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A Study on Ancient Temple Structural Elements Recognition Using Genetic Algorithm

Gurudev S. Hiremath*
Department of Computer Science and Engineering, UBDT College of Engineering, Davanagere, India
E-mail: devguruphd4u@gmail.com
ORCID iD: https://orcid.org/0000-0001-5968-2841
*Corresponding Author

Narendra Kumar S
Department of Computer Science and Engineering, UBDT College of Engineering, Davanagere, India
E-mail: narendra@jnnce.ac.in, nks.cse@gmail.com
ORCID iD: https://orcid.org/0000-0001-6466-279X

Shrinivasa Naika C. L.
Department of Computer Science and Engineering, UBDT College of Engineering, Davanagere, India
E-mail: naika2k6@gmail.com
ORCID iD: https://orcid.org/0000-0001-9019-1733

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Abstract: The systematic and scientific study of the lifestyle and culture of earlier peoples is known as archaeology. The Indian history of archaeology spans from the 19th century to the present status, it includes the region's history investigated by a wide variety of archaeologists. They don't have any such authentic digital methods to be quoted in research. Manual Recognition of ancient temple structural elements is quite difficult to recognize, has archaeologists face many complex problems because they don't have any automated Recognition method. Recognition is helpful for archaeologists to get more detailed information of ancient temples which is very important for further research. Thus, in this work it is proposed to develop automated method for Recognition ancient temple structural elements (vimana & pillars) for further archaeological research purpose. The proposed method extracts Genetic programming evolved spatial descriptor and classifies the temple structural elements visited by archaeologists based on linear discriminant method [LDA]. The proposed method is divided into 3 main phases: pre-processing, genetic programming evolution and Recognition. The Generalized Co-Occurrence Matrix is used in the pre-processing phase to change images into a format that genetic programming systems may use to process them. The second stage produces the best spatial descriptor to date in the form of a programme that is based on fitness Utilizing LDA, the Fitness is determined. Once the program's output has been received, it can be used for Recognition. Experimental results shows, it demonstrates relatively high accuracy in Recognizing both vimana(gopura) & pillars of different temples. The proposed method is implemented in MATLAB. These results will play very significant role in identification of temple architecture, which in-turn helps in conservation and reconstruction of temples. The proposed methodology will give 98.8% accuracy in pillars recognition and 98.4% accuracy in vimana recognition.

Index Terms: Archaeology, archaeologist, vimana, pillar, recognition, genetic programming.

1. Introduction

A. Archaeology

"The science of the treatment of the material remains of the human past" is how archaeology is defined. (Kenyon, 1940) [1]. In the olden days ancient peoples used to bury their wealth after the death. Initially Archaeology began as a search for treasure, later it has gradually evolved into a science. This science came into existence when a group of enthusiasts' peoples formed a Society called as Society of Antiquaries in London in 1707. "The science of archaeology encompasses all of life. Life is not sporadic; rather, it is an ongoing point of equilibrium where the past and present collide." (Ceram, 1954). This suggests that archaeology can provide the background of life in the region and throughout that time. Archaeology may demonstrate a civilization's development, environment, culture, religion, and much more. [2].

The Indian history of archaeology spans from the 19th century to the present status, it includes the region's history investigated by a wide variety of archaeologists. They are not authentic to be quoted in research. In the early 18th century Western European travelers were the scholars to take an interest in the archaeology of the Indian subcontinent [3]. The first director of the Archaeological Survey of India was Alexander Cunningham, who largely influenced the Scholarly investigation into the Indian archaeology.

Karnataka in India has rich information about ancient monuments and given a lot of importance to the history of archeology. Since it has its own heritage integrated with culture; the History, Culture and the development of Karnataka have been contributed by many empires and dynasties. Many numbers of ancient monuments were built by empires or ruling dynasties and their style, inbuilt, sculpture, architecture, technique, vastness, magnitude define their unique way of structuring. Many Dynasties have ruled the Karnataka among them kadambas, gangas, chalukyas of Badami and Kalayana, Rashstrakutas, Hoysalas were the major ones.

B. Structural Elements of Ancient Temple

In their original sanskrit words, the most important structural elements of a temple are vimana(goupara) and pillars. Nowadays, study on ancient Karnataka temple is very often required in this modern society both archaeology research scholars and public to mining archaeological knowledge through the digitization. Hence, a new approach required to bring this valuable information to the modern society by a proper platform.

This research work will play very significant role in identification of temple architecture, which in-turn helps in conservation and reconstruction of temples. Manual Recognition of ancient temple structural elements is quite difficult to Recognize, these archaeologists face many complex problems because they don’t have any automated Recognition method. Recognition is helpful for archaeologists to get more detailed information of ancient temples which is very important for further research.

This paper focuses on Recognition of ancient temple structural elements by using genetic algorithm for further archaeological research purpose. Section 2 describes about Recognition method in detail. Section 3 details the genetic algorithm. Section 4 describes the related work. Section 5 illustrates the experiment setup and results and finally section 6 presents the conclusions of the study.

