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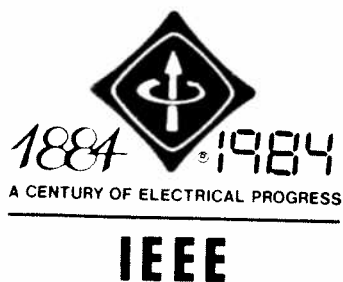
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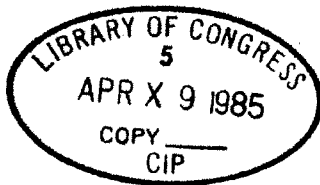
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LG Electronics Ex. 1021, pg 1



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# AUTOMATIC EVALUATION SYSTEM FOR CPT PICTURE CHARACTERISTICS

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## ABSTRACT

More precise inspection or evaluation system for CPT(Color Picture Tube) must be considered to get more beautiful TV picture and displays for computer terminals. The system installed a visual sensor, a high speed image processing unit and minicomputer, has a great advantages in an evaluation accuracy and a processing speed compared with conventional manual methods.

## 1. INTRODUCTION

NHK's high definition televisionsets<sup>1</sup> and computer displays are recent remarkable examples demonstrating highly improved accuracy for CPT. The televisionsets are required to offer picture same as color photographs and the computer display tubes must have a display capacity being far beyond ordinary televisionsets. These trends make the production field to assure high quality and to increase the yield. This implies the increased importance of picture characteristics evaluation. Conventionally, an inspector watched the CPT screen, and evaluated the picture characteristics visually or by using a simple measurement scale. This manual method suffered in following respects:

- (1) Substantial skillfulness required in successful evaluation
- (2) Low evaluation accuracy and individual differences in evaluation results
- (3) Inspector's fatigue from watching a CPT screen
- (4) Considerable time requirement for evaluation

In addition to these problems, following difficulties are involved in automation of the evaluation process:

- (1) There are no suitable evaluation methods because of particular structure and characteristics of CPT.
- (2) It takes considerable data processing time for overall CPT picture evaluation.
- (3) It is difficult to get more flexible system for many kinds of CPT.

To eliminate these problems, an automatic evaluation system for CPT picture characteristics, using a visual sensor, a high speed image processing unit and minicomputer, has been developed.

## 2. AUTOMATIC EVALUATION SYSTEM

The system consists of a visual sensor block, visual sensor positioning mechanism, and control block, as shown in Figure 1. Figure 2 shows the exterior view of the system.

### 2.1 Visual Sensor Block

This block consists of optical filters (each corresponding to relative spectral distribution, for red, green and blue phosphor), ITV camera and a high speed image processing unit. Figure 3 shows visual

