An Automated Sorting System Based on Virtual Instrumentation Techniques

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***Abstract*—The application presented in this paper represents an experimental model and it refers to the implementing of an automated sorting system for pieces of same shape but different sizes and/or colors. The classification is made according to two features: the color and weight of these pieces. The system is a complex combination of NI Vision hardware and software tools, strain gauges transducers, signal conditioning connected to data acquisition boards, motion and control elements. The system is very useful for students to learn and experiment different virtual instrumentation techniques in order to be able to develop a large field of applications from inspection and process control to sorting and assembly.**

***Index Terms*—Automated sorting, Data acquisition, machine vision, Strain gauge, Virtual instrumentation.**

I. INTRODUCTION

In the conditions of increased exigencies on world market both regarding the quality of the finite product and enlarging the capacity of production line, automated sorting becomes more and more important. Modern production lines, adapted to market requirements have automated sorting systems that ensure speed and accuracy in the sorting process. Most of the sorting systems from industry and manufacturing are based on machine vision type applications. Whereas computer vision is mainly focused on machine-based image processing, machine vision most often requires also digital input/output devices and computer networks to control other manufacturing equipment. Machine Vision is a subfield of engineering that encompasses computer science, optics, mechanical engineering, and industrial automation and it is used in the inspection and sorting of manufactured goods such as semiconductor chips, automobiles, food and pharmaceuticals [1] [2].

Most of the sorting systems contain technologies of image processing associated with automation and control elements. Through image processing can be analyzed parameters as: color, texture, reflection, shape or size of pieces [3] [4] [5].

Often, these sorting parameters resulted from image processing are not sufficient in order to obtain the desired results. That is why vision systems may be associated with those of mechanical, electrical type, etc [6]. So, a system for measuring the weight of the pieces may be an example. Strain gauges associated with proper conditioning circuits can be used for implementing this system.

Three major phases are covered in the sorting process (Fig.1) [7]. In the first phase there are identified the characteristics based on which the classification of pieces is done. In the second phase, named the *characteristic extraction phase*, the pieces are measured and the values obtained form the vector of characteristics used in the sorting process. The third phase refers to the classification of pieces. The result is purely a decision regarding the very class from all possible to which each piece belongs. A classification error appears if the transfer is done in an improper class.

In the case of the application presented in this work the vector of characteristics contains two elements: the color and the weight of the pieces to be sorted.

These characteristics may be represented in a two-dimensional space defined by the two parameters, having as result several classes of pieces as in Fig.2. By delimiting each class with a separating line, the two-dimensional space may be split in a region characteristic to each class, thus establishing a rule for classification and sorting.

