EXPERIMENTAL CAR PLATE RECOGNITION SYSTEM BY NEURAL NETWORKS AND IMAGE PROCESSING

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ABSTRACT

In this paper a system for Italian-style car license plate recognition is described, based on the use of general purpose feedforward neural networks and basic image processing algorithms. The neural network replaces the entire pattern matching module encountered in similar systems. The algorithm actually does not make use of large databases, and experiments were conducted by training the neural classifier on a purely artificial training set. Nevertheless, final results are similar to those of more complicated approaches, and could be further improved by on line learning. The use of neural networks, coupled with the fast BRLS training algorithm, can substantially enhance the global recognition speed.

1. INTRODUCTION

Car license recognition is important in several fields of application:

- traffic control in restricted areas;
- automatic payment of tolls on highways or bridges;
- general security systems wherever there is the need of identifying vehicles.

Some approaches exist and have been described in literature. They are mainly based on pattern matching and normalized correlation with a large database of stored templates.

In this paper we describe an experimental system for the recognition of Italian-style car license plates. The system is based on the use of a feedforward neural network (FNN) trained with the Block Recursive LS algorithm (BRLS), described in [1]. This learning approach has been shown to guarantee high rates of convergence and properties of stability and robustness of the solution. The data at hand consist of digitized images of cars, acquired by a high-resolution 35 mm photo camera and collected in a Photo CD. The processed images (see Fig.1) are 390 by 480 pixel wide. The distance and the angle of view simulate a car passing through a toll gate.

The recognition process starts with the search and the extraction of the portion of the original image containing the car plate. The characters contained in the plate are localized by a robust processing using a non-traditional DFT, and subsequently isolated and classified by the neural network. The scores are validated by a post-processor which takes into account the syntax of Italian-style plates.

The neural network is trained off-line on a set of error-free synthetic characters, where competing approaches need a large database of real-world images to extract features. The fast training convergence and the surface error model adopted in the BRLS approach allow to find reliably a local minimum in the mean squared error (MSE) cost function with a high grade of generalization capability. The overall recognition rate of the system has been the 90% on a validation set of fifty real-world images, with 8% of rejection rate and one (2%) false recognition. The percentage of correctly recognized characters has reached the 98.7%. Most rejections happened with old and dusty plates, almost unreadable also by human eyes.

With respect to a recently published work [2], our approach is able to reduce the complexity of the learning phase (no feature extraction and pattern matching required) and of the character recognition, speeded up by the parallel architecture of the FNN. The algorithm has been tested on a Pentium Pro PC 200 MHz with Matlab. The next step will be to write hand-optimized routines in a high-level language such as C++ to enhance the processing speed.

2. OUTLINE OF THE ALGORITHM

The algorithm is implemented as a cascade of building blocks. Each of them realizes a specialized task, is fed by the output of the previous stage, and makes use of relatively standard signal processing tools.

2.1 Image preprocessing

The digitized image (Fig. 1) is preprocessed by tone equalization and contrast reduction. This technique has been preferred to other alternatives, such as edge enhancement, for the better robustness and suitability to the next processing stage.

2.2 Plate location detection and extraction

Empirical evidence suggests that dimensions of the car and the plate in the image acquired by a typical toll gate camera should not vary more than about 15%. This fact enables for a fast localization technique avoiding an expensive search over large areas. The character spacing produces neat spatial harmonics in the horizonal direction. They can be revealed by a spatial frequency domain processing which sums out the energy contributions from all useful harmonics.

The horizontal stripe of the image containing the plate is found by searching for the maximum of the energy from the expected harmonics.

The harmonic decomposition is accomplished by a row-wise **DFT**, followed by a synchronized average in the spatial frequency domain, as shown in Fig. 2.

For example, a single average will involve the periodogram estimates { **P**(k), k=1, 2, …**N**/2 } obtained from the **DFT** { **X**(k), k=1, 2, …**N** } at bins 2, 4, 6, etc… The following estimator Q(p) of the harmonic standard deviation is employed:

$$Q(p) = \frac{1}{\mathbf{K}} \sum_{k=1}^{K<N/2} abs(\mathbf{X}(kp)), \qquad (1)$$

where the function abs(z) indicates the modulus of the complex argument. This particular estimator has been chosen also for the simplicity of implementation in most **DSP** processors and **VLSI** dedicated chips.

