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Virtual Instrumentation in the Diagnostic and Control Process for Industrial Applications

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Abstract. This paper brings a look on integration of virtual instrumentation to the industrial (mechatronic) applications. Virtual instrumentation conception enables higher level of user´s flexibility, system manageability and also cost saving. We designed two mechatronic systems with integrated virtual instrumentation and these systems are primarily intended for educational purposes (for specialization automation and mechatronics), but also they can be implemented immediately in industry. Replacement of human labour with automated approach follows the actual trends in many branches of industry.

Introduction

Nowadays, virtual instrumentation (VI) serves in many applications across several fields in science and industry. The simplest definition of VI says, that VI is replacement of huge amount of conventional measuring devices with software (virtual) one using universal I/O hardware (measuring cards) and suitable sensors [1]. VI also can take control over the processes in manufacturing, automation and industry with driving actuators (based on the processing of acquired information and signals from process). In addition, implementation of VI reduces the costs (usually the one universal instrument against several specialized device); work area is also more manageable in sense of VI's flexibility, complexity and modular solution.

Very important part of process in manufacturing or industry is diagnostics or automated measurement of critical quantities. Automated approach using VI can significant decrease the human faults in this task.

In this paper we want to introduce two models, where the integration of VI in mechatronic/industry solution can be present. First model is used for diagnostic purposes in car industry and also could be used for demonstrating functionality and communication of various parts in car (sensors, electric devices, mechanical devices) with control unit. The networking is based on CAN (Control Area Network) bus [2]. This model was developed also for educational purposes with support of BH Motorsport, Turany (Slovakia). Second model is based on machine vision algorithms for quality control in industry (contactless measurement, inspection and sorting). The key element is an inspection camera sensor and designing of robust algorithm for image processing and understanding.

In the next section, models and their functionality will be presented.

Car diagnostic model based on CAN networking and VI

As mentioned in the Introduction, this model based on VI and CAN (Fig. 1) is dedicated for car diagnostic and also for demonstrating car communication between parts and control unit (suitable for education). This model can operate in two modes:

- linked with real car control unit via CAN;
- link with gateway (via CAN) simulating car control unit (simulation mode).

