The International Workshop
on Discrete-Event System Design, DESDes'01,
June 27÷29, 2001; Przytok near Zielona Gora, Poland

AUTOMATIC SYSTEM FOR TV RASTER PARAMETERS TUNING

Raouf SADYKHOV*, Aliaksei KLIMOVICH*, Leonid PODENOK**

* Belarussian State University of Informatics and Radioelectronics, , 6 P.Brovka st., Minsk., BELARUS, phone 239-80-39, e-mail: *nil36@bsuir.edu.by*

** Institute of Engineering Cybernetics, Belarussian State University of Informatics and Radioelectronics, 6 Surganov st., Minsk, BELARUS, ph/fax +375 17 2310982, e-mail: *podenok@lsi.bas-net.by*

Abstract. *The automatic system of TV raster parameters tuning for television receivers has been worked out. For achieving a required precision of raster parameters and compensation of nonlinearity and geometric distortions the original algorithms of image processing are used.*

Key Words: *nonlinear system, neural network, Volterra series, approximation.*

INTRODUCTION

In modern TV receivers the problem of digital control such parameters of a raster as a vertical and horizontal shift, raster size horizontal and vertical, and also number of other parameters digitally is very actual. All these parameters as a rule depend on parameters of the deflector system and electronic circuits. Unfortunately scatter of parameters makes hard influence on characteristics of a displayed raster, that stimulates a problem of raster parameters tuning on the base of computer. In the industrial conditions this problem is executed by specially trained expert, who manually reduces distortions of a raster to a minimum. The development of automatic system for TV raster parameters tuning without human participation allows to reach required minimum distorsions of the raster and essentially reduce time of tuning. The created closed system satisfies the requirements for the computer vision systems and includes original algorithms of image processing, approximation of nonlinearities on the base of Volterra series and neural network approach.

1. METHODS AND ALGORITHMS OF TV RASTER IMAGE PROCESSING

For TV raster image capture the CCD colour video camera "Sanyo" has been used and the resolution of an obtained image is equal to 640x480. Unfortunately using of the video camera calls a number of problems connected with decrease image quality for TV raster. Since the video camera has an automatic system of image brightness adjustment, it results in the certain delay for obtaining an image. Furthermore brightness of separate areas of an image is received unequal because of the nonlinear distortions of the raster are present, and obtained image also can be hardly noised.

We have considered and tested various methods of image preprocessing such as a median and Gaussian filtration. As experiments have shown fast and qualitative outcomes Gaussian filtration with a size of the window 3x3 has shown. It allows to smooth some noise added into an image by an equipment and the external factors of illumination.

Further the histogram of image intensity is created, which has been used in future for determination of an average level of light exposure for image and calculation of black and white levels.

2. COMPENSATION OF DISTORTIONS

The image of the same grid field to be captured with CCD-camera and frame grabber depends on a lot of factors, such as curvature of the TV-screen surface, variable distance from the screen up to the CCD-camera, orientation angles of view point, geometrical and metric distortions, entered by the optics-electronic section. Each of the factors makes the specific distortions to the image of a grid.

All significant distortions from the point of view of the precision of parameter measurement are divided on two classes. The first one includes distortions, caused by an relative location and orientation of the CCD-camera and the TV-receiver. The second one includes distortions caused by a CCD-camera lens construction and lens mounting system and distortions caused by optics-electronic channel "CCD matrix image - memory image".

The model of second class distortions describes real geometrical distortions, which take place in a specific opto-mechanical state of real lens. The model uses two representations of distortions field. The first one is based on spline approximation and second one is based on polynomial approximation that is usually used by some optics manufacturers and its parameters are listed in the product manual.

The construction of spline model of lens distortion field is carried out on the basis of experimentally received data for every lens, particular opto-electronic path of the CCD-camera and coder/decoder circuits of capture board. Planar grid was used as the standard object to form the curved and distorted image in computer memory. The specially developed technique of the image processing of this planar grid is used. As a result the set of approximation data corresponding to distinct states of the lens was received.

