SOFTWARE CALIBRATION OF THE SENSORS FOR ACQUISITION BOARD SYSTEMS BY USING A MATHEMATICAL MODEL

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Abstract: *In this article, we are presenting a modeling method for the calibration of the sensors using mathematical means. Many sensors used in the digital technique measurements (temperature, pressure sensors or electrical force) give nonlinear output signals for the linear input sizes being based on a variety of physical phenomenon [1]. Well-known engineering methods which are applied in these cases are based on 'piecewise' linearization. The proposed method uses the physical-mathematical dependence of a sensor then is sampled and stored (during assignment and calibration of the channel), in the permanent memory buffer of proper port. It works like a digital mirror for an analogical signal. When an online sampling occurs during measurement of experimental data, the obtained current data values will be corrected by mathematical method by composition of functions. This procedure has been successfully tested and should be implemented on an acquisition data board, built on original design, with a 12-bit resolution.*

Keywords: *sampler function; online reading function; calibration of the channel; acquisition data system; mathematical model;*

1. General Introduction:

In this work, we are present a modeling method for the calibration of the sensors through mathematical model. It can be implemented from conceptual model to the application level, by using a mathematics model and software tool written in assembler language. The technical specification, in short lines, of the method proposed in this article is as per following: the physical-mathematical dependence characteristic of a sensor is sampled and stored, in the permanent memory buffer of proper port. When an online sampling occurs during measurement of experimental data, the obtained current data values will be corrected by mathematical method by composition of functions. The practical result consists in a range of values in which the measured phenomenon does not damage the sensor or transducer mechanically or physically, that will respond in a linear manifestation of the sensors, the measurements accuracy depending finally on the resolution 'analog-to-digital' conversion and power of the calculations of the microprocessor.

2. Equations:

2.1 For a directional set of data, acquired from a nonlinear sensor, we obtain the output data as per following: X [1, 2, 3, 4, 5, 6, 7, 8, 9, and 10], we can obtain at the output of the nonlinear sensor the next string values: Y [1.1, 1.9, 2.4, 3.5, 4.9, 6.1, 6.71, 7.22, 8.93, and 9.91]. With these sets of data, we can build a polynomial function with the Lagrange-Newton formula following:

Equation 1

$$Y_1(x) = \sum_{n=1} \left[\frac{x - x_2}{x_n - x_2} * \frac{x - x_3}{x_n - x_3} * \frac{x - x_4}{x_n - x_4} * \ldots\ldots\ldots * \frac{x - x_w}{x_1 - x_w} y_n \right]$$

We can name this function "Sample function". For our set of vectors, we obtain next polynomial form:

Equation 2

$$Y_1(x) = 0.17*10^{-5}*x^9 - 0.13*10^{-3}*x^8 + 0.0039*x^7 - 0.056*x^6 + 0.48*x^5 - 2.61*x^4 + 8.91*x^3 - 18.41*x^2 + 20.71*x - 8.009$$

2.2 In the domains where these functions are defined, we can build using translations of vectors [2], the symmetrical sets of vectors, in according with first bisectors, starting with initial values of the data:

$V_1 = (x_1, y_1).$ is becoming: $V^1{}_1 = (x^1{}_1, y^1{}_1).$,

$V_2 = (x_2, y_2).$ is becoming: $V^1{}_2 = (x^1{}_2, y^1{}_2).$

$V_n = (x_n, y_n).$ is becoming: $V^1{}_n = (x^1{}_n, y^1{}_n).$.

With this sets of vectors, we can build, the inverse function of sample function, as following:

Equation 3

$$Y_2(x') = \sum_{m=1} \left[\frac{x' - x'_2}{x'_n - x'_2} * \frac{x' - x'_3}{x'_n - x'_3} * \frac{x' - x'_4}{x'_n - x'_4} * \ldots\ldots\ldots * \frac{x' - x'_w}{x'_1 - x'_w} y'_m \right]$$

Equation 4

$$Y_2(x) = -0.57*10^{-5}*x^9 + 0.29 \; *10^{-2}*x^8 - 0.063*x^7 + 0.76*x^6 - 5.61*x^5 + 26.41*x^4 - 78.01*x^3 + 138.11*x^2 - 130.01*x + 50.11$$

We can name this function: "Online reading function", because if we acquire an online value through this function, from an nonlinear sensor, the obtained final variation of this function, will be linear. The inverse function can be found only from a bijection form of function [3], also in terms of differential geometry, knowing that a plane curve has a tangent vector, and for two plane curves we can obtain one set of vectors with a constant angle at different points of the plan.

Figure 1, is showing how the process of data acquisition does from the input of the sensor at the output of acquisition board.

Figure 2, shows the numerical model where one set of data is acquired from a non-linear sensor, is sampled, stored and is built "sampler function". In the second part of the figure data are interpreted by the sampler function and we obtain at the end - linear response from a nonlinear sensor.

