Smart Laser Micrometer

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***Abstract*-By analyzing the creation process of regular and non - regular profiles made out of plastic materials I have seen that a lot of raw materials are lost due to the recycling of non-conform products. The recycling is a time consuming process and causes economical problems for the manufacturers, and also environmental problems due to the discarding of the waste of plastic material. This paper provides a viable and non expensive solution to this problem. The loss reductions are caused by the fact that the measurement is done at runtime. The system either adjusts itself or it can warn a line operator how to adjust the raw material quantity. The measurement principle for linear objects like cables or pipes is the comparison with the nominal value and hysteresis whereas in the case of non-linear shapes like window PVC profiles we have an artificial learning mechanism. The given solution has been implemented with some variations in several cable and pipe companies.**

I. INTRODUCTION

Analyzing the production process of cables, pipes, tubes and other profiles made of regulate and non-regular plastic materials I have observed that a large number of products, that are manufactured through the process of extrusion, are measured and compared with the values from the technical prescriptions at the end of the fabrication process [6].

The deviation correction is realized with a delay, which is given by the fabrication process and as a result we obtain a large number of products that are not in conformity with the standards and are eventually destroyed and recycled.

The producers registered losses due to the consumption of raw material, and the spending done for recycling and remanufacturing.

The main objective of this study is the development of a measurement system that would measure in the process of fabrication thus eliminating the delay between the moment of fabrication and the moment of measurement. This system is adapted to the particularities of the production method which is through extrusion of plastic materials.

This method of production is very spread and encountered at the fabrication on a wide scale of the products above mentioned. The characteristics of the production method are the following [5, 6]:

- The temperature of the products after the extrusion process is between 100 and 200 ^{0}C (the products cannot be touched with classical measuring equipment such as caliper, micrometer etc);
- The products are fabricated at high speed (1 – 10m/s) that is why the information regarding the dimension has to be obtained as fast as possible, otherwise a quantity from the product may be non-conform.
- The information has to be sent to a supervising center where it must be stored and afterwards analyzed.
- The losses from the raw materials represent 1-8% from the used quantity and are recorded in the calibration periods of the production lines

The created system has been called Smart *Laser Micrometer* and its main characteristics are:

- Very robust, lasting design
- Extremely insensitive to dirt
- High accuracy and repeatability
- Measurement insensitivity to product positioning
- No moving parts
- Non contact measurement
- High scan rate
- Dedicated software with advanced functions of:
  - Data analysis and storage.
  - Live supervision
  - Trend function and cloud diagram
  - Test report generation
  - The possibility of learning unknown patterns for the analysis of non – regular shapes

Laser micrometer has the possibility of measuring regular as well as irregular shapes.

The regular or linear shapes such as pipes or cables are measured by comparing with the nominal value and the hysteresis of that specific product, data which is stored in the EEPROM memory of the device.

The pattern of the irregular shapes is learned and stored in the computer, and the response at the interrogation with a specific pattern is given with a certain degree of confidence.

The user has the possibility of thresholding the result in order to obtain a positive or negative response.

For both categories of products the software can generate test reports that certify the fact that the measured product is conform to the standards and can be sold.

During this paper I will refer to objects with regular shapes as being the kind of objects that maintain an aproximativelly constant diameter. The objects that have a diameter or a shape that is not regular will be referred to as irregular or non-regular objects.

II. HARDWARE ARCHITECTURE

The measurement system Laser Micrometer is schematically presented in Figure 1 and it was designed in order to measure objects with precision in the production flow time.

The symbols from the figure represent the following:

- Laser Sensor - the laser sensor used for the measurement
- Cable or pipe - is the product to be measured
- Display and control - is the box which the user accesses in order to perform the desired operations. Inside this box all the parts are stored (wires, development board, the display etc).
- PmodKYPD - is the keyboard used for entering data like the amplification coefficient which is used in the negative feedback loop.
- Optical and Acoustical Warning – is the warning system that signals when something goes wrong. It allows the viewing of the signals from distance even in places with high noise.Other features are:
  - Distinct colors for different warning messages;
  - Continuous warning or pulsatorious warning
- Xbee , USB cable - this is the acquisition part that gets the data from the computer and sends it serial to the computer. Even though in the presented design another development board appears (chip kit uno32), I have made the acquisition without using that board, instead I use an Explorer board for the xbee and connect it to the computer, thus reducing the cost of the overall design and the complexity of the project.
- Computer - is the computer on which the software application is running.

The non-contact measurement principle based on a laser sensor enures the precision, the repeatability and the stability of the object measurement even during the fabrication flow, offering the possibility of integrating the measurement system in the control and supervision part of the production lines.

A. Why laser?

If we take as an example the measuring of a cable, with classical devices, immediately after the extrusion process, we observe that the measuring of the cable diameter and the comparison with the standard values can be done only after the insulating material has cooled off [5].