To determine the relative location of the CCD-camera and TV-set the vectorization of light screen boundaries is carried out. The curve spline representation of that boundary is used to find the coordinate system transformation that minimizes variation of source object boundary. That transformation is used to compensate distortions related with non-focal view point location. To determine the current distance between camera lens and surface of the TV-set we have used angular dimensions of the screen.

The distortions are compensated in consecutive order, at first distortions caused by objective and opto-electronic section, then distortions caused by relative arrangement. Further after all distortions have been compensated the grid detection is carried out and signal frame center is found. After vectorization of the grid image distortions entered by TV-set deflector system are evaluated.

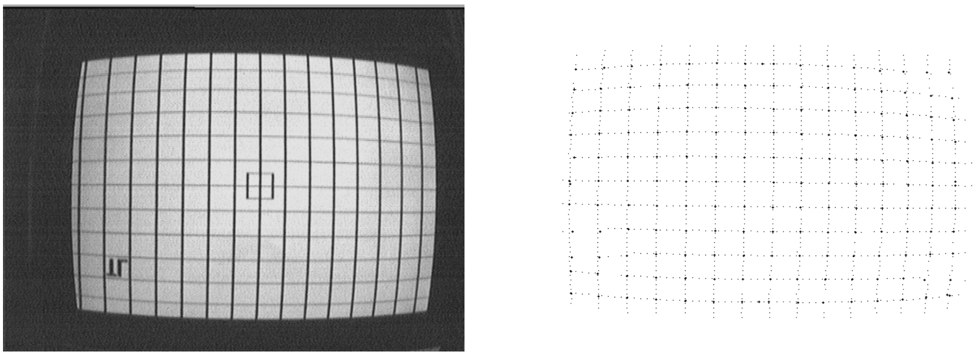

Fig. 1. The compensated image of the TV set raster and point of knots of vectorial representation.

The Fig. 1 shows one from stages of a vectorization of the compensated image.

3. IMAGE PROCESSING FOR SELECTION OF KEY DETAILSES

A primary problem of image analysis is determination of knots of an image grid. For determination of lines on an image the original filtration algorithm based on multilayer perceptron is used. The source vector that contains 25 values was generated as a residual of intensities between adjacent pixels of an image. Neural network was used to increase visibility of lines. The application of the given method has increased performance if previously trained neural network was applied. Neural network recognizes in the processed image a fragment of a standard line of a grid and produces coordinates of that fragment in the vector. This coordinate was used for the recognition of the line fragment in the source vector. For neural network training back-propagation algorithm with an adaptive learning step has been used. [1, 4]

4. APROXIMATION OF NONLINEARITIES

Further an obtained knots allow the calculation of geometric and nonlinear distortions of the raster. It should be noted that evaluation of nonlinear distortions is nontrivial problem. There is a set of methods and approaches to decide this problem. For calculation of vertical nonlinearity, the set of knots on the central vertical line was used. We have used the approximation of obtained points via polynomial of the n degree, where the n is maximum order of existing nonlinearity.

$$y(x) = \sum_{i=0}^{n} a_i x^i \qquad (1)$$

In practice it is sufficient to calculate nonlinearities up to the third order (n=3). The coefficient of the second order (a_2) corresponds to nonsymmetry, and third order (a_3) - to nonlinearity.

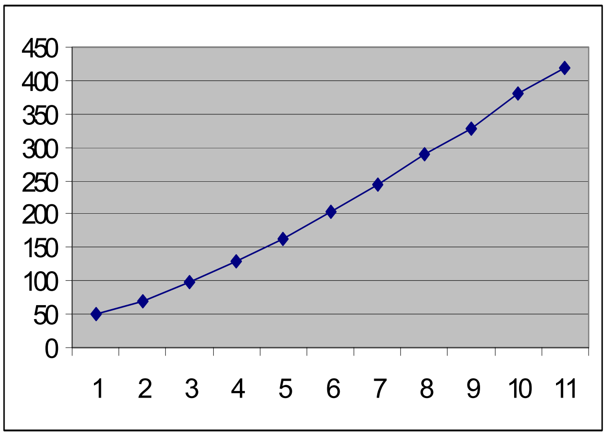

Fig. 2 Experimental data of the grid knots coordinates on the raster for an evaluation of nonlinear distortions.

