ANCIENT KANNADA DOCUMENT RECOGNITION - A DEEP LEARNING APPROACH

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Abstract:
Kannada language is a famous ancient languages and it is a formal reading, writing and speaking language in Karnataka state. Karnataka has one of the heritage states in India. The ancient Kannada scripts provides us the related information about tradition and culture. We can enhance our historical knowledge by retrieving these kinds of information from carving the stone, palm leaves and also from the documents written on the paper. Retrieving and recognizing ancient Kannada scripts is a tedious task because of occluded characters, less quality, less contrast scripts and differentiation of various periods. To lessen the above difficulty, in this work, an automated recognition technique is proposed using advanced and recent deep learning classifier with SIFT feature extraction method. The CNN model is adopted for classification and recognition of the ancient Kannada script. For experimentation, the various periods such as Satavahanaru, Chulukyaru, and Vijayanagar ancient Kannada datasets are used. As a result of this work, an average recognition rate of 92.45% is achieved.

Keywords: Ancient Document, CNN, Deep Learning, Kannada, PCA, SIFT.

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Introduction

Kannada is one of the famous and oldest historical southern Indian language, which has its own scripting style derived by Brahmic family. It is founded in before 230BC in the form of inscriptions. Inscriptions are the basic and primary form of any language, which are used to gain the historical knowledge, which includes an astronomy, traditions, medication, administration, politics, religion, art, educational and economic conditions and so on.

In order for Experimentation, Kannada inscriptions can be found in several historic locations like Shravanabelagola, Badami, Belur, Mysore, Hampi, Halebeedu, Nagarle, Hospet caves, etc are the have pool of ancient documents carved on the stones. We all know that, the inscriptions are completely different than the existing scripting language, it is highly tedious task to read and recognize the inscriptions [1]. Hence, it is very much necessary to recognize the inscriptions to gain the historical knowledge. The people, those who can easily recognize the inscriptions are known as epigraphers. But, in this modern era, it is highly impossible to find out the epigraphers for recognition of inscriptions. Even, if we find out the epigraphers, it is very time-consuming task to carry out manual recognition. This is a major drawback of manual recognition system of inscriptions.

With the advancement of science and technology, it is very much necessary to develop an automatic inscription recognitions technique to eliminate the problems of manual inscriptions recognitions technique. This recognition system scans the inscriptions, take out the relevant features, depending on the extracted features classification will be carried-out, and at the end recognizes the inscriptions. The inscriptions have collection of ancient characters.

As a preliminary task, in this proposed work, an effort has been placed to recognize the ancient characters of BC and AD periods by using deep learning classifier. Figure 1 shows the evolution of character from 3rd B.C to Present Kannada.

Figure. 1 Evolution of character from 3^{rd} B.C to present kannada

Related Work

In any research work and for every researcher, it is very much necessary to know the related work of the proposed research work. In this connection, authors have carried out the detailed literature survey in this section.

Recognition of Hoysala and Ganga's characters in Kannada stone inscriptions by using new recognition approach has been reported in Ref. [2].

The Standard Deviation, Mean, and Sum of Absolute difference Algorithm (SDMSADA) has been reported in [3] to recognize the Historical characters in Kannada stone inscriptions. Here, in the dataset, the Ganga and Hoysala periods characters are considered. The Markov Model is presented in [4] to recognize the Kannada handwritten character.

A new feature is proposed in 2015 and termed the 'Positional Distance Metric' for addressing the various challenges on the stone inscribed images of any language script. To achieve the encouraging recognition success rate, the zone and image based Normalized Positional Distance Metric features are computed and compounded along with the regional and structural characteristics. This procedure has been repeated to all the training images and inhibited into the list. Here, to classify and recognize the characters, the nearest neighbor classification technique is utilized. There are 350 characters are used in testing and achieved a better recognition rate of 84.8%, which nearly 10% higher compared to earlier techniques [5].