Figure 3, we shows the accuracy of the "online reading function" and we treated the problem as follow: one linear signal input is passing trough "online reading function" and at the output is obtaining a small nonlinearity of the entire system process, that is given a system error.

3. Diagrams, Tables and Figures:

The acquisition data method can be split in two parts as follow:

3.1 Calibration of the channel of the sensor.

Generating the linear variation at the input of the sensor, sampling with the analog-numeric conversion and store the string of numerical value data.

Using an inversion algorithm, we obtain the inverse sets of the vectors, in order to build the sample function.

Finding the "Sampler function" by mathematical means, for proper channel, and calculate the "Online reading function".

3.2 Online reading of the values from the sensor - method.

In the case of real acquisition of data value from the sensor, we convert actual data from analogical size in numerical size.

Calculating the value of the data acquitted, regarding the actual value from "online reading function".

Storing the final values of acquisitioned data, and sending to the computer.

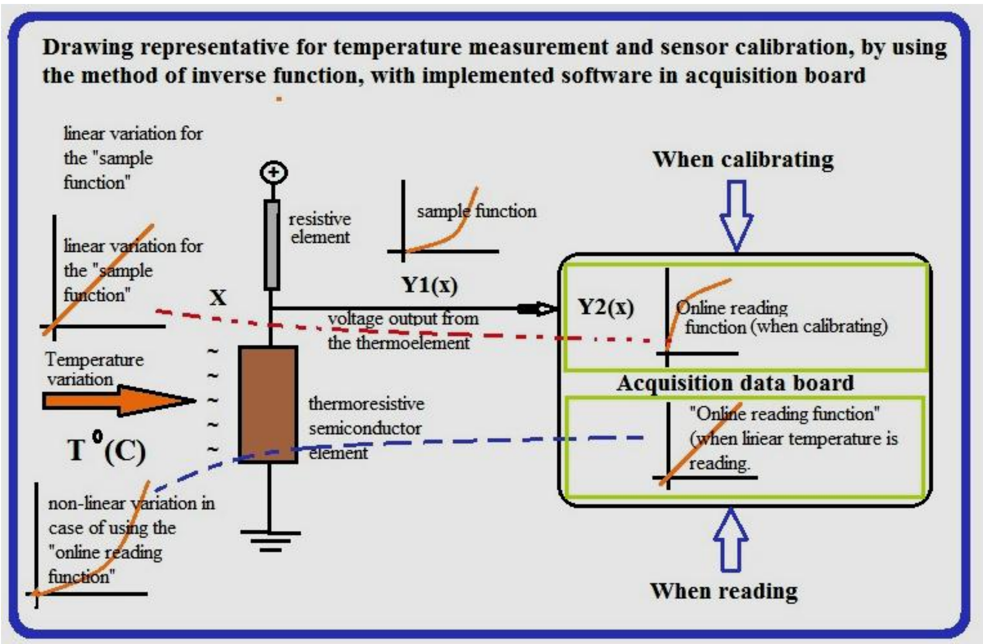
