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AUTOMATIC CALIBRATION SYSTEM FOR DIGITAL INSTRUMENTS WITHOUT BUILT-IN COMMUNICATION INTERFACE

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Abstract − In this paper a solution for metrological calibration of *digital instruments without built-in communication interface* (DIWIs) is presented. The solution is based on the conversion in numerical data of video camera images of DIWI display. The paper describes the vision algorithm used, illustrates the functionality of the realized software (in LabVIEW environment), and presents the results of an actual calibration experiment performed on a Fluke model 189 True RMS digital multimeter.

Keywords: instrument calibration, machine vision, automatic test equipments.

1. INTRODUCTION

A frequent need of laboratories, both industry and metrology ones, is to calibrate instruments and to verify or establish the traceability of the measurements. Calibration of instruments that do not have a built-in communication interface is a very time-consuming work, and the results of this process are prone to human mistakes. The calibration procedure, indeed, involves many reading operations by a competent technician, who must manually annotate the measurement provided by the device under test (DUT). As a consequence, each calibration point has a definite and considerable cost, and the number of points is reduced to a minimum, to the detriment of the final accuracy.

The present paper describes a low-cost solution, based on machine vision techniques, for the automatic calibration of digital instruments that do not have digital interface (i.e. GPIB, RS 232, LXI and so on). The work takes on others [1], [2] [3], [4], which deals with the use of machine vision on analog instruments and/or DIWIs. As an improvement, the paper illustrates in detail both the calibration procedure and the hardware/software system that implements it, which includes also a particularly user-friendly graphical user interface (GUI).

The paper is organized as follows. Section 2 presents the automatic calibration system; section 3 illustrates the measurement procedure; section 4 discusses the necessity to validate the system and presents the adopted solution; finally, section 5 discusses the results of the implementation of the measurements algorithm.

2. GENERAL STRUCTURE OF THE AUTOMATIC CALIBRATION SYSTEM

Fig. 1 a illustrates the block diagram of an automatic calibration system for DIWIs, involving the use of a personal computer equipped with GPIB controller, a calibrator, a video camera and the DUT not equipped with a computer interface.

In Fig. 1 b an alternative solution is shown, using a programmable power supply (PWS) with a digital multimeter (DMM), instead of a calibrator. This is the layout actually used by the authors to obtain the reported experimental results.

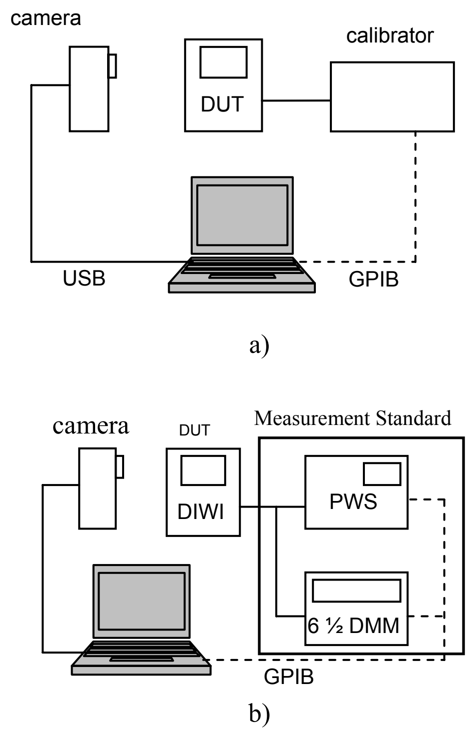


Fig. 1. Block diagram of the automatic calibration system: a) using the calibrator; b) the alternative solution.

Indeed, even if under many respects the layout of Fig. 1-a may be preferable, the adopted solution is suitable for a larger number of laboratories, since DMMs and power supplies are much more common than calibrators.