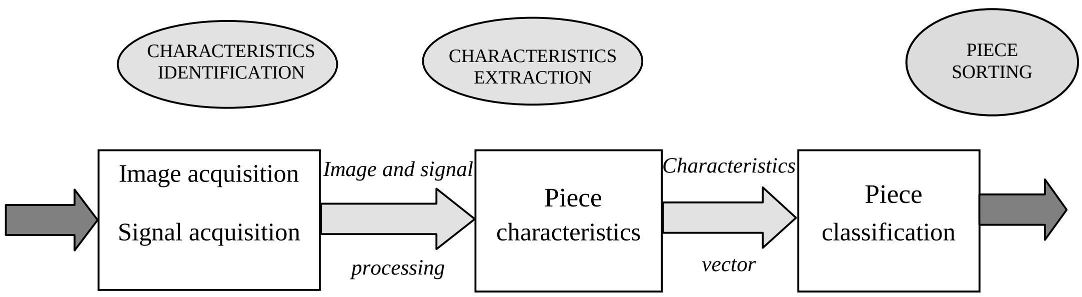

Figure1. The three major phases of sorting process

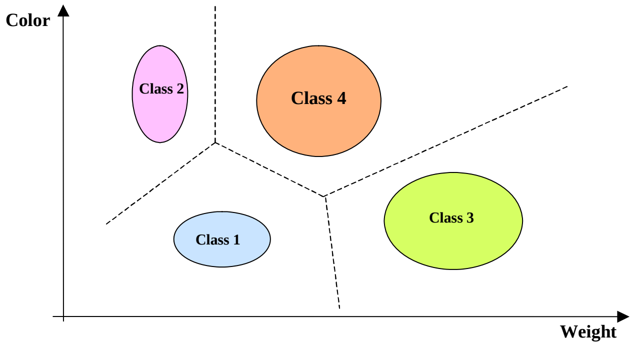

Figure 2. Two-dimensional space of the two characteristics: color and weight

Taking the advantage of NI LabVIEW software, vision and data acquisition hardware that can be synchronized products with advanced analysis capabilities, an automated sorting PC-based system can be implemented. The application is very useful for our students in order to learn and to apply such principles and algorithms and to extend and improve the system to an industrial one.

II. SYTEM OVERVIEW

We intended to perform an experimental sorting system of some pieces based on two criteria: weight and color. The pieces have the same shape and there are cases in which two pieces have the same weight but they have different colors or vice versa. Thus, classes of pieces with well defined characteristics have resulted. Also it has been foreseen the situation of the class of pieces different from those corresponding to the established criteria.

The system is composed by two basic subsystems (see Fig.3): that which makes the extraction of color characteristic (performed with a machine vision type module) and that which makes the extraction of weight characteristic (performed with strain gauges transducers connected to a data acquisition board).

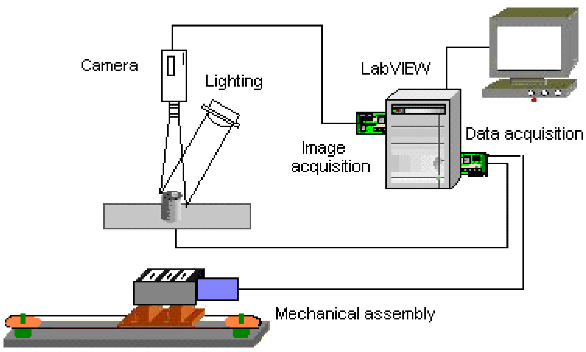

Figure 3. Sorting system general schema

The pieces to be sorted are placed on a platform and after their framing in a class of pieces the drawer with afferent compartments is moved to align the platform. The piece is introduced into the appropriate drawer by the help of a pushing system. In implementing the system (Fig.4) principles of virtual instrumentation as in [8] [9] have been applied, using in this respect a PC- based system that contains the following hardware and software components:

- Data Acquisition Board (AT-MIO-16E-10)
- Signal conditioning board (SC-2043-SG) that interfaces the NI DAQ directly to strain gauge transducers
- System for pushing the piece (DC motor and a CD tray type mechanism)
- System for positioning the drawers in which will be placed every separate piece
- Color analog camera image acquisition board (IMAQ PCI/PXI-1411)
- Color CCD Camera TP-1002DS TOPICA
- LabVIEW software from National Instruments

Figure 4. Implementation of the sorting system

A. *Weighting system. Hardware and software implementation*

The identification of weight of the pieces to be sorted uses the data acquisition board that is associated to the conditioning module that ensures: the bridge link of strain gauges, the powering of the bridge, offset compensation and signal amplification.

Measuring with strain gauges transducers supposes to perceive some extremely small variations of the resistance. So, for a quality measurement the proper choice and use of the bridge is needed. It has been chosen the half-bridge configuration, where the following relation is valid (1):

$$\frac{V_0}{V_{EX}} = -\frac{GF*\varepsilon}{2} \qquad (1)$$

Where v_0 is the output voltage, V_{EX}- bridge excitation voltage. GF-gauge factor and ε- the strain.

The shape and sizes design of the plate and also the correct positioning and orientation of the strain gages were things that were very important in the weighting system concept. On seizing, the fulfillment of linearity conditions was taken into account.

