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3—7 Automated TV-set Raster Tuning System

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Abstract

System for automated control and tuning of TV-set raster has been developed. The artificial intelligence elements such as multilayer perceptron, RBF and Cohonen networks effectively have been used in the system to tuning parameters of image correction algorithms, approximation of non-linearities and for the rough determination of a position of the TV-set relative to CCD-camera. The accuracy of raster tuning and compensating of the nonlinear and geometrical distortions carried out by system with the use of above-mentioned approach much exceed the ones, achievable via hand-operated tuning.

1 Introduction

Raster control system of TV-set and computer monitor contains special digital processor which controls such characteristics of the raster as vertical and horizontal position, size, pincushion, trapezoid, parallelogram and tilt. All these parameters depend on both state of digital processor and a lot of parameters of the deflector system circuits. Because of deflector system circuits have considerable variations of its characteristics there are not one-to-one correspondence between state of processor and visible raster state. To achieve good state of visible raster the tuning stage is used for every TV-set. The tuning stage of TV-set or monitor production process involves the human factor that increases the expenses. As far as we have digitally controlled TV-set, cheap high-performance computers and image-capture devices the raster tuning process can be fully automated.

TV-set raster is described by a set of target variables, which uniquely determines its visible state. Such variables in our case are the position, size, non-linearity, non-symmetry and other geometrical distortions of grid as pincushion, trapezoid and parallelogram, which forms a space of target parameters $\mathbf{f} = \{f_i\}$.

As the set of control parameters a regulation parameters have been used that formed a space of control parameters $\mathbf{g} = \{g_i\}$. This space includes vertical and horizontal position and size parameters, two parameters for every direction influencing on non-linearity and non-symmetry of the raster, and some parameters that directly force on pincushion, trapezoid and paralelogram. The space of control parameters is limited by surface formed by hyper-planes $g_i = g_{i,max}$ $g_i = g_{i,min}$.

Inside boundaries of non-singular states of the deflector system each point in the control parameter space $\mathbf{g}$ uniquely corresponds to a point in the target parameter space $\mathbf{f} = \hat{\mathcal{A}}\mathbf{g}$. Operator $\hat{\mathcal{A}}$ represents the operator of raster response on the TV control signal.

2 Raster tuning process

The process of raster tuning consists of the change of control parameter values in such direction, that the values of target raster parameters changes toward to ideal values $\mathbf{f}^\circ$ on each step. Because $\mathbf{f}^\circ$ lies on boundary of space of target parameters that corresponds to TV-tube luminescent area edge we should slightly reduce vertical and horizontal size of the raster. When process of raster tuning will be completed the size of the raster should be returned back and visible raster will correspond to the luminescent area.

Formally it is necessary to determine explicit form of the operator $\hat{\mathcal{A}}$ of the TV-set raster response and to solve the equation $\mathbf{f} = \hat{\mathcal{A}}\mathbf{g}$ relative to control parameter $\mathbf{g}$ when $\mathbf{f} = \mathbf{f}^\circ$.

A form of the operator $\hat{\mathcal{A}}$ describing response of the TV-set raster $\mathbf{f}$ on control influence $\mathbf{g}$ is unknown, moreover, for each TV-set installation it is

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different. In ones turn it is impossible to determine operator $\hat{A}$ for each particular case of TV-set, so equation has been solved by a secant method for multi-dimensional case with more accurate definition of the real response matrix component on each iteration step.

Equation $\mathbf{f} = \hat{A}\mathbf{g}$ can be represented in components and differential form as $df_i = \sum_j a_{ij}(\mathbf{g})dg_j$, where $a_{ij}(\mathbf{g}) = \partial f_i/\partial g_j|_\mathbf{g}$ – matrix of factors of the raster response on control influence. Formally this equation has solution $dg_i = \sum_j a_{ij}^{-1}(\mathbf{g})df_j$, where a_{ij}^{-1} – matrix inverse to a matrix of response coefficients a_{ij}.

