Human Face Recognition by Cognitive Model using Fuzzy Clustering Technique

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Abstract:
Face recognition by using the cognitive modeling has been introduced in this paper. Various existing tools and techniques which fit into the cognitive development has been highlighted. A new concept of "fuzzy clustering technique" of N samples with respect to R representative class has been introduced. The "distance of descent" from the few selected reference nodes are estimated for all the samples (N) and stored for the matching process. For recognition of an unknown face, the minimum distance is found out between the image-i and the reference images from N samples. The result shows a good result for a small database of size 100, which is illumination invariant.

1. Introduction

The word "Cognition" means mental activity, which involves in acquisition, storage, and retrieval of knowledge. In other word, it is the process of psychological development of human brain. Cognitive science is a contemporary field of study that tries to answer questions about the nature of knowledge, it's components, it's developments and it's use [19]. Cognitive scientists have the opinion that human thinking involves in the manipulation of internal representation of the external world, known as cognitive models. Only in recent part, the scientist tried to develop intelligent machines by using cognitive methods/approaches. Two main components of cognition are perception and learning.

Perception [8] is a process that uses our previous knowledge to gather and interpret the stimuli (outside world information) registered by the sensory organs. Two aspects of perception are most relevant for cognition. They are pattern recognition and attention. Pattern recognition involves identifying a complex arrangement of sensory stimuli, such as a letter of the alphabet, a human face or a complex scene. When one person recognises a pattern, his sensory processes transform and organise the raw information provided by the sensory receptors and he compares the sensory stimuli with the information stored earlier, in other memory location, called permanent memory or Long term memory. On the other hand, attention is responsible for our more extensive processing of some information, while other information is neglected or suppressed, for instance finding a face from the scene.

By definition, Learning is a process by which it involves with stimuli from the outside world in the form of examples and classifies these things without given any explicit rules [25]. For instance, a child cannot distinguish between cat and a dog. But as he grows, he can do so, based on numerous examples of each animals, given to him. Learning involves with a teacher, who helps to classify things by correcting each time, when the learner commits a mistake. In machine learning, a program takes the place of a teacher, who discover the mistake. It is better to mention here that since the invention of computers, it is not clearly known, how to make them learn. Over the periods of time, algorithms have been developed that are effective for certain types of learning. But only recently a theoretical understanding of learning borrows the ideas from diverse fields like artificial intelligence, probability and statistics, information theory, psychology and neuro-biology, philosophy, and control theory. There are numerous methods and techniques of learning available in literature [3], [6], [13], [18], [22]. In this paper, we have proposed the face recognition system by utilising the techniques of perception and learning.

The paper has been classified into five sections. Section-II highlights various tools and techniques of the face recognition. Section-III describes the cognitive method for image matching. Simulation and result have been given in section-IV. Conclusion has been given in Section-V.

2. Review of Literatures

Over the periods of time, there were various techniques developed for machine learning and perception. They were categories basically into four techniques namely, i) Template matching, ii) Prototype matching, iii) Distinctive feature comparison and iv) Computational techniques.

Usually non-human pattern recognition systems are based on templates. A template system [20] works well for computer that are provided with a standardised set of numbers. But the templates matching are totally inadequate

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for complex pattern recognition, because it is not flexible. It was used for recognition of only letters and numbers. Here an infinite numbers of templates were necessary to recognise all possible variations, found among numbers and letters. This process could not accommodate the variations of rotation and scaling. Secondly, this approach cannot handle complexities of human visual processing. Therefore, there was a need for more flexible system rather than matching a pattern against a specific template.

The second approach i.e. prototype matching is a flexible version of template matching. Here a set of abstracts and idealised patterns are stored in memory. Matching does not need to be exact, rather variations are allowed. If the match is closed enough, the stimulus is recognised. If the match is inadequate, the stimulus is compared with other prototypes, until a perfect match is located. It includes certain characteristics of facial features. The prototypes are stored in memory not as templates but like features such as hair style, fore head, presence of absence of glass, etc.. This method helps to recognise the variety of different representation of the same shape, variety of orientation of the shapes and fragmented view of shapes. It consists of the features common to all or most of the instance of pattern, such as a round heads, high forehead, long eye, high mouth etc.. But the demerit of this technique is that it is not full proof. Research are still going on, to find the exact matching algorithm.

