

DEVELOPMENT OF SOFTWARE FOR AUTOMATION OF CALIBRATION PROCESSES OF ELECTRICAL MEASURING DEVICES USING OPTICAL CHARACTER RECOGNITION

*Artur Augusto Martins*¹, *Regis Renato Dias*²

¹ Instituto de Pesquisas Tecnológicas (IPT), São Paulo/SP, Brasil, arturm@ipt.br

² Instituto de Pesquisas Tecnológicas (IPT), São Paulo/SP, Brasil, rrdias@ipt.br

Abstract: A computer software to perform optical character recognition (OCR) of seven-segment displays, to optimize the calibration process of instruments and meters that make use of this type of display is proposed in this paper. The software works with a conventional low cost webcam that captures images, which will be handled and processed by the OCR algorithm implemented in the software, obtaining a numerical value corresponding to the value indicated in the instrument display as ASCII format which is capable of being interpreted by other applications of numerical computation. This paper will give information on how to implement an full automatic calibration process solution using this application and will be shown a table with the performance results of the software to recognize different numbers in different operating conditions, noting their effectiveness to perform the reading and recording processes of calibration.

Key-words: calibration process automation, optical character recognition, seven-segment display.

1. INTRODUCTION

In industry many measuring instrumentation come with programmable interface, making feasible the automation of the measurement processes. Communication interfaces such as GPIB and RS-232, allow significant gains when repetitive tasks are involved [1-3]. A typical measuring routine consists of:

- (a) Setting the measuring equipment at the proper range;
- (b) Setting the value of the reference point to measure;
- (c) Taking the readings of measuring device under test;
- (d) Recording the reading on a log or a spreadsheet.

However, communication interfaces are not presented in all measuring instruments. That means the metrologist has to carry out all the aforementioned steps by himself, which can be very time-consuming and prone to operator errors during data transcription. For that reason the use of computer vision techniques to automate data collection has been chosen for cases where a seven-segment display measuring instrument is calibrated to a standard outfitted with a communication interface.

Under the context just described, the matter of this paper is to outline the design of an operator-free data collection system. By using OCR algorithms especially prepared for this case, manual calibration routines have been replaced by fully automatic calibration processes. Therefore, operator

influence during the calibration execution has been cut to a minimum, more reliable results could be produced, and the operator could be involved in more than one calibration at once. The main technical features are also discussed, such as ambient light fitting, fault detection mechanism and system test and validation.

2. AUTOMATION SOLUTION CONCEIVED

The main part of the automation solution proposed is related to the design and implementation of a rather comprehensive computer program for sampling, interpreting and presenting the data provided by the measuring device under test and the reference standard. The C programming language with OpenCV (Open Source Computer Vision), a library of programming functions for real time computer vision, has been chosen for the software development [4].

As a high-performance language, the computer program developed in C makes possible extracting real-time images taken from an off-the-shelf webcam. The user must connect the webcam to the computer; adjust the webcam focus on the display of the device under test; draw the area of concern in the image, which contains the measuring device figures, through a graphical interface. The application captures the images and converts them into black and white format. The OCR algorithm then expresses the black and white image in text format (ASCII), which gives the number to be stored in a database. The numerical value thus formed is stored in a database, which can be managed at any time by Structure Query Language (SQL). The retrieved data can be handled with common spreadsheets. The software also saves a copy of the image of the measuring instrument display in order to check any misinterpretation of the OCR algorithm and keep traceability.

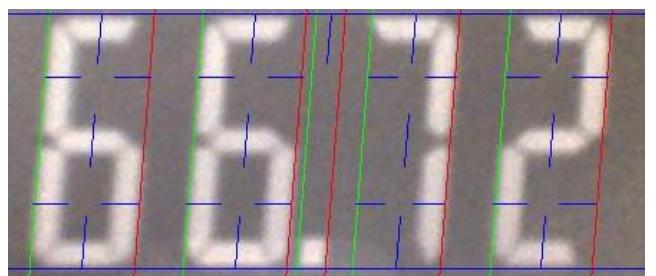


Fig. 1. Measuring device display image after running the OCR algorithm (note the recognition matrix)

The OCR algorithm identifies the initial and final position of each figure in the image and checks the existence of each segment in the array area. The figure “1” and the decimal point are recognized by checking if the height of the selected zone height is greater than or equal to three times the selected zone width (as shown in Fig. 1). The decimal point is distinguished by checking the presence of a segment in the upper part of the designated area [5].

