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UTILIZATION OF ADVANCED IMAGE PROCESSING ALGORITHMS IN COMPUTER CONTROLLED DIGITAL MEASUREMENT DEVICES CALIBRATION STAND

ABSTRACT *Digital measurement devices are still growing fraction of wide spectra of the measurement tools utilized in various disciplines of science and technology. Although many of such devices are equipped with advanced digital circuits, they have no digital interfaces. Therefore realization of the automated calibration process is impossible, and performing laborious and time-consuming comparison procedure of the standard and tested devices readouts is necessary. This issue can be solved by utilization of the automated calibration system equipped with the optical character recognition (OCR) feature, which will allow to perform the readouts without involvement of the human. In this work we present the computer-based readout recognition system for digital measurement instruments. Performed tests allowed to evaluate the quality of the recognition process and to confirm the effectiveness of developed solution as an alternative for the processes performed by the employees of the calibration laboratories.*

Keywords: *calibration, image processing, metrology.*

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1. INTRODUCTION

Analog and digital measurement devices are important equipment in many industries and research laboratories. To achieve periodic confirmation of the measurement consistency with national measurement standards, these instruments should be regularly calibrated according to the recommendations of the ILAC [1]. It should be noted that the calibration procedures, processing of obtained data and finally evaluation of metrological properties of the instrument are the subject of detailed documents to be followed by all calibration groups as well as the institutions functioning in accordance with the standards that define the system of quality management [2-6].

Many of the instruments that are currently in use, does not have digital interfaces which would allow its integration with the measurement system and perform the automated calibration process. Manually carried out calibration procedure, performed by laboratory personnel, is time consuming, expensive and does not allow to record all the effects that take place during the calibration such as readout settling time constant or the stability of the measurements.

The following paper proposes an advanced vision system for automatic calibration of measuring instruments utilizing computer image processing. The system’s reliability was verified by comparing the values obtained using the imaging with the value taken directly from the device through a digital interface. Our results showed that this system can be effectively used as an alternative for manual calibration, thus ensuring greater accuracy and reliability.

2. MEASUREMENT SYSTEM

The system includes Inmel SQ10 calibrator, the image sensor and a personal computer running LabView software environment 2010 with implemented OCR algorithms [7].

Recognition of digits required creation of software patterns of the character sets. For this purpose, the neural networks were used. For this purpose, the neural networks were used. The database includes typical characters for the most popular kinds of displays (Fig. 1), which allows to use the application for most devices without additional customization of the program. The algorithm can process and recognize both displays the dark and bright signs.

As various displays can differ in the intensities of displayed characters, the software thresholds adjustment in the characters segmentation algorithm was implemented. Furthermore, it also allows to define the maximum/minimum distance between the recognized characters and a maximum/minimum distance between the components of those characters.

a) b) c)

Fig. 1. Different kinds of the displays considered during development of the software:
a) 7-segment display, b) 14-segment display, c) graphic display

OCR feature allows to select several thresholding methods [8] which have a significant influence on reading accuracy. Depending on the lighting intensity and its spatial distribution, as well as the required speed of the algorithm, one can select appropriate method [9, 10]. Fixed Range method allows to control manually the threshold values. It is computationally efficient, but requires uniform illumination of the surface in ROI (Region Of Interest). Another methods are automated, therefore can generate threshold values depending on the content of ROI and type of detected signs (dark or bright digits). Uniform method calculates an individual threshold values for the entire ROI and, like Fixed Range, requires uniform lighting. Linear method divides the ROI into blocks and calculates separate values for the blocks on the left and right sides of ROI, and then performs a linear interpolation for blocks located between the left and right side. It is useful in cases where one side of the picture is brighter than the other. Non-Linear method, also divides ROI into blocks, but separate threshold values are calculated for each block.

SQ10 calibrator (from INMEL) allows performing the calibration within range of typical values of basic electrical parameters such as voltage, current and frequency. In order to provide communication with host unit, a serial interface RS 232 was utilized. Functional software block was designed in order to enable remote control the device and implement automated calibration procedures [11].

The image acquisition was performed with a sensor based on CMOS sensor with a resolution of 640x480 pixels, fixed focal lens $f = 3.25$ mm and aperture $f/2.4$. Sensor has automatic exposure control while the image sharpness is adjusted manually. By utilizing the interpolation process, the device allows to acquire the video data stream with a maximum resolution of 800x600 pixels and images with a resolution of 1280x960. Data is transmitted to the computer via USB 2.0 interface. Acquired images have 32-bit data format defining the intensity of the RGB color components. In order to perform OCR process, the 8-bit images are required, therefore only "G" channel (green) was used, as it contains the least amount of noise. The diagram showing the test setup configuration is shown in Figure 2. Although in general digital interfaces allowed to obtain bidirectional communication, the arrows indicate the main flow of the information.