Distinctive feature approach states that discrimination are made on the basis of small number of characteristics. These characteristics differentiate one entity from another are called distinctive features. A list of feature components for each entity are stored. Here the pattern recognition involves detecting specific important part of stimulus in contrast to the other matching models. There are many literatures available pertaining to this approach. We will be discussing few of them below.

Computation Approach aims at rapid and accurate recognition of three dimensional objects. The use of computers to simulate this perceptual processes is known as machine vision. There are various machine learning approaches for the 3D object recognition [24]. Our model is based on prototype matching and distinctive feature approach. We will elaborate it in next section. Before that let us briefly analyse few of the existing methods.

Brunelli and Poggio in their paper [5], implemented two algorithms. One is based on the computation of a set of geometrical features, such as nose width and length, mouth position and chin shape and the other is based on the gray-level template matching. They have reported that the face recognition based on geometrical features gives around 90% correct recognition where as template matching gives perfect recognition. But template matching is very time consuming and cannot handle large database of facial image. On the other hand, the feature based face recognition can handle large database of faces. But gives a result which is less than 100%. Krisnamurthy and Ranganath have reported a feature based face recognition system by using the Eigenspaces and Wavelet approaches [15], which gives comparatively good result. Chaddha, et. al. proposed a Neural Network based technique [7], for recognition of human faces, using the outline profile of the end view of the human face. This pattern yields a set of good discriminate features for identification. Here nose point, chin points, forehead point, bridge points, nose bottom points, throat points, upper lip point, mouth of centre lip point, chin curve point or lip bottom point, brow points are extracted and they are trained by using a back propagation Neural Networks. As a new face is given as the input of the network, it is able to recognise the face. The accuracy of the system is not good, as it was taking only the side face features. Sinha P. proposed an adaptive Neural network based approach [23], by which the pair of images to be compared should be presented to the Neural network as source (input) and target images. The Neural network learns about the symmetry between the pair of images by analysing the examples of associated feature pairs belonging to the source and target images. From such pairs of associated features, the Neural Network searches out proper locations of target features from the set of ambiguous target features by fuzzy analysis during its learning. If any of target features searched out by the Neural network, lies outside the prescribed zone, the training of the Neural network is unsuccessful. In case of successful training, the neural network gets adapted with appropriate symmetry relation between the pair of images. When the source image is input to the trained Neural network, it gives an processed source image as output which is later superimposed in target image and identity is established. Zhang and Fulcher reported a face recognition system using Artificial Neural Network Group-based Adaptive Tolerance (GAT) Trees [29]. It is a hierarchical classification, maps on to binary tree structures where each leaf node corresponds to a separate category of faces. Decisions are made in descending down the tree, through each intermediate node, as to whether the current input sample belongs to a specific subclass or not. Only an N-levels are required in practice to discriminate between a large (2N) categories. Robert and Ritter in their paper [21], propose an Artificial neural network method for human face recognition. They used three neural networks of local linear maps types, which enables a machine to identify the head orientation of a user by learning from examples. One network is used for colour segmentation, the second for localisation of the face and the third for the final recognition of the head orientation. This technique could not gain importance, because it suffers from mapping problems.

Goudail F. and et. al. in their paper [9], investigated the face recognition method based on the computation of Auto-correlation coefficients. Auto correlation coefficients are

computationally inexpensive, inherently shift-invariant and robust against changes in facial expression. But it can be further extended by segmentation of module based on template matching. T. Kondo and H. Yan reported a feature based face recognition using Cross correlation [14]. Wiskott, et. al. proposed a technique [26], where faces are represented by labelled graphs, based on Gabor Wavelet transform. Image graphs are extracted by an elastic bunch graph matching process and can be compared by a simple similarity function. It is a general method, used for recognising members of a known class of objects. But it is no way specialised to faces. Later Yeal Adini [1] improved the method using 2D Garber like function, which can recognise face with respect to the change in illumination condition. Larry S. Davis went a little further and proposed a method [27] to recognise to human facial expression by long image sequence optical flow. Narendra Ahuja [2] proposed a transformation technique to extract image regions at all geometric and photometric scales. It is intended as a solution to the problem of multiscale, integrated edge and region detection or low level image segmentation. Lanitis and et. al. have reported in their paper [16], recognition of human faces using shape and gray level information. In their approach, they have represented the face by using a small number of parameters, which can be used to code the overall appearance of faces for classification. The approach control both inter class and intra class variations. Discriminant analysis techniques are employed to enhance the effect. This method reported a good result w.r.t. variation of viewpoint, illumination and facial expression.

