Building, Le-Chun Building, International Conference Centre, Experiment Building, and a swimming pool. By using the blue color histograms, Administration Building and a student dormitory can be separated without any difficulty. It is the same for a green color histogram to separate the Spiritual Fort. As we can see from Figure 4, there are some white objects in the image. This is because white colour is composed of red, blue and green colours. The unwanted objects were removed by a labeling program, in which the objects in the image were labeled with numbers and small objects were removed as compared with the campus building.

After removing the small objects, the colour image of Gin-Ye Building was converted into a gray-level image and then turned into a binary image by an optimal threshold. As mentioned previously, a bi-valued image can reduce a lot of details about the image itself. Therefore, the gray-level image of Gin-Ye Building was converted into a binary image via an optimal threshold method. If a gray-level pixel is greater than or equal to the optimal threshold, it is given a white colour. Otherwise, it is replaced by a black colour. The gray-level image of Gin-Ye Building and its binary image are shown in Fig. 5.

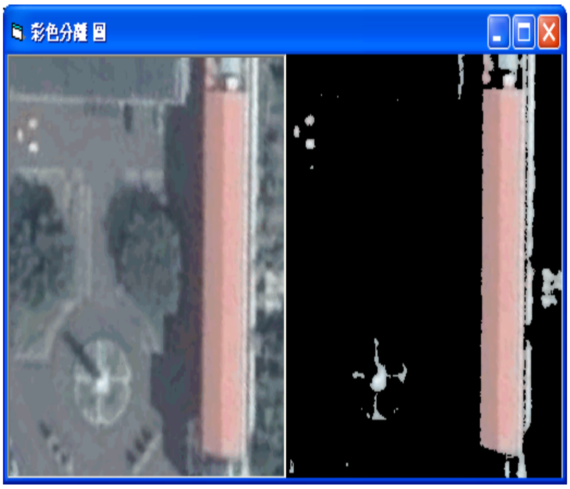

Fig. 4 A colour satellite image and its image after colour separation (Source: Google Earth)

Six features from the binary image of the campus building were abstracted, i.e. area, height, width, perimeter, gravity centre in the x coordinate and gravity centre in the y coordinate. A normalization process is necessary to keep the features abstracted from the campus building independent from their size, direction, and angle.

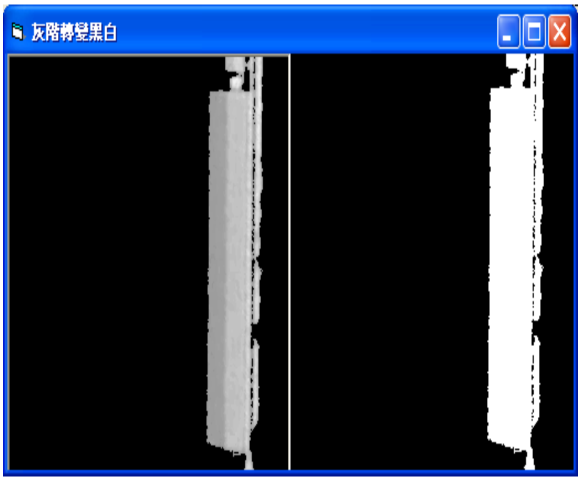

Fig. 5 A gray-level image of the Gin-Ye Building and its binary image

Six normalized features along with six features are shown in Table 1. They are defined in the following:

1) Area is defined as the count of white pixels in the binary image.

2) Perimeter is referred to as the count of white pixels having a black pixel in its 8-neighbors in the binary image.

3) Height as its name implies is the height of the rectangular shape that surrounds a campus building.

4) Width as its name implies is the width of the rectangular shape that surrounds a campus building.

5) Gravity in x-axis is the average of white pixels in the x coordinate.

6) Gravity in y-axis is the average of white pixels in the y coordinate.

7) Arc is defined as 4π times Area divided by Perimeter square.

8) Height to width ratio is defined as the ratio of Height to Width.

9) Normalized Area is defined as Area divided by the product of Height and Width.

10) Normalized Perimeter is defined as Perimeter divided by two times of the sum of Height and Width.

11) Normalized Gravity in x-axis is defined as the centre of gravity in the x coordinate divided by half of Width.

12) Normalized Gravity in y-axis is defined as the centre of gravity in the y coordinate divided by half of Height.