In [6], for recognition of Kannada handwritten characters, two techniques are presented by using Tesseract tool and Convolution Neural Network (CNN) respectively are presented. The key idea behind these proposed techniques is for extracting the text from the scanned images and identifying the Kannada alphabets accurately. These recognized Kannada letters are stored for future usage. An average recognition rate of 86% and 87% is obtained with the Tesseract tool, and CNN respectively.

A novel SDMSDA (Standard Deviation, Mean, and Sum of Absolute Difference Algorithm) approach to recognize the Ganga and Hoysala Ganga period alphabets is proposed in 2015 by Rajithkumar [3]. The said historical alphabets are recognized and converted into modern Kannada scripts based on the ADMSDA values. Then have chosen 16 characters of forty datasets and achieved a better efficiency in time and higher and efficient recognition accuracy of 98.75% in testing results.

An efficient approach to recognize the Kannada handwritten characters is presented in 2020. This approach uses the various digital image processing methods for enhancing the image quality and for exploring the deep learning method for extracting the various features from the given image. This approach is very simple and easy for understanding by the user. The dataset called 'CHARS74K' was utilized for testing process of the proposed work. Recognition process is carried out on handwritten vowels and consonants of Kannada language, which consists of 657 classes of 25 handwritten characters. For validating the proposed approach, the Categorical Cross Entropy Loss Function (CCELF) is utilized along with the 15 epochs for measuring the error rate. This approach is very useful for documentation purpose in government offices. This approach yields the overall average recognition rate of 95.11% and 86% in training and testing datasets respectively [8].

Hamid [9] portrayed a deep learning-based characterization technique for effective characterization of production of sample document datasets of Medieval Paleographical Scale (MPS) dataset. This technique very useful for historical manuscript dating. With the adaptation of transfer learning on the number of favorite trained CNN (Convolution Neural Networks) approaches. Using this technique, they have decreased the MAE (Mean Absolute Error) which are recorded in the state of art approaches.

In 2019, a new classification and recognition system has been proposed using deep leaning techniques especially Neural Network (NN) to classify and recognize the handwritten Kannada characters. This system is as easy to the users as it does not contain any data preprocessing stage. This decreases the load of the user to make the task more promising. This system is trained with the good number of data, which includes the handwritten Kannada characters. This system provides an average accuracy of 93.2% and 78.73% by experimenting two varieties of datasets. As per the authors' opinion, this recognition system can be upgraded to classify and recognize the words and sentences as their future scope [10].

With the effective usage of statistical feature extraction techniques, in 2019, a new recognition method is portrayed to identify the Devanagari handwritten historical manuscripts. This method involves the 3 stages, they are feature extraction, classification and recognition. In first phase, the various features such as open endpoints, intersection points, horizontal and vertical peak extent, and centroid are extracted using various feature extraction techniques. In second phase, the neural network, the CNN, Random Forest, RBF-SVM, and Multilayer Perception techniques are used for classification process. The pre segmented datasets of 6152 samples were used for testing in the proposed system and by the simple majority voting scheme, this system yields an average recognition rate of 88.95% [11].

A data visualization technique based; a highly scalable retrieval system is presented in 2017 to retrieve the Nandinagari characters. For detecting the point of interests (POI) and to derive the feature descriptors, the SURF and SIFT techniques are used. This proposed technique is very useful to recognize even the images having occlusion without or minimal preprocessing operations. The key aim of this technique is to achieve the robust and efficient descriptors which are very useful for calculating the dissimilarity matrices. In SURF, the calculation time is lesser than SIFT technique but the SIFT is more robust the SURF. In both the SURF and SIFT descriptors, the dissimilarity matrices are subjected to distinct clustering techniques for grouping the similar Nandinagari handwritten characters. For specifying the cluster numbers, the PAM and K-Means algorithms are used and PAM is better than K-Means. For the said descriptors, the agglomerative clustering technique is much suitable [12].

Panda [13], provides an outcome of spectral clustering approach and K-Means approach to the printed vowels of Odia language. For experimentation, they have considered the small set of symbols and achieved a better result using K-Means clustering technique than spectral clustering technique.