The horizontal location of the plate is found roughly in the same way, by using a small column-wise **DFT** on the candidate(s) stripe(s) found in the previous step (Figs. 2 and 3).

2.3 Character localization and segmentation.

After the plate has been located, the relative image portion is quantized to binary values according to an adaptive threshold established directly through a two-class clustering of tones. The characters are segmented by finding white areas between columns with higher density of black pixels (Figs. 4 and 5).

Isolated black pixels are wiped out and the character size is resized to the standard measure of (10 by 6) pixels with a factor-2 decimation (Fig. 6).

Removing of isolated pixels has been found to improve the resistance of the character recognizer with respect to artifacts produced by the photographic film.

2.4 Recognition by the FNN

The **FNN** has been trained with a synthetic English character set by the **BRLS** algorithm [1]. For each character, several replicas, shifted by one pixel in each direction have been presented to the **FNN**, in order to enhance the generalization capability [3].

The fast convergence of the algorithm, combined with the low misadjustment noise with respect to the classical backpropagation, has driven the working point of the network toward a well-behaved minimum. In fact, the **BRLS** algorithm is able to find an extremum surrounded by a nearly quadratic hypersurface, typical of near **M**aximum **L**ikelihood [4] (e.g. good) estimator of neuron weights.

The **FNN** used was two-layered with 60 input, 30 hidden and 35 output neurons, acting as a demultiplexer of the 35 possible characters.

2.5 Plate validation

The plate number is reconstructed from the sequence of recognized characters. Gross errors are limited by comparison with a database of acceptable sequences of characters, typical of the Italian plate numbering scheme.

3. CONCLUSIONS

The presented application is an example of the capability of neural networks to perform complex signal processing and classification tasks with real-world data. It is worth to point out that this performance has been achieved with a training set formed by artificially-generated examples. The **FNN** replaces all alignment, filtering, template correlation and winner selection procedures required by traditional processing with a parallel architecture realizable with **DSP VLSI** circuits, with the capability of a very high speed of recognition at low costs.

The **BRLS** algorithm once more demonstrated its intrinsic resistance to the presence of ill-shaped regions of the error surface (non-convex, nearly flat) and of local minima that do not have the basic requirements for being locally good estimators of neuron parameters. The fast (superlinear) convergence speed was not a prerequisite for the particular application, since the training can be done off-line. Anyway, the **BRLS** reduced greatly the setup times for experiments and is suitable for on-line adaptive training when needed to compensate for miss-modelling.

The search for typical spatial harmonics generated by the nearly regular character spacing on the plate is also a distinctive feature of the proposed procedure, remarkable for the overall robustness and near optimality of the detection. The **DCT** could be considered as a substitute for the **DFT** with possible reduction in computational costs.

4. ACKNOWLEDGEMENT

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5. REFERENCES

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Fig. 1: **O**riginal image.

Fig. 2: **I**mage of Fig. 1 after preprocessing and horizontal **D**FT.

Fig. 3: Vertical **D**FT.

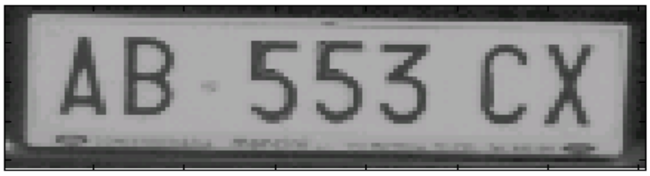

Fig. 4: **E**xtracted plate.

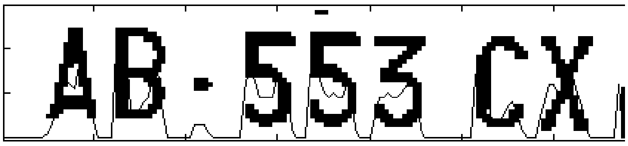

Fig. 5: **C**haracter localization.

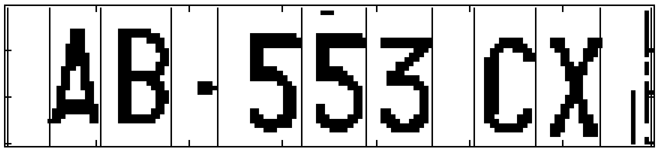

Fig. 6: **C**haracter segmentation.

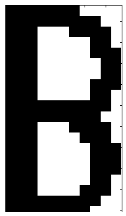

Fig. 7: **C**haracter '**B**' extracted and digitized.