During experiments (fig.2) we have clarified that nonlinearity and nonsymmetry are correlated with each other and are non-correlated with the next tuning parameters (horizontal position and vertical size of a raster).

Another approach to calculate the nonlinearity and nonsymmetry values is using a Volterra kernels. The Volterra series is a well-known method of nonlinear system describing. The Volterra approach characterises a system as mapping betwen two function spaces of that system. The Volterra series is an extension of Taylor series representation to cover dynamic systems and has the general form

$$y(t) = h_0 + \int_{-\infty}^{+\infty} h_1(\tau_1)u(t-\tau_1)d\tau_1 + \int_{-\infty}^{+\infty}\int_{-\infty}^{+\infty} h_2(\tau_1,\tau_2)u(t-\tau_1)u(t-\tau_2)d\tau_1 d\tau_2 + \ldots \quad (2)$$

where $y(t)$ is the output of the system at time t, $u(t)$ is the input at time t, and $h_n(\tau_1, \ldots, \tau_n)$ is the n-th order Volterra kernel.

For a practical systems with finite memory the equation becomes

$$\begin{aligned} y(t) = h_0 &+ \sum_{\tau_1=0}^{T} h_1(\tau_1)u(t-\tau_1) + \sum_{\tau_1=0}^{T}\sum_{\tau_2=0}^{T} h_2(\tau_1,\tau_2)u(t-\tau_1)u(t-\tau_2) + \ldots \\ &+ \sum_{\tau_1=0}^{T} \ldots \sum_{\tau_n=0}^{T} h_n(\tau_1,\ldots,\tau_n)u(t-\tau_1)\ldots u(t-\tau_n) + \ldots \end{aligned} \quad (3)$$

where T is the memory of the system (i.e. the number of time sampled values to be needed to describe the dynamics of the system).

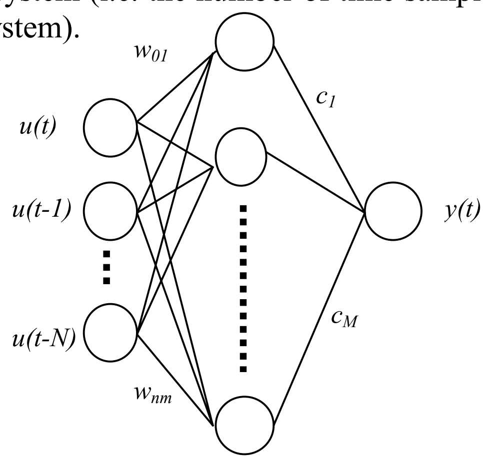

Fig.3 A neural network architecture for time series prediction.

This network (fig.3) is trained to perform a certain mapping between its input layer (on the left) and its output by altering the weights associated with each internal connection. These weights are altered by a training algorithm which takes pairs of ideal input/output data and changes the weights to make the network reproduce the mapping described by the data pairs.
A typical node processing function is

$$op_i = \sigma_i\left(b_i + \sum_{j=0}^{N} w_{ji} u(t-j) \right) \qquad (4)$$

where op_i is the output from the hidden unit i, σ_i is the activation function of hidden unit i, w_{ji} is the weight connecting input unit j to hidden unit i, $u(t-j)$ is the input u at delay j, b_i is the bias input to unit i, and $N+1$ is the number of input units. A typical output function, σ, is of sigmoidal shape such as hyperbolic tangent (*tanh x*).
The Volterra kernels are given by

$$h_0 = \sum_{i=1}^{m} c_i a_{0i} \qquad (5)$$

$$h_1(j) = \sum_{i=1}^{M} c_i a_{1i} w_{ji} \qquad (6)$$

$$h_2(j,k) = \sum_{i=1}^{M} c_i a_{2i} w_{ji} w_{ki} \qquad (7)$$

and so the general n-th order kernel is given by

$$h_n(v_1, v_2, ..., v_n) = \sum_{i=1}^{M} c_i a_{ni} w_{v_1 i} w_{v_2 i} ... w_{v_n i} \qquad (8)$$