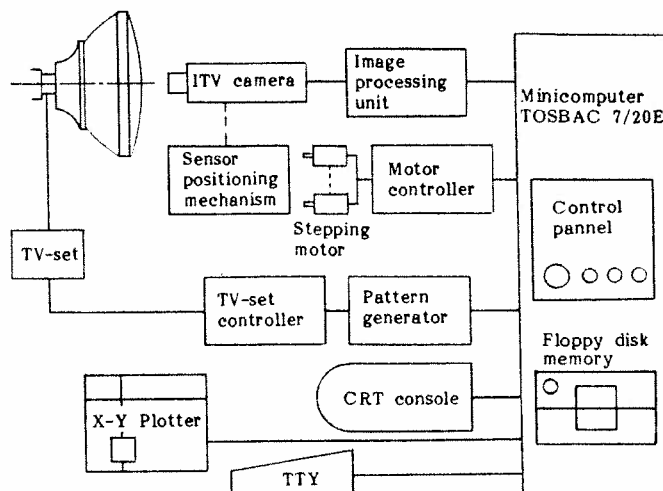


Figure 1 System configuration

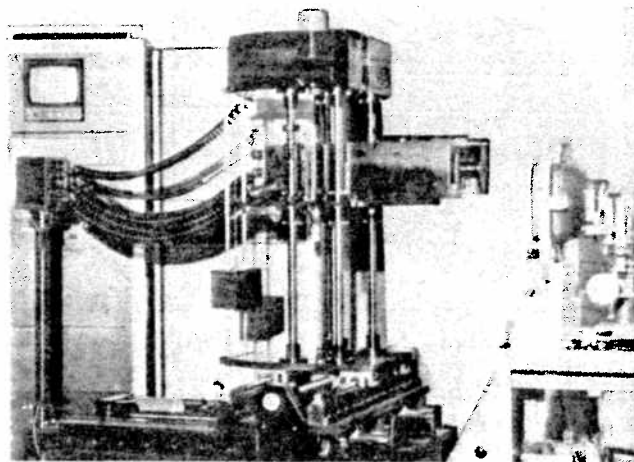


Figure 2 The exterior view of the system

sensor block configuration. Optical filters including red, green, blue and ND filters, can be mechanically selected. The ITV camera, with stepping motor, can be automatically set optical magnification and focus according to the tube category and evaluation items concerned. Measuring three points on the screen determine the parameters of CPT screen(sphere) equation which can be used for focusing any point on the screen. The high speed image processing unit produced by TOSHIBA, consists of an image input/output interface, an image memory(max. 8 pieces) and an image processor. The speed image processing unit includes hardware functions as listed in Table 1<sup>2</sup>. In this evaluation system, data conversion, histogram computation, affin coordinate transformation and pixel operation functions are used for image processing. The image data are 512 \* 512 pixels \* 256 levels/screen.

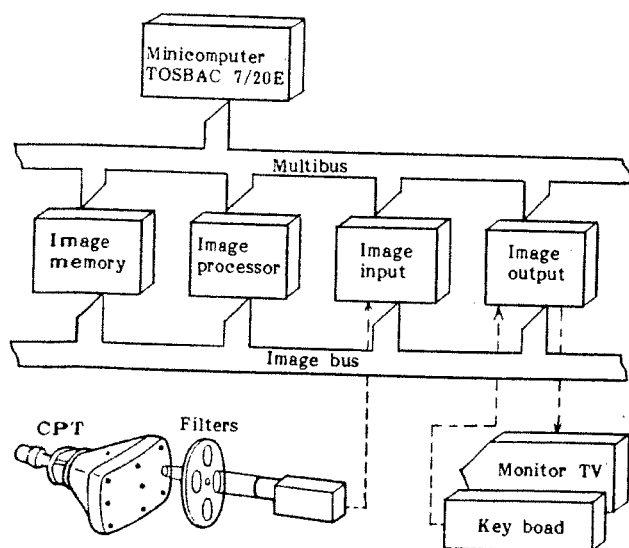


Figure 3 Visual sensor block configuration

Table 1 Hardware functions of image processing unit

Function	Applications	Execution Time
Two-Dimensional Convolution	Laplacian, Smoothing	360 ns/pixel
Logic Filtering	Feature detection Thinning	120 ns/pixel 120 ns/pixel
Region Labeling	Region separation Particle measurement	240 ns/pixel 360 ns/pixel
Data Conversion	$\gamma$ -correction Thresholding	120 ns/pixel 120 ns/pixel
Histogram Computation	Frequency counting	120 ns/pixel
Affin Coordinate Transformation	Enlargement with rotation, Axis skewing	1 us/pixel 1 us/pixel
Pixel Operation	Logical operation Arithmetic operation	120 ns/pixel 120 ns/pixel
Gradient Operation	Edge detection	240 ns/pixel

## 2.2 Visual Sensor Positioning Mechanism

This mechanism consists of the following sections:

- (1) Sensor positioning section (three dimensional) made from an XYZ table with ball screws (accuracy : 12.5  $\mu$ m, maximum speed : 125 mm/sec)
- (2) Optical magnification setting section (adjustable according to the tube category and evaluation items)
- (3) Automatic focus detecting and adjusting section

Control by the above mechanism allows the ITV camera to move to any arbitrary position compatible with the tube category and evaluation items concerned. In this way, a proper optical magnification is set up and the optical system is focused, followed by compiling necessary data.

## 2.3 Control Block

Pattern generator, TV set control circuit, stepping motor controller and data I/O equipment (CRT console, TTY, X-Y plotter) are connected to the minicomputer. The pattern generator displays the evaluation pattern (5 categories) according to the evaluation item. The TV set control circuit selects the screen brightness level (9 levels) and the electron gun (red, green or blue)

according to the tube category and evaluation items. The stepping motor controller with a microcomputer performs automatic acceleration/deceleration for high speed ITV camera movement. Picture evaluation conditions are input by CRT console and control panel. The evaluated results are output on the TTY and the X-Y plotter.