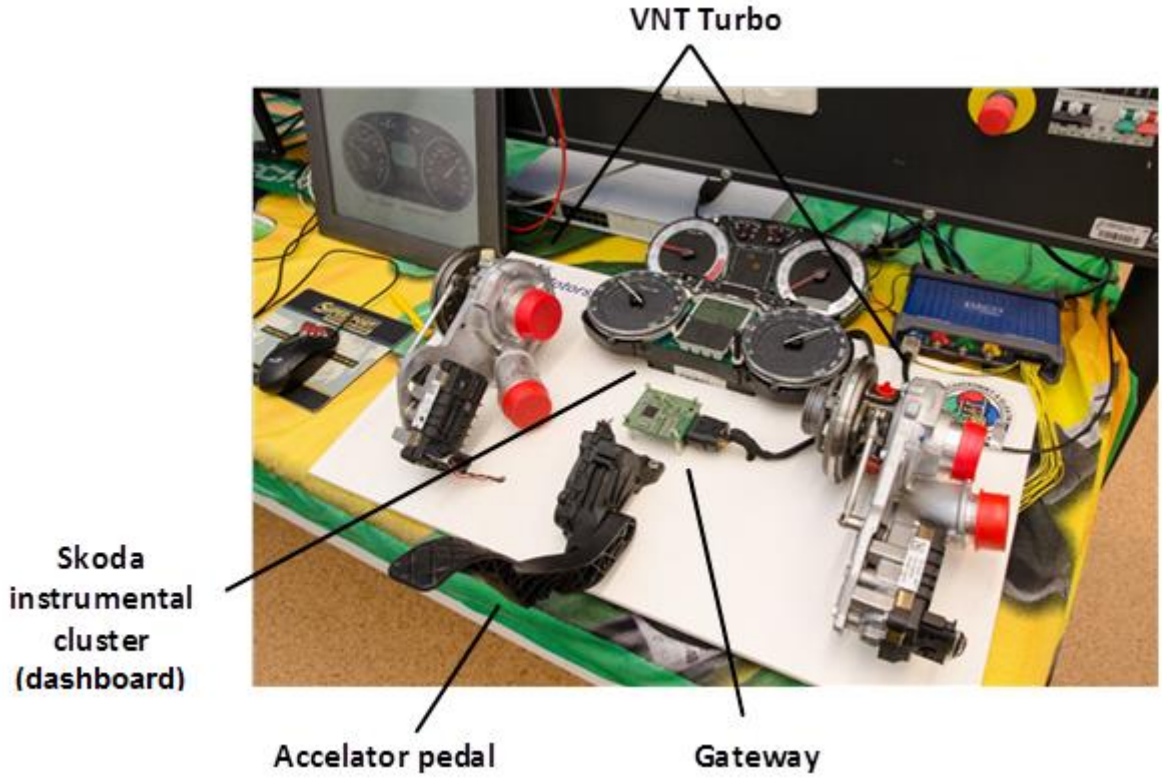

Fig. 1 Car diagnostic model

In both modes, National Instruments cRIO (FPGA controller) with high-speed duplex CAN channel and touch panel is a display portal for visualizing the processes.

The main part of model in simulation mode is **gateway** which simulates CAN message transmitted from engine control unit. Simulated CAN messages contain data for processing engine revolutions, speed of vehicle, coolant temperature and accelerator pedal position.

Second element is **accelerator pedal**. The accelerator pedal position sensor detects the amount of travel of the accelerator pedal. This sensor outputs a voltage signal, which corresponds to the amount of pedal travel, to the A/D converter of the gateway. The accelerator-pedal module (APM) comprises an accelerator pedal and a potentiometer or a non-contacting Hall sensor as angular-position sensor. This sensor registers the movement and the position of the accelerator pedal. From this information, the engine management calculates the required torque and accordingly addresses the throttle device and the injection system. The accelerator-pedal module can output analog or digital signals [3].

Next section is two **turbochargers with variable geometry**. In a VNT turbo, the exhaust flow through the turbine wheel is controlled by a row of vanes that move to match the exact boost requirements of the engine. At low engine speed, the variable nozzle turbine vanes close to restrict flow of exhaust gases through the turbine, thereby increasing boost pressure. At high engine speeds, the vanes open to maximize the exhaust gas flow, thereby avoiding turbo over-speed and maintaining the boost pressure required by the engine. Position of the vanes is controlling by servo engines directly through CAN bus.

The last segment of model is **instrument cluster of Škoda Octavia**. Instrument cluster (dashboard) shows only speed, rpm and coolant temperature. Messages of other indicators are not simulated and fuel gauge is analog.

CAN communication

The Controller Area Network (CAN) is a serial communications protocol that efficiently supports distributed real-time control with a very high level of data integrity. Though conceived and defined by BOSCH in Germany for automotive applications, CAN is not restricted to that industry. CAN fulfils the communication needs of a wide range of applications, from high-speed networks to low-cost multiplex wiring. For example, in automotive electronics, engine control units, sensors and anti-skid systems may be connected using CAN, with bit-rates up to 1 Mbit/s. At the same time, it is cost effective to build CAN into vehicle body electronics, such as lamp clusters and electric windows, to replace the wiring harness otherwise required [2].

The content of a message is described by an identifier. The identifier does not indicate the destination of the message, but describes the meaning of the data, so that all nodes in the network are able to decide by message filtering whether the data is to be acted upon by them or not. Within a CAN network, it is guaranteed that a message is accepted simultaneously either by all nodes or by no node. Thus, data consistency is a property of the system achieved by the concepts of multicast and by error handling.

Message transfer between nodes (sensors, parts) is manifested and controlled by four different frame types:

- A **Data frame** carries data from a transmitter to the receivers.
- A **Remote frame** is transmitted by a bus node to request the transmission of the Data frame with the same identifier.
- An **Error frame** is transmitted by any node on detecting a bus error.
- An **Overload frame** is used to provide for an extra delay between the preceding and the succeeding Data or Remote frames [4].

