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Detection of Quantitative Faults in Pencil Packet by Analyzing its Capacitance

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ABSTRACT

This paper presents an automated technique for detection of quantitative irregularity in a pencil box. Objective of the proposed work is to design a system for checking the number of pencils in a sealed packet. Dielectric property of pencil is made used to compute the change in capacitance for variation in number of pencils in the pencil box. This change is capacitance is further converted to voltage for quantitative analysis using fuzzy logic algorithms. On identifying the faulty packets, action is taken to reject the packet by moving it away from conveyor. Proposed technique was designed and implemented for real life implementation in factory environment. Validation of designed system was made by testing it for a large set of pencil packets, result produced show successful implementation of proposed work.

Keywords*:* Automation, Capacitance, Fuzzy System, Quantitative analysis.
Mathematics Subject Classification: 94Cxx, 94Dxx
Computing Classification System: I.4

1. INTRODUCTION

Packaging is a key requirement in production industries, as marketing of the end product with safe and presentable way is final target for any production industries. Industries will concentrate on packages as much as they concentrate on production. Packages safe guard the end products during transport, provide necessary information related to the product and also tries to attract the customers. Customer will rely on the information provided on these packages regarding the product while purchasing it. Like in any other production line, packaging plays a very vital role in production of pencils.

Pencil industry is a very old industry and is growing because of the demand by consumers. Pencil is a tool used mainly by school kids with which they develop their writing skill. Increased competition in these industries impose industries to be more perfect in manufacturing the end products. Taking care of number of pencils present in pencil packets is a must. Mostly industries quantity testing is carried on by manual inspection of sample pieces, or density check. Mostly density check procedure involves a large set of packets, thus the accuracy of it is very less. And even though a system is able to detect fault, identification of a particular packet in a large set is time consuming.

Many researchers have reported works in the area of quantitative analysis. Few of which are discussed in the following paragraph.

An automatic method to count the objects moving on a conveyor using memory efficient algorithm is discussed by (Subramanian and Bhadrinarayana, 2009). (Foster, Petrell, Ito, and Ward, 1995) developed an algorithm to count the food pallets in a sea cage by observing the recorded image sequences. Checking of tablets in each blister before it is sealed using automated visual inspection system is discussed in (Joze, Bostjan, Rok, Dejan, Franjo, 2003). An approach for counting the number of flowers in a plant is discussed in (Stephan and Nicole, 2009) by taking images in different angles by rotating the plant in front of camera. An algorithm is reported by (Guruprasad, Vassilios, and Nikolaos, 2009) to estimate the traffic of pedestrian and bicycles in bicycle paths using image processing techniques. In (Garcia-Bunster and Torres-Torriti, 2012), a method for predicting the count of people waiting at bus stops by using image processing techniques is discussed. A system for detection and counting of objects using image processing technique is discussed in (Chomtip, Fuangchat, and Sorawat, 2008). A traffic management system is reported by (Ankush, Ankur and Ganesh, 2007) for prevention of traffic congestion by counting the crowd near the crossing, through audio and video data. (Donatello, Pasquale, Gennaro, Mario, 2013) discussed a method for estimation of moving people in a crowded scene for video surveillance applications. In (Kazuhiko, Chihiro, Satoshi, Katsuya, Nobuyuki, 1998) a people counting system by using human information system which consists of pyro electric array detectors placed in the passage area is discussed. A method for detection of the crowd count using 3D depth sensors is reported by (Giovanni, Alessandro, Pietro, 2015) for the management of building energy. A method for detecting and counting vehicles in urban video sequences is discussed by (Pablo, Christiano, Fabiano, Jacob, 2015) through particle cluster identification. In (Ikezawa, Wakamatsu, and Ueda, 2012) an application of laser in the quantitative analysis of copper and silver nanoparticle ink is reported. A method for identification of overlapping white blood cells using region based and boundary based approach is proposed in (Chastine, Diana, Victor, Faried, 2014). (Maksims, 2015) reports a technique for analyzing the traffic conditions using image processing technique to count the number and pattern of travel of vehicles. In (Yiling and Guo Qin,2014) a vehicle detection system using novel Bayesian fusion algorithm, and classification of vehicles is carried out using fuzzy support vector machine. (Ramdan, Bani, Seri, Siti, 2016) discussed the technique of identifying human movement using image processing technique. In (Zohaib, Baranyai, Lajos, Csaba, 2015) a method for crop seed counting using cell Profiler's algorithm from the camera and scanned images is reported. Design of an optical sensor based analysis system to detect the surface of steel plate in industries is reported in (Lopera, Diaz, Linera, Perez, 2014). In (Xiaolong, Zuhua, Xue, Manli, Li, Haiyan, Peter, Xu Xu, Xianzhen, Jiwen, 2015), an image processing technique is reported for analysis of sedimentation in a non homogenous mixture. An analysis of automation technique in a bottle filling industry is discussed in (Tobias, Stefan, Peter, 2015). Analysis of surface defects using gaber feature extractions is reported in (Najafabadi, Pourghassem, 2012).