## 3. EVALUATION METHOD

The premeasurement and picture characteristics are evaluated in this system.

### (1) Premeasurement

Evaluation accuracy is improved by the following three premeasurements which eliminate the setting position gap of CPT, and effects of the discrepancy in screen brightness due to the kinds of the CPT.

#### (1) Screen position measurement

The center position and tilt of the CPT screen are measured. Then the evaluation data are corrected.

#### (2) Automatic focus measurement

Since the CPT screen is formed with a curved surface, and the optical magnifying power of ITV camera is high, therefore, the focus adjustment by each evaluation point is necessary. Three points on the CPT screen are measured, and the equation of the screen (sphere) is determined. From the equation, the focus adjustment value for each point is calculated.

#### (3) Screen brightness measurement

The standard value to process grey level image data are determined. For instance, the light image data of the CPT screen are processed on the basis of the brightness data obtained herein depending on the brightness.

### (2) Picture characteristics evaluation

#### (1) Raster Shift, Raster Rotation

The difference between the center position of the displayed pattern and the physical center of the screen is calculated. This difference is caused from the error during assembling the electron gun and deflection yoke with tubes. And also, tilt evaluation is done.

#### (2) Convergence

The relative discrepancy value of red and blue electron beam at each position on the screen, is evaluated.

#### (3) Raster Distortion

The value of pattern distortion is evaluated, which occurs by the deflection yoke characteristics and assembly error.

#### (4) Halo

The electron beam fading value is evaluated, which occurs by characteristics of the electron gun and deflection yoke.

As typical examples of the above items, the evaluation methods for the Screen position measurement, Convergence and Raster Distortion, are explained as follows.

### 3.1 Screen position measurement

The screen surface forms a sphere, and the glass thickness in front of the screen is 20 to 30 mm. This causes the error depending on measurement position. It is difficult to obtain the accuracy of 0.5 mm or less in the screen position measurement performed so far by manual. In this measurement, ITV camera is moved eight points (A to H) on the screen as shown in Figure 4(a) to detect the edge position on the screen. From these values, the screen surface center position ( $X_0$ ,  $Y_0$ ) and tilt ( $H_0$  and  $V_0$ ) are obtained.

Measuring procedure(1) Setting of measuring condition

Pattern : Blanked pattern

Optical magnification : 50 um/pixel

Optical filter : ND filter

(2) Image data fetch

ITV camera is moved to the measuring position and is adjusted to the focus. The data are fetched into the image memory. The data size are 512 \* 512 pixels \* 256 levels. In case of the screen edge detection (E,F,G and H points) in the horizontal direction, the processed data are 160 \* 400 pixels, and that (A,B,C and D points) in the vertical direction, they are 400 \* 160 pixels.

(3) Preprocessing

The detail around the point F in (a) in Figure 4 is (b). The one screen element which consists of three emitting portions of phosphor, is arranged at the different height of 0.4 mm to the next element. But in manual evaluation, an inspector regards these elements as the straight line. So in the developed system, the calculation is done as an inspector does. The image memory data (b:left) added the image memory data (b:right) which are shifted by horizontal direction arrangement pitch  $p$  makes the image of (c). Next, the black stripe portions among each emitting portion of phosphor are made the same in brightness as emitting phosphor. After making the binary image data with a suitable level, an dilatation process is performed with a 3 \* 3 filter shown in (d). At this time, the black stripe portions disappear. But the screen edge positions move upwards by 1 pixel. To put it back in position, a shrinking process is performed with a 3 \* 3 filter. These processes realize same standard image as that of manual evaluation. And the process are performed with the hardware of the high speed image processing unit of which processing time is approx. 23 ms.