2. Recogniation

A variety of decision-theoretic methods are used in Recognition to Recognize photos (or parts thereof). All Recognition methods are predicated on the idea that the image in question contains one or more features, each of which is representative of a different and exclusive class. (*e.g.*, Spectral regions in the case of remote sensing or geometric components in the case of factory Recognition systems). The classes may be predetermined in advance by an analyst (as in supervised Recognition) or automatically clustered into sets of prototype classes (i.e., as in unsupervised Recognition), where the analyst only provides the necessary number of categories. (Recognition and segmentation have aims that are closely related to one another because the former is a different way of labelling a component that might lead to the segmentation of different aspects in a scene.)

Image Recognition categorizes data by analyzing the numerical characteristics of different image attributes. Training and testing are the two processing processes that are frequently used in Recognition techniques. An individual description of each Recognition category, or training class, is made using salient qualities of common image features that are isolated during the initial learning phase. These feature-space partitions are applied to classify picture characteristics in the subsequent estimation step.

The most crucial step in the Recognizing process is the description of the learning classes. In supervised Recognition, class descriptors can be extracted using distribution-free methods or statistical techniques that rely on prior knowledge of probability distribution functions. Clustering methods are necessary for unsupervised Recognition in order to automatically divide the learning data into prototype groups. In either scenario, the following factors should be considered when creating learning classes:

- Independent: i.e., the value of one learning class should not vary if its description does.
- Discriminatory: Distinct image aspects should have descriptions that are noticeably different from one another. and
- Reliable: A learning group's common, conclusive descriptions should be shared by all of the picture characteristics within that group.

Using a feature vector (v1, v2,..., vn), where n is the number of attributes that characterize each picture feature and learning class, is an easy approach to construct a parametric description of this kind. In the n-dimensional Recognition space, this representation enables us to use each picture feature as occupying a point and each learning class as occupying a sub-space (i.e., a representative point surrounded by some spread, or deviation). When seen in this light, the Recognition challenge is Recognizing the sub-space class to which each feature vector belongs.

3. Genetic Algorithm

Darwin's theory of evolution, according to which "the survival of an organism is affected by rule - the strongest species survives," served as the foundation for Goldberg's genetic algorithm. According to Darwin, an organism can perpetuate its life through the processes of reproduction, cross-pollination, and mutation. Darwin's idea of evolution is then applied to computational technology to naturally solve the problem of objective function. Chromosomes are solutions represented by genetic algorithms, while populations are collections of chromosomes. A chromosome is made up of genes, and depending on the puzzle you're trying to solve, the value could be numerical, binary (as in zeros and ones), symbolic, or even character-based. These chromosomes will undergo a procedure known as a fitness function to evaluate how well the solution produced by GA fits the problem. Through a process known as crossover, some chromosomes in a population will mate, giving rise to new chromosomes termed offspring, the genes of which are a combination of those of their parents.

A few chromosomes will also experience gene mutation during the course of a generation. The crossover rate and mutation rate value determine how many chromosomes will undergo a crossover and mutation. According to the Darwinian evolution rule, the chromosome in the group that will endure for the following generation will be picked; the chromosome with the better fitness value will always have a higher possibility of not being rejected again in the following generation. The chromosome value will eventually converge to a precise value that is the best way to solve the issue after a number of generations. Fig.1 shows the algorithm's flowchart.

The following is the genetic algorithm process: [4]:

Step 1. Calculate the value of the generation, mutation, crossover, and chromosomal number.

Step 2. Create a population-wide chromosome-chromosome number and initialise the starting value of each gene's chromosome-chromosome with a random number.

Step 3. Repeat steps 4–7 until the required number of generations has been reached.

Step 4. By computing an objective function, chromosome fitness is evaluated.