Chandrakala et.al. [14] proposed DCNN (Deep Convolution Neural Network) method to recognize the Kannada handwritten historical characters. This method was tested with the digitized Kannada historical stone inscription, which belongs to 11th century and better results are noticed.

Proposed Work and Methodology

The process flow diagram of the proposed work is depicted in Figure 2, which consists two key phases; cognition and recognition.

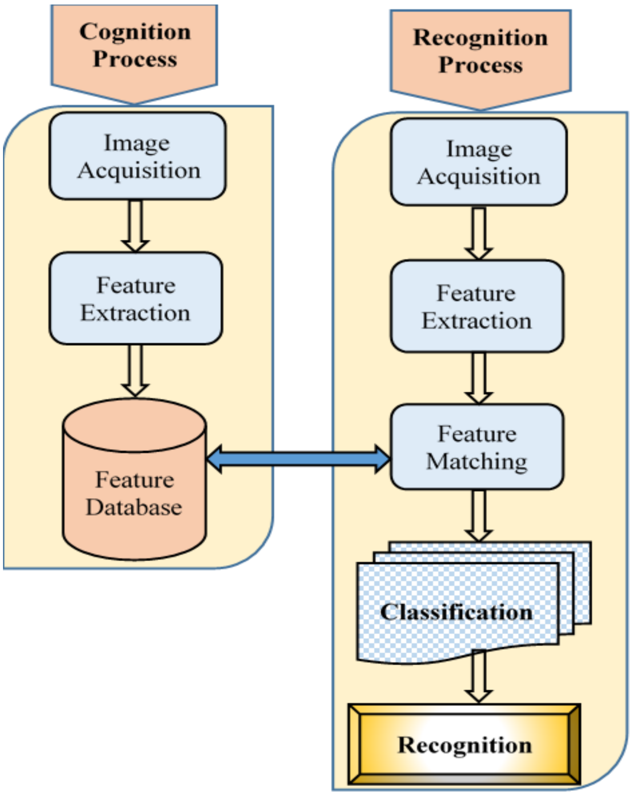

Figure. 2 Process flow diagram of the proposed method

Initial two step processes are common in both the cognition and recognition phase i.e., Image acquisition and Feature Extraction. Image Acquisition is performed using a mobile phone camera. Once the input image is acquired, various key features are obtained by the SIFT (Scale-Invariant Feature Transform) technique. Then, these extracted key features are loaded to the database called feature database, and the same will be used in the recognition phase for feature matching.

In recognition phase, once the features are extracted, these extracted features are matched with the features already available in the cognition phase database. These matched features are passed to classification process. For classification and recognition, the deep neural network-based CNN (Convolution Neural Network) classifier is utilized. As a resulting part, recognized image is displayed with the proper label.

The following sub-section explains the methodology/techniques used in the proposed work.

3.1 SIFT Descriptors

It is one of the well-known feature extraction technique in digital image processing. SIFT is generally used to depict neighborhood locales from an image in scale and rotational way [15]. The SIFT technique, which receives the digital image and extracts the large collection of various local features from it. These kind of vector components is subject to interpretation, scaling, and turning of the digital image. The SIFT technique works in 4 separate phases.

3.1.1 Scale spacing extrema detection

The first phase distinguishes the areas and the scales which are recognizable using distinct views on the identical type of articles. This viably be trained by the 'scale space' exertion. Further, this has been exposed below reasonable suspicions and it should establish on the Gaussian limit which is denoted by the equation (1).

$L(y, z, \sigma) = G(y, z, \sigma) * I(y, z)$ (1)

In equation (1), '*' is a convolution operator, G(y, z, σ) is the variable-scale Gaussian, and I(y, z) is a input digital image. Gaussian quantification is a type of context, finding out the scale-space extrema, D(y, z, σ) which enrolls the difficulty between both the digital images, one with scale 't' times compared with the other. D(y, z, σ) is denoted as in (2).