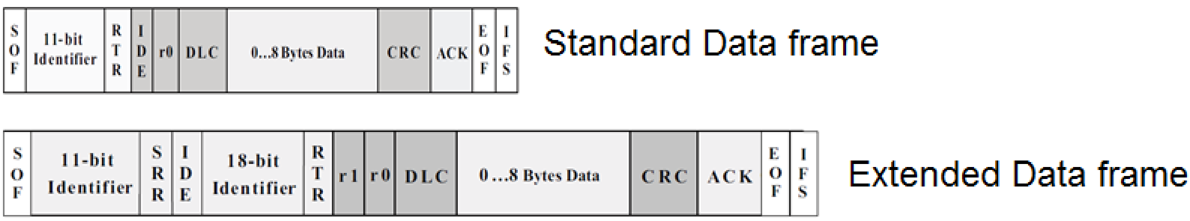

Fig. 2 Vision inspection model for industrial application

Two types of Data frames (Fig. 2) are defined in CAN protocol. Standard Data frames can contain 8-byte data and are used for simple CAN structure, on the other side, Extended Data frame is used for communication where the nodes are divided into groups and classes.

Whenever the bus is free, any node may start to transmit a message. If two or more nodes start transmitting messages at the same time, the bus access conflict is resolved by bit-wise arbitration using the identifier. The mechanism of arbitration (Fig. 3) guarantees that neither information nor time is lost. If a Data frame and a Remote frame with the same identifier are initiated at the same time, the Data frame prevails over the Remote frame. During arbitration, every transmitter compares the level of the bit transmitted with the level that is monitored on the bus.

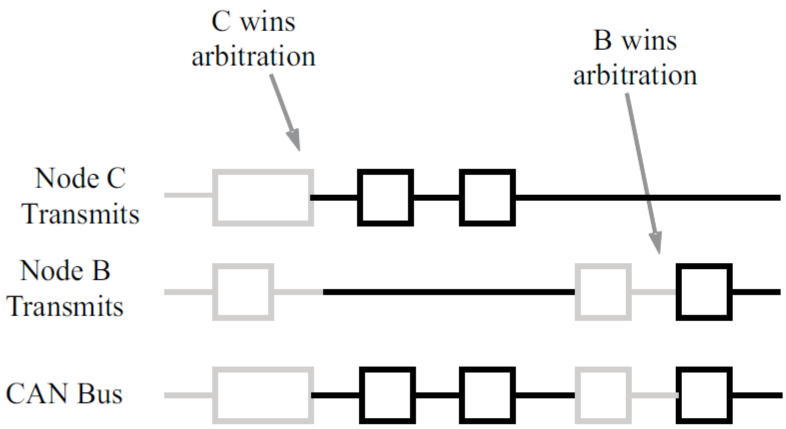

Fig. 3 Arbitration of CAN bus

If these levels are equal the node may continue to send. When a recessive level is sent, but a dominant level is monitored, the node has lost arbitration and must withdraw without sending any further bits [2].

Visualizing the data from CAN bus

Visualization of the data acquired from CAN bus of a model is done in LabVIEW application as a virtual instrument (virtual Škoda dashboard) (Fig. 4) and also physically on real instrumentation cluster of Škoda Octavia. Virtual instrument runs on NI TouchPanel.