(4) Software processing

The image data obtained from the above, are transferred to the memory in a minicomputer. The screen edge position is calculated from

the above processed data. These measurements from (2) to (4) above, are repeated at eight points on the screen. The screen position ( $X_o$ ,  $Y_o$ ) and tilt ( $H_o$  and  $V_o$ ) are obtained from result.

$$X_o = (X_A + X_B + X_C + X_D)/4$$

$$Y_o = (Y_E + Y_F + Y_G + Y_H)/4$$

$$H_o = ((X_A + X_C) - (X_B + X_D)) * K_H / 4$$

$$V_o = ((Y_F + Y_H) - (Y_E + Y_G)) * K_V / 4$$

The measuring accuracy of 0.1 mm has been obtained with this measuring method, which is accurater by four times or more than that performed so far.

3.2 Convergence

An arrangement of electron beams, shadow mask and phosphor are shown in Figure 5. Electron beams are selected and transmitted with the shadow mask. Only a part of beams hits phosphor. As a Convergence calculation depends on the position of phosphors which emit at regular intervals, a high accuracy cannot be obtained. The evaluation performed so far by an inspector is 0.2 mm minimum. In this evaluation, the following two problems are considered.

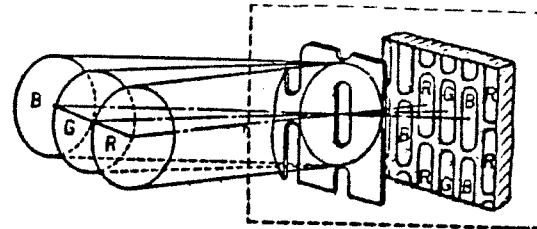


Figure 5 Arrangement of electron beams, shadow mask and phosphor

(1) Color separation of red, green and blue pattern

The simplest method is a method that emits phosphor one by one, by changing voltage applied to electron gun of the CPT. But this method has not been adopted, because discrepancies of 0.05 to 0.1 mm in the electron beam position occur between three colors emitting case and one color emitting case. A method which separates the three colors by recognizing the shape of emitting phosphor, has been discussed. But the method lacks reliability in the practical use. In this system, three filters, of which characteristics are almost the same as spectral characteristics, are placed in front of ITV camera. Color separation is performed with the filter. Spectral characteristics of phosphor and optical filters are shown in Figure 6.

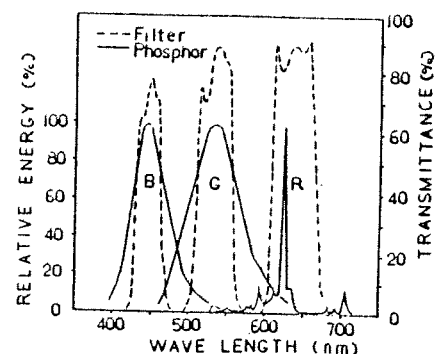


Figure 6 Spectral characteristics of phosphor and optical filters

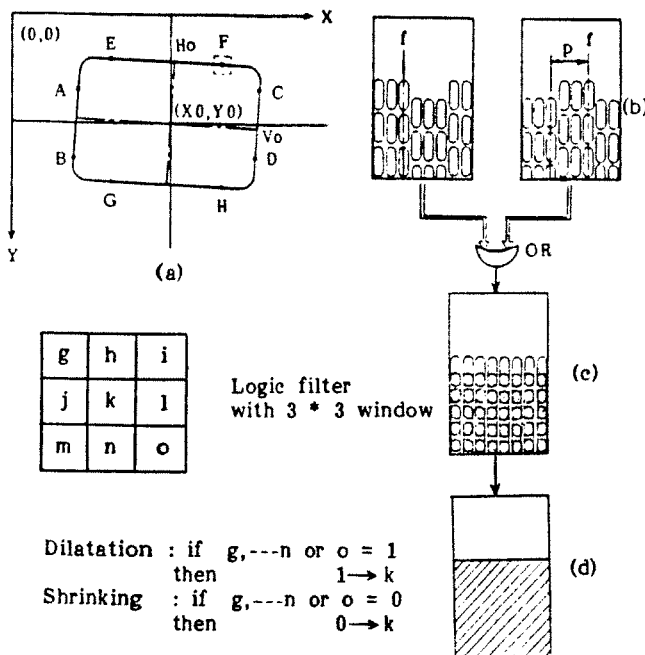


Figure 4 CPT screen position measurement

## (2) The error from the structure of CPT

The pattern shape and size are very important to calculate the center of the picture. Figure 7 shows an example of round pattern. The difference (L-R) between the center of electron beam (R) and the center of the pattern (L), is curved as a function of relative position between the electron beam and the phosphor. The position being no error appears periodic, but the relative position between the electron beam and the phosphor is at random. And the maximum error depends on the parameter of detecting pattern diameter in Figure 7. The Figure 8 shows the maximum error versus the detecting pattern diameter. The curved in Figure 8, has 7 minimum points. Considering limitation of detecting area of ITV camera, the diameter of pattern 4.9 mm is chosen in this system. This diameter provides minimum deviation of 0.025 mm in the detection.

