FAST AND ROBUST GRAPHIC CHARACTER VERIFICATION SYSTEM FOR TV SETS[1]

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ABSTRACT

In this paper, we present a flexible system to verify any kind of graphic TV character or symbol in television charts. The proposed approach is very robust towards translations, rotations, changes in scale and illumination variations of the graphic characters. Another important attribute of the proposed system is its speed. The system should be very fast since the characters have to be verified in a real production line of TV sets. The proposed system is composed of fast and accurate preprocessing modules in order to normalize the characters, and a PCA-based verification method. Results show a very high performance with verification rates over the 99.8%.

1. INTRODUCTION

Optical Character Recognition (OCR) is one of the most successful and mature field of automatic pattern recognition [1-4]. Nevertheless, usually OCR techniques or commercial applications [5,6] are specific for some type of characters or limited to a small set. In this paper we proposed a flexible system which can be used for any type of graphic characters including logos in an image acquired from a TV set. This huge flexibility, combined with a fast and robust method which is invariant to color, displacements and scale, are the main contributions of this paper. Our character verification system consists of the following processing steps (Fig 1):

- *Image pre-processing*: Conversion from color to gray scale.
- *Region of Interest selection*: Segmentation to isolate individual characters.
- *Feature extraction*: PCA module
- *Character recognition*: Verification using an error distance classifier like Mean-Nearest Neighbor.

The initial requirements of the system that we have developed were:

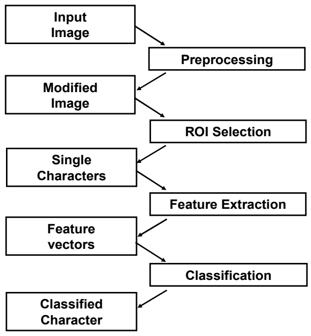

Fig 1 Steps in a character recognition system

1- Large variety of size in input characters.
2- Any kind of character, graphic or symbol should be verified independent of the background and character color.
3- More than 100 characters should be verified in less than half a second.
4- Correction of illumination and displacements.

These strict requirements have been solved by including several pre-processing modules that can cope with the large variety of size and types of characters. A Principal Component Analysis (PCA)-based approach has been integrated to the system to solve the large number of character class.

The rest of the paper is organized as follows. Section 2 gives an overview of the flexible verification system including some aspects of the image acquisition system, and the training stage tool. Section 3 gives some details about the modules added in the system for normalizing, and verifying the characters, whereas in section 4 the results of the TV character verification system are presented. Section 5 summarizes the final conclusions.

2. INITIAL CONSIDERATIONS

As already mentioned, the system presented in this paper has been designed to verify any type of TV alphanumerical characters like a 'C' or non alphanumerical like a '→'. In this section we will explain

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the different steps that should be considered for training the system.

2.1 Image Acquisition System

The image acquisition system is composed of a command sequencer which sends TV charts to a TV set. Those TV teletext charts are acquired by a high resolution camera so that small characters could also be verified. The set of characters includes any size, color and typography as shown in Fig 2.

The acquired image can present the following distortions:

1. Translation due to a movement of the high resolution camera at the moment of acquiring the image.
2. Illumination variations due to environment conditions.
3. Scale variations due to changes of the aspect ratios (16:9, 4:3).
4. Perspective distortions due to some misalignments of the TV set in the production line.

2.2 Training Stage

Every verification or recognition system needs first to be trained in order to get some information to perform the verification or recognition. Thus, we have developed an interface tool where we select a reference image with the Teletext chart that includes the graphical characters to verify. With the help of this tool, we can select and mark all the characters that should be later verified on the production line. The interface tool permits also to define Regions Of Interest (ROI) by specifying the color of the character (foreground) and the color of the background. These background and the foreground colors are computed using the mean value of a neighborhood of pixels that has previously discarded the extreme values (outliers). These ROIs will be used to make the system invariant to the colors of the characters and the background of the Teletext Charts as explained in section 3.1.2. The output of this interface tool is the position and color of each character as well as the color of the background.

Once these positions have been stored is would be easier to find the characters in the image on a different TV set during the verification stage in the production line.

The second step in the training stage is to compute a feature space which compacts all discriminative information on a small set of coefficients. This is very important, since the verification method should be fast and robust to the illumination variations. So, if we performed a comparison between characters in the pixel domain, this will probably lead to errors and also it would require a higher computational burden. Thus, PCA will be used to find the best set of vectors (basis or feature space) that represent a certain set of training images containing

Fig 2 Example of characters

the characters.

Hence, a training set of M pictures provided by the Image Acquisition System is used to extract the feature space using the PCA method. The output of this stage is a set of features which are the best representation of the initial set of characters. For more details about PCA the reader is addressed to [1].