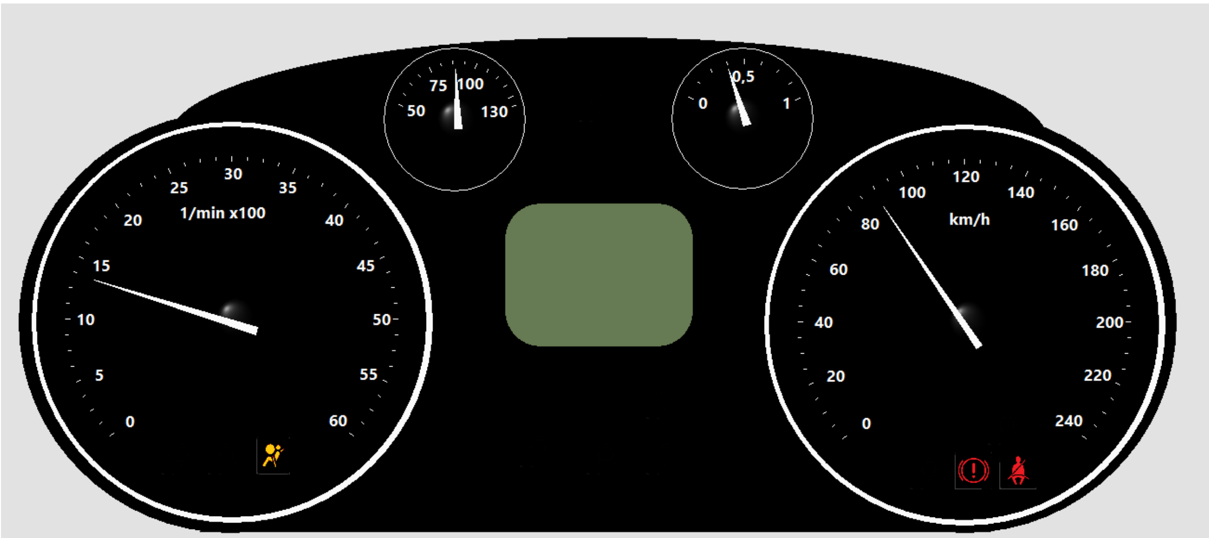

Fig. 4 Virtual instrument – Škoda dashboard

The I/O part of virtual instrument consists of NI CompactRIO 9082 FPGA controller with NI 9853 high-speed duplex 1 Mb/s CAN bus module (Fig. 5) [5] – [8].
In the LabVIEW virtual instrument, we selected relevant Standard Data frames acquisition with relevant identifiers and data content. The main part of application was frame filtering for sorting the data for individual indicators of the screen.

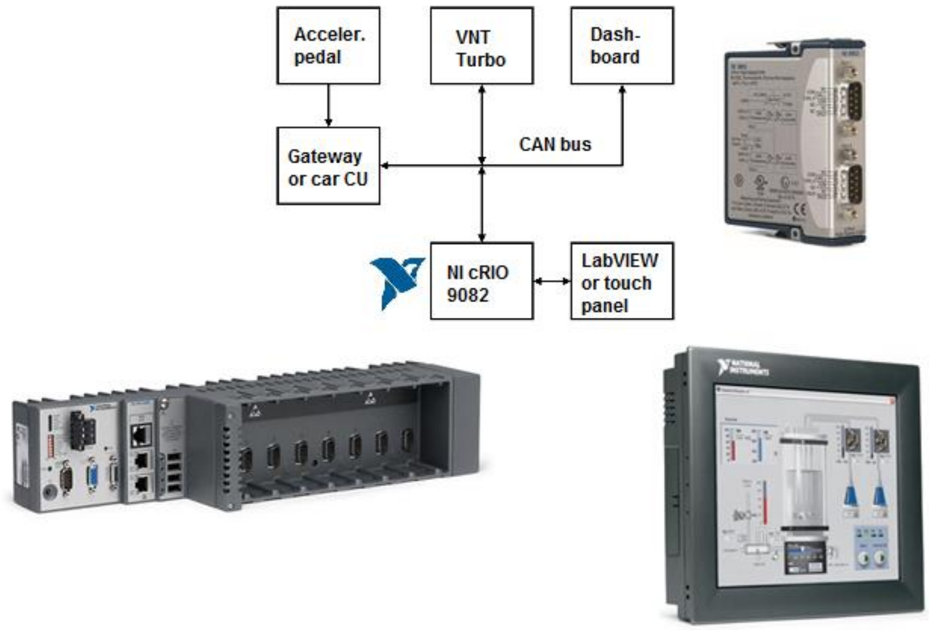

Fig. 5 Interconnection of parts in model

In some indicators we had to normalize or interpolate the values (e.g. coolant temperature) from raw sensor data.

Visual inspection system for industry applications based on VI

Visual inspection can be defined as a common method of quality control, data acquisition, and data analysis. Visual inspection provides quality and quantity checking and control of components.

Visual inspection is simple as compared to other methods. Despite this, it still has several advantages over more high-tech methods. Compared to other methods, it is far more cost effective. For similar reasons also one of the easiest techniques to perform inspection. It is also one of the most reliable techniques. The main tasks of visual inspection are control product type, quantity, dimensions, completeness, obvious defects, colour, material and inspection speed.