Many researchers have reported work on counting of objects using various image processing techniques by using camera as the sensor to acquire the information regarding the count of objects/people. But using these imaging techniques for checking the quantity/count of objects placed inside a closed container is not suitable as the images of objects inside the closed container cannot be taken from outside. To overcome the above said difficulty, a technique is proposed for measurement of the pencils inside a closed package through measurement of capacitance.

This paper is an improvement of (Santhosh, Bhagya, 2014) where an image processing technique was used to analyze the pencils count in a pencil box. But the earlier reported technique used image processing algorithm for analysis, this technique can be used only when the package is open. Normally testing of quantity of products inside the packages will be carried before the packaging is done. As the quantity inside the package in terms of units cannot be seen once the product is fully packed.

The proposed technique is designed to perform quantitative analysis while the box is completely packed (end product). A capacitive plate arrangement is made so as to measure the capacitance of the packed box, on analyzing this information we can evaluate whether or not desired number of pencils are present in the box. Here we use a set of analog circuits and fuzzy logic algorithm to perform the analysis.

The paper is organized with introduction in section-I, followed by the problem statement in Section-II. Experimental setup used to demonstrate the work is discussed in Section-III. Methodology for achieving the set objectives is presented in Section-IV, followed by results and analysis section in Section V. Finally conclusion is discussed in Section-VI.

2. PROBLEM STATEMENT

Packaging of any commodity is done for the purpose of protection, transportation from one place to another, along with purpose of giving it an identity, and also used as a medium to provide information about the product to user. On the other hand, more importantly it standardizes the items in terms of specific quantity. Thus it becomes very essential for the manufacturer to have a thorough check of quantity before and after the packing process.

Figure 1 shows the packed pencil box, it can be seen that the packaging is made to identify the brand of the pencils, type of pencils, quantity, and also cost of pencils. But one can understand that it is not possible for the buyer to know about the status of pencils within. It is always assured that desired number of pencils are present.

Manufacturing of pencil’s at present is carried on with automated processes. Once the manufacturing of pencils is done, it is sent to packaging which is also automated. Further it is seen that quantitative analysis of pencils is carried by sample test or density check of consignment. Often these processes have a tolerance band associated with them, i.e. in a huge consignment of pencil box, missing of one or two pencils would not vary the density. But for a customer who buys the pack of pencil box with 10 pencils would have greater loss if one or two pencils are missing.

Figure 1. Pencil case

Figure 2. Arrangement of pencils in box

Pencils are placed inside the box in an arrangement as shown in Fig. 2, before being sealed. Customer will have no access to check the number of pencils without tampering the seal. So, in view of above, a system is proposed having the following objectives

1. Design an automated technique which will count the number of pencils in closed box within a constraint of time.
2. If in case the number of pencils is not as per desired, the faulty packet is moved off the conveyor for corrective actions.

3. EXPERIMENTAL SETUP

An attempt is made in the proposed work to replicate the model of production line using a conveyor arrangement as shown in Fig. 3a. Conveyor belt is operated using shaft driven by motors. Controlling of motor is done by NI Motion control hardware. Pencils boxes after packing is completed moves on the conveyor. An arrangement consisting of two conductor plates in parallel is made such that the pencil box passes through it. A proximity sensor is placed just next to the plate such that, it triggers once the pencil box is in between the parallel plates. Conveyor is halted for a movement and capacitance across the plates is measured.

This signal is processed for analyzing the quantity of pencils in the box and a solenoid is placed at a preset position to strike faulty pencil box away from the conveyor as shown in Fig. 3b.