$D(y, z, \sigma) = L(y, z, t\sigma) - L(y, z, \sigma)$ (2)

While differentiating closer minimum and maximum of $D(y, z, \sigma)$ every individual point was compared and its 8 neighbors at the equal scale. Suppose, if this value is the breakpoint or base for all the centres and this breakpoint point will be an scale spacing extrema.

3.1.2 Keypoint Localization

This cracks for wiping out distinct focuses by the run-down of keypoints by choosing those with less intricacy on the edge which are ineffectually restricted. Area of extremum, 'E', is denoted as:

$$E = -\frac{\partial^2 D^{-1} \partial D}{\partial X^2 \partial X} \qquad 3)$$

where, 'D' is difference of Gaussian scale space and 'X' is the location of the extremum.

3.1.3 Assigning Orientation

These advances emphasis for rolingout the consistent route for the keypoint depending on the nearby digital image key features. The descriptor keypoint, showing in the next subsection, is in contrast with this direction, interpreting the uprising invariance. Key focus scales for choosing smooth Gaussian image 'L' by registering slope greatness 'm' and denoted as in the given equation (4).

$$m(x, y) = \sqrt{(L(x+1, y) - L(x-1, y))^2 + (L(x, y+1) - L(x, y-1))^2} \quad (4)$$

Calculate the orientation, θ which is given in (5)

$$\theta(x, y) = tan^{-1}\left(\frac{L(x, y+1) - L(x, y-1)}{L(x+1,, y) - L(x-1, y)}\right) \qquad (5)$$

3.1.4 Keypoint Descriptor

In 4th phase of SIFT descriptor, keypoint descriptors is performed by close by edge information, which is discussed in earlier section. Angle data pivoted for aligning with the keypoint route and consequently weighted using Gaussian with 1.5*keypoint scale variation. This data is utilized to make a huge amount lot of histograms among the keypoint-focused window. Keypoint descriptor typically uses the sixteen histograms, mounted in a 4 x 4 frame, and are individually with 8 directions. For every basic compass bearing and also one for every mid-purpose of such headings. The process is depicted in Figure 3.

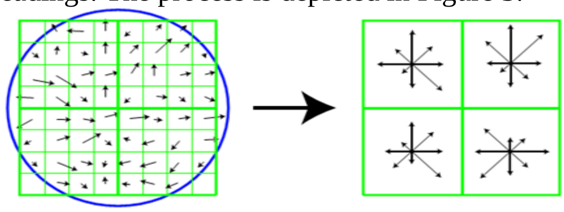

Figure. 3 Image gradients and keypoint descriptor

Convolutional Neural Networks

Deep Learning (DL) is new trend and branch of machine learning. One of the DL frameworks i.e., Convolutional Neural Network (CNN) has recognized its proficiencies in the classification and recognition of digital images era. Presently, all the models of computer vision and pattern recognition in an audio-visual or text domain are determined by the handcrafted feature sets. However, in case of image data, this can not be able to compare the human proficiencies. For addressing these kinds of issues, many researchers performing in pattern recognition field are discovering the might of Deep Learning and CNN. The general architecture of CNN is shown in Figure 4.

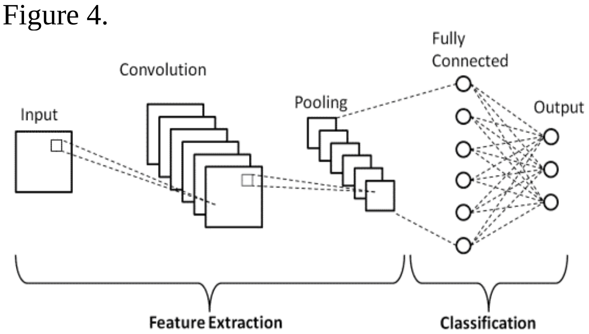

Figure. 4 CNN architecture

An abstract description of the CNN structure is given in the equation (6), which is run layer-by layer.