Before a system is selected the all requirements for the machine vision system should be clearly defined. Not all criteria can be met by all system types so that the choice is quickly narrowed down to the appropriate test system. The starting point for this consideration is the object to be inspected and the process environment in which the system must be installed. Detailed knowledge of this is essential to establish a stable plant process and to implement an economically viable application. [9] – [11]

A variety of basic conditions and parameters must be weighed for the selection of the image processing system (Fig. 6):

The description of created video inspection system is presented in the following paragraph. The hardware and software platform for machine vision is virtual instrumentation. The main part of visual system is a camera. The camera must be suitable for required task. The IEEE 1394 camera MARLIN F-046B was used for this visual inspection system. This camera based specification is: grayscale, 60 fps (frames per second) and resolution 780x582. The goal of video inspection system is sort and quantified components such as screws, screw pads and nuts. In application the quantified element can be selected and algorithm then search the captured scene. Search algorithm is based on matching techniques. The most important technique is pattern matching technique. This algorithm is based on cross correlation algorithm (1).

$$R(i,j)=\frac{\sum_{x=0}^{L-1}\sum_{y=0}^{K.1}\left(w(x,y)-\overline{w}\right)\left(f(x+i,y+j)-\overline{f}(i,j)\right)}{\sqrt{\sum_{x=0}^{L-1}\sum_{y=0}^{K.1}\left(w(x,y)-\overline{w}\right)^2}\sqrt{\sum_{x=0}^{L-1}\sum_{y=0}^{K.1}\left(f(x+i,y+j)-f(i,j)\right)^2}} \tag{1}$$

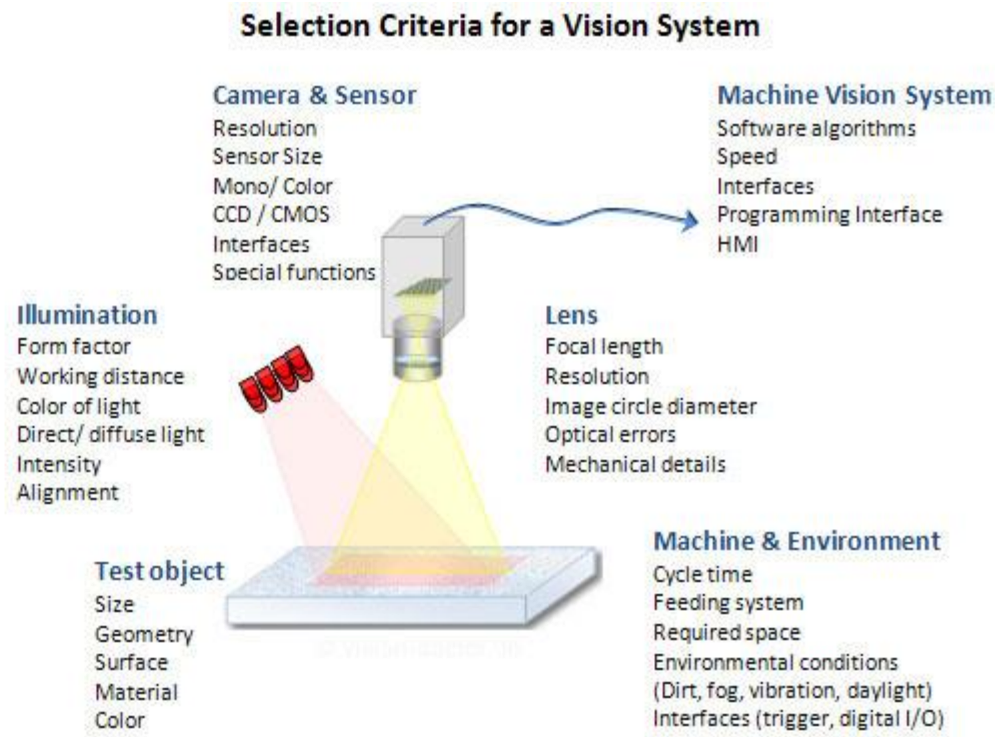

Fig. 6 Selection criteria for a vision system

In first step of algorithm the searched component is selected and then the shape of element is described by mathematical functions. In the next step of algorithm the whole captured image is scanned to detect the similarities with template. The areas in image is classified by score value, which determine the similarity with template. Based user setting the most significant areas with similarity is then sign as an area with coincidence. The higher value of score means the higher similarity with template.

The concept of workplace is shown at Fig. 7. The workplace consist from inspection camera with lens, stand for conveyor belt simulation and PC with evaluation software. The connection between inspection camera and PC is realized through measuring card. This card support communication with virtual instrumentation LabVIEW. The application software then receive data from camera and evaluate and displayed images ten times per second. The inspection can perform faster if the visualisation will be realized only in case of fault detection. The condition of evaluation is set by user (which components are wanted for evaluation, how fast the inspection is performed).