The actual calibration system has been realized with a set of low-cost hardware components, consisting in a Windows-based personal computer (PC) equipped with GPIB controller, a webcam (Philips ToUcam Pro II PCVC 840K), a programmable Power Supply (Agilent E3631A), a programmable DMM (Agilent 34401A). and a Fluke 189 True RMS Digital Multimeter [5] as DUT. This particular instrument has been chosen as a DUT because it has a standard LCD, like many typical DIWIs, but it is actually equipped with an RS-232 interface. This allowed the automatic validation of the actual calibration system, described in Section 4.

As regards the software part of the calibration system, it has been realized entirely in LabVIEW® environment, making use of *NI Vision Assistant* ver. 8.2.1, and *NI-IMAQ for USB Cameras* 1.2.0 driver.

3. CALIBRATION PROCEDURE AND SOFTWARE

The errors in the calibration procedure should be identified and quantified to get the estimation of the calibration uncertainty. The *Test Uncertainty Ratio* (TUR) is defined as the ratio between the uncertainty of the DUT and the estimated calibration uncertainty. So, in our case, the measures obtained by the DMM (6½ digit), compared with the DUT measures (4 ½ digit display), can be considered as reference values because it was verified that the TUR is greater than 5 [6].

The set of measurement points for the calibration procedure of the DUT has been chosen according to the *Guidelines on the Calibration of the Digital Multimeters* [7]. The calibration procedure is conceptually easy to understand: by applying a known input, coming from the PWS, it is possible to calculate the error of the DUT

$$E_x = V_x - V_c\,, \qquad (1)$$

where V_x is the voltage measured by the DIWI (which is acquired by means of webcam and machine vision), and V_c is the voltage measured by the DMM (which is acquired via GPIB interface).

In the automatic calibration procedure, whose flow-chart is shown in Fig. 3, there are three key phases:

1. adjustment phase;
2. measurement phase;
3. data storing phase.

The first phase consists in a step of (manual) alignment of the webcam with the DUT display, a step of preliminary image acquisition (with the video camera set for acquiring 32-bit RGB images), a step of processing/recognition of the image converted at 256 gray levels, and a last step of definition of the *region of interest* (ROI), a rectangular shaped area that defines the application of the Optical Character Recognition (OCR) algorithm.

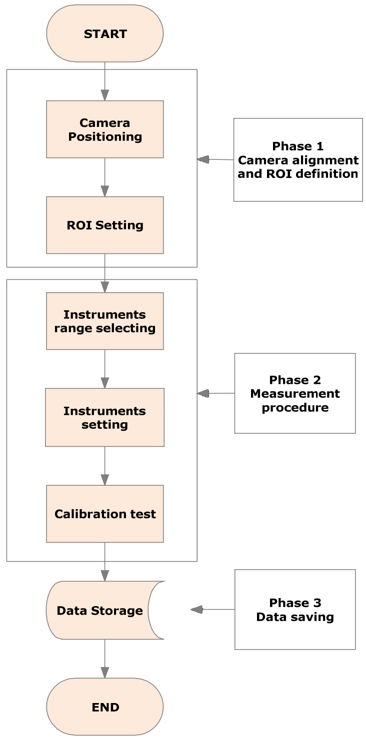


Fig. 3. Block diagram of calibration procedure.

The ROI is easily selected with mouse-dragging. Firstly, the coordinates of the global rectangle of interest must be identified (Fig. 4); afterwards, all the rectangles that edge each digit displayed (Fig. 5) must be drawn. The relevant data are transcribed by the software in the ROI descriptor (Fig 6).

Fig. 4. ROI – global rectangle.

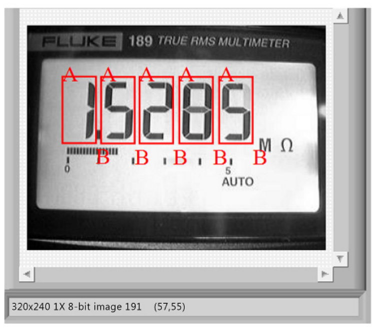


Fig. 5. ROI – single digits.