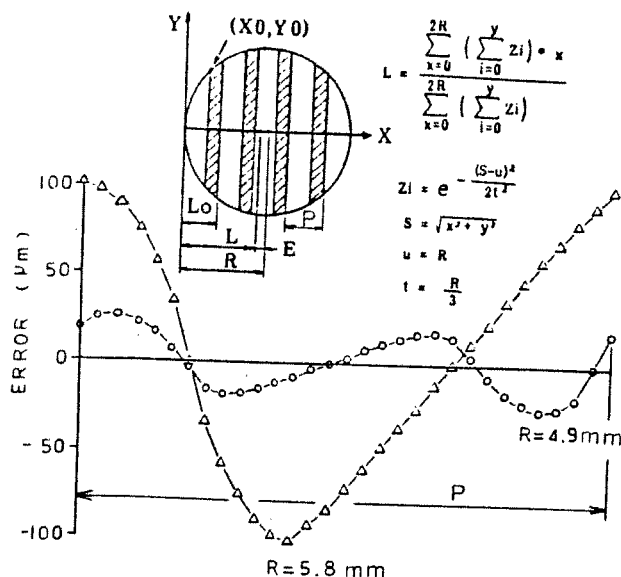


Figure 7 Difference between the center of electron beam and the center of pattern

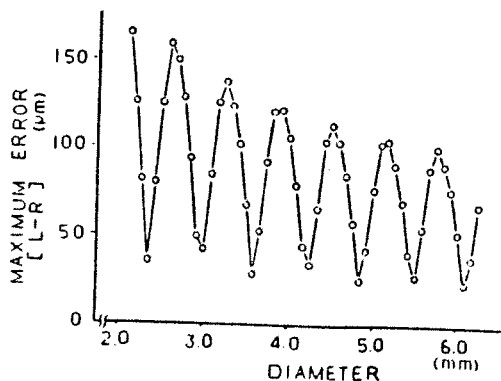


Figure 8 Maximum error versus the detecting pattern diameter

## Evaluation procedure

## (1) Setting of evaluation condition

Pattern: Dot pattern

Optical magnification: 25 μm/pixel

Optical filter: green (red, blue) filter

## (2) Image data fetch

Fetch data : 512 \* 512 pixels \* 256 levels

Processing data : 400 \* 400 pixels \* 256 levels

## (3) Data conversion

Data below (except phosphor emitting portion) a suitable brightness level (The) are deleted. The The is determined on the basis of a processing image histogram obtained, since the delicate setting is required.

$$\text{If } D_{ij} < \text{The}, 0 \rightarrow D_{ij}$$

$$\text{If } D_{ij} \geq \text{The}, D_{ij} - \text{The} \rightarrow D_{ij}$$

The data conversion is performed by the data conversion function in the high speed image processing unit with table memory previously prepared.

## (4) Pattern position calculation

The Pattern brightness center is obtained in Figure 9. To get same calculation for red pattern, the green filter is changed to red. (same as (2) to (4)) The optical filter is set to blue and the blue pattern position is obtained. (same as (2) to (4)) The relative discrepancy of red and blue patterns from green pattern, is calculated. ITV camera is moved to the next point to repeat above flow. The number of marks for the evaluation is 13 to 29/screen, and it can be preset.