After the cooling of the cable we take samples to see if it respects the standard imposed values. In the case of a PVC surplus the newly created cable has to be recycled in order to save the cupper from inside.

All these processes consume time and material resources.

The laser technology allows for the cables or pipes to be measured during the extrusion process.

Only by using the laser light it has been possible to create a diameter measurement system that is not sensitive to temperature, vibrations, dust or movement and which has additionally a very high precision and measurement accuracy, useful usually in the case of small tolerances.

B. Warning system

Laser Micrometer contains an optical and acoustical warning system which informs the line operator how to limit the speed of the product creation.

Also the device contains a menu in which the operator can set an error amplification coefficient. This coefficient will be used in a negative feedback loop system in order to automatically control the speed at which the product is manufactured.

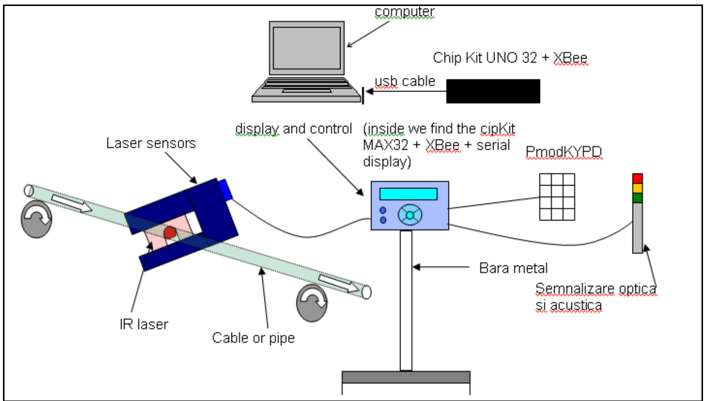

Figura 1. The Schematic drawing of the system

C. Communication Protocol

The device communicates with the computer through a ZigBee protocol. It sends the acquired values from the sensor to the computer for further processing.

The application also contains dedicated software that offers the user the possibility of viewing the obtained data even though he isn't physically near the device.

D. The development board

The device revolves around a chip kit max 32 board. This development board was chosen due to high computation power, fast data acquisition and many IO pins which are needed for the end devices.

E. The measurement process of linear objects

The measurement process represents a comparison between an unknown quantity and another quantity of the same nature which is known and is taken as reference [7].

During the measurement process the measured value is affected by errors. We denote the error by ε and the measured value by x_m. We can say that the actual value x is bounded by the measured value plus, minus the error [7].

$$x_m - \varepsilon \le x \le x_m + \varepsilon \qquad (1)$$

This equation is equivalent with the following one

$$x - \varepsilon \le x_m \le x + \varepsilon \qquad (2)$$

In the current project x represents the nominal value, ε is the tolerance or hysteresis and of course x_m is the measured value.

Whenever the measured value is smaller than $x - \varepsilon$ the device signals a red light telling the line operator that there is not enough raw material on the product.

Analog the line operator is warned by a yellow light if there is too much raw material on the created product.

In the case of cables, because the measurement is done at extrusion time the line operator knows how he can modify the quantity of PVC when warned by the device.

The device also has an option which self adjusts the quantity of PVC falling on the created cable.

III. SOFTWARE ARCHITECTURE

The minimum requirements of the system for which the software application has been tested are:

- Operating system : Windows XP Service pack 3
- 896 MB of RAM
- .NET framework 3.5
- SQL server 2008 r2
- Free disk space for the installation 10 MB

The software part comes to enforce the hardware part in order to create a more efficient and reliable product.

The application has been developed to be reliable, so under the same conditions it has been tested it should work for an undetermined period of time.

The software application has been developed to consume minimum amount of resources and the algorithms used are efficient [4].

The application is fault tolerant meaning that in case of certain anomalies it suggests to the user the possible cause of the given exception.

This software part of the system offers to the user the possibility of creating new objects with linear characteristics, the modification of the existing objects, the possibility of doing measurements at distances for the stored products and the visualization of a trend function and a cloud diagram in the process of measurement.

In this software application there is also the option of creating objects with a non-regular shape and the learning and interrogation with a certain pattern.

In the followings I will explain the functionality of the most important components as well as the theoretical background that led to the choosing of a specific method.

