Geometrical calibration television measuring systems with solid –state photo detectors

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ABSTRACT

The various optical measuring methods for deriving information about the size and form of objects are now used in difference branches - mechanical engineering, medicine, art, criminalistics. Measuring by means of the digital television systems is one of these methods. The development of this direction is promoted by occurrence on the market of various types and costs small-sized television cameras and frame grabbers. There are many television measuring systems (Beyer H. A., Kersten T., Streilein A) using the expensive cameras, but accuracy performances of low cost cameras are also interested for the system developers. For this reason inexpensive mountingless camera SK1004CP (format 1/3 ", cost up to 40 $) and frame grabber Aver 2000 were used in experiments.

1. INTRODUCTION

Information about sizes and forms of objects in contactless digital television systems is received from digital images. Digitized images consist of elementary fragments - pixels, which are operated at the further processing. The pixel sizes are one of the basic characteristics of these systems. Every pixel corresponds to an element of image plane coinciding with plane of photo detector in television systems. On the other hand the output signal of used camera is analog and is connected to photo detector structure by an implicit manner. The pixel sizes depend both on topology of the photo detector and as well the used frame grabber. In the paper a technique, equipment and results of geometrical calibration of television measuring systems - definition of the pixel sizes are considered.

It is necessary to note, that the photo detector plane is arbitrary situated in space and the television camera has no technological surfaces, which could be accepted as a base.

2. EQUIPMENT AND TEST ORGANIZATION

To measure the pixel size the image of reference structure with known geometrical characteristics (further - cliche) is projected on photo detector surface. Having fixed this image in a computer memory, there define distance between the marks of a cliche in pixels and, knowing the geometrical characteristics of a cliche, determine the pixel sizes.

Distance between a photo detector plane and its protective glass is less than 2 mm. The projection of a cliche to a photo detector plane has to carry out in parallel beams for increase of the accuracy. The method of a shadow projection was used to create the image of a cliche on a photo detector plane. The optical schema of the plant for defining pixel sizes is submitted in a fig. 1.

The base part of the plant is a collimator. The aperture illuminated by LED is situated in its focal plane. LED is used to eliminate a chromatic aberration. To simplify the plant design the LED has diffusing radiating surface and is established close to the aperture plane. The focal length of collimator is 240 mm, the aperture diameter is equal 0.1 mm.

Thus, the linear error of a cliche projection on a photo detector plane does not exceed 0.42 μm. The sizes of the photo detector element of the camera are 9,6*6,3 μm.

The camera together with a cliche is located down after collimator. The cliche projection on the photo detector plane is occurred in a parallel beams without use a objective, as it can bring additional errors.

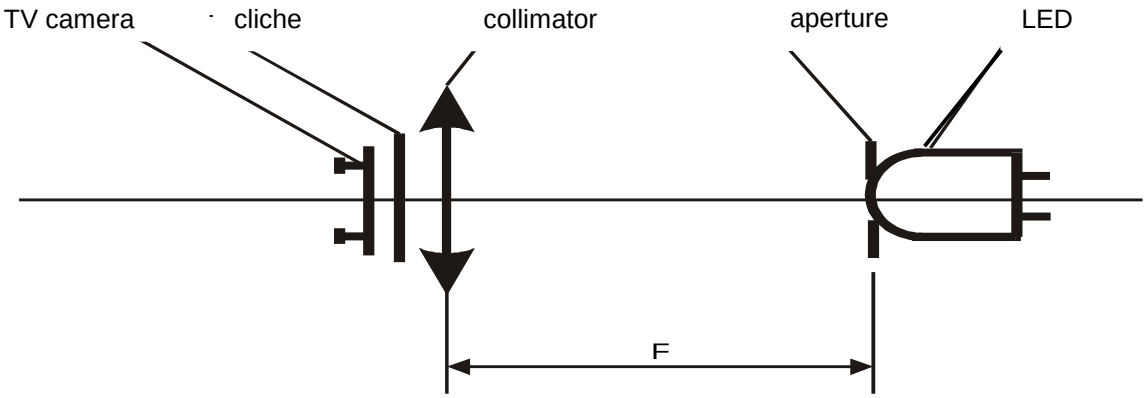

Figure 1

The researched camera is established on a mobile platform. The platform provides an exhibition of the photo detectors plane in parallel of the cliche plane. The cameras of a different format - 1/3”,1/2 " and 3/4 " can be researched by the plant. The generic view of the plant for definition of the pixel sizes is submitted in a fig. 2.