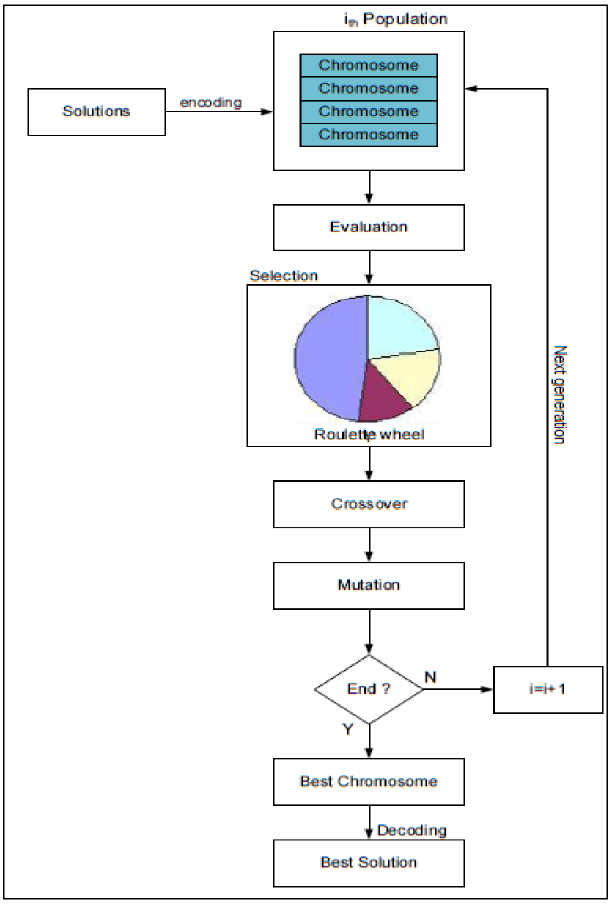

Fig. 1. Genetic Algorithm

Step 5. Choose chromosomes

Step 6. Crossover

Step 7. Mutation

Step 8. Solution (Best Chromosomes)

In order to refine complicated systems, genetic algorithms (GA) are a non-deterministic algorithm that are not artificial, novel methods, and substantial resultsDigital image processing, which includes image feature extraction and picture segmentation, inevitably results in some inaccuracy. The genetic algorithms used in image processing refinement calculations are entirely competent in reducing these flaws. Image segmentation, picture Recognition, image reconstruction, pattern recognition, and other tasks have been effectively accomplished using the current methodology.

The Genetic Algorithm is an approach that can be easily implemented and is quite easy. Numerous issues, including restricted and unconstrained optimization issues, nonlinear programming, stochastic programming, and combinatorial optimization issues, can be solved using it. The Genetic Algorithm has the advantage of working more accurately during global optimization, especially with objective functions that behave badly, such as those that are not continuous or have numerous local minima. Additionally, it performs most accurately with challenging computational problems(Zheng, 1999)[5].

To categorize all of the pixels in a digital image into one of several land cover types, or "themes," is the goal of the Recognition process. The thematic mapping of the land cover depicted in an image can then be created using these grouped data. The spectral pattern included in the data for each pixel is employed as the numerical basis for grouping under categories when multispectral data are typically used to do the Recognition(Lillesand and Kiefer, 1994). The goal of image Recognition is to recognise and represent the features that appear in an image in terms of the object or kind of land cover these features actually depict on the ground as a distinct grey level (or colour). The most crucial aspect of digital image analysis is thought to be image Recognition. It is advised to have a "beautiful picture" or graphic that depicts a range of colours that represent different aspects of the underlying topography, but this is meaningless if the colours' meanings are unknown. Supervised Recognition and Unsupervised Recognition are the two primary methods of Recognition.

Unsupervised Recognition is a method that looks for a lot of unknown pixels and classifies them based on how naturally the image values are grouped. Unsupervised Recognition does not rely on analyst-specified training data, in contrast to supervised Recognition. The fundamental tenet is that data from various classes should be comparably widely separated from one another (i.e., have extremely dissimilar grey levels), while values within a given cover type should have a minimum distance between them in the measurement space (i.e., have matching grey levels) (Lillesand and Kiefer, 1994)[6]. Examples of the classes (such as the type of land cover) of interest in the image can be found by supervised Recognition. They are referred to as "learning sites." Later, a statistical characterization of the reflectance for each information class is created using the image processing software system. Often referred to as "signature analysis," this stage entails creating a characterization that can be as straightforward as the mean or range of reflectance on each band or as sophisticated as in-depth assessments of the mean, variances, and covariance over all bands. After each information class has been statistically characterized, the image is subsequently categorized by determining which of the signatures each pixel's reflectance most closely resembles(Eastman, 1995).[7]

Genetic Algorithms (GA) use principles of natural evolution. There are five important features of GA are, Encoding, Fitness Function, Selection, Crossover, Mutation. Advancing features of Genetic Algorithms:

- Parallelism.
- Global optimization.
- A larger set of solution space.
- Requires less information.
- Provides multiple optimal solutions.
- Probabilistic in nature.
- Genetic representations using chromosomes.

4. Methodology and Implementationa

1. Reading of Images

Some picture files have information that can be examined to reveal an image's characteristics. Consider a digital photo as an example. It might have metadata that can be analysed to reveal the brand and model of the camera that took the picture. You may read already-existing metadata and add new metadata to image files using GDI+.

2. Creating Database

Align the training set T1, T2, T3, and so on up to TM, which consists of images of temples or pillars. Then, convert all of the training database's 2D images into 1D column vectors. Put each of these 1D column vectors in a row to create the 2D matrix "T" later. The "T" column's contents are training images that have been converted into 1D vectors. P is the overall amount of MxN training images, and C represents the number of classes.

3. Pre-Processing

Here the image is resized and GCM is calculated which is called as genetic programming i.e. It is calculated for repeatedly occurred pixels and plot the energies i.e. the intensity of the pixel with which we can easily classify the images.

4. Recognizing Step

The images of the two monuments are projected into space at this point, and the Euclidean distance between them is calculated to compare the two. The projected test image and the projection of all the concentrated learning pictures are separated by Euclidean distances. The distance between the test image and its related image in the training database should be as little as possible.