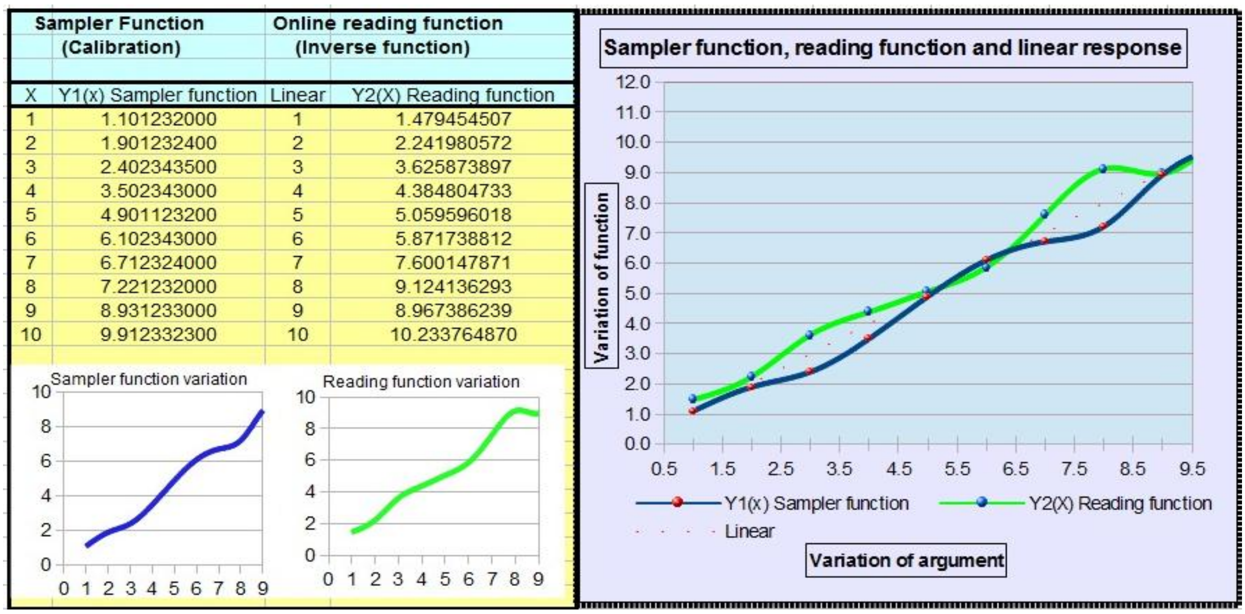
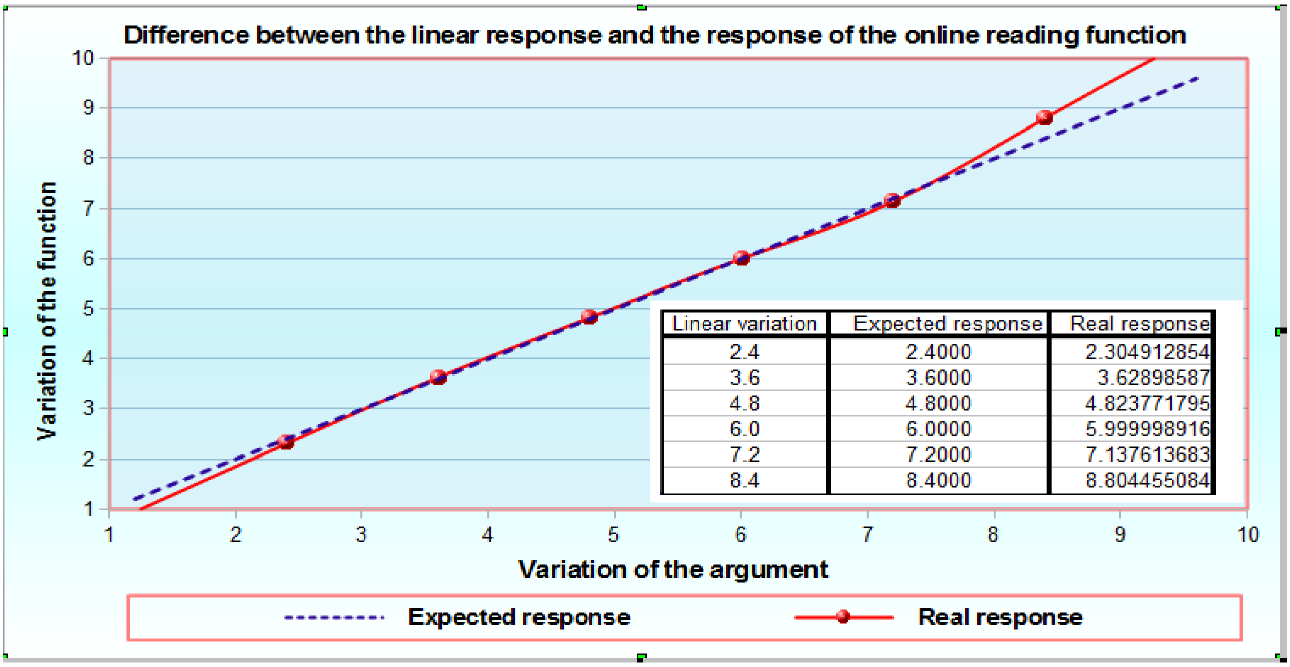


Figure 1



Sampler Function (Calibration)		Online reading function (Inverse function)	
X	Y1(x) Sampler function	Linear	Y2(X) Reading function
1	1.101232000	1	1.479454507
2	1.901232400	2	2.241980572
3	2.402343500	3	3.625873897
4	3.502343000	4	4.384804733
5	4.901123200	5	5.059596018
6	6.102343000	6	5.871738812
7	6.712324000	7	7.600147871
8	7.221232000	8	9.124136293
9	8.931233000	9	8.967386239
10	9.912332300	10	10.233764870

Figure 2



Linear variation	Expected response	Real response
2.4	2.4000	2.304912854
3.6	3.6000	3.62898587
4.8	4.8000	4.823771795
6.0	6.0000	5.999998916
7.2	7.2000	7.137613683
8.4	8.4000	8.804455084

Figure 3

4. Conclusions

The proposed method it is possible to obtain a linear response for a real process by a nonlinear sensor. The main result of this mathematical model will be implemented in a software language of the microprocessor. Effectiveness of the model can be accomplished via software and hardware methods of this type of calibration of sensors which can be implemented on-board of the data acquisition system.

5. References:

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