Now, broadly speaking we can divide the human face recognition process into two categories, i.e. from the geometrical features (such as nose width, mouth position and chin shape) or from gray level template matching. In geometric feature-based matching, a face can be recognized even when the details of the individual features are no longer restored (such as eyes, nose, mouth). The remaining information is, in a sense, purely geometrical and presents, what is left at a very course resolution. In template matching, the image, which is represented as a bidirectional array of intensity values, is compared using a suitable metric (typically the Euclidean distance) with a single template representing the whole face. Several full templates may be required for the recognition from different viewpoints. On the other hand, if for a single viewpoint, multiple template is considered, then a face is stored as a set of distinctive smaller templates. Here a single template is used together with a qualitative prior model of how a generic face transforms under a change of view point. The deformation model is then heuristically built into the metric, used by the matching measure. This underlying idea is popularly known as elastic templates matching.

In geometric feature based Matching, the extracted features must be some how normalized in order to be independent of position, scale, and rotation of the face in the mage plane. Translation dependency can be eliminated once the origin of co-ordinates is set to a point that can be detected with good accuracy in each image. To achieves scale and rotation invariance by setting the inter-ocular distance and the direction of the eye-to-eye axis. The normalization rescales the template and image energy distribution so that their average and variances match. To make collection more robust against illumination gradients, each image has to pre-normalized by dividing each pixel by the average intensity over a suitable large neighborhood. As Correlation is computationally expensive therefore, it is performed starting from the lowest resolution level progressively reducing the area of computation from level to level by keeping only a progressively smaller area.

3. Image Matching by Cognitive Method

Psychological studies [8] reveals that the human being recognizes the face from the selected features of the face such as pattern of the eye, structure of the nose, size of the mouth, shape of the eyebrow, forehead etc. This human like reasoning is exploited here to design a cognitive model for face recognition using fuzzy clustering technique. A large number of the existing clustering techniques without supervision are available for image matching [28] [4]. Among them nearest mean classification [10], Non parametric clustering [11], Hierarchical clustering [10] and Interactive Clustering [28] are important.

Let us see how to create the R-dimensional matrix out the facial database images. First the facial image template is partitioned into few distinct segments like eye, nose and mouth. The process is done through a moving window of eye, nose and mouth over the facial image. These selected segments of the face such as eye, nose and mouth are compared with the few representative nodes of eyes, nose and mouth respectively, shown vide fig-1. These representative eyes, noses and mouths are selected based on an intuitive method to cover all the variations of facial features, such a long eye, short eye and normal eye, long nose, flat nose and moderately small nose, long lip mouth, short lip mouth and normal mouth. These representative nodes are the cluster centers of their respective clusters. After comparison, with all the representative nodes the distances of descent of the eye, nose and mouth of a facial image are recorded in a matrix say the “Fuzzy Scatter Matrix”, shown in fig.-2.

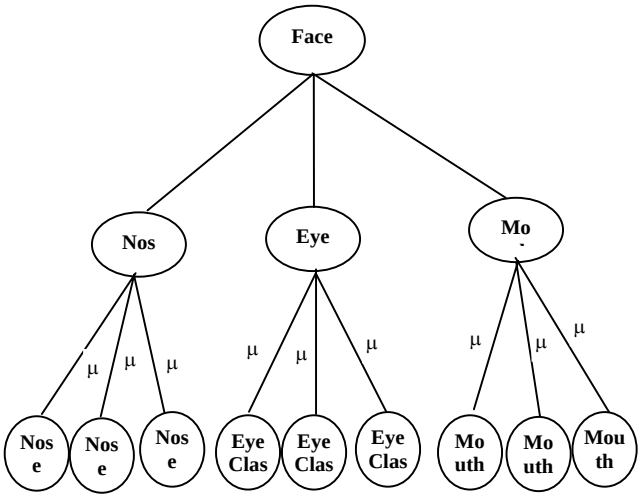

Fig. 1: Representative Node of Nose, Eye and Mouth

During the recognition process, matching of the test face with the entire facial database is not required, but the comparison is done only with 'R' representative nodes, thereby saving the processing time by a factor of (R/N). we will be discussing the fuzzy clustering representation in this section followed by image matching algorithm