The geometry of the plate on which strain gauges were glued is based on the value of the maximum value of the bending stress and also on the relation between strain and stress (Fig.5) [10]:

$$\sigma_{max} = \frac{M}{I} = \frac{6 \cdot M}{b \cdot h^2} = \frac{6 \cdot P \cdot x}{b \cdot h^2} \qquad (2)$$

$$\sigma_{max} = E \cdot \varepsilon_{max}, \qquad \varepsilon_{max} = 10^{-2} \div 10^{-4} \quad (3)$$

In relation (2) **M** represents the blending moment, **I** is the moment of inertia and **P** is the load.

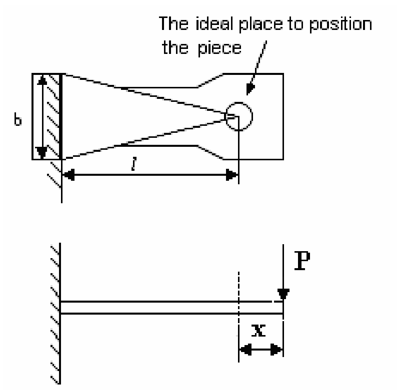

Figure 5. Geometry of the plate on which strain gauges are glued

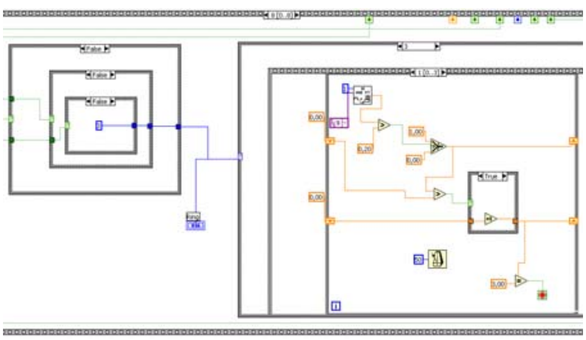

Figure 6. Block diagram. Sorting pieces on their weight

For the mechanic module (which contains the drawers positioning system and the system for pushing the pieces) were used two direct current motors powered from the acquisition board, photo diodes and a system of lateral mirrors.

On identifying the weight of the pieces (Fig.6) the program verifies its framing in a preset interval, the values of all possible weights being a priori known through an operation of calibration.

B. *Color identification system. Hardware and software implementation*

The color identification has been performed by the use of: video camera, image acquisition plate as well as algorithms of color matching offered by the programming software package IMAQ Vision for LabVIEW (National Instruments) (Fig.7). Optimal conditions were created both for positioning the camera and illuminating the area for analysis. The strategy for an efficient algorithm development was the using of the Vision Assistant software as a prototyping platform. The optimized sequence solution was then used to create the color identification LabView frame in the main sequence structure.

C. *The decision algorithm*

The main virtual instrument uses a sequence structure that contains the weighing and color identification frames, the decision frame where the proper drawer is chosen, the frames where the dc motors for conveyer movement and pushing action are supplied. The flow chart of the sorting decision algorithm is given in Fig.8

The real time and historical monitoring of the measured parameters as well as the displaying of the sorting result is done through the user-friendly frontal panel of the application (Fig. 9).

The presented sorting system performed in virtual technique has the advantage of a great flexibility and adaptability regarding the sorting conditions, the used hardware as well as the algorithms and logics of sorting.