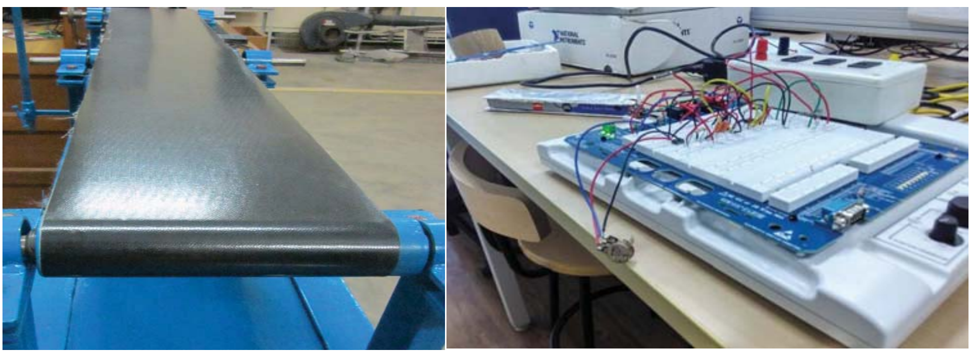

Figure 3. Laboratory setup of a) conveyor and b) sensor and signal conditioning circuit

4. PROBLEM SOLUTION

To accomplish the above discussed objectives, a system is proposed for counting the number of pencils inside the packet and analyzing it for any deficiency of pencils. Figure 4 shows the block diagram of proposed system.

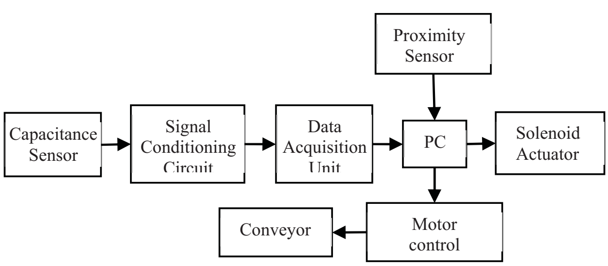

Figure 4. Block diagram of proposed technique

4.1. Capacitance sensor

In the proposed work, a parallel plate capacitor is made use for checking the presence of pencils. Pencil box is placed in between two parallel conductor plates as shown in figure 5. Capacitance can be calculated when the geometry of the conductors and dielectric property of insulator between the conductors are known (Larry, 1997), ([Alan, 2001). Capacitance thus computed is given as (1)

$$C = \varepsilon_r \varepsilon_0 \frac{A}{D} \qquad (1)$$

Where

A – Cross section area of parallel plates

D – Distance between two plates

ε_r - Permittivity of dielectric constant

ε_o – Permittivity of air

A pencil box in between conductor plates can be equivalently considered as a parallel capacitor as shown in Fig 5. For computation we will consider the equivalent dielectric of each block as K_0, K_1, K_2….K_9. To derive the equivalent capacitance of the pencil box,

$$C_{eq} = C_x \; series \; C_y \qquad (2)$$

C_x – Capacitance of top layer and is given by (3)

C_y – Capacitance of bottom layer and is given by (4)

$$C_x = \frac{2\varepsilon_0 A}{5D}(K_0 + K_1 + K_2 + K_3 + K_4) \qquad (3)$$

$$C_y = \frac{2\varepsilon_0 A}{5D}(K_5 + K_6 + K_7 + K_8 + K_9) \qquad (4)$$

$$C_{eq} = \frac{C_x . C_y}{C_x . + C_y} \qquad (5)$$

From (3) and (4)

$$C_{eq} = \frac{2\varepsilon_0 A}{5D} . \frac{(K_0+K_1+K_2+K_3+K_4)(K_5+K_6+K_7+K_8+K_9)}{(K_0+K_1+K_2+K_3+K_4+K_5+K_6+K_7+K_8+K_9)} \text{ F} \qquad (6)$$

Where

Similarly (6) can be extended for the cases with missing pencils. Fig 6.a & 6.b shows the cross section representation of pencil box with one and two missing pencils respectively. On substituting (6) to compute equivalent capacitance for the case shown in Fig 6.a and 6.b is given by (7) and (8)