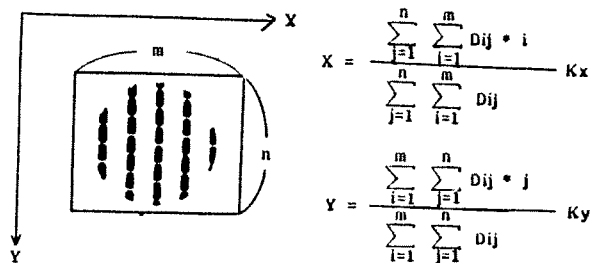


Figure 9 Example of pattern position calculation

## 3.3 Raster Distortion

It is necessary to collect many point data (maximum : 58 points) in this evaluation. The detecting position is changed depending on the characteristics even in the same category of tube. Therefore, this evaluation is the most difficult problem for the inspector. The error by manual evaluation is 0.5 to 1.0 mm. Figure 10 and Table 2 show evaluation categories.

## (1) Evaluation Pattern

Three patterns of the dot pattern, vertical pattern, and horizontal pattern are used as the evaluation pattern. The evaluation standard positions are determined with dot pattern. The distortion in horizontal direction is detected with the vertical pattern, and the distortion in vertical direction is detected with the horizontal pattern. The evaluation pattern color is green (in case of in-line type electron gun). The purpose is to eliminate the Convergence error.

## (2) Evaluation position

The CPT screen forms a sphere shape. When the detecting angle is changed, a shifted pattern position is detected. For instance, a detection is performed with 1 degree tilted down to the tube axis at a distance of 20 cm from the tube at a screen edge of a 14" tube, a discrepancy of approx. 0.1 mm occurs in the vertical direction when it is compared with a case where a parallel detection is performed to the tube axis. This causes most of the detecting error by manual. This system is designed to within 0.2 degree to the tube axis.

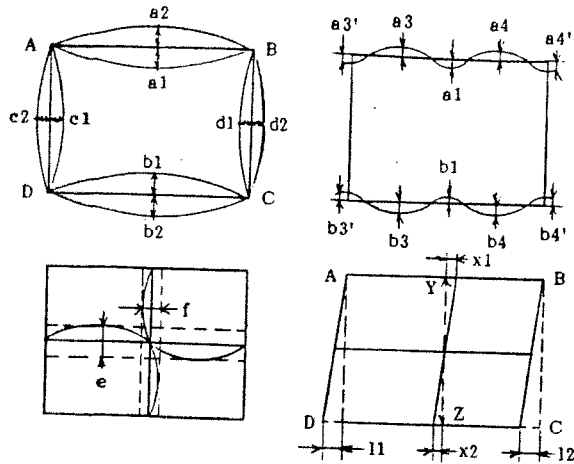


Figure 10 Raster Distortion evaluation categories

Table 2 Raster Distortion evaluation categories

Symbol	Category	Definition
BH	Top bottom barrel	$2 \frac{a2 + b2}{AD + BC} * 100$
BV	Left right barrel	$2 \frac{c2 + d2}{AB + CD} * 100$
CH	Top bottom pincushion	$2 \frac{a1 + b1}{AD + BC} * 100$
CV	Left right pincushion	$2 \frac{c1 + d1}{AB + CD} * 100$
TH	Top bottom trapezoid	$\frac{ AD - BC }{AD + BC} * 100$
TV	Left right trapezoid	$\frac{ AB - CD }{AB + CD} * 100$
KH	Top bottom bow	$2 \frac{f}{AB + CD} * 100$
KV	Left right bow	$2 \frac{e}{AD + BC} * 100$
A	Intersectionality	$\frac{x}{YZ} * 100$
11 or 12	Parallelogram	11 or 12
SG	Seagull	$\frac{3}{2} \frac{(a1+b1)-(a3+a4+b3+b4)}{AD + BC} + \frac{1}{4} \frac{(a3'+a4'+b3'+b4')}{AD + BC} * 100$

**Evaluation procedure****(1) Evaluation condition setting**

Pattern: Dot pattern, Vertical pattern,  
Horizontal pattern  
Optical magnification: 50 um/pixel

**(2) Image fetch**

The green dot pattern is displayed to detect positions of A,B,C and D at screen corners. This detecting method is same as that of the above Convergence. Four points at corners are equally divided to determine the detecting position. Next, the vertical pattern (or the horizontal pattern) is displayed on the screen to fetch the image data.