3.1 Fuzzy Clustering Technique

Let us now define the fuzzy clustering in a formal way. It is a numeric value (FC) assign to every possible classification of a collection of samples. Here, the domain of FC is the set of all possible classification of a collection of samples and the range of FC consists of the real numbers classifications which are good in the sense that the adapted definition of a cluster are assumed to correspond to extreme values of FC. Thus given the value of FC, any particular classification can be evaluated.

It is generally impractical to calculate FC for every possible classification. Therefore in classical clustering methods, a clustering algorithm is required to efficiently determine the best classification with respect to a particular class CI . But in the proposed fuzzy clustering technique, it has been attempted to assign membership values to each of N samples, characterized by n-dimensional vector, w.r.t each R known classes (C1, C2 ….. CR), where R is apriori known/ selected nodes. Each sample has a member value w.r.t. each of the known class denoted by CKI (K=1, …….R; I=1, …….N). Here each sample is clustered into a R-representative class and a fuzzy membership value is assigned to it. A representation Ω, is a vector made up of the WKI's and a configuration X* is a vector made up of the XI's that is :

$\Omega = [W_{K1}\, W_{K2.}, \ldots, W_{KN}]^T$ and

$$X^* = [X_1^T X_2^T \ldots\ldots\ldots X_N^T]^T$$

The Fuzzy clustering is a representation of distance of descent of each sample from each representative classes and denoted by

$F_C = F_C(\Omega; X^*) = F_C(W_{K1}\ W_{K2,}\ \ldots,\ W_{KN},\ X_1, X_2, \ldots, X_N)$

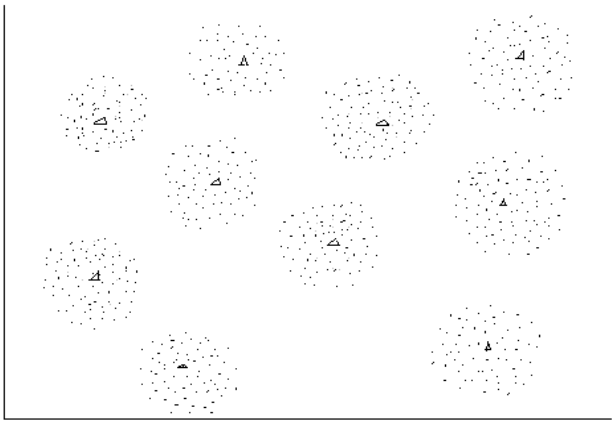

Fig. 2: Representation of the Fuzzy Clustering in R-dimensional Space

Selection of Representative nodes: The selection of the proper representation nodes is the most difficult task in fuzzy clustering technique. No unified theory for choosing the representative node has been developed. Therefore we have used heuristic approach in selecting the nodes, which cover all the variations of facial features, such a long eye, short eye and normal eye, long nose, flat nose and moderately small nose, long lip mouth, short lip mouth and normal mouth.

In our experiment, the distance of descent of each feature is estimated from the respective representative nodes by the measurement of fuzzy cross correlation, derived in the next subsection. The input to the program is a data matrix of front face image of 64X64 pixel size taken either by a CCD camera or scanner.

3.2 Fuzzy Cross-Correlation

The concept of fuzzy cross-correlation is borrowed from the classical cross-correlation [11] with the exception that the (+ and $\times$) is replaced by fuzzy $\otimes$ operator. The properties of classical correlation i.e. reflective around the middle element is preserved too in the fuzzy correlation. The concept is illustrated in Example-1. Fuzzy cross-correlation estimates the two sequences of fuzzy matrices. Fuzzy auto-correlation is a special case of correlating the matrices with it self. The relation is defined by the equation (1):

$$R_{ab}(m,n) = \bigvee_{i=0}^{M-|i|-1} \bigvee_{j=0}^{N-|j|-1} (A(i,j) \wedge B\Sigma(i+m,j+n)) \quad (1)$$

where A(i,j) is indexed from 0 to M-1 and 0 to N-1;
BΣ (i,j) is indexed from 0 to M-1 and 0 to N-1 reverse in time ;
$R_{ab}(m,n)$ from -(M-1) to (M-1) and -(N-1) to (N-1);
and M=2*i-1 , N=2*j-1.
It's operation is like convolution with one of the two sub sequences reversed in time [12].