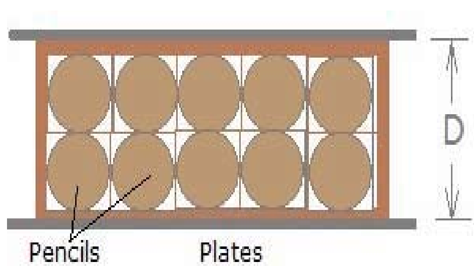

Figure 5. Representation of pencil box as parallel capacitor

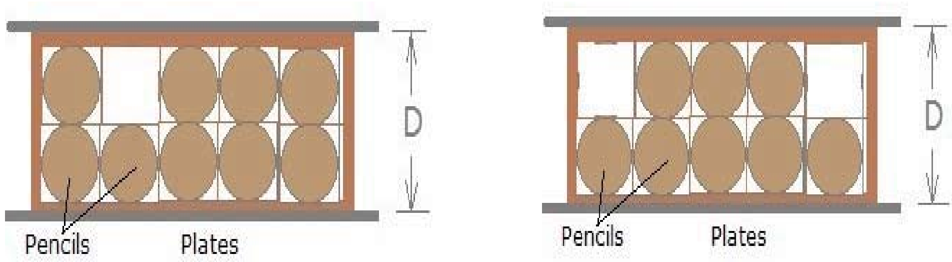

Figure 6. Representation of capacitor a) with one missing pencil b) with two missing pencil

$$C_{eq} = \frac{2\varepsilon_0 A}{5D} \cdot \frac{(K_0+1+K_2+K_3+K_4)(K_5+K_6+K_7+K_8+K_9)}{(K_0+1+K_2+K_3+K_4+K_5+K_6+K_7+K_8+K_9)} \text{ F} \quad (7)$$

$$C_{eq} = \frac{2\varepsilon_0 A}{5D} \cdot \frac{(2+K_1+K_2+K_3)(K_5+K_6+K_7+K_8+K_9)}{(2+K_1+K_2+K_3+K_5+K_6+K_7+K_8+K_9)} \text{ F} \quad (8)$$

In the proposed work we consider a pencil box whose dimensions are 0.038 x 0.22 x 0.015m. Substituting the dimensions (6), (7), and (8) can be rewritten as (9), (10), (11) respectively.

$$C_{eq} = 1.97 \frac{(K_0+K_1+K_2+K_3+K_4)(K_5+K_6+K_7+K_8+K_9)}{(K_0+K_1+K_2+K_3+K_4+K_5+K_6+K_7+K_8+K_9)} \text{ pF} \quad (9)$$

$$C_{eq} = 1.97 \frac{(K_0+1+K_2+K_3+K_4)(K_5+K_6+K_7+K_8+K_9)}{(K_0+1+K_2+K_3+K_4+K_5+K_6+K_7+K_8+K_9)} \text{ pF} \quad (10)$$

$$C_{eq} = 1.97 \frac{(2+K_1+K_2+K_3)(K_5+K_6+K_7+K_8+K_9)}{(2+K_1+K_2+K_3+K_5+K_6+K_7+K_8+K_9)} \text{ pF} \quad (11)$$

4.2. Signal conditioning circuit

Output capacitance is converted to active signal with the help of signal conditioning circuit consisting of a bridge circuit, followed by rectifier, filter, and instrumentation amplifier.

4.2.1. Desauty's bridge

Desauty's bridge is a kind of AC bridge shown in figure 7. Bridges work on the principle of impedance balancing. At balance condition, voltage drop across e_1 and e_2 will be zero. On varying capacitance, voltage drop across e_1 and e_2 will vary. In the proposed technique capacitance output of the sensor is connected across the bridge (Jacob, 1996). Output voltage across the bridge for variations in capacitance is computed by (12) and (13)

$$e_1 = e\left(\frac{r_3}{r_3 - {}^{1}/_{2\pi f C_1}}\right) \quad (12)$$

$$e_2 = e\left(\frac{r_4}{r_4 - {}^{1}/_{2\pi f C_{eq}}}\right) \quad (13)$$

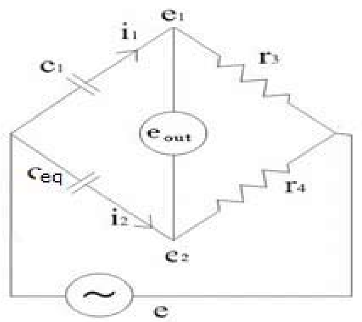

Figure 7. Circuit of Desauty's bridge

4.2.2. Rectifier and Amplification Circuit

Capacitance output from the sensors in terms pencil number inside pencil box is converted to potential change using the circuit as shown in figure 8. To convert this output in a form to be acquired on system full wave rectifier using opamp is designed. Output of rectifier circuit is filtered by using a RC filter. Further the output is converted to DC voltage using a single stage instrumentation amplifier [23].