$x^1 \rightarrow w^1 \rightarrow x^2 \rightarrow \cdots \rightarrow x^{L-1} \rightarrow w^{L-1} \rightarrow x^L \rightarrow w^L \rightarrow z$ (6)

where, x^1 is input, w^1 is tensor, x^2 is the output of 1st layer and it is an input to the 2nd layer. Similarly, x^{L-1}, w^{L-1} are the input and tensor of the last but layer, called softmax layer of the CNN structure. Finally, x^L, w^L, and z are the input, tensor and output of the last layer, called Loss layer.

Equation (6) can be written as a simple loss function z as in the equation (7) to measure the descripancy between the x^L and t.

$$z = \frac{1}{2}||t - x^L||^2 \qquad (7)$$

Where, t is the corresponding truth i.e., target, and x^L CNN predection.

Results and Discussion

In any research work, results and discussion is an important and key section to evaluate the proposed work. In this connection, authors have evaluated and discussed the proposed work in this section. In this proposed work for experimentation, authors have created their own image database to evaluate the system.

Tables 1 to 3 shows the overall average classification performance (F-measure average) achieved by the proposed shape description for Shaatavahana, Chaalukya and Vijayanagar datasets respectively with three distinct SIFT feature such as DOG SIFT-I, DENSE SIFT-II and PHOW SIFT-III.

F-measure is computed by the equation (8).

$$Fmeasure = 2 * \frac{(P*R)}{(P+R)} \qquad (8)$$

Where, P and R are the Precision and Recall respectively.

To evaluate the ability of the proposed system, an exhaustive experimentation has been carried-out on distinct dataset viz. Shaatavaahanaru, Chaalukyaru and Vijayanagara. A progression of investigations are led for 50 irregular parts of preparing and experimenting the tests in the proportion of two groups i.e., 60:40 and 50:50 individually. The demonstration of the presented system is surveyed using the normal *F*-score/measure for all the datasets mentioned. The shape interpretation plans with the other distinctive SIFT plans and the normal *F*–measure are classified in the accompanying as in the tables for every considered dataset.

Table 1. Overall average classification performance of shaatavaahana script

Shape Features	**60:40**	**50:50**
	Average F-Measure	**Average F-Measure**
DOG SIFT-I	84.32	81.32
DENSE SIFT-II	89.69	89.91
PHOW SIFT-III	91.22	89.43
Average	**88.41**	**86.88**
	87.64	

Table 2. Overall average classification performance of chaalukya script

Shape Features	**60:40**	**50:50**
	Average F-Measure	**Average F-Measure**
DOG SIFT-I	87.23	86.40
DENSE SIFT-II	96.60	96.20
PHOW SIFT-III	95.43	95.99
Average	**93.08**	**92.86**
	92.97	

Table 3. Overall average classification performance of vijayanagar script

Shape Features	**60:40**	**50:50**
	Average F-Measure	**Average F-Measure**
DOG SIFT-I	97.26	93.84
DENSE SIFT-II	97.98	94.52
PHOW SIFT-III	97.90	98.92
Average	**97.71**	**95.76**
	96.74	

From the Table 1, 2, and 3, for all the three scripts, it is noticed that 60:40 groups provide more accuracy than the 50:50 groups. It is also noticed that the Vijayanagar scripts yields the highest average accuracy of 96.74% compared to other two scripts used in this proposed work which is shown in figure 5.

