Convolutional Neural Network Based Handwritten Marathi Text Recognition

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Abstract— **Among several Devanagari scripts available in India, Marathi compositions are also rich source of the information. Comparatively large work has been done on OCR like English, Arabic, Sanskrit, and Kannada and so on however; very little work was accounted on recognition of Marathi contents. Over the recent years, the handwritten Devanagari text recognition has attracted numerous researchers to do the investigation. Different procedures were proposed by the various researchers to perform the recognition. Deep neural systems are picking up the popularity in the field of Computer Vision (CV) and Machine Learning (ML). Recognition of handwritten Devanagari characters is a difficult errand, however, Deep learning can be adequately utilized as an answer for different such issues. In this paper, we proposed a CNN based OCR framework which precisely perceives manually written Marathi words and delivers great quality printed Marathi text. We have proposed a character segmentation free methodology for perceiving the manually written Devanagari text written in Marathi language and reproduced the perceived words in printed form. Because of the limited availability of the Marathi training dataset, we have arranged our own training dataset. The dataset is prepared with assistance of individuals belonging to age group of 8 to 45 years. Our dataset has 9,360 words (104 words with 90 images each). The training accuracy of CNN model is 94.76 %. In the proposed framework, conventional character segmentation step is avoided and direct words are considered for feature extraction. The features acquired during the training and features obtained from the segmented words are mulled over to make the judgment. The novelty of the proposed OCR is its robust behaviour to different handwriting styles, which settles on it as perfect choice for digitizing manually written Marathi contents. The outcomes accomplished through this proposed strategy are excellent, 98 % words are accurately recognized.**

Keywords— **Convolutional Neural Network, Devanagari word recognition, handwritten OCR, Marathi OCR, Handwritten Devanagari OCR, handwritten to Printed OCR**

I. Introduction

Numerous Indian Government as well as private workplaces are utilizing Devanagari Script for correspondence as well as keeping the records. Most of the time printed or handwritten paper reports/documents are captured by digital means and put away as computerized records. Through the use of DIP strategy, paper documents are stored in a computerized but processable/configurable format. Best in class Optical Character Recognition (OCR) strategies are equipped for giving adequately high correctness on printed archives [1].

The OCR can likewise be exceptionally helpful for postal location acknowledgment [2], cheque acknowledgment, video text identification, re-establishing of old and authentic reports [3] etc. In the event that somebody needs to change or modify some portion of document, the entire report should be physically arranged with the assistance of human composing administrators. With the scanned document images of various reports, we can't utilize the search tool to find/locate a specific word or expression. Another advantage of digitizing the archive is the space required to store the records is less when contrasted with direct putting away the scanned report pictures.

This paper basically focuses around "textual handwritten data handling and recognition". The offline OCR procedure uses the stored computerized pictures and online strategy manages to record the composing when somebody is composing on the computerized surface utilizing some information gadget like the pointer of light-pen [4]. So as to encourage digitization of text reports, we assemble an Optical Character Recognition System (OCR) utilizing Convolutional Neural Network (CNN), explicitly for handwritten Marathi content. In the ongoing years, a few OCRs have been produced for different Indian dialects, for example, *Hindi* [5], *Bangla* [6], *Telugu* [7] and so forth. Very less work has been done to grow automatic OCRs for handwritten Marathi language. Some work was reported earlier to recognize and reproduce the Marathi characters without any modifiers as well as with few modifiers. The greater part of the ongoing Indic OCR frameworks Support Vector Machines (SVMs) and Artificial Neural Networks (ANNs) to categorize letters in the picture [8]. In the course of recent years, Deep Learning (DL) approaches have been fruitful in different regions, for example, natural language processing (NLP), image classification [9] and so on. So as to build up a strong OCR framework with high precision, we proposed the utilization of Convolution Neural Networks (CNN). The CNN pre-trained models, such as the GoogLeNet [10], ResNet [11], VGG Net [12] have accomplished best in class results for 3 channel images. The OCR methods follow a fundamental pipeline [13] of data acquirement, pre-processing, feature/attribute extraction and classification. Deepti Khanduja [14] in their paper exploited the structure level properties of a characters and used end points, convergence points, branch points, and quadratic polynomial coefficients as highlighting features. Gyanendra K. Verma [15] investigated the curvity of characters and utilized curvelet transform for feature extraction and k-closest neighbour (KNN) as classifiers. A CNN comprises numerous convolution layers followed by fully connected layers that interface each neuron in one layer with every neuron in another layer [16]. There are various choices [13] that a CNN developer needs to choose before convolutional learning. A choices are: Number of the convolution layers, Number of filters and size of filters, Number of pooling layers with step size, Number of masked (hidden) neurons in dense layers, and enhancement algorithm to be utilized, etc.