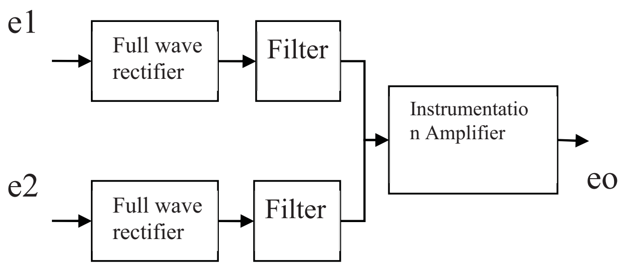

Figure 8. Block diagram of rectifier and amplifier

4.2.2.1. Data acquisition

Once the signal corresponding to number of pencils is converted to voltage, it is acquired on to PC using National Instrument DAQ device-Elvis. Since, computation for achieving the objectives is programmed on LabVIEW platform.

LabVIEW is a graphical user interface platform for designing an automation related program. It consists of two panels one being front panel and other block diagram. Front panel is used as human machine interface between the program and user. It consists of control and display units. On the other hand block diagram is used to create functional items using build blocks called as palettes (Sanjay, 2010).

In the proposed work front panel is designed as shown in figure 9. It consists of a manual override button to start and halt the process. This button also acts as an indicator for showing the status of the process. An LED indicator shows the quality of the pencil box. It is green when the pencil box has desired number of pencils, and turns to red when the number of pencils is less than desired. Numerical indicator "No. of pencil missing" displays the difference in actual number of pencils to that of desired. A Seven segment display is also designed to indicate the actual number of pencils in the pencil box.

Block diagram of the proposed work consists of a DAQ Assist to acquire the input in the form of voltage (output of instrumentation amplifier) is feed to analog input (AI1) of NIElvis. Once the voltage is acquired it is normalized in the range of 0 to 1. For normalization of voltage (14) is used

$$V_N = \frac{(V_{max}-V)}{(V_{max}-V_{min})} \qquad (14)$$

Table 1 shows the output in terms of voltage output and normalization values for varying samples in terms of number of pencils inside pencil box.

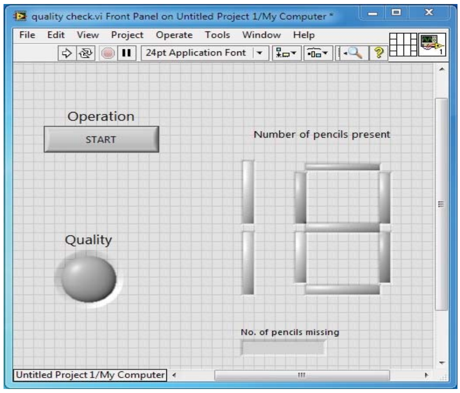

Figure 9. Front panel of VI for proposed technique

Table 1. shows variations in output at every stage corresponding to pencil number

Sl. No.	No. of pencil missing	Position of missing pencil	Voltage in Volts	Normalized Output
1	0	-	0.54	1.00
2	1	K_0	0.576	0.98
3	1	K_1	0.552	0.99
4	2	K_3, K_4	0.612	0.95
5	2	K_0, K_5	0.6	0.96
6	3	K_0, K_1, K_2	0.66	0.92
7	4	K_0, K_1, K_2, K_3	0.744	0.87
8	5	K_0, K_1, K_2, K_3, K_4	0.972	0.72
9	6	K_0, K_1, K_2, K_3, K_4, K_5	1.152	0.61
10	7	K_0, K_1, K_2, K_3, K_4, K_5, K_6	1.452	0.42

4.2.2.2. Fuzzy block

Once the normalized value is computed it is fed to the fuzzy block for computation of missing pencils. Fuzzy logic algorithms are used because the relationship found for the number of pencils to voltage levels are nonlinear. Secondly, interpretation of output in a fuzzy is more generic.