5. Recognition

In order to distinguish between various objects inside an image, Recognition of remotely collected data is employed to produce equivalent levels with respect to groups with comparable features. The class is the level. Recognition will be carried out based on spectral properties in the feature space, such as density, texture, etc. On the basis of a decision rule, it may be claimed that Recognition categorizes the feature space into different groups. [8]

Recognition will be done in accordance with the steps listed below:

1. Definition of Recognition classes

The Recognition classes should be precisely established in accordance with the goal and the characteristics of the image data.

2. Selection of Features

Multi-spectral and/or multi-temporal characteristics, textures, and other features should be used to create features that distinguish between the classes.

3. Sampling of training data

To determine the best decision rules, learning data should be sampled. On the basis of the training data sets, Recognition approaches such as supervised or unsupervised learning will then be chosen.

4. Estimation of Universal Statistics

The learning data will be compared to a variety of Recognition methods in order to determine the best decision rule for further Recognition.

5. Recognition

All pixels are categorised into a single class when the decision rule factor is taken into account. Regarding segmented regions, there are two methods: per-field Recognition and pixel-by-pixel Recognition. Using Principle Component Analysis (PCA) and Linear Discriminant (LD), this step identifies the characteristics that can best distinguish between photos of pillars and temples. [9]

This procedure generates a 2D matrix with all of the training picture vectors and outputs 4 results that are drawn from the training database.

Let's say that Ti is a training image that has been transformed into a 1D vector. P is the overall amount of MxN training images, and C represents the number of classes. V_PCA transfer matrix first maps centred Ti onto a (P-C) linear subspace:

$$Z_i = (V\_PCA) * (T_i - m\_database) \tag{1}$$

Then, by projecting Zi onto a (C-1) linear subspace, Zi is changed into Yi, causing images of the same class (or individual) to move closer together and images of different classes to move farther apart:

$$Y_i = (V\_Fisher') * (Z_i) = (V\_Fisher') * (V\_PCA') * (T_i - m\_database) \tag{2}$$

6. Verification of results

Accordingly, the categorised findings should be examined and checked for accuracy and dependability.

Fig.2 shows how Recognition works. In order to classify the images, we need to have at least 2 classes of images in train database and any number of classes in test database. The features are extracted from the trained image and compared with the test image.

The differences in the pixels are calculated. The image with the least difference is taken as the best match and is Recognized.

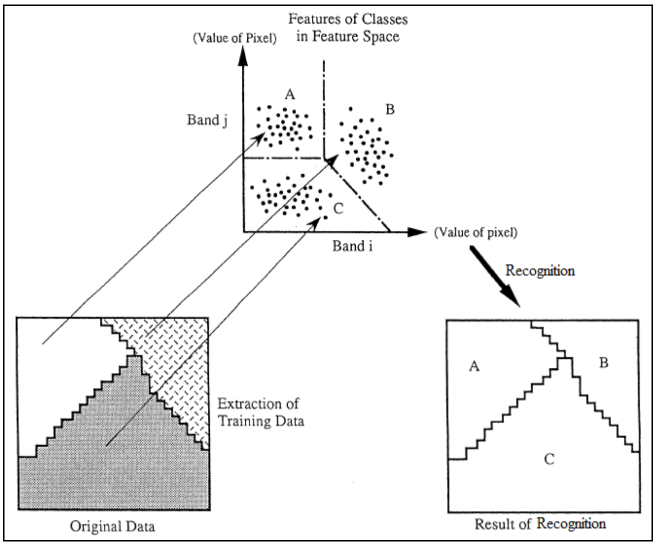

Fig. 2. Concept of Recognition

Fig 3 describes the steps involved in the Recognition. At first we have to create two databases i.e test database and train database. Pre-processing is applied i.e the GCM is calculated for the image in the test database. Features are extracted from the images in train database and it is compared with the specific image, which is selected from the test database. Lastly difference between the pixels is calculated and the image with least distance is taken as the best image and Recognized. A very effective Image processing analysis through machine vision [10]. There are different categories of recognition techniques for various applications [11]. The most commonly used statistical measures based on various research papers [12].