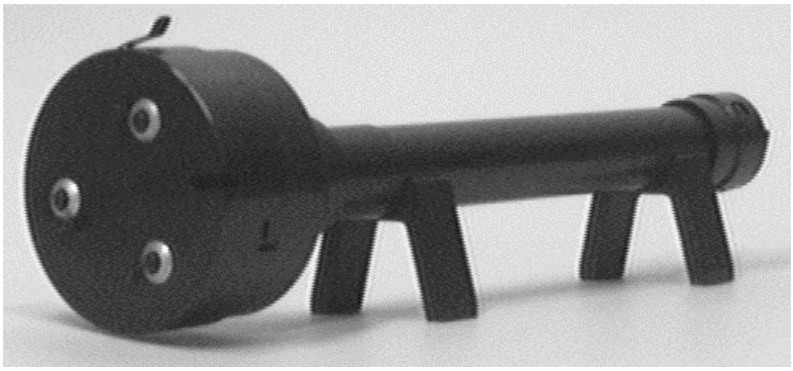

Figure 2

The cliche is a set of 64 identical marks (squares) located in two regions:

- 46 squares are located in external frame;
- 18 squares are located in the central zone.

The squares are located on identical distance from each other within the zone. Distance between squares in the central zone is not multiple to distance between squares in external frame. It is made that they occupy various situations against photo detectors structure. The squares of the central zone are not used at calculation of the pixel sizes, there are serviced for an estimation of the received results. The topology of a cliche is submitted in a fig. 3.

Breadboard of a cliche previously makes on a sheet of À1 format and then photographically transfer on a glass plate with the appropriate reduction. The sizes of squares and distances between them are determined after manufacturing cliche. The results of measurements have shown that the average size of a square is 119,3 μm. Standard deviation of the centers of squares forming the bottom and left parties of a frame does not exceed 0,64 μm. The center of a square located in a right top corner of a cliche, is displaced on 3 microns upwards (concerning a square located in the left top corner) and on 2 microns to the left (concerning a square located in a right bottom corner). The appropriate proportional shift is observed at all squares located on the top and right parties of a frame.

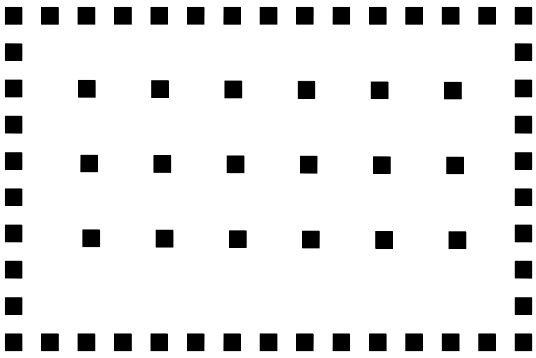

Figure 3

As mentioned above to increase the accuracy of measurements it is necessary to situate the cliche and photo detectors plane parallel to

each other. Therefore the researched camera is established on a mobile platform rotating against the cliche. At the first the roll coordination carry out. The elimination of a mutual roll is very important as the pixel size is not equal on both coordinates. The roll coordination has been fulfilled when the centers of images of squares forming the left and bottom horizontal parties of a frame are parallel to lines and column of photo detectors. Therefore it is necessary to rotate a cliche until standard deviation of the appropriated pixel coordinates of the centers of the squares images should be minimal.

After the roll coordination is finished, changing a spatial location of a photo detector plane so, that it should be parallel to cliche. For this purpose define average area of a square using five squares symmetrically located in corners of an external frame - actually angular and two contiguous to it in vertical and horizontal direction. The comparison of the "left" and "right" average squares gives the information about turn the photo detector plane concerning a vertical axe, "top" and "bottom" - concerning horizontal. The error of an angular mismatch is close to 30 angular seconds in all cases.

After coordination are over count up number of pixels between images of square in lines and columns. Correlating them with data of a cliche, define the pixel sizes at the given adjustment of the frame grabber.

3. IMAGE PROCESSING ALGORITHM

The calculation of the pixel sizes is performed in an automatic mode. The image processing algorithm is steady against non-uniformity of brightness distribution and various sort to nonlinear distortions, for example, diffraction. The image used at the definition of the pixel sizes is submitted in a fig. 4.