In the iterative process of reducing the TV-set raster to an ideal shape the relation $\Delta g_i = \sum_j b_{ij}(f_j^\circ - f_j)$, based on the finite differential form of approximate solution has been used. Here $b_{ij} = \sum_k d_{ik}a_{kj}^{-1}$, where a_{kj}^{-1} – is a matrix inverse to a matrix of response coefficients and matrix d_{ik} is intended for dumping of algorithm convergence preventing auto-excitation owing to approximated character of modeling. In our experiments we have used diagonal matrix of dumping factors.

At first stage we have used linear model for TV-set raster response corrected after each tuning step. As an initial response factor matrix has been used one, calculated as mean result of all the matrices in near-central area of control parameters when several real TV-set installations were experimentally investigated. To reach the good results in practical tuning such the 'mean' matrix should be calculated for every TV-set model.

To construct response matrix more close to real TV-set behavior we have used neural networks (NN) for modeling response of the raster on control influence described by matrix $\hat{A}$. For an optimum choice of the matrix elements Kohonen NN [1, 2] has been used. This NN allows to clusterize learning sample. An indication of qualitative clusterization is fact, that the vectors of parameters corresponding to nearest states of the TV-set are arranged by a NN in one cluster. In this connection we have considered some sets of parameters for every TV-set type. In an outcome with the help of Kohonen NN optimum parameter set for learning of multilayer perceptron has been selected. Above-mentioned perceptron was used to solve the system $\mathbf{f} = \hat{A}\mathbf{g}$ relative to control parameter.

To finish iterations the criterion based on Chebyshev metric has been used. All the components g_i of control parameters $\mathbf{g}$ for a real control system accept only discrete values and the discretization step is more than sufficient for achieving the requirements of raster tuning accuracy. In this connection the iterations may be stopped, as soon as all the Δg_i became less than half of quantum of control parameter on appropriate coordinate.

3 Image processing.

One of the tasks to be solved during of operating the tuning system is the analysis of the grid field image. That grid is formed by deflector system of the TV-set on surface of the TV-tube from test video signal. Main goal of that analysis is the measurement of distortions that have been brought in by deflector system. Results of these measurements are used to form a batch of control signals to be issued into control processor of digital scanning of TV-set to reduce non-linear and geometrical distortions of the TV-raster and other target parameters.

The image of TV-set screen is captured using the CCD-camera and frame grabber connected to computer system at every step of the tuning process. Because of the image obtained from a camera has significant noise distortion, the preliminary filtration is required. At this stage the noise which are brought in by CCD-camera and opto-electronic path of the grabber were eliminated with the smoothing.

The basic task of image analysis is the selection of nodes of a grid on the image. For selection of lines on an image the original directed algorithm of a filtration based on the multilayer perceptron NN has been used. The input matrix 5×5 was formed as a difference of intensities between adjacent pixels of an image. Neural network has been used to increase contrast of lines of a test grid. The application of the given method raises speed, since the processing of an image is carried out by blocks 4×3 with beforehand trained neural network. NN recognizes in an processed image a fragment of standard grid line or node and produces the coordinates of that fragment in the matrix. These coordinates have been used to increase contrast and improve selection of the required line. For learning the NN the error back-propagation algorithm with an adaptive step has been used.

For approximation of lines on the base of obtained nodes two approaches were investigated: spline-approximation and approximation with the Radial Basic Function (RBF) NN [3, 4, 5]. The approximation with the RBF has shown good result in speed, since the NN was already trained on an averaged line and not great amount of learning steps was required.

On the base of obtained nodes the evaluation of geometric and nonlinear raster distortions was made. It should be noted that the evaluation of nonlinear distortions is one of the nontrivial tasks. There are some methods and approaches to solve this task. For an evaluation of nonlinear distortions of vertical scanning the set of nodes of a standard grid on central vertical line has been used. One of the methods is the approximation of an obtained points with a polynomial P_n, where n – maximum order of the present nonlinearity. The evaluation of non-linearities up to the third order is enough for practice. The terms of 2-rd order correspond to non-symmetry, and 3-nd order – to non-linearity of scanning.

During experiments we have clarified that non-linearity and non-symmetry are correlated with each other and are non-correlated with third tuning parameters (horizontal position and size of a raster, for example).