Example-1: Let A and B be two arbitrary matrices and C be the fuzzy auto-correlation of A and D be the result of fuzzy cross-correlation of A with B.

$$A=\begin{pmatrix} 0.1 & 0.6 & 0.3 \\ 0.8 & 0.5 & 0.2 \\ 0.9 & 0.7 & 0.4 \end{pmatrix} \text{ and } B=\begin{pmatrix} 0.7 & 0.8 & 0.9 \\ 0.6 & 0.5 & 0.7 \\ 0.3 & 0.2 & 0.4 \end{pmatrix}$$

Then the matrices C and D are given by:

$$C=\begin{pmatrix} 0.1 & 0.4 & 0.6 & 0.6 & 0.3 \\ 0.4 & 0.7 & 0.8 & 0.1 & 0.3 \\ 0.4 & 0.7 & 0.9 & 0.7 & 0.4 \\ 0.3 & 0.6 & 0.8 & 0.7 & 0.4 \\ 0.3 & 0.6 & 0.6 & 0.4 & 0.1 \end{pmatrix}$$

$$D=\begin{pmatrix} 0.1 & 0.4 & 0.4 & 0.3 & 0.3 \\ 0.4 & 0.6 & 0.5 & 0.6 & 0.3 \\ 0.7 & 0.6 & 0.6 & 0.6 & 0.3 \\ 0.8 & 0.8 & 0.7 & 0.6 & 0.4 \\ 0.9 & 0.8 & 0.7 & 0.7 & 0.4 \end{pmatrix}$$

After obtaining the fuzzy correlation of two relational descriptor, the degree of similarity is measured by the relation given below.

$$\text{Degree of similarity} = 1/2 \sum_{i=0}^{n} \sum_{j=0}^{n} (a_{ij} - a_{(n+1-i)(n+1-j)}) * (a_{ij} - a_{(n+1-i)(n+1-j)}) \quad (2)$$

The outcome of the above relation will be zero if the matrices are the same. In the above example the result is zero for matrices C and a non-zero quantity for matrices D.

Distance of Descent: During the matching process the distance is computed for the unknown image, w.r.t. 'R' representative class. Next, these distances are compared with N samples of n vectors. The minimum distance known as distance of descent is found out from the N samples denoted by

$$Fuzzy\ \ distance\ \ of\ \ descent\ = \max(\bigvee_{i=1}^{N} \bigwedge_{j=1}^{R} C_{ij})$$

Similarly fuzzy distance of descent is found out for each features. Finally, the image is recognized by a fuzzy If Then rules. The algorithm for matching is given in the next subsection.

3.3 Matching Algorithm

The algorithm of the facial image matching is given below:

Procedure: Creating a Fuzzy Scatter matrix from the Facial database
Begin:
Select the representative classes of nodes by a heuristic method //The different sizes of nose, mouth, eye pattern is selected for representative class//
For image- i= image-1 to image-N
Find the distance from the each of the representative class node // Each nose, mouth and eyes of a face is compared with representative nose, mouth and eye respectively by cross correlation method and distance of descent is estimated by expression no (2)//
Develop a Fuzzy Scatter matrix in a tabular form.
End ;

Procedure: Image Matching using the Fuzzy Clustering Technique
Begin:
Find the distances of descent of unknown face w.r.t. the same representative class of node.