The light conditions of the test ambient define a crucial factor in the success of a computer-based vision system. The developed solution handles lighting effects by compensating poor light conditions. The segment detection and the image transient time may be modified by adjusting the following parameters:

- Threshold: RGB intensity required for each image pixel to be converted into black and white.
- Filtering: quantitative criteria for determining whether a segment is lighted or not based on the number of active pixels in the area of interest.
- Consecutive readings: number of consecutive readings taken in order to avoid misleading image interpretation due to reading variation.



Fig. 2. Black and white output images over good lighting conditions (on the left) and over poor lighting conditions (on the right)

These configurations are available to the user in the program interface and are adjustable by virtual tuning dials. Fig. 2 illustrates the system output for two extreme lighting conditions after adjusting the parameters aforementioned.

2.1. Data recording

As measurement results are processed, data is recorded in the SQLite database [6]. The database contains a primary key called *mkey* that generates a unique identification for each reading and another field called *meas* of type VARCHAR size 30 to store the readings. This structure allows running queries in order to capture the last reading performed with their unique identification by using a SQL statement, as described in Fig. 3.

“SELECT mkey, meas FROM data ORDER BY mkey DESC LIMIT 1”

Fig. 3. SQL statement used to get the last read performed by the OCR software

However, the last reading recorded in the database may not be related to the current indication, as that reading may be related to an event in a much earlier time, due to the fact that even if the readings are recorded sequentially as they occur, the old information is kept in the database. Using information of the primary key “*mkey*” from the previous query, we can execute another SQL statement that will only return readings that occurred after the last query, as described in Fig. 4.

“SELECT meas FROM data WHERE mkey > lastMkey ORDER BY mkey DESC LIMIT 1”

Fig. 4. SQL statement string used to get the last read performed by the OCR software, were primary key “*mkey*” will be greater than the “*lastMkey*” variable value

Due to a likely delay in image processing, it may happen that the SQL query does not return a reading, so it is appropriate to use an algorithm to check the existence of the reference reading and the subsequent reading. The flowchart shown in Fig. 5 describes how a software procedure can be implemented to perform queries using SQL statements to retrieve measurements.

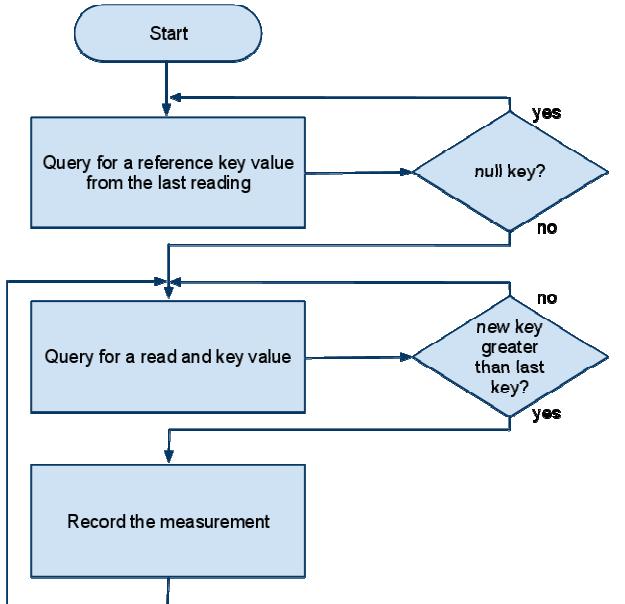


Fig. 5. Procedure to ensure that the automation system is acquiring the current measurement

2.2. Numerical computation software integration

The solution presented was developed considering also the simple integration with other applications. As previously described, the use of a database allows the OCR information to be accessible by client software with database connection and support to SQL command implementation. This way, any application that supports connection to the available SQLite database data (e.g. Microsoft Excel, OpenOffice, Matlab, Scilab) can be integrated with this application.

In order to present a versatile and practical use of the OCR software, an Excel spreadsheet running Visual Basic (VB) routines has been implemented. It shows how to operate the software in order to carry out automated calibrations. The effectiveness of the proposed solution can be thus evaluated. Excel spreadsheets are widely employed in calibration laboratories to develop uncertainty budgets in general, which explain their choice in the OCR software conception. The spreadsheet developed (illustrated in Fig. 6)



The diagram illustrates the integration of an OCR software with a metrology-oriented application. A digital multimeter is connected to a computer, which runs the OCR software. The software interface includes a table for inputting calibration points and a button labeled '> Automatizar' (Automate) to initiate the data collection process.