Now to start the operation, fuzzification is carried out using the input and output membership functions. Member ship functions used in the proposed work is shown in Figure 10 and Figure 11. We use a Mamdani scheme for designing the fuzzy tool (Timothy, 2010).

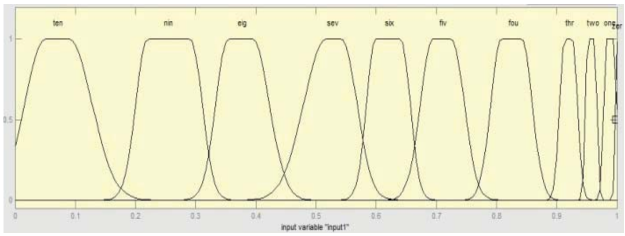

Figure 10. Input membership function

In the proposed work we have taken ten stages indicating the levels of output when a particular number of pencils are missing. Since the distribution of output is nonlinear we have used a Gaussian function to represent the variables. Obtained membership function shown in Figure 10 was obtained after trial and error.

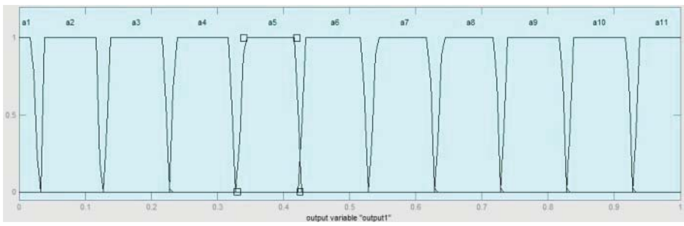

Figure 11. Output membership function

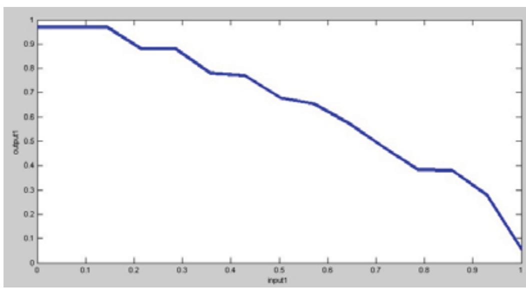

Figure 12. Surface graph for fuzzy logic algorithm

Here trapezoidal function is considered for representing output membership function. De-fuzzification is carried on using rounding off method to obtain the output in terms of number of missing pencils.

Surface graph obtained for the tuned fuzzy membership function is as shown in Figure 12. Once de-fuzzified output is obtained it is converted to de-normalized value to indicate the actual number of pencils which are missing.

Output of the fuzzy block is displayed as in the form of seven segment display. For this a decimal to seven segment converter is used. Once the actual number of pencils is computed it is compared with the desired number of pencils. Desired number of pencil is fed by the user based on the brand of pencil box. If the number of pencil is less than desired, an alarm is initialized along with that a solenoid is triggered so that defective pencil box is pushed away from the conveyor.

5. RESULTS AND ANALYSIS

In this paper, an automated technique is designed to identify the defective pencil box having less number of pencils in comparison to desired number. The technique was primarily designed for the cello brand pencil box. This can be extended to any brand with some minimal tuning at software level. The system once designed and implemented was tested using set of pencils box's having variations in number of pencils. Around 200 such cases were tested to validate the designed system for real life application. Output in terms of number of pencils found and missing in a particular box was displayed on the front panel of designed VI. Along with this information, an indicator displays the quality of pencil box in terms of whether/ not the box has desired number of pencils. If the pencil box was found faulty, particular box will be deviated from conveyor belt. Output as seen from the front panel of the proposed system for sample cases can be shown in Figure 13, Figure 14, and Figure 15.