TABLE 1 FEATURES ABSTRACTED FROM THE BINARY IMAGE AND THEIR NORMALIZED FEATURES

Area	Height	Width	Perimeter
35426	437	96	2293
Arc	**H/W ratio**	**Norm. Area**	**Norm. Perimeter**
0.085	4.552	0.844	2.151
Gravity in x-axis		**Gravity in y-axis**	
223		61	
Norm. Gravity in x-axis		**Norm. Gravity in y-axis**	
1.016		0.984	

3. THREE RECOGNITION SYSTEMS

Three recognition systems were implemented, namely, statistic, fuzzy logic and neural network recognition systems, and described as follows.

3.1. The Statistic Recognition System

In this statistic approach, it took 34 sets of normalized features as its training samples. By summing up all normalized features, it took the average of them to become average normalized features, as shown in the Table 2.

TABLE 2 AVERAGE NORMALIZED FEATURES

Average features	Fort	Gin-Ye.	Le-Chun	Admin ..
Arc	0.086	.008	0.218	0.078
Height to width ratio	1.114	4.891	4.826	2.119
Norm. Area	0.6832	0.822	0.864	0.725
Norm. Perimeter	2.519	2.267	1.34	2.665
Norm. Gravity in x-axis	0.971	1.024	1.022	1.049
Norm. Gravity in y-axis	0.9997	0.973	0.9996	0.972

Average features	Dorm.	Int'l Conf. Ctr.	pool	Experi-ment
Arc	0.036	0.402	0.161	0.389
H/W ratio	5.095	1.944	1.234	2.443
Norm. Area	0.491	0.871	0.798	0.829
Norm. Perimeter	2.418	1.253	2.070	1.178
Norm. Gravity in x-axis	1.064	0.939	0.992	0.991
Norm. Gravity in y-axis	1.130	0.973	1.03	1.069

The statistic recognition system took a testing sample as input and computed 6 normalized features of the campus building. By computing the distances between the normalized features of the testing sample and the average normalized features, a minimal distance of them was picked up and the testing sample was therefore classified into the same class as that of the average normalized feature.

As we can see from Fig. 6, the arc value of the campus buildings is small. This is because the shape of the campus buildings is simple and not so complicated.

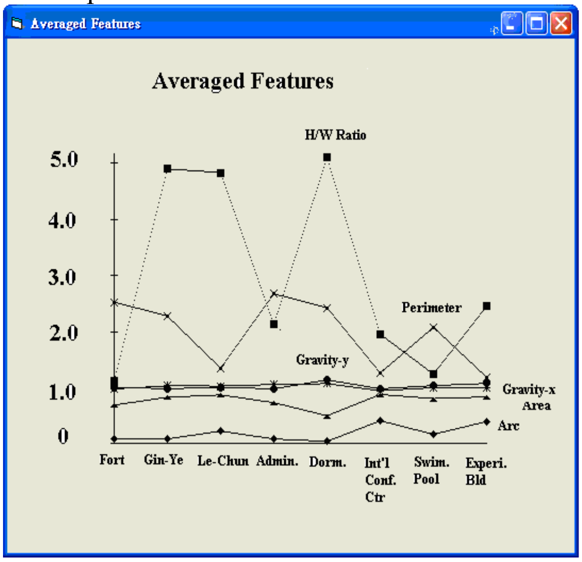

Fig. 6 Comparison of average normalized feature

As the shape of spiritual fort is round, its height to width ratio (H/W ratio) is nearly to 1. The height to width ratio of the swimming pool is also nearly to 1 since it is square in shape. The Gin-Ye Building and the Le-Chun Building and the student dormitory are long and slim, making a high height-to-width ratio of 5. The International Conference Centre, Experiment Building, and Administration Building are rectangular in shape. Their height-to-width ratios lie between 2 and 3. The normalized centre of gravity and normalized area of all campus buildings are approaching 1. We concern them as bad features for the campus buildings. However, the greatest peak value in the colour histogram and the colour of the campus building might be considered as good features from our point of view. The normalized perimeters of the Gin-Ye Building, the Le-Chun Building, and a student dormitory, affected by high frequency component of the image, ranges from 1 to 2.6. Since the Spiritual Fort is round in shape, its normalized perimeter is 2.519, different from the theoretical value of $\pi/2$.