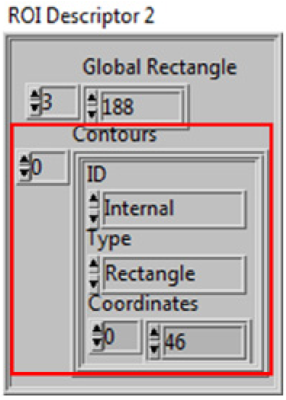


Fig. 6. ROI descriptor.

The second phase consists in a first step of settings of the measurement parameters, and a second step that carries out the calibration test.

In Fig. 7 the front panel relevant to the settings of the instruments is shown. The power supply range and the number of measurement cycles are set. Besides, the general instruments parameters, that enable them to communicate via GPIB interface, are fixed.

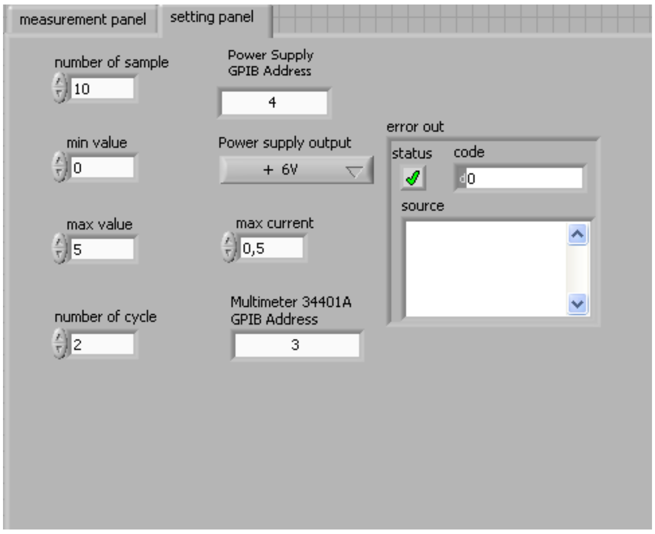
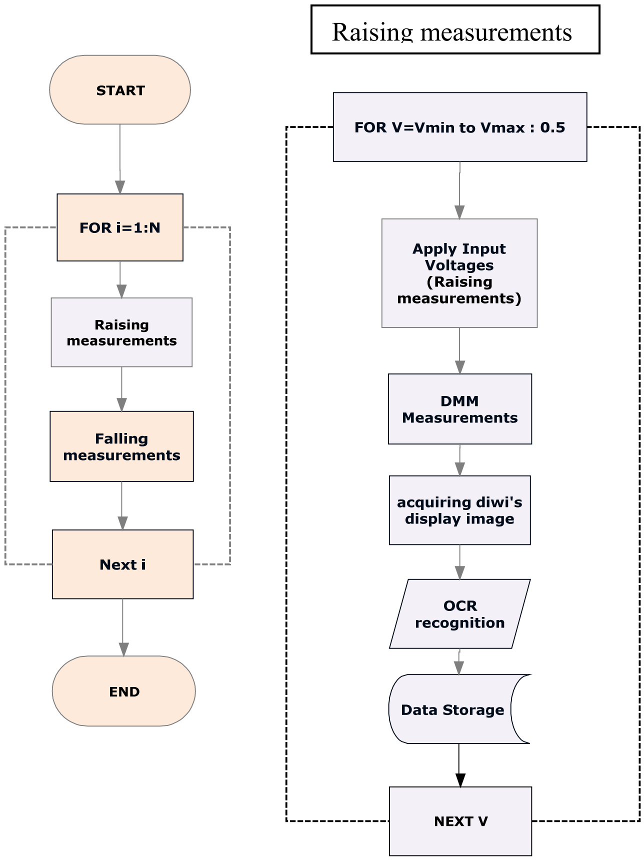


Fig. 7. Setting panel.