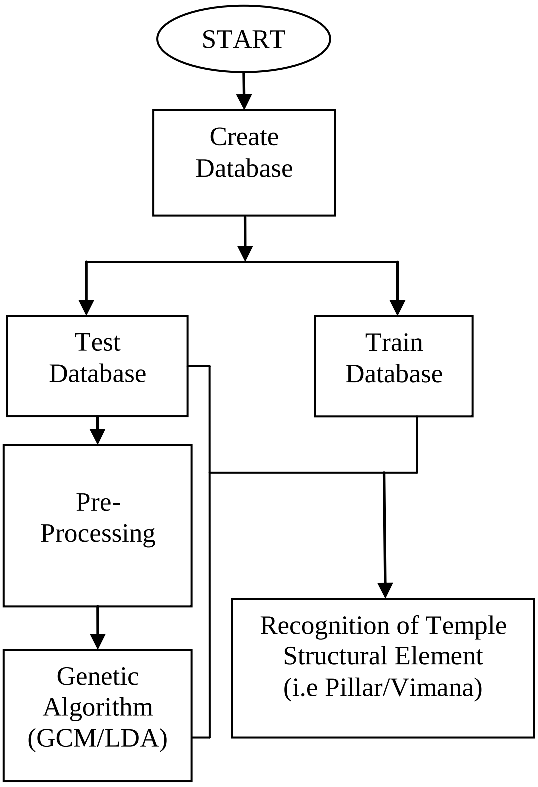

Fig. 3. Steps Involved in the Recognition

In this research work, A better recognition mechanism are defined on Vimana (Goupra) and Pillars datasets by adopting the above explained methodology through Genetic Algorithm as shown in Fig.3. This sincere work can be extended to further steps of Image Processing like feature extraction, identification and classification. This work will play very significant role in conservation and reconstruction of temples.

5. Experiment Setup and Results

This section discusses about the results of the study on genetic programming based evolution using image processing techniques for Recognition of Indian ancient temple structural elements.

A. Preparation of Dataset

Since there isn't a direct dataset accessible for the work at hand, gathering data is the most crucial activity. We have chosen 8 different temples for the preparation of dataset which are in and around shivamogga. In our data set totally 8 different classes of temples and their respective pillars are considered namely: 1) “Amruteshvara” temple in amruthapura, 2) “Lakshminarsimha-Swami” temple in Bhadravathi, 3) “Aghoresvara” temple in ikkrei, 4) “kedareshvara” temple in balligavi, 5) “kaitabheshwara” temple in kubuturu, 6) “harkeshwara” temple in,koodhi, 7) “lakshmi narasimha-swamy” temple in baggavali, 8) “mallikarjuna-swamy” temple in hirenallur.

For each mentioned class, minimum 2 images are captured/collected, one for temple & other for pillar by visiting all 8 places. For training and testing purposes, images are taken in a variety of postures. For each class, images are taken from the front, far, 45 degree left-side, and 45 degree right-side views at various times, such as morning, afternoon, and evening. Posing subjects (such as those standing or sitting) in front of temples are also taken into consideration in order to achieve diversity. Figure 4 displays a few illustration pictures. This dataset has been published in Kaggle web portal & our JNNCE college web portal only for research purpose[13,14].

B. Test Dataset and Train Dataset

Fig.4 shows the test dataset used to apply the Recognition technique. Here we have taken all images of temple and pillars for all 8 classes.

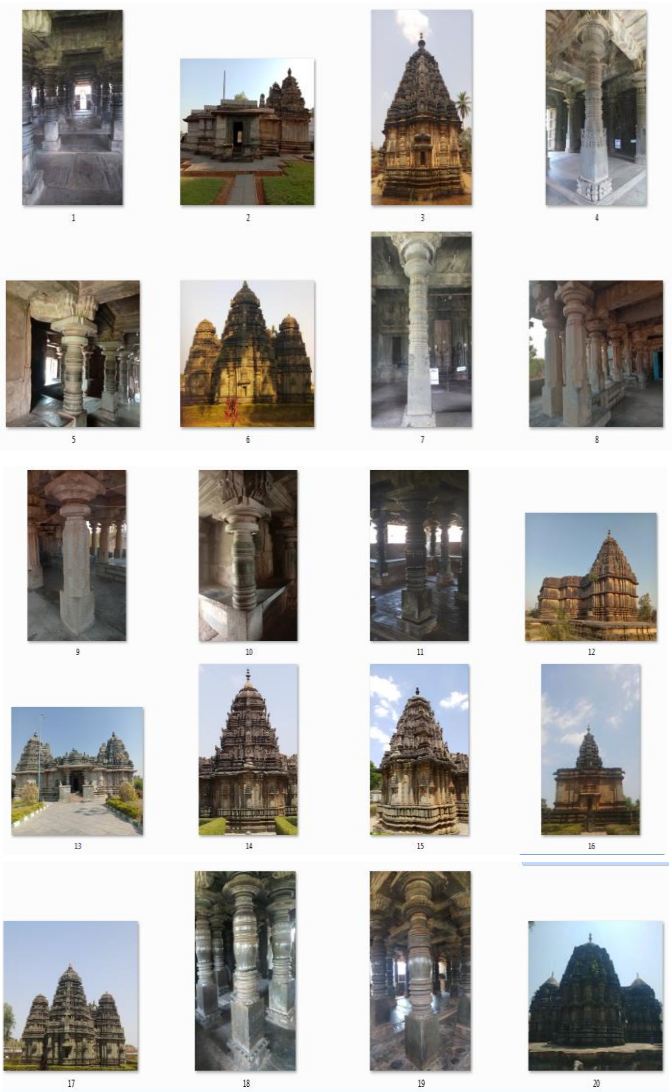

Fig. 4. Test Dataset

Fig.5 shows the training dataset collected for each image in the test dataset. It contains 2 images for each class of image.