3.2. The Neural Network Recognition System

A Three-layer architecture of neural network [4] was used as shown in Fig. 7.

The basic theory behind a back-propagation neural network approach is in that it employs a gradient steepest descent method to minimize the root mean square error between the network output and the target output.

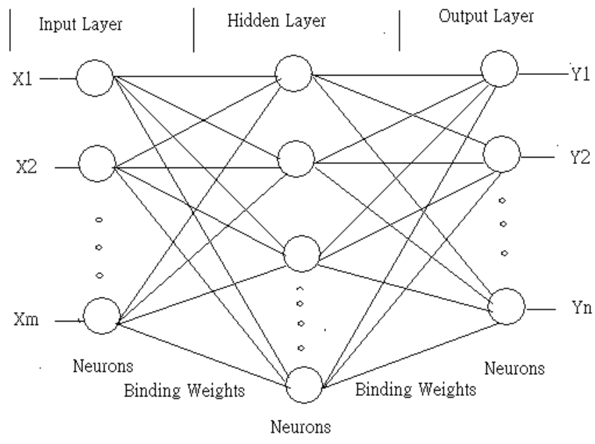

Fig. 7 Architecture of a Back-propagation neural network

In the back-propagation neural network, it computed the root mean square error between the network output and the target output and propagated them backward to hidden layer and input layer for adjusting the binding weights between neurons in two adjacent layers. This process was repeated until the root mean square error between the network output and the target output reached a predefined small value. The training samples were used to build up the binding weights between neurons in two adjacent layers. Once the neural network was trained, it took a testing pattern as input and computed the distances between the network output and the target output. The minimal distance between the network output and the target output was obtained and the testing sample was then classified into the same class as the target output had.

In this research, 34 sets of training samples were collected. Among them, 8 sets of the Spiritual Forts were selected as shown in Fig. 8. The features of the Spiritual Forts don't change significantly except perimeter. The back-propagation neural network had six neurons in the input layer, eight neurons in both the hidden layer and the output layer. In the learning stage, it was trained for 2600 times for obtaining a set of suitable binding weights. The set of suitable binding weights was then used for building classification in the recognition stage. The overall recognition rate was 0.971, the highest one among three recognition systems. Only one out of 34 testing samples was incorrect as a result of too small size of the testing sample.

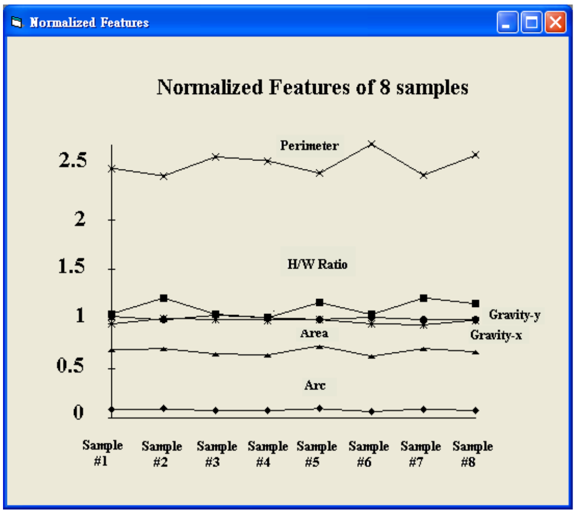

Fig. 8 Features of the Spiritual Fort's 8 samples

3.3 Fuzzy Logic Recognition System

In the fuzzy logic approach [5]-[6], the Fuzzy C-Mean Clustering method was adopted for building classification. The average normalized features, instead of random numbers, were used as initial centers for a convergent reason. The fuzzy logic recognition system could provide several candidate classes as it output. However, only the first one in the candidate classes was regarded as correct. The recognition rate of fuzzy approach was 0.794.

4. Experiment Results

The source satellite images in different angles and sizes were taken from Google Earth in 2007 and 2008. Some of them were used for generating training samples and normalized features, while others were used for making testing samples. The normalized features were used as training samples of the neural network recognition system and as average normalized features of the statistical recognition system as well as initial centers of the fuzzy logic recognition system.

One of the experimental results from the three recognition systems was respectively shown in Figs. 9, 10, and 11.