In Fig. 8 the block diagram of the calibration test is reported. N measurement cycles are performed, each including a phase in which raising voltage values are generated, and an identical phase with falling voltage values. This allows one to detect a possible hysteresis phenomenon in the DUT. In this phase also an evaluation of repeatability is carried out, according to the standard guidelines in [8].



a) b)

Fig. 8. a) Block diagram of calibration test b) Flowchart of the raising measurements block (the falling measurements block is identical).

The third phase consists in inspecting the data obtained during the measurement phase, to check for possible obvious failures in performing the measurements, and saving the data.

4. VALIDATION OF THE OCR-BASED CALIBRATION SYSTEM

It is know that OCR algorithms cannot guarantee a 100% reliable reading. For example, the recognition can be critically affected by the lighting of the LCD of the DUT. On the basis of this consideration, the calibration system has been validated – as regards the OCR subsystem – with a specific procedure.

Since the Fluke 189 DMM, chosen as a DUT, is equipped with an RS 232 serial port, it has been possible to compare the optically recognized values with the true measurements transmitted over the RS-232 interfaces. This is performed by a separate LabVIEW VI.

5. RESULTS AND DISCUSSION

Fig. 9 reports the results of three measurements cycles performed on the DUT, taken in the range [0, 5] V, with steps of 0,5 V. It can been seen that the measurements are randomly different from each other, highlighting the absence of drift and hysteresis.

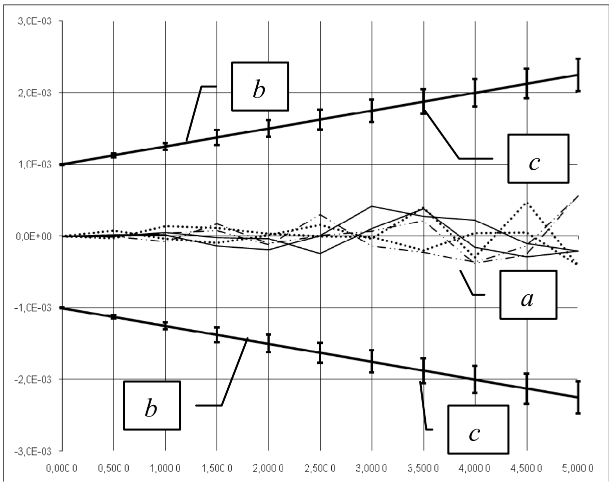


Fig. 9. Results of three measurement cycles (summing up to 6 curves), in terms of measurement errors as a function of the applied voltages. Curves (a) are the measurement errors, lines (b) represent the uncertainty limits of the DUT, errorbars (c) represent the uncertainty of the reference instrument.

Fig.10 shows the front panel of the graphical interface. It is clear that the images captured by the webcam match with the values recognized by the OCR algorithm.

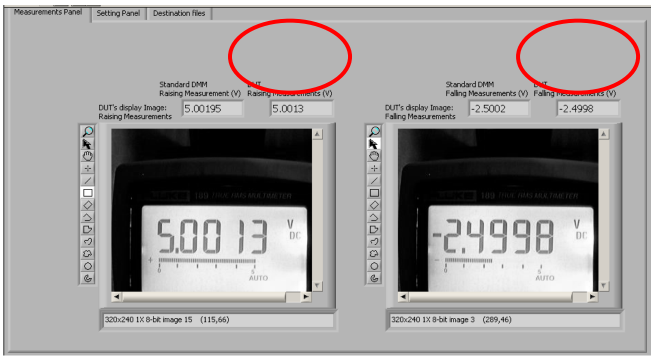


Fig. 10. Front panel - graphical interface.

6. CONCLUSIONS

The use of automatic calibration system for digital instruments not equipped with PC interface that was presented, allows all laboratories to calibrate their instruments.

In this paper only the DC voltage calibration procedure is described, but the calibration procedure presented can be applied to digital instruments able to measure AC/DC voltage, AC/DC current and resistance.

A solution for metrological calibration of DIWIs was presented and the vision algorithm was illustrated. Results are shown and discussed.

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