When network has been trained, then the Volterra kernels of all dimensions of this system can be extracted.
In the results the network was trained with the training data set from the TV raster grid nodes, using with the back-propagation algorithm.
So, as we have found the Volterra kernels of 2-nd and 3-rd order are corresponds to such control parameters of TV raster as nonsymmetry and nonlinearity.

5. EXPERIMENTAL INSTALLATION

As controlled and tuned object some serial TV-sets supplied with spherical or toroidal tube were have been used. All these TV-sets had digitally controlled deflector system and were equipped with external data link.
Hardware equipment of the experimental installation consists of the personal computer under OS/2 Warp v.4, CCD-camera and PCI video-capture board. To form the grid field with a TV-frame center mark on the surface of TV tube precise test pattern generator was used. Some the CCD cameras, capture boards and lens systems have been investigated to determine minimal resolution that allow to evaluate the distortions of raster with accuracy that is necessary the raster to be tuned. To reach large non-linearity and non-symmetry of the vertical and horizontal scanning with the purpose of checking the limits of the control algorithm some special changes were brought in to the electronic circuits of the deflection system. The experimental installation is shown on fig.5.

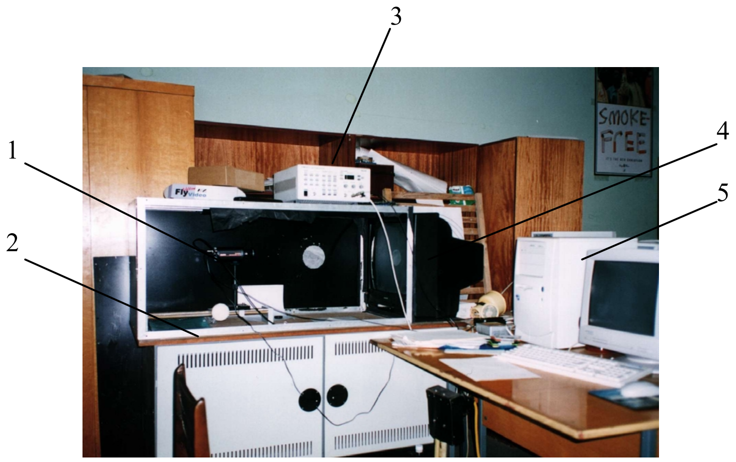

Fig. 5. Structure of an experimental system of automatic TV raster parameters tuning.
1 - CCD the camera; 2- chassis; 3 - generator of a standard signal; 4 - TV set; 5 - control computer.

CONCLUSION

The developed system satisfies to required requests, on quality of set-up for parameters of the raster. The system has shown a high accuracy and performance of tuning, on a comparison with tuning with the help of expert by a manual method. As a rule system defines all the parameters of a raster less than for 25-30 seconds, while the person for entering in control mode, makes tuning at the best 1-2 minutes. And in case of tuning by the person could be quality defects.

REFERENCES

[1] Kohonen, T. "Self-Organization Maps" Springer, 1995.
[2] E. Tsao "Fuzzy Kohonen Clustering Networks" Pattern Recognition, v.27, n.5, 1994, pp. 757-764.
[3] Powell, M.J.D. "Radial basis function for multivariable interpolation: a review" In J.C. Mason and M.G. Cox (Eds), Algorithms for Approximation, 1987, pp. 143-167. Oxford: Clarendon Press.
[4] Y. Hwang "Recognition of Unconstrained Handwritten Numarals by a Radial Basis Function Neural Network Classifier" Pattern Recognition Letters, v.18, n.7, 1997, pp. 657-664.
[5] Moody, J. and C.J. Darken "Fast learning in networks of locally tuned processing units" Neural Computation 1 (2) 1989, 281-294.