To receive set of parameters to be used as control data multilayer perceptron with four inputs and four outputs has been used. The output neurons show how many it is necessary to change the control values to target parameters came in a norm.

To determine position of a camera relative to TV-set it is necessary to construct a three-dimensional model of a visibility of the surface TV-tube. RBF NN was used for this purpose.

The network has shown a high performance and good quality of approximation. For acceleration of learning process beforehand prepared weights of NN [6] trained on a set of the TV-tube surfaces have been used.

4 Distorsions and its compensation

The image of the same grid field captured with CCD-camera and frame grabber depends on a lot of the 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 opto-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 the 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 $\mathbf{X}' = \mathbf{D}_{RP}(\mathbf{X})$. The second one includes distortions caused by a CCD-camera lens construction, lens mounting system and distortions caused by opto-electronic channel "CCD matrix image - memory image" $\mathbf{X}' = \mathbf{D}_{OE}(\mathbf{X})$.

The model of second class distortions $\mathbf{D}_{OE}$ 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 lens parameters are often 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 source 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 normal image 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 $\mathbf{D}_{OE}$, then distortions caused by relative arrangement $\mathbf{D}_{RP}$. 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.

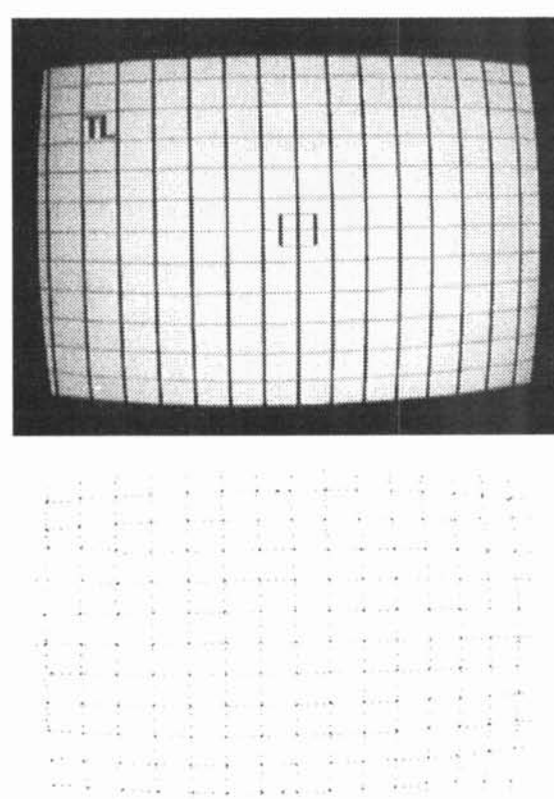

Fig.1. Compensated TV-set screen image and node points of vector representation.

Fig.1 shows one of stages of vectorization of the compensated image. Because of algorithm used to carrying out the node selection has not been adopted to recognize the non-regular component in source video signal represented by pattern "TL" visible distortions at top left corner of the second image take place. Subsequently at practical implementation of the tuning system the video signal without any unnecessary patterns has been used.

5 Practical realization

As controlled and tuned object some serial TV-sets supplied with spherical or toroidal tube were 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 communicate with digital processor of the TV-set deflector system computer contains a I^2C interface card. 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 to tune the raster. To reach large non-linearities and non-symmetries of the vertical and horizontal scanning with the purpose of checking the limits of control algorithm some special changes were brought in to the electronic circuits of the deflection system.

6 Conclusion

The TV-set raster tuning can be worked out with 380 TV lines CCD-camera for remote monitoring connected to TV-capture board based on Bt878A[1] video capture chip. All these units may be installed into x86-based computer under OS/2 Warp[2] supplied with the appropriate interface to communicate with digatal processor of the TV-set deflection system. Practical experiments in conditions close to industrial ones have shown that above-mentioned approach allows to achieve such the accuracy of raster tuning and compensating of the nonlinear and geometrical distortions carried out by computer system that much exceed the distorsions, achievable via hand-operated tuning.

[1]Bt is registered trademark of Rockwell Semiconductor Systems

[2]OS/2 is registered trademark of International Business Machines Corporation

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