Dot pattern: 400 \* 400 pixels  
Vertical pattern: 120 \* 400 pixels  
Horizontal pattern: 400 \* 120 pixels

**(3) Data conversion**

The vertical pattern image data example is

shown in Figure 11(a), (b). The fetched image data (Dij) below a suitable brightness level (Thd) is detected like the method in Convergence.

**(4) Pattern position calculation**

The data-converted 400 \* 120 pixels \* 256 levels image data are added to the vertical direction (to the horizontal direction in the horizontal pattern). The result is shown in Figure 11(c). From this value, the pattern center (Pc) is obtained. By calculating PL and PR, the detecting error is made small, which causes the phosphor arrangement.

**(5) ITV camera is moved to the next evaluation point to repeat the detection.**

After the detections are completed, contents in Table 2 are calculated to output them on the XY plotter and TTY.

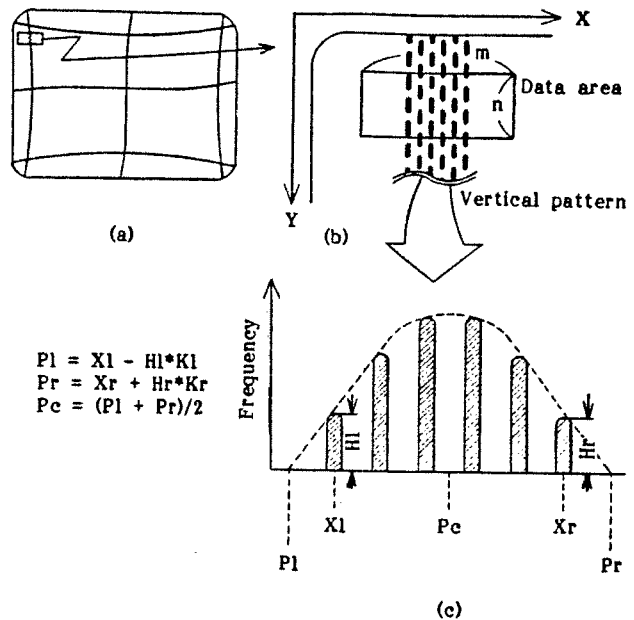


Figure 11 Raster Distortion detecting method

**4. PROCEDURE OF THE EVALUATION SYSTEM**

The evaluation procedure is shown in Figure 12. First, the tube to be evaluated is set into the system. This setting up operation is only preparatory, to determine the screen position, and need not be very accurate. The category, evaluation items, evaluation count, result output format, and other conditions are input through control panel and CRT console. These conditions are displayed in a form of a list on the CRT console. Errors in conditions, if any, are corrected. If there are no errors, the START button is pressed to start evaluation. Numerical data are output on TTY and graphical data are output on X-Y plotter.

**4.1 Evaluation Result**

In line with evaluation operation, evaluation results are output on TTY and X-Y plotter sequentially for each items. Differing from conventional visual evaluation, this automatic system does not require data rearrangement and arithmetic operation on the desk and it provides evaluation results correctly and rapidly. Examples of evaluation results for Convergence and Raster Distortion are shown in Figure 13 and 14. Evaluation results are shown in two dimensional graphic form, with enlarged evaluation point at a required scale. A color pen is used for better visibility.