Some key challenges [17] while recognizing handwritten Marathi text are: Variation in strokes of handwriting, overlapping handwritten character, *matra* or *ukar* may be sometimes disjoined from the letters, variations in spacing, skew at character or word level, degraded quality due to ill advised handling and preservation, lack of availability of dataset etc. Recognizing individual Marathi characters is an even troublesome task in light of the fact that some characters in Devanagari *lipi* are fundamentally the same as one another like "*ma*" and "*bha*", or "*va*" and "*ba*" or "*sa*" and "*ra*" etc. and numerous others as referenced in Figure 1. These letters/characters have approximately same features because of same appearance and same strokes while writing them. This may further lead towards producing the incorrect recognized output.

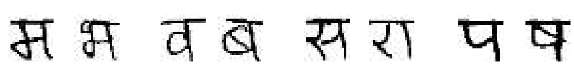


Fig. 1 Approximately similar Devanagari (Marathi) characters

In printed Marathi text, unique and similar font and styles are used throughout the entire document. So the features could be easily extracted. But in case of handwritten Marathi text document the writing styles may vary person to person. The variation of individual's writing style is the key challenge in developing handwritten OCR system. This is because variations in the handwriting will make it difficult to identify the exact features [18].

Fig. 2 Sample handwritten Marathi Words

Couple of cases of variations in handwriting are shown in figure 2. First image has inclined Shirorekha whereas others have exact flat Shirorekha. In addition with this, few writers may have habit to extend the lower modifiers like ukar long enough so that they overlap with the next subsequent character (refer second image of figure 2). Because of overlapping of such modifiers it became difficult to segment the characters. If the written text/words have the fused/composite characters (image 3) then the character segmentation task becomes further difficult. In our proposed system, we are eliminating the character segmentation stage. The complete word will be given as input for training the CNN model. The CNN model is proficient for learning the features automatically from the training samples in an unsupervised manner. The CNN model itself will take care of all the features to be extracted. The available pre-trained CNN models were designed for color images. For our proposed system, the pre-trained CNN models are not suitable; hence we have designed our own simple 20 layer CNN model.

The paper is organized in four different sections. Section II has the overview of the Devanagari script. The Deep Learning concept and CNN architecture overview is described in section III. The proposed methodology is demonstrated in section IV. Section V contains the experimentation results.

II. Devanagari Script

Devanagari is the most fundamental script for the huge number of dialects, like Marathi, Hindi, Gujarati, Nepali, Konkani, Bhojpuri, and so forth. Devanagari lipi is utilized in the establishment of 12 well-known dialects in India. Devanagari characters hang down from a flat straight line (header line or Shirorekha [8]) composed at the head of the each character. The main stroke, or strokes, in a character, are composed from the left of page to right side and are then trailed by any down strokes and lastly the head strokes are included. It ordinarily takes somewhere in the range of three and five strokes to compose a Devanagari character. The vowels in the Devanagari content transpire as altered shapes in words. These transformed characters are called allographs or modifiers [19]. They additionally have plenty of bends that are absent scripts like English and few more dialects [16]. Marathi text comprises of a few compound characters which are shaped by various blends of half letter and full letter consonants. A few instances of compound characters are referenced in figure 3.

Fig. 3 Examples of compound Marathi characters

III. DEEP LEARNING

Deep learning is a part of Machine Learning (ML) that encourages PCs to do learn from facts like humans learns from their experience over the period of time. Deep learning is particularly most appropriate for recognizing the images and shapes. A Convolutional Neural Network (CNN or ConvNet) is one of the most well-known algorithms for deep learning. They gain knowledge legitimately from pictures itself to classify them eliminating the need of manual feature extraction. Like other neural systems, a CNN is made out of an input layer, an output layer, and many concealed (hidden) layers in the middle.