The transformation of the initial image was carried out before the beginning of processing. The image consisting only of even lines was formed (Shortis M. R., Snow W. L.) according to formation algorithm of video signal in solid-state camera. The iterative binarization was used for initial definition of the squares arrangement. As the images are differ on brightness, and the separate regions of the image may be blacked or clarified, the binarization was carried out for several levels of brightness and all recognized objects were put down in a database. Then the objects selection was carried out: the objects closed to patterns (squares) had been chosen from all registered. The term "close" means, that the root-mean-square deviation from pattern does not exceed the given value. Best percent of recognition was received at the following parameters: the pattern for a square was an object by the size 20x10 (asymmetry is explained by increase of an interval discretization on a vertical in two-times) and area was equal 200 units. After this the structure of fragments was formed for the subsequent processing of the initial image by subpixel methods. Four squares which center coordinates to be closed to corners of the cliché image were got out from all selected squares and further all coordinates of fragments were generated by linear interpolation. The size of generated fragment is equal the size of a limiting rectangular binary image of testing square plus the size of a limiting border extending 3-4 pixels.

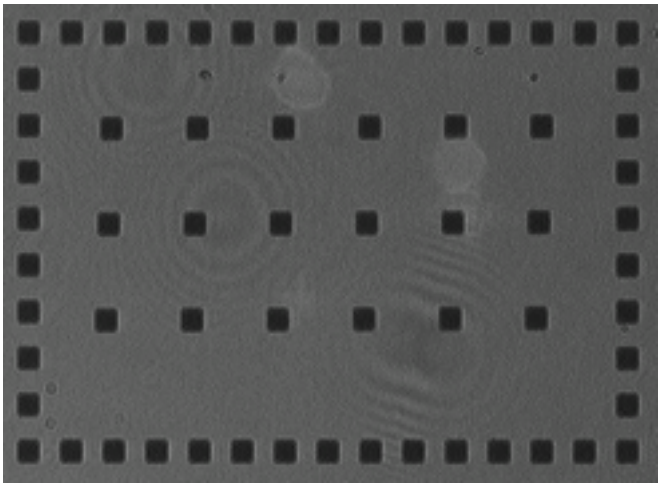

Figure 4

The algorithm of definition the coordinates of the square center is invariant to an arrangement of the square in a fragment space, local brightness and contrast of object and background. For this purpose the part of a background (bordering curb extending 2-3 pixels) and part of test object (square with the side at 15-20 pixels) were allocated in a testing fragment. The dimensions of these parts have to exactly belong to chosen area (according to a background and cliche), and on the other hand the pixel amount in cutting area should be sufficient for representative sample. Ensemble expectation and RMSE of the brightness fields of received samples have been calculated and then are used for normalization and calculation of the area of the received figure and its coordinates of the center of weight.

4. RESULTS

The pixel sizes in both coordinates and the measure estimation of the error linear size in photo detectors plane are received. The squares located within external frame was used to define the pixel sizes and the squares located in the central zone was used to define the error of measurements. The size of the registered images was 680*512 pixel according to parameters of frame grabber. The results of measurements are submitted in the table.

μ_x µm	μ_y µm	σ_x µm	σ_y µm	σ_x^m µm	σ_y^m µm	σ_x^p pix	σ_y^p pix
6,8728	**12,597**	**0,00134**	**0,00463**	**1,0763**	**0,6628**	**0,1353**	**0,1055**

μ_x – ensemble expectation of the pixel size on a horizontal
μ_y - ensemble expectation of the pixel size on a vertical
σ_x – RMSE the pixel size on a horizontal
σ_y – RMSE the pixel size on a vertical
σ_x^m – RMSE horizontal distances between squares located in the central zone of a cliche
σ_y^m - RMSE vertical distances between squares located in the central zone of a cliche
σ_x^p – RMSE horizontal distances between the images of squares
σ_y^p – RMSE vertical distances between the images of squares

The difference of the horizontal and vertical pixel spacing is defined by the generating characteristics of a television signal in solid-state cameras .

Attended accuracy is in a range from 1/10 up to 1/15 pixel spacing.

The comparison of last 4 table columns shows that the developed algorithm of sizes definition fills in to the data of measurements.

5. CONCLUSION

The opportunity of creation the television measuring systems using inexpensive mountingless television cameras have shown. The application of such cameras provides not only sufficient accuracy of measurements, but also allows minimization the size and price of created equipment. The accuracy reduction of determination the object location, in comparison with (Beyer H. A., Kersten T., Streilein A), is connected with increased noise level of used cameras and small number of sensor elements.

6. REFERENCES

1. Beyer H. A., Kersten T., Streilein A., 1992. Metric Accuracy Performance of Solid-State Camera Systems. SPIE Vol. 1820 Videometrics (1992), pp. 103-110.

2. Shortis M. R., Snow W. L., Calibration of CCD cameras for field and frame capture modes. Proceedings, Digital Photogrammetry and Remote Sensing ' 95, SPIE, Vol. 2646, pp.2-13.