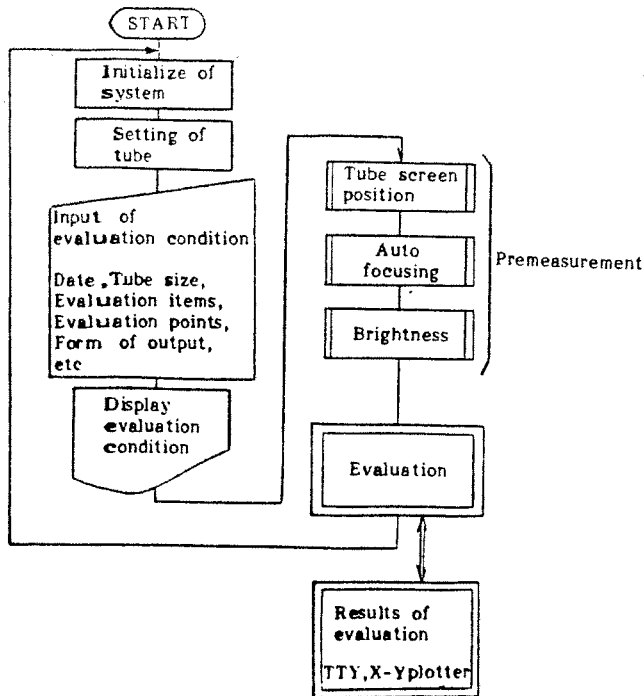


Figure 12 Evaluation procedure flow diagram

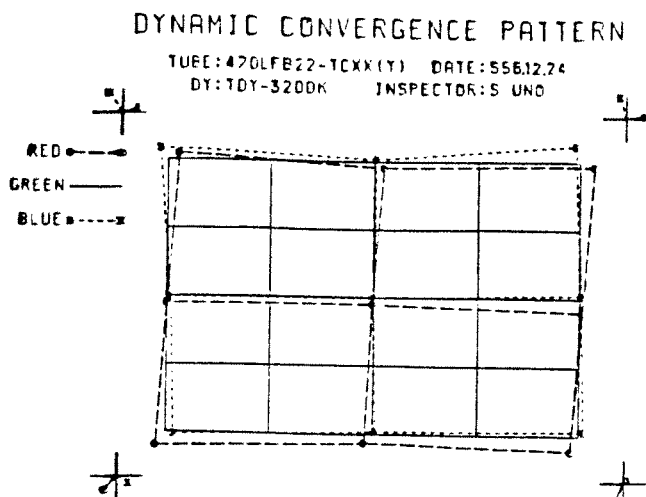


Figure 13 An example of Raster Distortion evaluation output

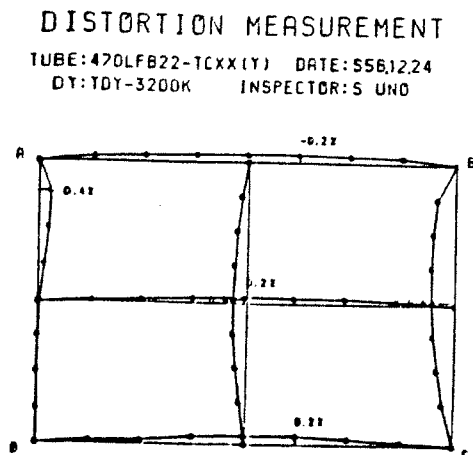


Figure 14 An example of Convergence evaluation output

## 5. THE PERFORMANCE OF THE EVALUATION SYSTEM

Automatic CPT picture characteristics evaluation has achieved substantial improvement in evaluation accuracy, quantification of manual evaluation and saving evaluation time.

### Major performances:

Evaluation items: 5 ; Raster Sift, Raster Rotation, Raster Distortion, Convergence and Halo

Applicable type: 14 sizes (from 9 inch to 26 inch)

Evaluation accuracy: as shown in Table 2

Evaluation time: 10 min (1/10 of manual)

Evaluation output: TTY, X-Y Plotter (Graphic display in 8 colors)

Table 3 Evaluation accuracy

Item	Detecting Point	Image Data	Accuracy	Output Device
Premeasurement				
Tube Screen Position	8	2 levels	0.1 mm	—
Auto Focusing	3	—	0.05 mm	—
Brightness	1	256 levels	—	—
Raster Shift	4	256 levels	0.1 mm	TTY
Raster Rotation	4	256 levels	0.1 degree	TTY
Raster Distortion	5 * 5 9 * 9	256 levels	0.1 mm	TTY PLOTTER
Convergence	13, 19, 29	256 levels	0.02 ~ 0.05 mm	TTY PLOTTER
Halo	5, 9	256 levels	0.05 mm	TTY

## 6. CONCLUSIONS

The author developed the automatic evaluation system for CPT picture characteristics using a visual sensor, a high speed image processing unit and minicomputer. Results are as follows.

- (1) The accuracy has been improved four times as compared with the conventional visual evaluation.
- (2) The system has eliminated the unreliability by replacing manual evaluation with the objective quantification evaluation.
- (3) The high speed image processing unit has reduced the data processing time and evaluation time is now 1/10 of the conventional method.
- (4) The system can handle 14 sizes of CPT, from 9 inch to 26 inch.

The system can be now applied to production of high definition color display tubes.

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