A. *CNN Architectures*

The CNN is a assembled of three essential layers [13] which are: convolution layer, pooling layer or sub-sampling layer and classification layer as appeared in figure 4.

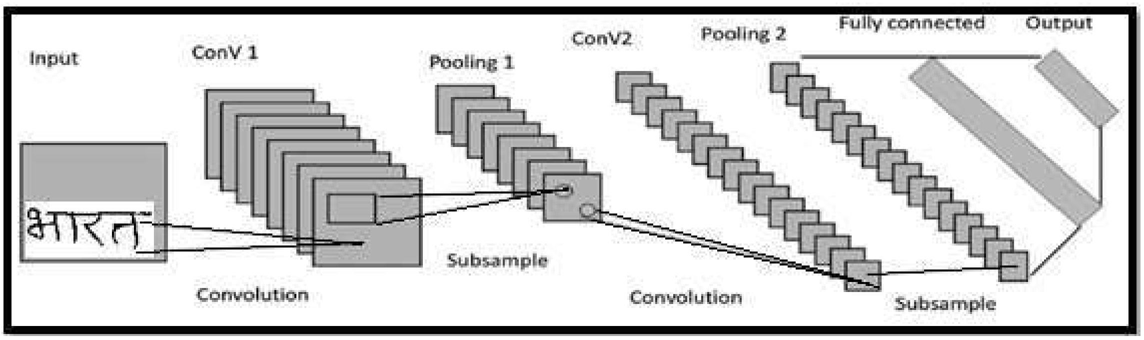


Fig. 4 Layers structure of CNN model

The input to this CNN architecture is the picture/image to be classified. The input is the raw picture/image that could possibly be pre-processed or not pre-processed. The overlapping fragment of weighted filter is known as the receptive field. Mainly the convolution layer extracts the features [13] from the input image. With nearby receptive fields within this layer, the neurons can extricate primary information like corners end points, edges, and so forth [20]. These extracted features are then utilized as a contributing input to succeeding layers so superior level features can be extracted from the image. A convolution layer contains numerous filters so as to extract various prominence features at every stage. Along these lines, the filter is convolved over the whole image and diverse activation maps are acquired as appeared in Figure 4.

1) *Image Input Layer*

The input layer of CNN accepts the input image to be classified. An input layer indicates the picture size. For example 28 x 28 x 1 (grayscale picture of 28 x 28 pixels) or 28 x 28 x 3 (color picture with pixel size 28 x 28).

2) *Convolution Layer*

Convolution layer is also called as feature extractor layer since features of the input image are extracted within this layer. In CNN model there could be multiple convolution layers. The initial convolution layer will extract the major features and subsequent layers extract the fine details. The filter size is usually smaller than the input and the sort of augmentation is a dot product between them. The output height and width of a convolution layer is

$$(Input\ Size - ((Filter\ Size - 1)\ x\ Dilation\ Factor\ +\ 1)\ +\ 2\ x\ Padding)/Stride\ +\ 1.$$

3) *Batch Normalization Layer*

Batch normalization layer is generally utilized between convolution layers and nonlinearities (ReLU) to normalize the activations and gradients propagating from start to finish of a system. The normalized activations are calculated with equation

$$\widehat{x_i} = \frac{x_i - \mu_B}{\sqrt{\sigma_B^2 + \varepsilon}}$$

Here, ε improves mathematical steadiness when the mini-batch variation is especially small.

4) *ReLU*

The convolution and batch normalization layers are frequently followed by a nonlinear activation function such as a rectified linear unit (ReLU). The ReLU doesn't modify the dimensions of the input rather it does thresholding, where any input value less than zero is set to zero, that is,

$$f(x) = \begin{cases} x, & x \geq 0 \\ 0, & x < 0 \end{cases}$$

5) *Max Pooling Layer*

Pooling layer discards some of the spatial information in order to minimize the parameters. It reduces the dimensions or parameters by taking a compilation of neurons and sinking them to a single value for succeeding layers to accept as new input.

6) *Fully Connected Layer*

It interfaces neurons in a single layer to neurons in another layer. This layer joins all the features learned by the past layers over the picture to recognize the bigger patterns. The last fully connected layer consolidates all the features and classifies the images as per their properties. The output size parameter of this layer is equivalent to the number of classes of the dataset.