Figure 2. The settings window

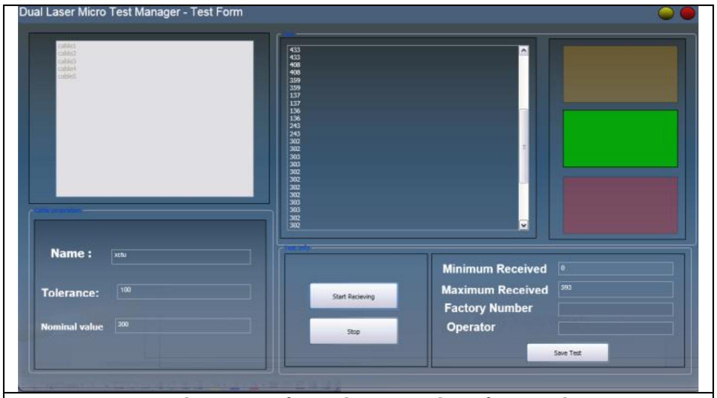

Figure 3. The testing of a product using the software aplication

A. *The general menus of the aplication*

The main meniu offers the user the so called on screen help for each other option, so it is easy for a new commer to find what he is looking for without too much trouble. Here the user can also select the supervision option in case he whants to use the software as a monitorisation application and view in real time what is going on near the device.

The Settings option allows the user to modify and store the default serial port configuration. This meniu also allows the testing of the choosen port configurations.The user inputs a certain interval of time in which data will come serial thus proving the connection between the hardware and software has been established. A picture of the operations from this option in progres is shown in Figure 2.

The products option allows the user to view existing products and to generate test reports for selected products.

The Add/Remove option allows the user to submit,modify or delete products.

The Test window allows the user to make tests for the products created on the computer. The user can save the tests if he will need to show in the future that the products is in the corect standard. In case of values that are not in the given range the software will warn the user by lighting the red of yellow squares. If everything is ok the green square will be highlighted. An image ilustrating this concept can be seen in Figure 3.

The Diagrams option ilustrates the evolution of the measurement process through different kinds of graphs and charts.

For example :

- The transient response graph shows how the measure pattern varies between the impose bounds.
- The Chart diagram allows the user to visualize how the measurment process evolves for a several samples.
- Histogram - which shows the distribution of the received values. This diagram shows clearly which are the values that are not in the given range.

B. The estimation of non linear objects

The process of measurement of an object with a non regular form is not an actual process of measurement, it is a variation of a more general pattern recognition algorithm.

In order for the user to recognize a certain pattern he must first train the program to recognize the specific features of that pattern. After the training process the user can present different patterns to the program and get a response with a certain degree of confidence.

To get a yes or no response from the application the user has to apply a threshold to the given response. He will be able to see the boolean result in the response text field. The general layout of the Machine Learning window can be seen in Figure 4.

1) Why artificial neural networks

Artificial neural networks (ANN) have been developed as generalizations of mathematical models of biological nervous systems. An artificial neural network is an adaptive system that changes its behavior based on internal or eternal information that flows through the network.

The most important property of ANN is that they learn from example, so I do not need to know how the shape of a presented function looks like, the neural network will determine that on its own [2].

2) The choosen model for ANN

There exit sevral types of architectures [1] for neural networks, however the one chosen in this work is the single layer perceptron with 10 inputs.

This type of neural network is a simple kind of feed forward neural network, where the inputs are connected to the outputs via a series of weights [2]. A schematic of the ANN model for n inputs is shown in Figure 5.

The output of the network is given by the formula [1]:

$$y = \sum_{i=1}^{n} x_i * w_i \qquad (3)$$

In the given formula x_i is the input and w_i represent the synaptic weights for each input.

I have chosen this type of model because it gives the desired results and the space-time trade-off is very good.

Figure 4. The Machine Learning window

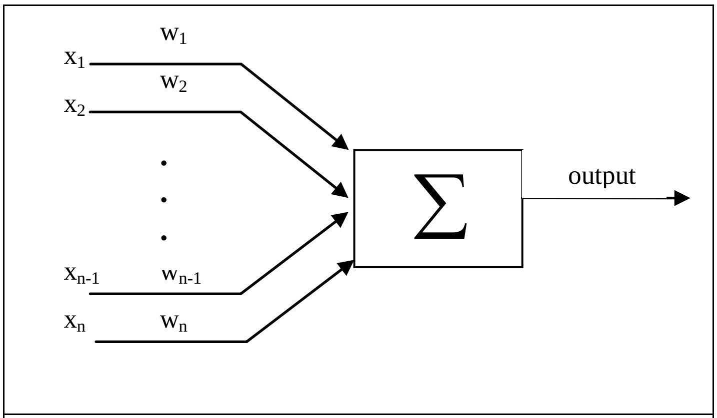

Figure 5 Block diagram of a single layer perceptron

In order to train the perceptron i have choosen a supervised type of learning method based on the gradient descent algorithm and that is the delta rule [3].