3. VERIFICATION STAGE

Given a new image that contains characters, the verification process is performed as follows:

1- Segmentation of the characters in the test image, using as start point the positions of the characters of the reference image that have been stored at the training stage.

2- Normalization of the segmented characters using a pre-processing module.

3- Projection of the normalized character into the feature space obtained at the training stage, for computing a small set of coefficients that will be used for computing an error distance (Euclidean distance).

4- Verify if the error distance is below an adaptive threshold. In this case the character will be accepted

3.1 Pre-processing steps

The pre-processing steps are a key component for the system because they provide the invariance in color, scale, rotation and translation making the TV character verification system very robust.

3.1.1 Affine Projection

An affine transformation has been implemented to solve the problems of translations, rotations and scale. When an image is provided by the Image Acquisition System is possible that the picture presents some perspective distortions or displacements. It is important to correct all these problems because the PCA-based verification method is very sensitive to small changes in rotation and translation.

3.1.2 RGB to Gray Scale Projection

One important aspect that we have already remarked is that our system can verify any type of character independent of the color. For this reason, a RGB to gray scale projection module has been added to the system. A character image can be represented by a background and foreground color. These colors have been defined for each

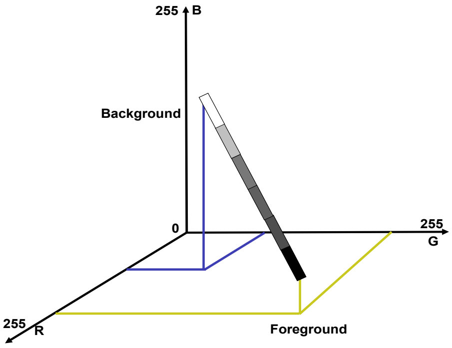

Fig 3 Gray scale projection

character by editing the ROIs in the images. This module converts the background (RGB) to white and the foreground (RGB) to black. This transformation is a projection of a point of 3 coordinates into a straight line defined by the background and foreground color. Thus, the system becomes invariant to color. This step is performed inside the "Normalized Char Module" explained in the next section and illustrated in Fig 3.

3.1.3 Normalization of the character

Once the perspective distortions and the color of the characters have been corrected, the last step is to normalize the character to an output image of a specific resolution.

The input of this module is an image and the characters positions of the Reference Image that has been stored in the training stage. The method projects the positions into the input image and looks pixels corresponding to the character. When the complete character is found, it is normalized as follows:

1. The character is over-sampled to a resolution of 80x60.
2. Then, this 80x60 is divided in 5x5 pixel regions. An output character of 16x12 pixels is created by computing the integral of those regions.
3. Finally, the output character format is normalized so that the minimum value is 0 and the maximum 255.

These pre-processing steps provide color, translation, scale and rotation invariance to the system.

3.2 PCA-based verification approach

The PCA module is used to extract the feature space of all the characters. This statistical method is a technique for simplifying a dataset, by reducing multidimensional datasets to lower dimensions for analysis. Thus, the system is faster, because is more efficient in terms of computational cost. The input of the PCA-based verification approach is a set of *N*x*M* normalized test character images of 16x12 with their supposable identity,

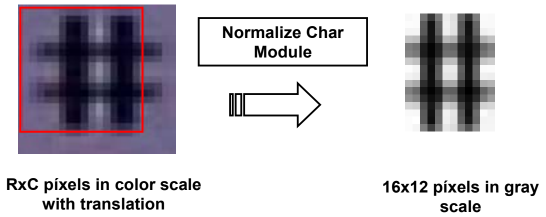

Fig 4 Normalize character process

and the output is the Euclidean distance between the coefficients of the test character after projecting it to the feature space and the coefficients of the claimed identity (supposable character) stored in the database. If the test character is really the claimed supposable character then this distance between both coefficient vectors should be small and if it is not, then the distance should be large. The verification of more than 100 characters once the input image has been acquired is performed in less than half a second for input images of aprox. 1Mpix.

The specifications of the PCA-based verification system used for obtaining the results of section 4 are:

- One reference image has been used to mark the points to be verified as explained in section 2.2.
- A total of 10 training images are used for computing the feature space. All the training images have been passed through all the pre-processing modules explained in this section.
- The centroids of each character using this training set are used as the most representative samples for each graphic character (gallery set). These centroids are projected to the feature space obtaining a vector of coefficients (= relevant information). Only 20 coefficients are used for performing the verification.
- The gallery set (=number of characters to be verified) are 15.