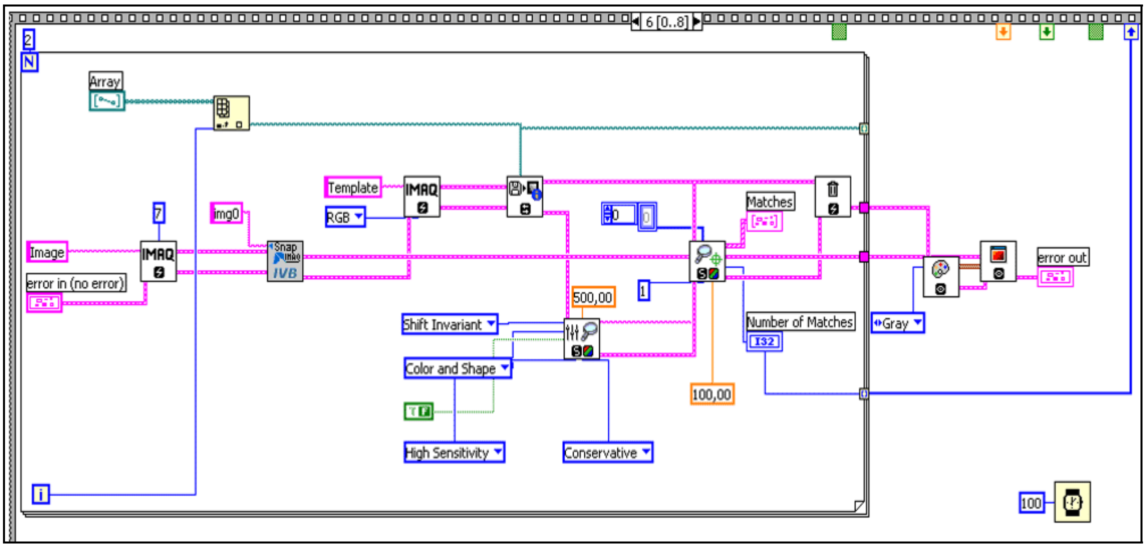

Figure 7. Block diagram. Color matching algorithm

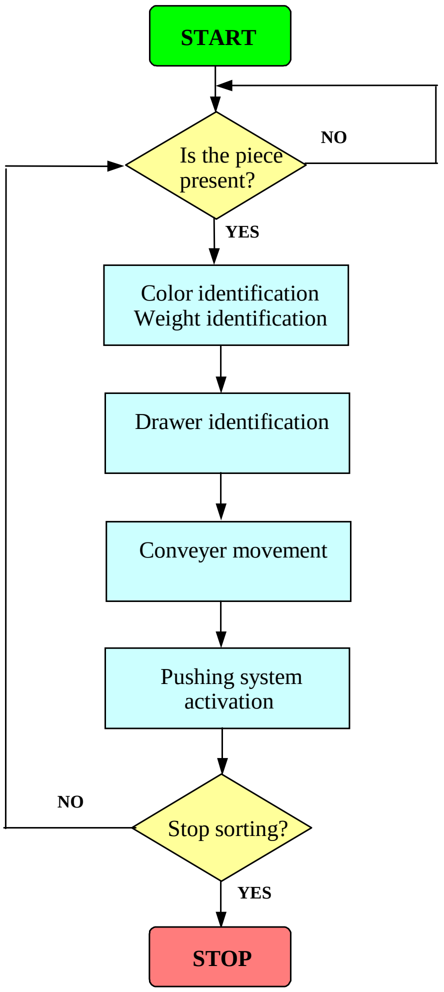

Figure 8. The flow chart of the sorting algorithm

III. SYSTEM DESIGN CONSIDERATIONS

The automated proposed sorting system is a virtual instrumentation machine, based on an open framework that can be redesigned by the user function of the customer requirements. Virtual instrumentation also provides the flexibility to adapt and extend as needs change. High flexibility and modularity of virtual instruments allow our students to easily customize, integrate the new solution and upgrade with new proposed hardware and software components.

In the conditions in which the application is experienced in the virtual instrumentation laboratory, students have the chance to go through the necessary steps to implement a system for sorting. Thus they will have to answer the following issues:

- To identify the system hardware. In this sense they have to analyze the performance of these components and to propose, on a reasoning basis other possible configurations of the system. The parameters that will be followed are real-time processing, speed image acquisition, accurate synchronization etc.
- To follow the logic of sorting. Other items may be proposed (except color and weight) to define the vector of characteristics (shape, size, roughness, texture, etc.) also specifying the way
- they will change the sorting algorithm in terms of hardware and software
- To follow and understand the software implementation of the application. Other techniques to extract the sorting characteristics (color and weight) may be proposed: specifying the algorithms of data acquisition and processing. They will be argued in terms of accuracy, implementing facility and hardware flexibility.
- To test the system by establishing the sorting limit conditions and parameters involved in these (max / min pieces size, sorting speed, precision). Solutions to extend these limits may be proposed.