7) *Softmax Layer*

The output of fully connected layer is normalized by the Softmax activation function. Usually, the Softmax layer produces an output which consists of positive numbers whose sum is equal to one; they are considered as classification probabilities by classification layer for further processing.

8) *Classification Layer*

The probabilities defined by the Softmax layer are utilized by this layer to allocate the input to one of the mutually exclusive classes. Within the classification layer, the values from the Softmax function are considered and allocated to every input to one of the K mutually exclusive classes.

IV. PROPOSED METHODOLOGY

The proposed method starts with scanning of handwritten Marathi text, followed by pre-processing steps. The pre-processed images were utilized for line and word segmentation by finding blank row and column respectively. The segmented words are feed to CNN network. The CNN network will extract the features and make the judgement to produce the recognized result. The workflow of proposed method is mentioned in figure 5.

Fig. 5 Handwritten Marathi OCR framework using CNN

A. *Data Acquisition*

The mobile phone document scanner is utilized to scan the handwritten Marathi text documents. To obtain the picture of sensible quality high resolution cameras are preferred. We have used 16 MP mobile Camera for scanning the document images. The acquired pictures were put away in one folder for performing pre-processing operations.

B. *Preprocessing*

Generally document image pre-handling steps are used for improving the appearance of secured images for extracting highlighting features. Mobile camera or Optical scanner may incorporate clatters and clamours while capturing the document images; like unwanted shadows, additional dark spots, dispersed lines, variations at the edges etc. [21]. Hence, before starting the actual word recognition process, the immaculate image must be obtained from the scanned image. Generally, image binarization is used to diminish a maximum pixel data in grayscale image to a little amount. In image binarization stage, each pixel in an image is supplanted with a dark pixel if the intensity of image pixel I(i,j) is less than certain value T (pixel = 0; if I(i,j) < T) or a white pixel if the image pixel intensity is more T (pixel = 1; if I(i,j) > T).

C. *Skew Correction*

Skew is the angle made by the image contents with the horizontal direction. The skew correction is done on complete scanned document rather than correcting the skew of individual word. The skew may hamper the accuracy of line and word segmentation therefore for proper word segmentation the skew correction is essential. For recognizing and adjusting the skew, we have utilized Radon Transform [22] technique. By utilizing the Radon Transform we are figuring the projections of a picture along with specific directions. Projections are figured along any edge Θ. For the most part, Radon transform of function f(x, y) is the line basic of corresponding to the y-axis

$$R_\theta(x') = \int_{-\infty}^{\infty} f(x'\cos\theta - y'\sin\theta, x'\sin\theta + y'\cos\theta)dy$$

D. ***Feature extraction***

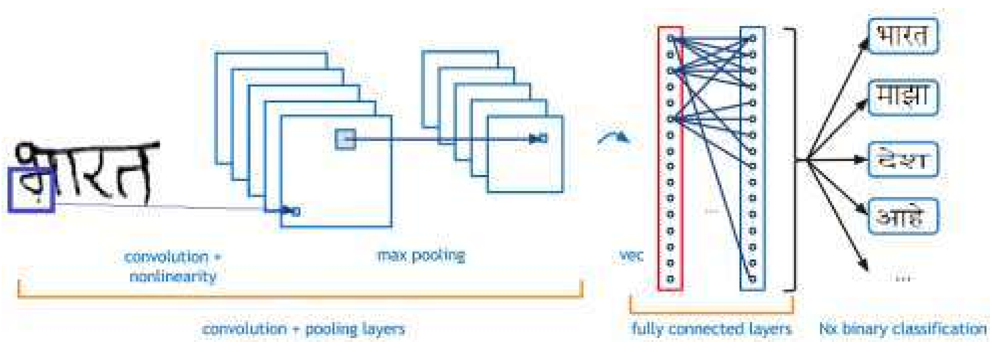


Fig. 6 A simple CNN framework of OCR

A simple 20 layer CNN model is proposed for handwritten Devanagari word recognition. The handwritten OCR framework is shown in Fig 6. The first layer in OCR framework is input layer that comprises of the raw pixel values from the 36 x 96 binary pictures. The initial convolution layer is C1 has 96 filters with size 3 x 3. C1 extracts the feature map which appears in the figure as 2D planes. All the units in a feature map share a similar arrangement of weights thus they are initiated by similar features at various places. Every unit in a layer gets its contribution from a tiny neighborhood in the same position from the earlier layer. Since all the units are actuated distinctly from the information taken from a nearby neighborhood they identify nearby features like corners, edges, and end points. C1 has 1 input and 1 output.