The recognition rate of the three recognition systems as in Table 3 showed that the back-propagation neural network approach was 0.971, the highest one, while the recognition rate of fuzzy logic approach was 0.794, the lowest one. The recognition rate of the statistical recognition system was in between, 0.912. Judging from the appearance, the Gin-Ye Building and the Le-

Chun Building, as shown in Fig. 1, looked like the same in shape and size. Besides, they were parallel to each other. It is really hard for us to tell which is which. However, both neural network approach and statistical approach could recognize them.

TABLE 3 THE COMPARISON OF RECOGNITION RATE

Systems	Neural Network	Statistical \	Fuzzy Logic
No. of Testing Samples	34	34	34
No. of Mistakes	1	3	7
Recognition Rate	97.1%	91.2%	79.4%

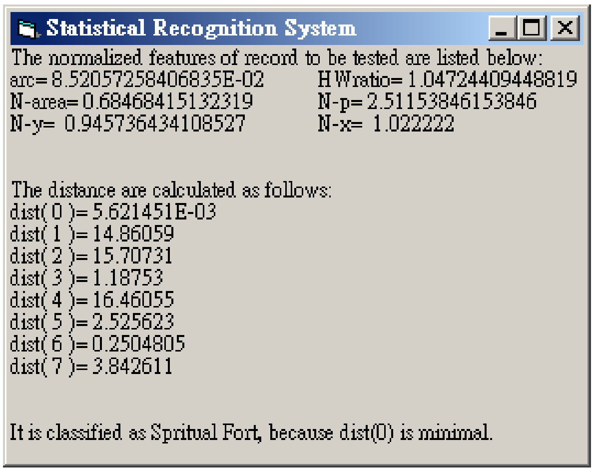

Fig. 9 An output from the Statistical recognition system.

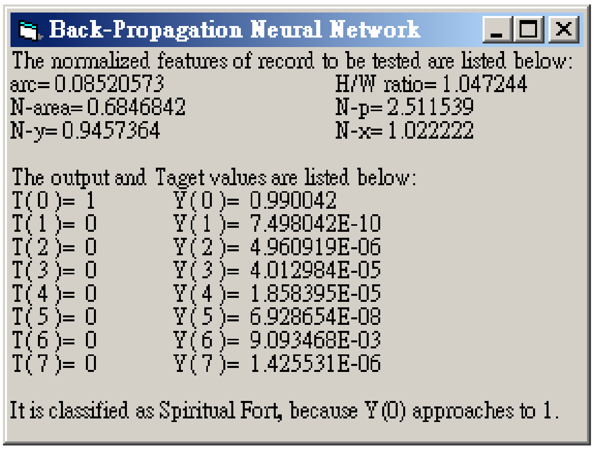

Fig.10 An output from Neural Network system.

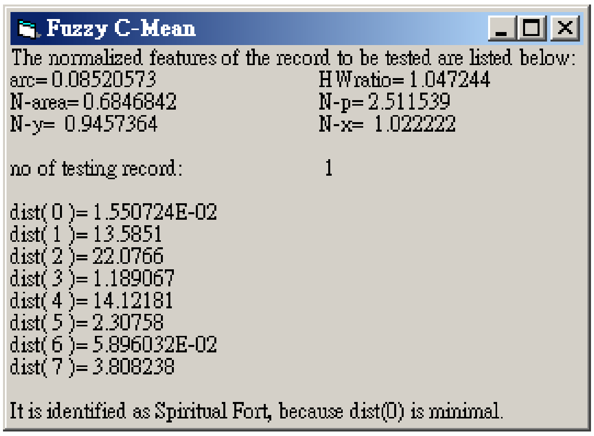

Fig. 11 An output from Fuzzy recognition system.

5. CONCLUSIONS

The paper is to explore the characteristics of satellite images from Google Earth: low contrast and illumination. Seeing from the gray-level histogram, the distribution of gray-level ranges from 50 to 220, not uniformly distributed over from 0 to 255. The contrast value is only 170. In addition, the distribution of gray-level is not continuous, but scattering on ten or more gray levels. Moreover, the satellite images are not brilliant and have only a few colors. The satellite images of our campus buildings have three major colors, i.e. red, blue, and green. Therefore, a campus building can be easily separated from the image by a red color histogram, a blue color histogram, or a green color histogram. In the process of building separation, a peak is searched for and its two adjacent valleys in the histogram are used as two thresholds for separation. The gray-level pixels within two thresholds are kept. Otherwise, they are removed. There is one drawback associated with a color separation process. That is to say, the white color pixels are still present after separation. A further process is necessary to be taken in order to remove those white pixels. A labeling algorithm is used to remove white pixels because they are in small size as compared with the campus building.