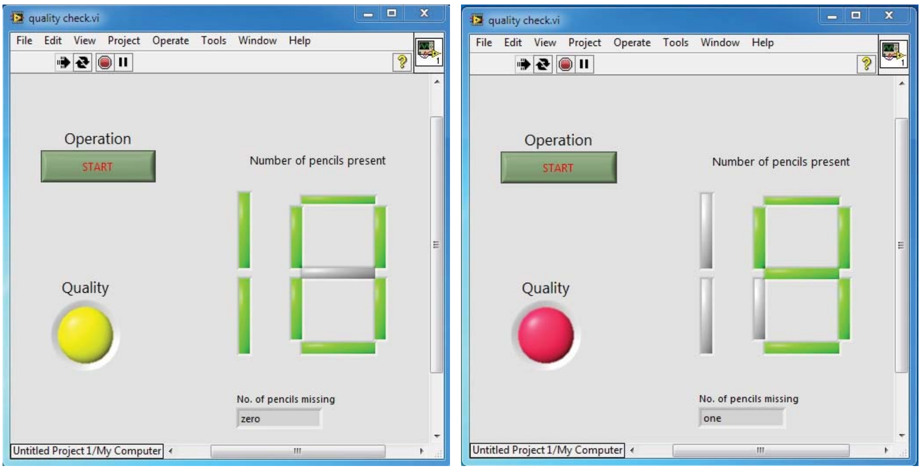

Figure 13. Result obtained for packet with a) correct number of pencils, b) one pencil missing

Figure 13a shows the output of the proposed when the pencil box contained desired number of pencils. Figure 13b, Figure 14a, Figure 14b and Figure 15 shows the front panel when every time a faulty pencil box was used with 1, 2, 10, and 4 number of pencils missing in the pencil box. From the result obtained it can be understood that system produced accurate information about the number of pencils in the pencil box even though it is closed. Along with displaying information about the box quality, action is also taken to divert the faulty pencil box from the conveyor.

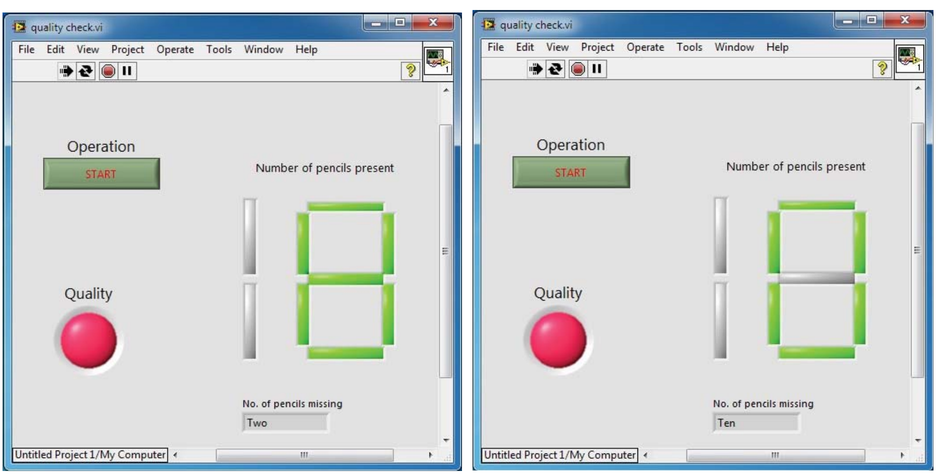

Figure 14. Result obtained for packet with a) two pencils missing, b) all pencils missing

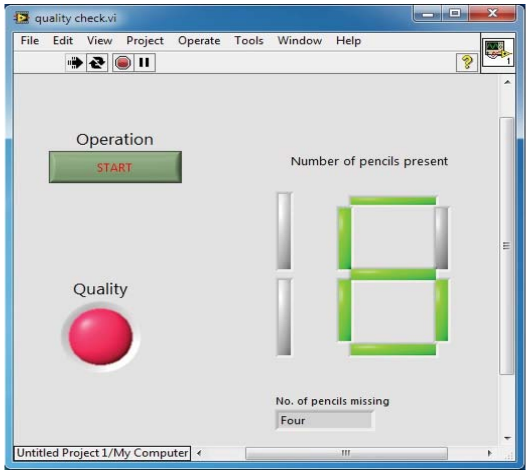

Figure 15. Result obtained for packet with five pencils missing

6. CONCLUSIONS

An automated technique for quantitative analysis of pencils box moving on the conveyor was designed. The technique uses analysis of capacitance measured for computation of number of pencils in the closed pencil box. Analysis and processing was carried out using fuzzy logic algorithm on LabVIEW platform.

Proposed system was designed to operate under real time situations. For the purpose of validation it was tested with several cases of faulty and correct pencil boxes consisting of varying number of pencils in different arrangements. Results produced by the proposed technique shows successful implementation of the work and can be used for industrial applications

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