4. RESULTS OF THE VERIFICATION SYSTEM

In this section we present some results of the flexible verification system. A total of 200 images provided by the Image Acquisition System in different sessions (so illumination conditions may vary) have been used in the verification stage for obtaining the results shown in the next figures. Fig 5 represents the verification of a numerical character '5', Fig 6 of a letter 'C' and finally Fig 7 of a non-alphanumerical character like '↑'. The interpretation of the graphs is as follows:

The x-axis corresponds to the total number of test images (in this case 200).

The y-axis corresponds to the Euclidian distance (or error-similarity distance) between the projection of the selected character and the projection of the centroids of the gallery set. The red curves of the figures represent the distance between the coefficients of the test character and the identity he claims to be of the gallery set. The blue cloud of points (14 points for each test image) represents the

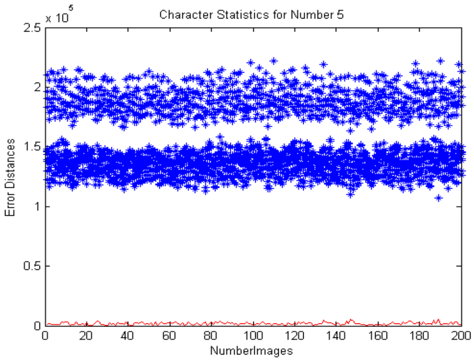

Fig 5 Verification of character '5'

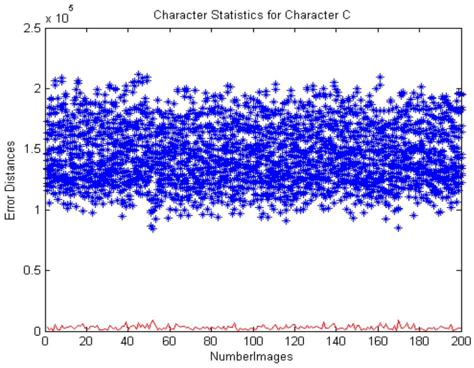

Fig 6 Verification of character 'C'

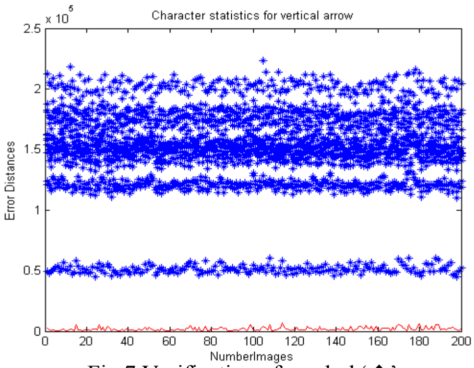

Fig 7 Verification of symbol '↑'

distance between the selected character and the other ones. On the other hand, the blue points are the distances between the test character and the rest of identities (characters of the database). The 200 test images have passed the test since the three characters have been verified correctly.

Although the system has been developed as a verification system, it could also works as a reliable character recognized. As it can be seen in all three graphics, a large gap between the red line and the blue cloud of points is presented. The larger the distance between the red and the blue points the more robust the verification will be. In the case of the vertical arrow (Fig 7), the cloud of points that is closer than the rest corresponds to the capital I. But still there is no problem in differentiating both characters

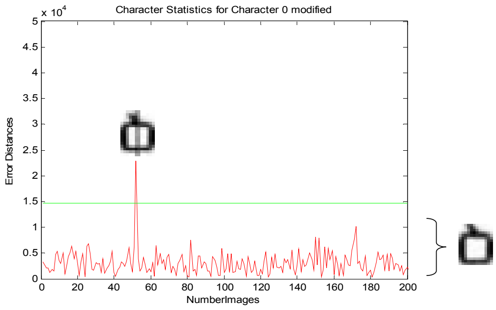

Fig 8 Error detection

(notice that the Euclidean error distance is of order 10^5). In fact, in our system we propose an automatic threshold for each character using the following equation:

$$Character_{th} = \mu + K*\sigma \qquad \text{where } K \text{ is fixed to 5.}$$

Using this threshold which is computed for each character during the training process using the training set of images leads to a 99.8% verification rate. The unique error we have detected so far is due to a very high perspective distortion when acquiring the image. This makes our system segment the neighbor character and not the correct one. This has happens because both characters where very close together in the teletext chart.

A final experiment would be performed to show the reliability of the system in detecting even small errors in the character. For this reason, we have incorporated a wrong character in an image (number 52 on the statistics of Fig 8). We can observe that an error peak takes place at image 52. This value overcomes the threshold (represented as a green line) and the error is detected.

5. CONCLUSIONS

We have presented in this paper a very fast and robust system for verifying any kind of graphic characters in teletext charts. This could also be extended to detect logos or any other king of graphic object. The verification rate we have obtained after training the system with 100 images is 99.8% using more than 10,000 test images.

6. REFERENCES

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