In the paper three recognition systems have been implemented. The results have shown that the neural approach has the highest recognition rate and fuzzy approach has the lowest one. In view of this, we therefore strongly recommend that the recognition system should employ a neural network approach and shouldn't employ a fuzzy approach for the campus building recognition.

The future direction of this research will focus on how to increase the recognition rate, especially for the fuzzy approach. Furthermore, we will emphasize our study on the adjustment of neural network architecture, such as the number of hidden layers and related network parameters, so as to raise the recognition rate.

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REFERENCES

[1] Ragael C. Gonzalez and Richard E. Woods, Digital Image Processing, 2nd ed., Prentice Hall, 2003.
[2] Ragael C. Gonzalez and Paul Wintz, Digital Image Processing, 2nd ed., Adison-Wesley, 1987.
[3] Fang-Yie Leu, Shau-Tang Yu, Min-Shiung Shiu and Chau-Li Lin, "An Application of Image Database on Facial Recognition – The Database of Lawbreakers," Journel of Tunghai University, No. 1, pp. 103-122, Jul. 1999.
[4] Yun-Long Lay, Chung-Ho Tsai, Hui-Jen Yang, Chern-Sheng Lin and Chuan-Zhao Lai, "The application of extension neuro-network on computer-assisted lip-reading recognition for hearing impaired," Expert Systems with Applications, vol. 34, pp. 1465-1473, Feb. 2008.
[5] Cheng-Jian Lin, I-Fang Chung and Cheng-Hung Chen, "An entropy-based quantum neuro-fuzzy inference system for classification applications," Neurocomputing, vol. 70, pp. 2502–2516, Aug. 2007.
[6] Achim Röder, Joachim Hill, Beatriz Duguy, José Antonio Alloza and Ramon Vallejo, "Using long time series of Landsat data to monitor fire events and post-fire dynamics and identify driving factors. A case study in the Ayora region (eastern Spain)," Remote Sensing of Environment, vol. 112, pp. 259-273, Jan. 2008.
[7] Carlo Colesanti and Janusz Wasowski, "Investigating landslides with space-borne Synthetic Aperture Radar (SAR) interferometry," Engineering Geology, vol. 88, pp. 173-199, Dec. 2006.
[8] A. Ghosh, N.R. Pal and J. Das, "A fuzzy rule based approach to cloud cover estimation Remote Sensing of Environment," Geomorphology, vol. 100, pp. 531-549, Feb. 2006.
[9] Avijit Gupta, Lim Hock, Huang Xiaojing and Chen Ping, "Evaluation of part of the Mekong River using satellite imagery," Geomorphology, vol. 44, pp. 221-239, May 2002.
[10] I.D. Novak, N. Soulakellis, "Identifying Geomorphic features using LANDSAT-5 /TM data processing techniques on Lesvos, Greece," Geomorphology, vol. 34, pp. 101-109, May 2000.
[11] Min-Yen Liu, "Locating and Tracking of the Typhoon from Infrared Satellite Images," M. Eng. thesis, Tatung University, Taiwan, Jul. 2006.
[12] Yi-Hui Tu, "Feasibility study of large/medium scale topographic map revision using high resolution satellite imagery," M. Eng. thesis, Chinese Culture University, Taiwan, Jul. 2001.
[13] Wen-Wei Lin, "A Neural-Network Application of Cloud Classification for MODIS Data," M. Eng. thesis, National Central University, Taiwan, Jul. 2004.
[14] Gui-Bin Tsai, "Estimation of Clouds in Satellite Images Using Neural Network," M. Eng. thesis, National Chung Cheng University, Taiwan, Jul. 2006.
[15] Mon-Chen Wu, "Canonical Correlations Analysis Apply to Change Detection in Remote Sensing Image," M. Eng. thesis, National Central University, Taiwan, Jul. 2005.
[16] Cheng-Bing Chuang, "Segmentation Technique for Classification of High Spatial Resolution Satellite Images," M. Eng. thesis, National Central University, Taiwan, Jul. 2006.