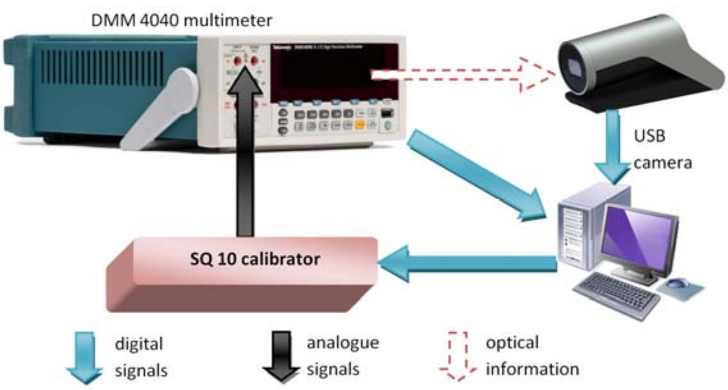

Fig. 2. The simplified diagram showing the test setup

3. MEASUREMENT VALIDATION TESTS

In order to perform the measurement validation tests, Tektronix DMM4040 6.5 digit resolution multimeter [12] was utilized. As this instrument is equipped with a digital interface, it was possible to compare both: OCR decoded values and direct readouts.

A test application was developed in order to carry out the procedure (Fig. 3). Control sections 1 and 2 are used to set OCR parameters. In section 1 it is possible to select a set of characters corresponding to the display, which is currently being decoded as well as other parameters.

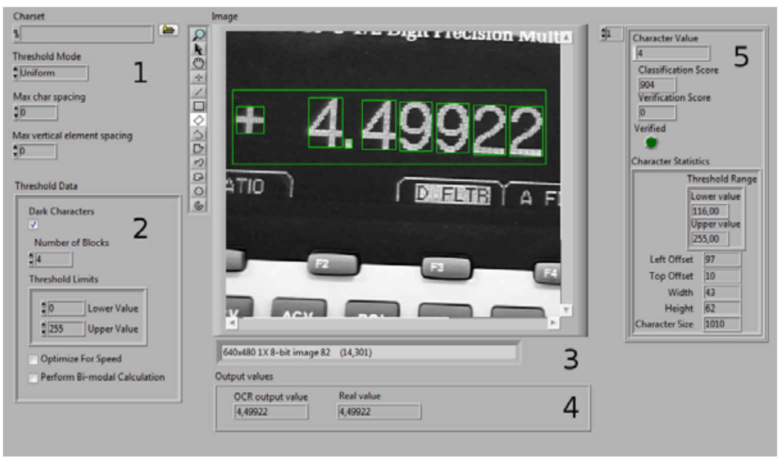

Fig. 3. The view of the test application interface with marked functional sections

Section 2 allows to set the thresholding parameters – selection of the type of character contrast (dark characters) and the thresholding limits for the method of Fixed Range. In section 3 the current camera image is displayed. Using special tools, one can select a part of image to be analyzed (ROI). Section 4 shows the current values of OCR (OCR output value) and the value returned by a digital interface (Real value). Section 5 displays the information concerning recognized characters such as: classification points, position of the recognized character in the image and its dimensions, the current calculated thresholding value.

The test was carried out by changing adjustments of the calibrator in range 0-9.5 V with 0.5 V step. In order to observe the entire process of the variation of measured value, the time interval for single voltage step was set at 10 s and a data processing and recording interval at 0.1 s.

The multimeter measurements were performed within a single measurement range in order to provide the proper execution of the test procedure for the intended range voltage. Processing time constant of the multimeter was about 100 ms. As the 10 V measurement range was used, the measurement resolution was 10^{-5} V.

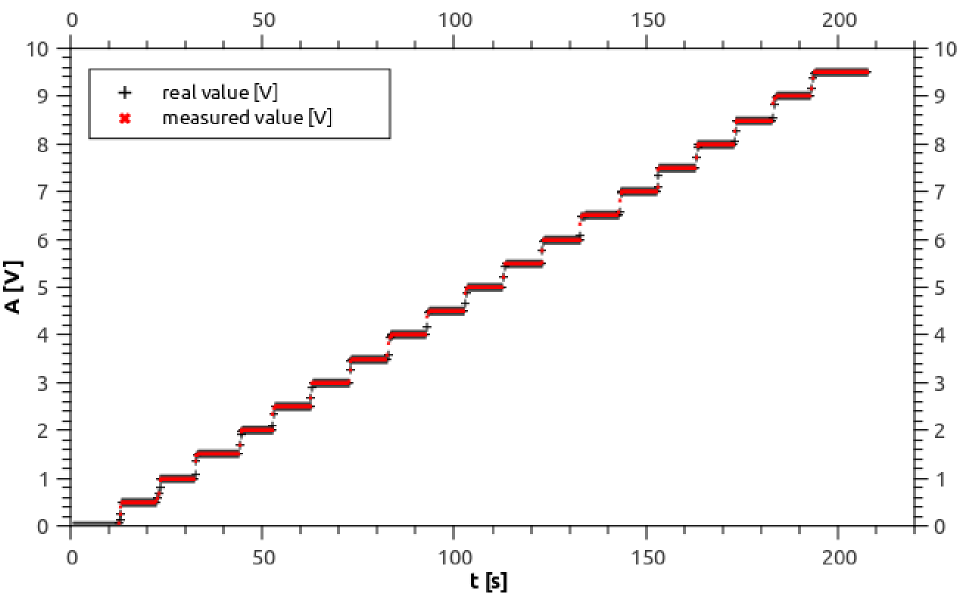

Fig. 4. The graph presenting changes of the measured value by the multimeter in time-domain – digital interface readout and the decoded displayed value