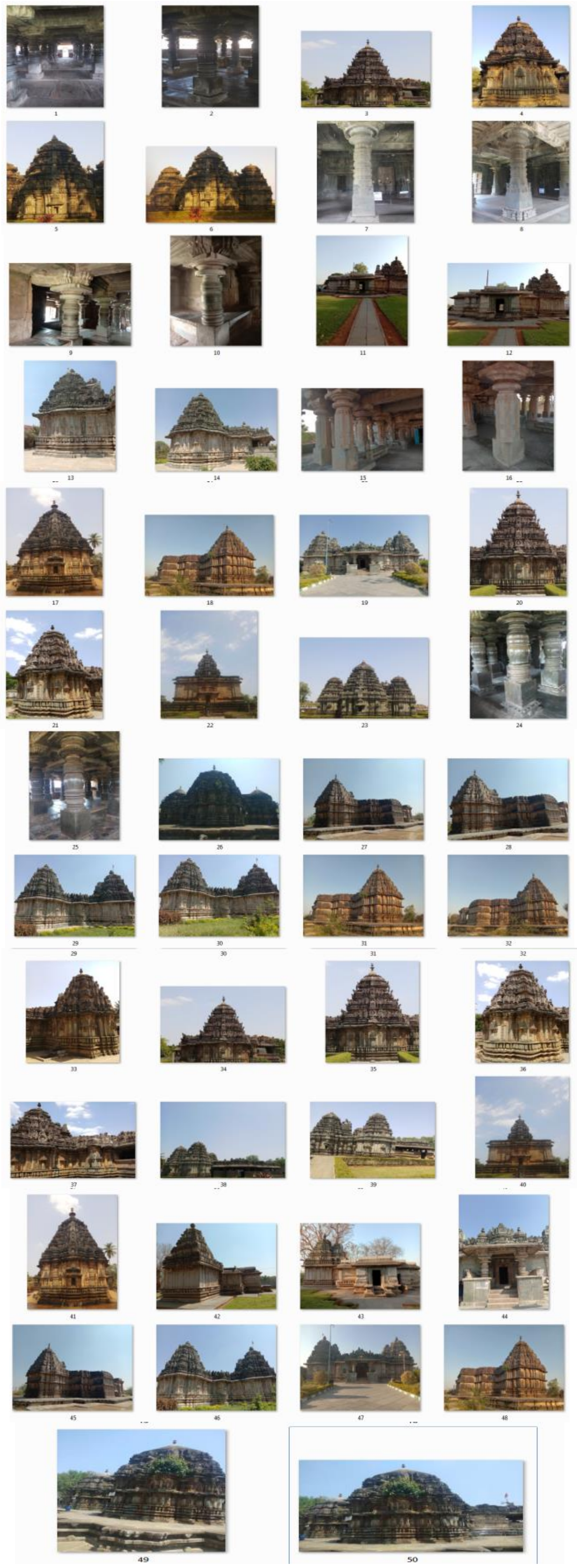

Fig. 5. Training Dataset

C. Graphical user interface

Fig.6 shows the Graphical user interface, which contains Browse cover image button, pre-processing button , and classify monuments button.

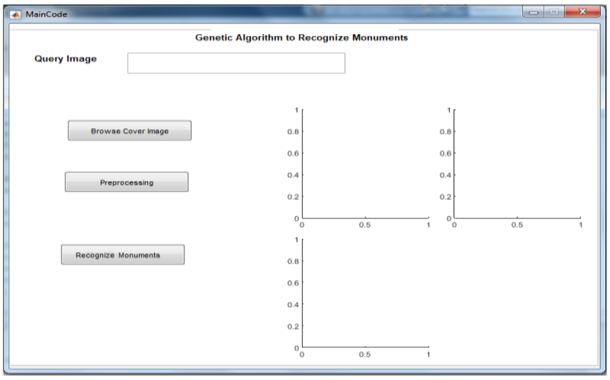

Fig. 6. GUI

Browse Cover Image- When this button is selected, any one of the image which we select from the test set will be displayed on the scale.

Pre-processing- When this button is clicked, the GCM for the image that was previously chosen is calculated. Blocks with varying energy levels will be used here as the depiction of the matrix.

Recognize Monuments- When this button is selected, the image which is similar to the image , which we browsed from the test set will be displayed .

Query image- the image number in the 1st scale will be displayed.

D. Selecting the query Image

When browse cover image button is selected, a window showing test dataset and train dataset is displayed. We have to choose any one of the images from test dataset which is then displayed on the GUI. Fig.7 shows the snapshot of selecting the pillar image of Aghoresvara temple from test dataset.