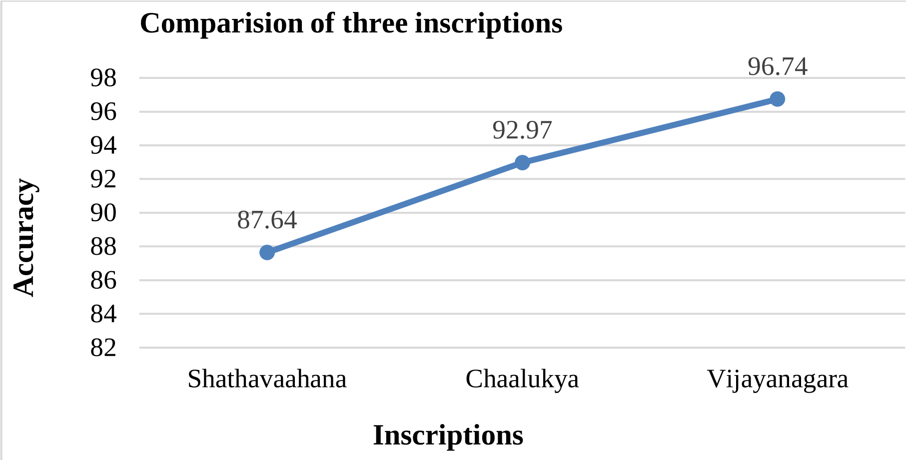

Figure. 5 Comparison of 3 scripts

Table 4 gives the details of some of the existing works, their feature extraction techniques and classifiers used in recognition of ancient Kannada documents.

Table 4. Some of the existing works

Authors & Ref. No.	Features and Classifier Used
Abhishek S. Rao et. al., [8]	Deep Learning Techniques
H. T. Chandrakala et. al., [14]	A Deep Convolutional Neural Networks (DCNN) and SVM
Ravi .P et. al., [16]	LBP, Gabor filter and GLTP features with Symbolic classifier
A Soumya et. al., [17]	Normalized Central Moments, Zernike Moments and Random Forest (RF)

The comparative average recognition accuracy of some of the existing works and proposed work in recognition of ancient Kannada documents is depicted in Figure 6.

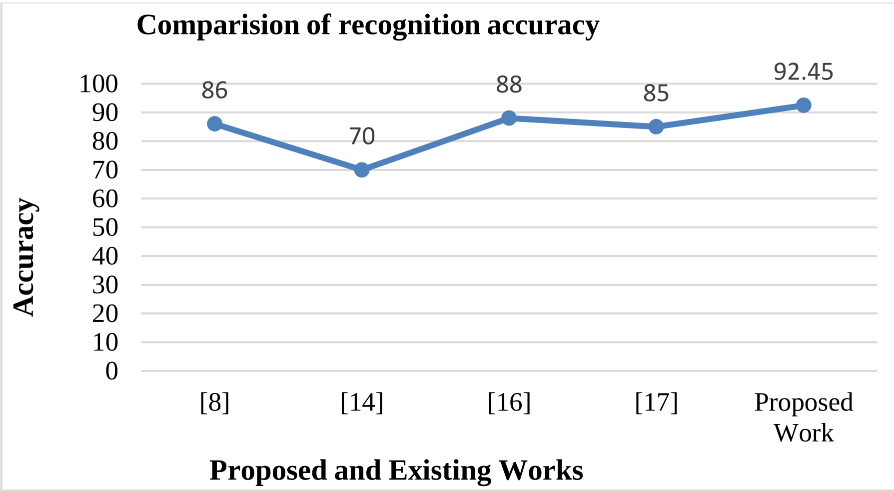

Figure. 6 Comparison of recognition accuracy

Conclusions

In this research article, authors have proposed an automated recognition technique using advanced and recent deep learning classifier with SIFT feature extraction method. For experimentation, the various periods such as Shatavahanaru, Chulukyaru, and Vijayanagar ancient Kannada datasets are used. Figure 1 shows the evolution of character from 3rd BC to present Kannada. The system architecture of the proposed work is presented in Figure 2, consists retrieving an input, extracting the various features from the input using SIFT technique. The CNN classifier is utilized for efficient classification of the input by using extracted features. At last, based on the classification result, recognition of script is obtained. As a result of the proposed work, Figure 5 and 6 shows the average recognition rate three various scripts used in the proposed work and also the proposed work with other existing works. It is noticed that the proposed work yields the average recognition rate of 92.45% which is better than existing works.

Conflicts of Interest

The authors declare that they have no conflict of interest regarding this paper.

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