Ponto Normal	pref.	Unidade	Freq.(hz)	Incerteza	Valor VVC	Faixa (UUT)	Pref.	Leitura 1	Leitura 2	Leitura 3	Leitura 4
25	m	V		60	0,1%	2,50E-02	100	m	25,00100	25,00100	25,00100
50	m	V		60	0,1%	5,00E-02	100	m	50,00100	50,00100	50,00100
75	m	V		60	0,1%	7,50E-02	100	m	75,00100	75,00200	75,00100
99	m	V		60	0,1%	9,90E-02	100	m	99,00200	99,00200	99,00200
0,25		V		60	0,1%	2,50E-01	1				
0,5		V		60	0,1%	5,00E-01	1				
0,75		V		60	0,1%	7,50E-01	1				
0,99		V		60	0,1%	9,90E-01	1				
2,5		V		60	0,1%	2,50E+00	10				
5		V		60	0,1%	5,00E+00	10				
7,5		V		60	0,1%	7,50E+00	10				
9,9		V		60	0,1%	9,90E+00	10				
25		V		60	0,1%	2,50E+01	100				
50		V		60	0,1%	5,00E+01	100				
75		V		60	0,1%	7,50E+01	100				
99		V		60	0,1%	9,90E+01	100				
250		V		60	0,1%	2,50E+02	1000				
500		V		60	0,1%	5,00E+02	1000				
750		V		60	0,1%	7,50E+02	1000				
990		V		60	0,1%	9,90E+02	1000				

Fig. 6. Spreadsheet template used for sampling data automatically

requires the user to provide information of points to be calibrated, unit to be measured, the permissible error of the equipment under test and information about the measuring standard used, like calibration uncertainty and GPIB commands for initializing and setting points. Using Excel formulas, it has been possible to set the standard setting point command according to the parameters previously defined, making easier the automated procedure creation.

After providing the necessary information, the automation will take effect by pressing the button. The VB macro is then executed and responsible for interfacing with the OCR software database and collecting the readings, which are recorded in the worksheet cells. The spreadsheet has features that alert the user when the equipment under test range needs to be changed and when the reading is far

different from the expected value.

2.3. Automation software integration

Some metrology oriented applications for laboratory automation already have modules that allow performing automated calibrations. However, most of these applications are not open-source software, and they do not permit creating routines to integrate with external applications. The OCR software presented in this paper has a feature that allows other software to be connected via serial port, and to retrieve recognized measurements. That means any other computer can read the measurements from a master computer that is running the software. However, it is not ideal to use a computer only to serve as a communication interface to another computer. A solution to this problem would be to create a virtual interface that establishes