I am modifying the sinaptic weights by adding to their existing values the value of Δw_{ij} [3],whose expresion is given in equation (5), in order to minimize the error between the ideal output and the actual output.

$$w = w + \Delta w \qquad (4)$$

$$\Delta w_i = \eta * e * x_i \qquad (5)$$

where

e - is the error given by (6):

$$e = ideal\ Output - actual\ Output \qquad (6)$$

η - the learning rate

x_i - given input

We can see that in the supervised type of learning the user has to provide the actual output for the given pattern. However in order to get an exact response we would need know the precise values in each specific point for all samples from the input for a non regular shape, a thing which is not very convenient.

However, if for all the presented input for a given pattern we provide the same output, a single number, we can verify very easily the resemblance between two patterns by seing how close is the obtained output from my neural network to the provided number.

For clarification here is one of the examples used to tain the network for a single product.

Pattern 1 : 11, 12, 14, 20, 80, 100, 100, 60, 20, 10
Pattern 2 : 10, 13, 16, 20, 60, 80, 100, 60, 20, 11
Pattern 3 : 12, 15, 30, 60, 100, 100, 80, 60, 20, 15
Pattern 4: 15, 16, 20, 40, 80, 90, 100, 80, 60, 30

Ideal : 1000

If my response is in the range

$$y - T \le ideal \le y + T \qquad (7)$$

The presented pattern resembles the trained pattern.

In equation (7) y represents the output from the neural network, T is the threshold chosen by the user for a pattern and ideal is the ideal input.

The more patters we feed to the network the more chances we have to get a more acqurate result.However the more patterns we feed the more time we have to wait for the network to get trained. For the above four given patterns the time is aproximative instant (for the computer configuration presented at the begining of section III).

The given response y will be a response with a degree of confidence.

In order to get an actual result the user has to put a certain threshold to the obtained result. Due to the fact that the perceptron is trained with delta rule the software class is called Delta. Each non regular product containes its own delta object where the trained synaptic weights are kept. All the Deltas are held in a hash map data structure for the fast retrieval of objects. The wrapper object of the hash map is called memory map due to the fact that it holds all the neural networks.

IV. RESULTS

Due to the 100% inspection, it is possible to achieve zero-defect production and to certify the wire and pipe quality.

The *Laser Micrometer* measuring system is able to guarantee suitable shielding and dust resistance; all of which have been proved to be ideally suited for on-line operation, often in heavy duty industrial environments.

The software application allows the manufacturer to make high speed on line product measurements for various types of objects.

The results of the software and the hardware measurements are accurate and the user can provide certificates that guarantee the business viability of the created products.

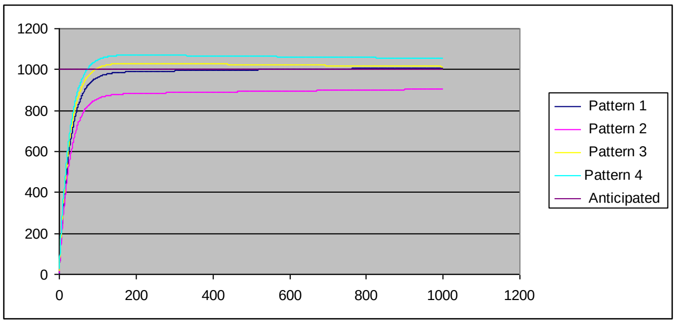

Figure 6. The evolution of the synaptic weights

The graph in Figure 6 illustrates how the results obtained at the interrogation of the neural network change while I am training the network with the four different patterns for a certain product.

As it can be seen after 1000 epochs the results to the presented patterns are very close to the actual result, giving a very small overall error.

V. CONCLUSIONS

The smart laser micrometer is a system that allows measurements of regular and non-regular objects. Due to the reduced costs and very well defined key features it is an excellent tool for manufacturers of cables, pipes, tubes and other profiles made of regulate and non-regular plastic materials.

Several variations of the laser micrometer system have been developed and implemented in several cable companies and the manufacturers were very pleased with the results.

The device brings benefits and the investment is rapidly recovered. One of the main benefits is the reduction of the losses of the raw material which brings immediate benefits.

Reducing the loss of the raw material implies a reduction in the waste quantities, which resulted, in the case of cables, after the cupper recuperation process and the elimination of the PVC. This brings major benefits for the environment.

The product can be easily modified for the characteristic requirements of the manufacturers, leaving only the desired key features that they need.

The device can also be improved. One of the improvements would be the addition of a voice recognition module that would help the line operator choose a specific option from the laser micrometer without touching the device. This would be very helpful especially when the line operator has his hands full and needs to make some critical settings. Also the device could have a SD card shield for mass storage, in which one could store more products.

The Smart Laser Micrometer offers a cheap dynamical solution for the non-contact measurement of products during the process of manufacturing, with different kinds of shapes. This system can be further improved according to the costumer's requirements, thing that makes it a very good business viable tool.

VI. REFERENCES

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