The convolution layer is followed by batch normalization and ReLU layer. The batch normalization layer normalizes the activations and gradients received from convolution layer. The ReLU is nonlinear activation function which is generally used to minimize the features by thresholding technique. The pooling layer (S1) follows the ReLU layer. The pooling layer lessens feature map components obtained from the convolution layer by averaging the features in the local area for the greatest value. Since the specific position of feature changes for various pictures of a similar word, it is desirable that the framework should not learn the features from absolute position rather they should gain proficiency with the relative position of the features. The pooling layer accomplishes this objective and makes the classifier progressively safe to move and twist.

The next convolution layer (C2) has 128 filters of size 3x 3 trails this sub-sampling (pooling) layer. Each feature map in the C2 layer is created by taking a contribution from previous layer S1. The units in C2 get their contribution from the 3 x 3 neighbourhood at the indistinguishable position of certain layers in S1 and not all. The reason behind not connecting C2 parameters with all parameters of S1 is to trim down the trainable parameters. The yield of this convolution layer is subsampled, convolved, and sent to next layer. Here, we have used total 4 convolution layers followed by batch normalization and ReLU layers. Dropout layer with probability of 0.5 is used before the fully connected layer. The fully connected layer has 104 output classes. The depth of the network and the size of various layers to be utilized within the network system rely incredibly upon the training dataset.

Thus, during experimentation, we have tested various designs by changing the number of layers and parameters of each layer (number of filters and size of filters etc.) and proposed the simple 20 layer CNN architecture for recognizing the handwritten Devanagari words which reproduces the recognized words in the printed form. The results of the experimentation are presented in results section.

V. EXPERIMENTATION AND RESULTS

A. ***Training dataset***

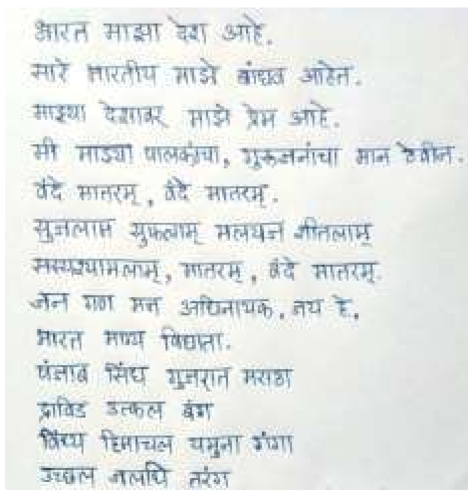
Due to unavailability of standard Marathi words dataset, we have prepared our own training dataset. The sample training words are collected from the several persons belonging to 8 to 45 years age groups including primary and secondary school students as well as college students. As the writing may change depending on the mood of the writer and quality of writing material/instruments, some sample training words are collected in the morning, few are collected in the afternoon and maximum are collected in the evening. For experimentation purpose, we have used 104 words while preparing the samples. 104 words, with 90 samples of each are considered here. Each word is resized into 36 x 96 pixels to maintain the uniformity. Out of 9,360 samples images, 80 % data is used for training the CNN model and 20 % is used for validation. This dataset could be increased in future with all possible Marathi words. The Natural Language Processing or Computational Linguistics (NLP/CL) lab of IIT Hyderabad has their own Hindi dataset. This dataset could be used in future with few modifications.

Fig. 7 Sample training dataset images (size 36 x 96 x 1)

The sample training dataset images are referenced in figures 7. Each training image is binary image of size 36 x 96. Sizable number of experimentation was done by changing the number filters and size of filters in convolution layer, activation functions, initial learning rate, number of epochs, validation frequency, mini batch size etc. The best validation accuracy obtained is 94.76 % with learning rate of 0.1.

B. Testing

The original scanned copy of handwritten Marathi text document image having 13 lines and 55 words (67 including punctuation marks) is shown in figure 8. The document is pre-processed to improve its quality by removing the shadows and black spots or clamours introduced at the time of scanning. The pre-processed document is utilized for line segmentation.