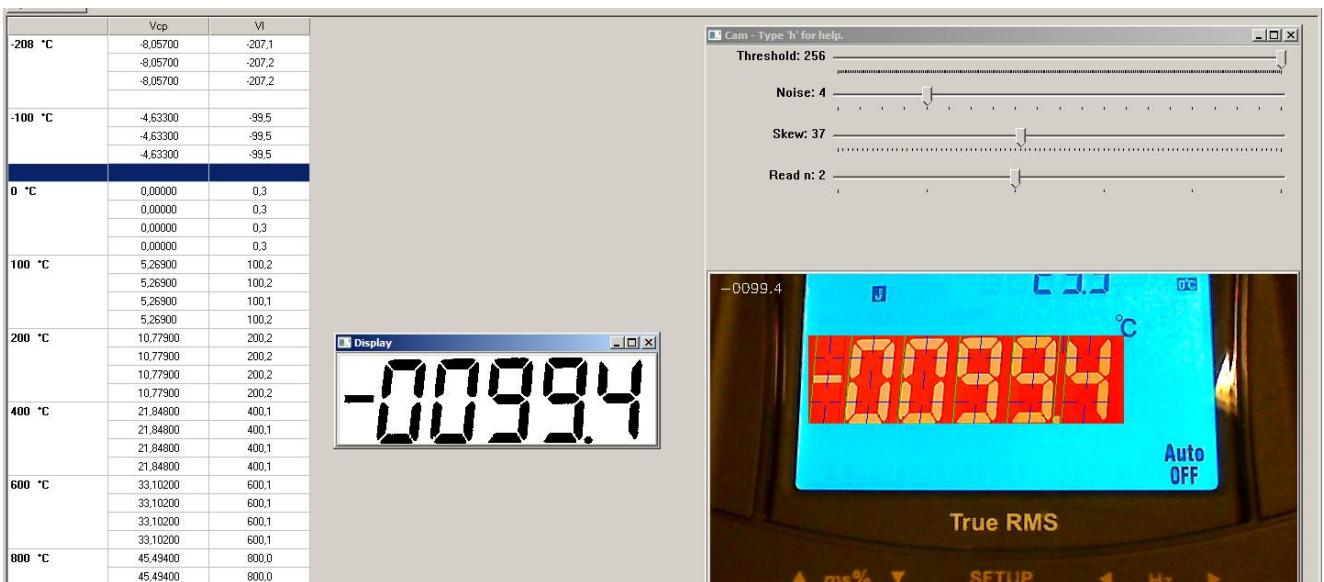


Fig. 7. OCR software communicating with a metrology-oriented application through a virtual serial port

communication between two applications (illustrated in Fig. 7). Another solution would involve using a nullmodem configuration connection between two physical interfaces on the same computer. The use of virtual interfaces would be preferred though, as no cables and no physical serial interfaces are needed.

The driver used to deploy this solution was provided by *com0com free software* that allows the user to define how the serial ports should be connected. As the OCR software runs, the readings become available through the port name "COM5" by default. When creating a pair of virtual ports named "COM5" and "COM4" interconnected in a *null-modem* configuration, the last reading of the OCR software is sent to the interface "COM4" when the "COM5" port receives from remote interface the "?" character, which was defined as a query command for reading this application.

3. RESULTS

In order to test the performance of the system proposed two different experiments have been designed. The first case involved fifty (50) readings on a 4½ digit multimeter under different lighting conditions. The actual value displayed in the multimeter was compared with the value obtained through the software. The algorithm performance is shown in Table 1.

Table 1. Performance analysis of the readings on a 4½ digit multimeter using the developed system

Lighting conditions	Readings		Characters	
	Total	Miss Rate	Total	Miss Rate
Good	50	2%	250	0,4%
Poor	50	56%	250	22%

In the second test, four metrologists performed the measurements of a thermocouple indicator range from a 4 ½ digit multimeter, using a calibrator and doing upward and downward cycles. The average time spent by technicians to perform the reading without transcription errors was 18 min with a standard deviation of 3 min, and the time spent by the software was only 4 minutes without the occurrence of readings misinterpreted by the software.

4. CONCLUDING REMARKS

From performance test results of the optical character recognition system one can realize a significant time reduction for calibrating measuring devices with seven-segment display. For good lighting conditions the miss rate can be regarded as satisfactory for an under-development metrology-applied system. That means measuring reliability is not lost when compared to manual data collection process. Proper results may be chiefly attributed to the real-time image treatment processes included in the proposed metrology-applied software.

However, for poor lighting conditions, despite the image treating process, the results have not been robust enough to enable autonomous calibration of seven-segment measuring devices. For cases in which the lighting conditions are not favorable, and it is not feasible to improve the lighting, manual readings should be preferable to automatic ones due to the found miss rate according to the preliminary tests just performed. Manual readings also mean viewing the images stored by the software in the file system.

REFERENCES

- [1] G. Andria, G. Cavone, L. Fabbiano, N. Giaquinto, M. Savino, "Automatic Calibration System for Digital Instruments Without Built-in Communication Interface", Proceedings of the XIX IMEKO World Congress Fundamental and Applied Metrology, September 6-11, 2009, Lisbon, Portugal.
- [2] F. Corrêa Alegria, A. Cruz Serra, "Automatic Calibration of Analog and Digital Measuring Instruments Using Computer Vision", Proceedings of the IEEE Transactions on Instrumentation and Measurement, vol. 49, no. 1, February 2000.
- [3] Noara Foiatto, João Miguel Lac Roehe, "Sistema Automatizado para Medidores Digitais a Partir da Captura de Imagens e Interface de Comunicação GPIB (IEE 488)", Proceedings of the ENQUALAB-2006, June 2006, São Paulo, Brasil.
- [4] G. Bradski, A. Kaehler, *Learning OpenCV*. O'Reilly Media, Sebastopol, 2008.
- [5] Seven Segment Optical Character Recognition.
Available at:
<http://www.unix-ag.uni-kl.de/~auerswal/ssocr>
[Accessed 15 March, 2011].
- [6] SQLite Database Engine.
Available at:
<http://www.sqlite.org> [Accessed July 4th 2011].