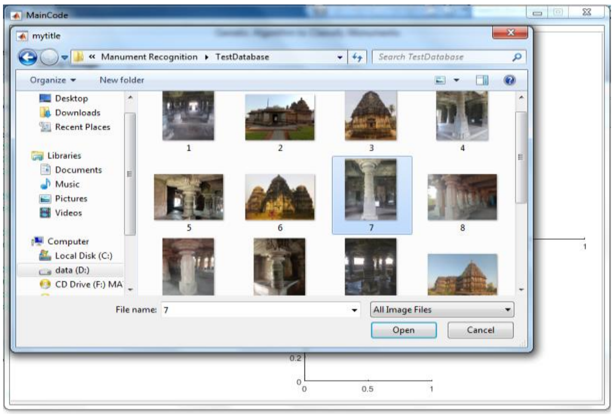

Fig. 7. Browsing the Image from Test Dataset

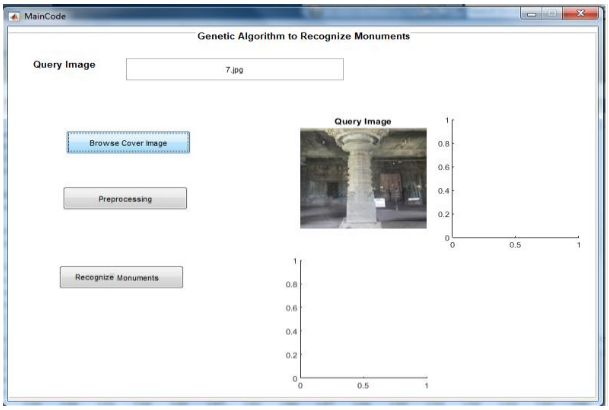

Fig. 8. Query Image

Fig.8 shows the snapshot of selected query image from test dataset.

E. Preprocesing

When the pre-processing button is selected, it will calculate the GCM for the image selected in the previous step. The GCM is represented in the form of blocks in the GUI. Fig.9 shows the snapshot after pre-processing is applied i.e GCM is calculated for the query image.

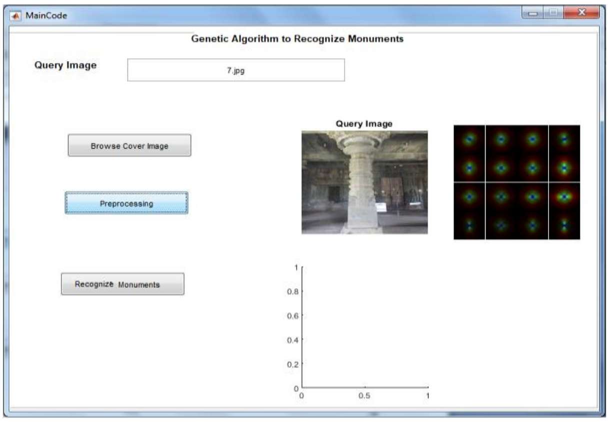

Fig. 9. Applying Pre-Processing for Query Image.

F. Recogiziation

Fig.10 shows the Recognizied pillar image of aghoresvara temple for the image which we browsed from the test dataset. This is done by genetic algorithm which uses , linear descriptive method. The image in the train dataset with least difference of pixel value is selected as the best image.

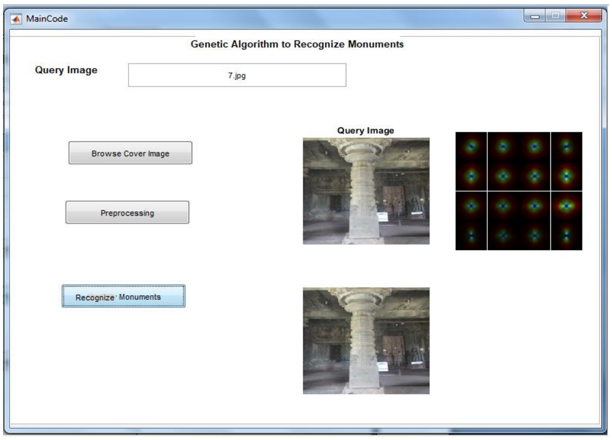

Fig. 10. Recognized Pillar Image of Aghoresvara Temple.

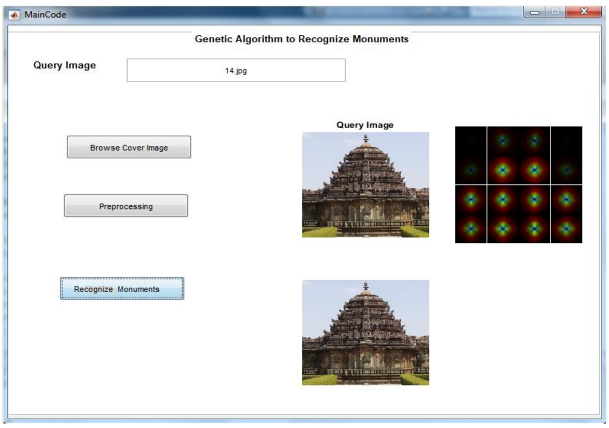

Fig. 11. Recognized Vimana(Goupra) Image of Amruteshvara Temple

Fig.11 shows the Recognized vimana image of amruteshvara temple for the image which we browsed from the test dataset.