For image- i= image-1 to image-N
Find the fuzzy distance of descent of the unknown face w.r.t. the extracted features
eye, nose and mouth.
Recognize the exact face from fuzzy distance of descent by the fuzzy IF THEN rule.
End ;

4. Simulation and Results

In our experiment the facial images are taken in the environment given in table-1. This technique has been tested with a database of 400 size, of 40 classes. But for the demonstration of the algorithm let us see the result for a smaller database of 14, shown in fig 3. Here the figures are not free from noise and blurring. Secondly it has been taken at various intensity of light. The prominent features such as eye, nose and mouth are extracted by the cross-correlation method, given in expression-1. Each eye, nose and mouth is compared with the representative eye, nose and mouth of three each. In the Simulation, Nose of Facial image 1, Facial image 3, Facial image 4 and Facial image 12 are taken as Reference Nose class to include all the varieties of size and shape. Similarly Eyes of Facial image 1, Facial image 3, Facial image 6 and Facial image 10 are taken as Reference Eyes and Mouths of Facial images 3, Facial image 4, Facial image 9 and Facial image 13 are taken as Reference Mouth class. These fuzzy scatter matrices are estimated by fuzzy MAX/ MIN operator after getting the fuzzy distance of descent for eye, nose and mouth. During the recognition phase, the face is recognized by a (fuzzy IF .. THEN) rule. For instance any test face has to be matched with the existing database. Here the eye, nose and mouth of the test face is first extracted and the measurement of the distance from the reference classes are found out then, this R-dimensional vector is compared with the fuzzy scattered matrix. The distance of the descent is estimated from the N dimensional sample data and the matched image is found out.

Table 1: Experiment environment

Conditions	***Training Images***	***Test Images***
Lighting conditions	Variable	Variable
3D moments	No	No
Expression	Variable	Variable
Distance from camera	Fixed	Fixed
Spectacles	Yes	Yes
Beards	No	No
Mustaches	No	No
Hair style changes	No	No
Background	Variable	Variable

The following test images are fed into the process for recognition. This shows 97% success rates on the target image with the failing 3% due to wearing of eye glasses, rotated faces beyond 50 and blurred image.

Fig 3. Sample Database of Facial Images

Table 2: Fuzzy Scattered Matrix estimated from the Distance of the Sample Classes from the Reference Nodes using Cross-Correlation Operator

Image Faces	N1	N3	N4	N12	E1	E3	E6	E10	M3	M4	M9	M13
F1	0	12.3	9.7	19.4	0.0	16.7	41.5	31.1	4.9	13.3	14.7	18.9
F2	21.3	31.6	22.8	36.3	25.2	12.7	19.6	24.0	18.7	17.4	21.9	20.8
F3	12.3	0	13.8	8.5	16.7	0.0	18.1	14.6	0.0	12.6	13.7	20.2
F4	9.7	13.8	0	20.4	18.0	9.8	25.3	13.0	13.2	0.0	15.7	18.9
F5	16.4	9.4	20.5	8.1	35.5	22.4	24.7	30.9	39.4	14.6	6.2	15.9
F6	9.2	6.6	13.8	16.1	41.5	18.1	0.0	18.2	12.6	29.5	41.6	9.8
F7	27.2	38.9	29.7	44.1	40.6	22.7	19.5	26.9	12.2	18.6	21.9	16.2
F8	7.6	19.5	9.8	27.1	34.7	15.8	12.9	21.5	41.2	16.9	21.7	29.6
F9	4.8	18.0	12.2	25.8	36.4	16.6	12.0	21.7	14.8	29.8	0.0	30.6
F10	4.1	16.1	9.4	23.5	31.1	14.6	18.2	0.0	12.9	22.7	16.8	29.7
F11	10.3	5.8	15.3	14.2	39.5	18.9	13.8	25.5	21.6	29.6	13.7	6.0
F12	19.4	8.5	20.4	0.0	20.7	5.7	15.8	16.4	13.9	21.7	23.6	9.5
F13	13.8	4.2	16.3	11.4	29.7	8.8	11.6	14.8	29.1	26.5	9.6	0.0
F14	21.2	32.7	26.0	38.1	22.9	6.6	19.3	17.0	11.2	9.8	13.6	15.8

5. Conclusions

Human face detection and recognition have drawn considerable interest and attention from many researchers for decades. It has several applications such as criminal investigation, authentication in secure system bank teller machines etc. The first step of face recognition process is the face location process or briefly saying eye location step. Accurate detection of eye components will enable the development of an accurate face recognition system. When face orientation is more than 20% towards either side of normal to the plane, the eye detection fails. In this situation, mouth can be taken as a reference object. A standard detection technique such as normalized correlation template matching is one among the few techniques used for face recognition. In this paper we have exploited the fuzzy clustering technique for the face recognition process. The experiment shows a result of 97% with the free environment.

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