भारत माझा देश आहे.
सारे भारतीय माझे बांधव आहेत.
माझ्या देशावर माझे प्रेम आहे.
मी माझ्या पालकांचा, गुरुजनांचा मान ठेवीन.
वंदे मातरम्, वंदे मातरम्.
सुजलाम् सुफलाम् मलयज शीतलाम्
सस्यश्यामलाम्, मातरम्, वंदे मातरम्.
जन गण मन अधिनायक, जय हे,
भारत भाग्य विधाता.
पंजाब सिंध गुजरात मराठा
द्राविड उत्कल बंग
विंध्य हिमाचल यमुना गंगा
उच्छल जलधि तरंग

Fig. 8 Handwritten Devanagari document

The blank row information was used to segment the text lines. The scanned image then segmented to separate the textlines. The segmented textlines are stored in “Lines” folder. The result of line segmentation is shown in figure 9.

Fig. 9. Result of line segmentation

During next step, the earlier segmented text lines were considered and checked for the blank column. The segmented texlines from “Lines” folder are read one by one and then the columns are examined. When the algorithm finds the blank column the words are segmented and stored in “words” folder. The dimension of segmented words are made uniform i.e. 36 x 96. The result of word segmentation after resizing is shown in figure 10.

Figure 10. Result of word segmentation with resizing

These segmented words were allowed to go through the designed CNN model. The extracted features from CNN model were analysed to make decision about recognition and output is produced in text file. The recognition result obtained for image (figure 8) is shown in figure 11. Out of 55 words, 54 words are correctly recognised and reproduced. The only one word from line number 10 is incorrectly recognized i.e. "*gujarat*" is recognized as "*hyantach*". The handwritten to printed Marathi text conversion accuracy is 98.19 %.

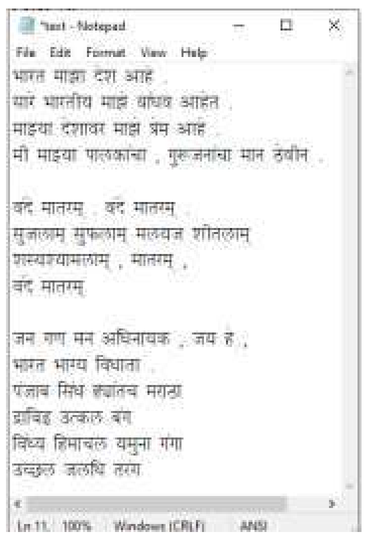


Figure 11. Result of handwritten Marathi text recognition

The results obtained with the proposed method are compared with the earlier research done on handwritten Devanagari character recognition. The details of the comparative study of performance analysis can be found in table 1

TABLE I
COMPARATIVE STUDY OF PERFORMANCE ANALYSIS

Authors	Methods	Recognized	Classes	Accuracy
Shailesh Acharya et al. [9]	Use of Dropout layer in CNN	Handwritten Characters	46	98.47 %
Madhuri Yadav et al.[13]	Various optimization algorithms	Handwritten Characters	41	97.95 %
Deepti Khanduja et al.[14]	Local and global features using MLP	Handwritten Characters	10	93.4 %
Prasad Sonawane et al. [23]	Fine tuning of CNN with transfer Learning	Handwritten Characters	22	95.46%
Savitha Shetty et al. [24]	Use of Dropout layer in CNN	Handwritten Characters	46	97.46 %
Shalini Puri et al. [25]	SVM Classifier	Handwritten Characters	51	98.35 %
Surendra Ramteke et al. [26]	Weighted SVM Classifier Based on SCA	Handwritten Characters	33	95.14 %
Proposed model	20 layer CNN model	Handwritten Marathi words	104	98 %

VI. Conclusion

Many researchers used the word as well as character segmentation approach for recognizing the handwritten Devanagari letters. With the proposed methodology, the requirement for character segmentation is totally eliminated. Moreover, the issues identified with upper and lower modifiers and combined/fused characters are resolved to great extent. With this experimentation and results acquired, it tends to be unmistakably observed that ordinary handwritten Marathi text can be effortlessly changed over into printed Marathi text with 98 % accuracy. The Handwritten Marathi word recognition and replicating them into the printed structure has accomplished great outcomes utilizing Convolutional Neural Network (CNN) which reduces the manual human efforts to a huge degree.

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