6. Results Validation

In this section, the results are validated on basis of following points:

1) Comparing Recognizied photos with earlier techniques, such as the Manual Means, which the Karnataka archaeological department is still employing, is a more time- and labor-intensive conventional method of acquiring information from an archaeologist.
2) The Eight different temple images were used in the experiments. In this case, there are two input photos from each temple, either of a pillar or a vimana (Goupra), and the Recognition rate depends solely on wrong matches and not on the quantity of inputs.

Tables 1 and 2 exhibit the Recognition rate of a certain temple's pillar and vimana (Goupra). The Recognition rate [15] can be obtained by formula

$$\sigma = \delta - \gamma \tag{3}$$

Where σ is Recognition rate, α is sum of correct match, γ is sum of incorrect match, δ is Number of test samples.

Table 1. The Recognition Rate Analysis of Pillars for Different Temples.

Test Images	**Recognized Images**	***α***	**γ**	***δ***	**σ (in %)**
		**100**	**0**	**100**	**100%**
		**100**	**0**	**100**	**100%**
		**96**	**4**	**100**	**96%**
		**100**	**0**	**100**	**100%**

		**98**	**2**	**100**	**98%**
Average Recognition Rate of Pillars		**494**	**6**	**500**	**98.8%**

Table 2. The Recognition Rate Analysis of Goupra for Different Temples.

Test Images	**Recognized Images**	***α***	**γ**	***δ***	**σ (in %)**
		**100**	**0**	**100**	**100%**
		**98**	**2**	**100**	**98%**
		**97**	**3**	**100**	**97%**
		**100**	**0**	**100**	**100%**
		**97**	**3**	**100**	**97%**
Average Recognition Rate of Goupra		**492**	**8**	**500**	**98.4 %**

From Table.1 it is shown that Recognition rate found is 98.8 % accuracy in Recognizing the pillars of different temples.

From Table.2 it is shown that Recognition rate found is 98.4 % accuracy in Recognizing the vimans(Goupra) of different temples.

7. Conclusion and Future Scope

A simple and effective Recognition method was developed for Recognition of pillars and vimans(Goupra) of different temples. Here, we use a standard digital camera with a 16 Megapixel resolution to take the photographs, making it incredibly simple to use and completely free in comparison to other techniques. This is a useful tool for the researcher to quickly and easily recognize the pillars and vimans (Goupra) of various temples. This tool can be easily adopt and used by archaeologists for Recognition of pillars and vimans(Goupra) of different temples across world. It is also helpful for archaeologists to get more detailed information of ancient monuments which is very important for further research. The suggested method extracts genetically programmed, developed spatial descriptors for the Recognition procedure and identifies the temple structural elements as pillar or vimana(gopura) based on Generalized Co-Occurrence Matrix and linear discriminant method [LDA]. The proposed method is quite effective for recognizing the structural components of a temple, according to experimental data. This research work will play very significant role in conservation and reconstruction of temples. This sincere work can be extended to further steps of Image Processing like feature extraction, identification and classification. Recognition is helpful for archaeologists to get more detailed information of ancient temples which is very important for further research in the field of Archaeology.

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Authors’ Profiles

Gurudev S. Hiremath received Graduation (B.E.) in 2010 from Information Science and Engineering at Visvesvaraya Technological University, Belagavi and Post-Graduation (M.Tech.) in 2012 from Computer Science and Engineering at JNN College of Engineering, Shivamogga, affiliated to Visvesvaraya Technological University, Belagavi, Karnataka. He also pursuing Ph.D. in Computer Science and Engineering, UBDTCE research center affiliated to VTU, Belagavi, Karnataka, India. He is currently working as Assistant Professor in Department of Computer Science and Engineering, KLE Institute of Technology, Hubli, Karnataka, India. His research interests include Image Processing and Computer Vision, Deep Learning, IOT, Pattern Recognition, Web development.

Narendra Kumar S. received Graduation (B.E.) in 2005 from Computer Science and Engineering at Visvesvaraya Technological University, Belagavi and Post-Graduation (M.Tech.) in 2012 from Computer Science and Engineering at BIET, Davangere, affiliated to Visvesvaraya Technological University, Belagavi, Karnataka. He also pursuing Ph.D. in Computer Science and Engineering, UBDTCE research center affiliated to VTU, Belagavi, Karnataka, India. He is currently working as Assistant Professor in Department of Computer Science and Engineering, JNN College of Engineering, Shivamogga, Karnataka, India. His research interests include Image Processing and Computer Vision, Deep Learning, IOT, Pattern Recognition, Web development.

Shrinivasa Naik C. L., he obtained his Graduation (B.E.), Post-Graduation (M-E.) from University Visvesvaraya College of Engineering, Bangalore University. Received Ph.D. from Indian Institute of Technology (IIT)-Guwahati, Assam, India. He is currently working as a Professor, DOS in Computer Science and Engineering, UBDT College of Engineering, Davangere, Karnataka, India. He published many papers in National and International journals, conferences. His research interests include Image Processing and Computer Vision, Deep Learning, Data Science, Pattern Recognition.

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