Figure 4 shows two datasets of the measured voltage: received via the digital interface and recognized displayed value. In order to analyze the effectiveness of the OCR process, a graph of the absolute error value of the decoded value (Fig. 5) is presented. It can be noticed that the full consistence of the digital and optical readouts is obtained after three seconds, as the error reaches zero level. Until then, the error is significantly higher, but this is related to the processing of the measured value and the determination of the indications on the display. While the OCR algorithm provides data immediately and the serial bus communication protocol introduces about 100 ms delay, it causes the differences between the values from both sources.

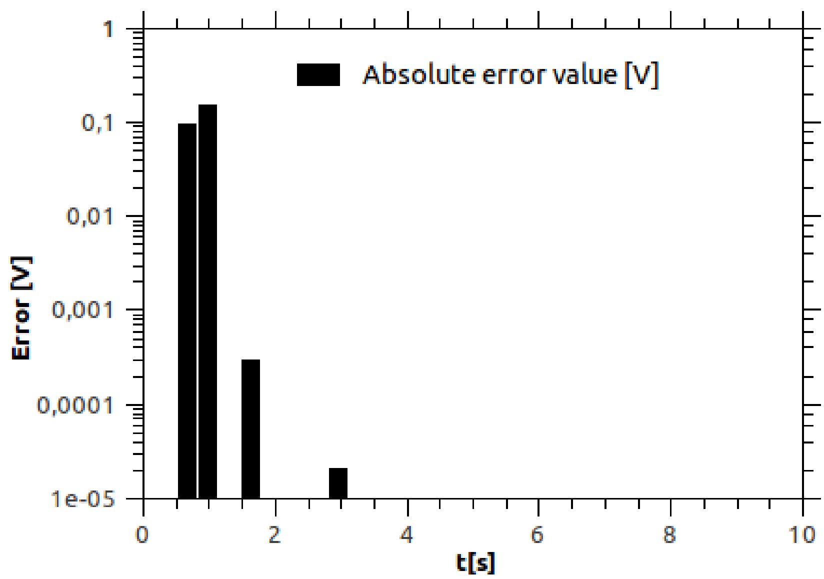

Fig. 5. Time domain graph showing the absolute error value of the decoded value displayed by the multimeter, for 0,5 V voltage value

3. CONCLUSIONS

Obtained test results proved reliable and accurate recognition of the data displayed by the measurement instrument. In addition, OCR algorithm works without noticeable delay, therefore results can be obtained faster than the readout by the digital interface. As we've tested the solution with one of the most demanding devices (6,5 digits resolution, complex digits display), one can assume, that the recognition process in case of any other measurement device will be also accurate and fast.

Presented advantages of developed system show, that the system can effectively replace the readings made by the service personnel, while bringing additional benefits such as lower labor costs, increased speed and reliability of the process. Additionally, extra features can be implemented, as estimation of the readout stability or the readout settling time. Further integration of control algorithms in the calibration software will allow performing the automatic calculation of the uncertainty of the instrument and the amendments, as well as generation a report in the a specific format of the document.

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ZASTOSOWANIE ZAAWANSOWANYCH ALGORYTMÓW PRZETWARZANIA OBRAZU W KOMPUTEROWYM STANOWISKU WZORCOWANIA CYFROWYCH PRZYRZĄDÓW POMIAROWYCH

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STRESZCZENIE *Cyfrowe przyrządy pomiarowe są wciąż rosnącą frakcją dużej grupy narzędzi pomiarowych wykorzystywanych różnych dziedzinach nauki i techniki. Pomimo obecności w konstrukcjach tych urządzeń zaawansowanych cyfrowych układów elektronicznych, w niektórych przypadkach nie są one wyposażone w interfejs cyfrowy. Dlatego też przeprowadzenie zautomatyzowanego procesu wzorcowania jest niemożliwe, co wymusza wykonanie całej procedury przez personel laboratorium, przez co czynność ta jest czasochłonna i kosztowna. Problem ten można rozwiązać poprzez zastosowanie zautomatyzowanego stanowiska wzorcującego wyposażonego w moduł optycznego rozpoznawania tekstu, które umożliwia dokonywanie odczytu wskazań przyrządu bez zaangażowania człowieka. W niniejszej pracy prezentujemy komputerowy system rozpoznawania tekstu dedykowany do cyfrowych przyrządów pomiarowych. Przeprowadzone testy pozwoliły na zweryfikowanie jakości procesu rozpoznawania i potwierdzenie skuteczności opracowanego rozwiązania jako alternatywy dla wzorcowania wykonywanego przez personel laboratoriów.*