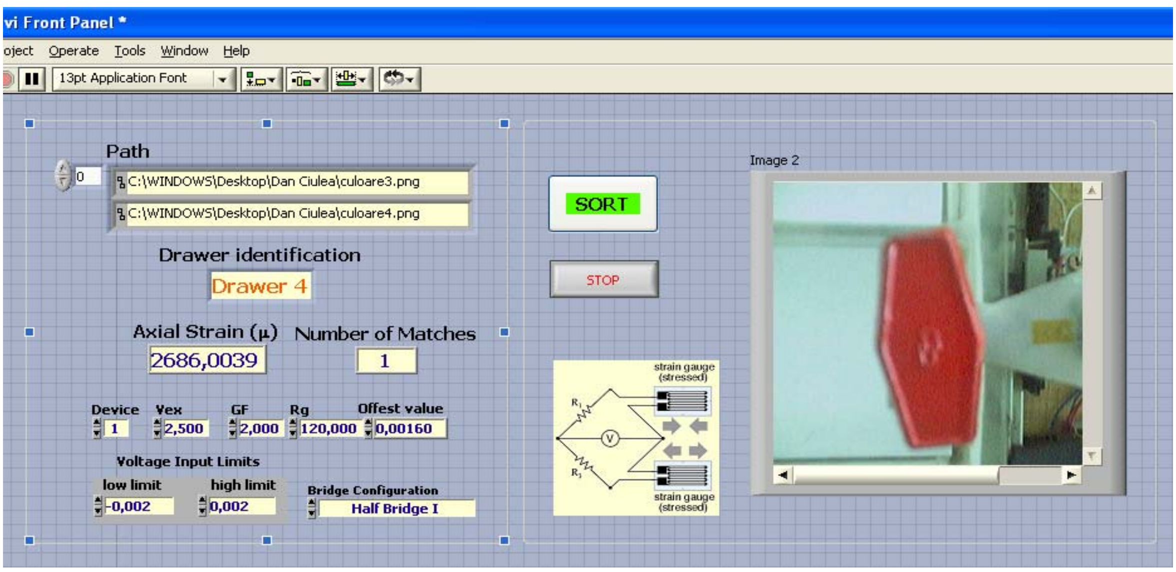

Figure 9. Frontal panel of the application

- To analyze the system in terms of its implementation at industrial level. There will be studied the implications of such an implementation regarding the fusion of mechanical engineering with electronic and intelligent computer control in the design and manufacturing of industrial products.
- To point out the advantages and disadvantages of using the virtual instrumentation techniques in performing the system compared to other techniques used in the process of sorting and assembly.
- To specify different fields of application where the proposed sorting system can be adapted and used.

IV. CONCLUSIONS

The paper presents an automated sorting system that uses two classifiers: color and weight of the pieces to be sorted. The vision system integrates mechanical parts, an illuminating system and an interface with the user, all controlled by VI Vision tools. The weighting system integrates mechanical parts, gauge sensors connected to an eight-channel strain gauge signal conditioning accessory that interfaces signals coming from those sensors to a NI DAQ board.

The application has a string didactic feature; it has been made within the department of Electric Measurements of the Technical University from Cluj-Napoca, so as the students who study the principles of virtual instrumentation have the opportunity to experiment a complex system containing elements of: mechanics, electro-technique, electronics and data acquisition and at last but not least elements of graphic programming (LabVIEW). The modularity of the application enables an easy upgrade of the system, being easily adaptable to an industrial automated sorting process.

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