The results of described algorithms is shown at Fig. 8. The robustness of algorithm can be seen at Fig. 8 where is shown the result of inspection for screw pad. In presented result is shown that the screw pads can be detect when are alone in simulated conveyor belt or when are overlapped with another components. The algorithm searches screw pads on simulated conveyor belt according to user's criteria. The user can select component which will be searched and maximal numbers of matches for each component.

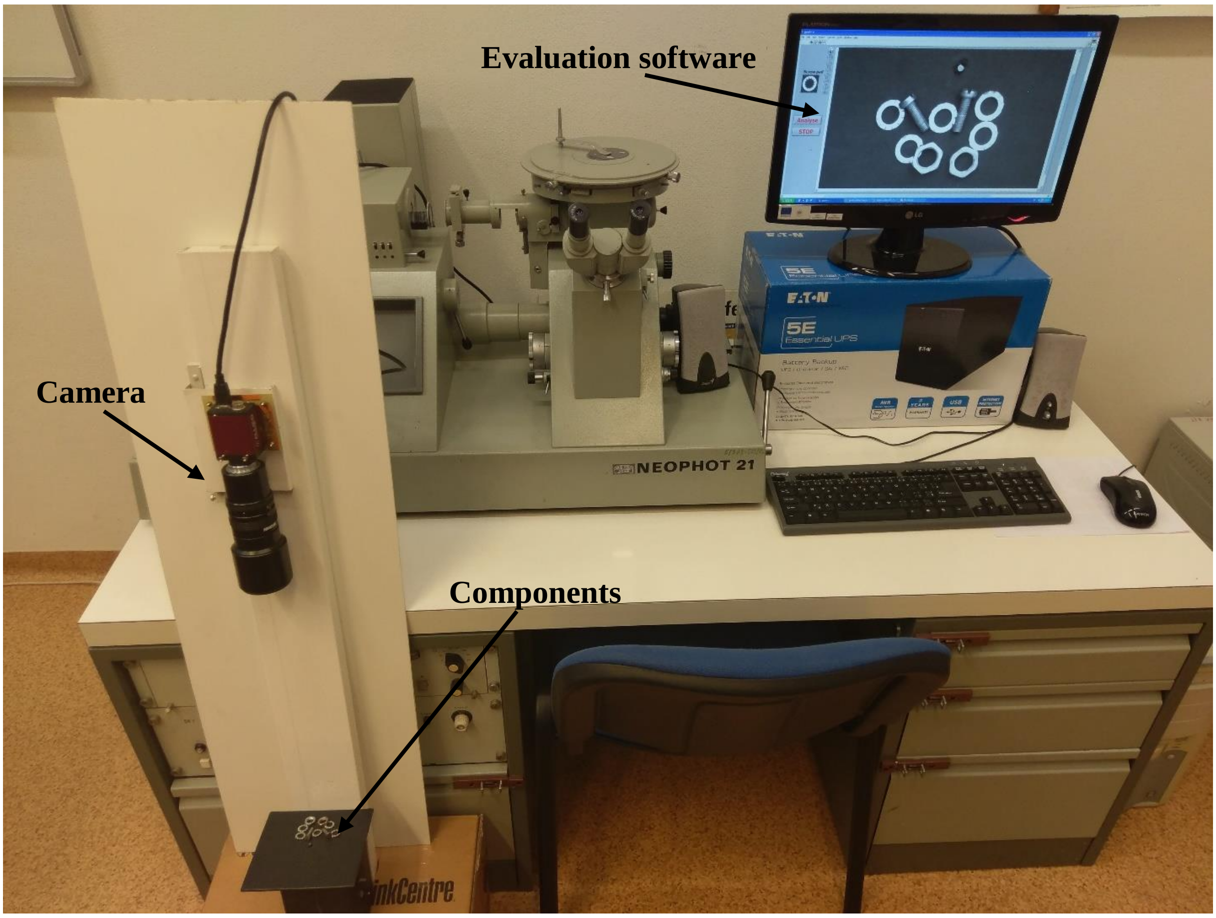

Fig. 7 Simulation of video inspection workplace

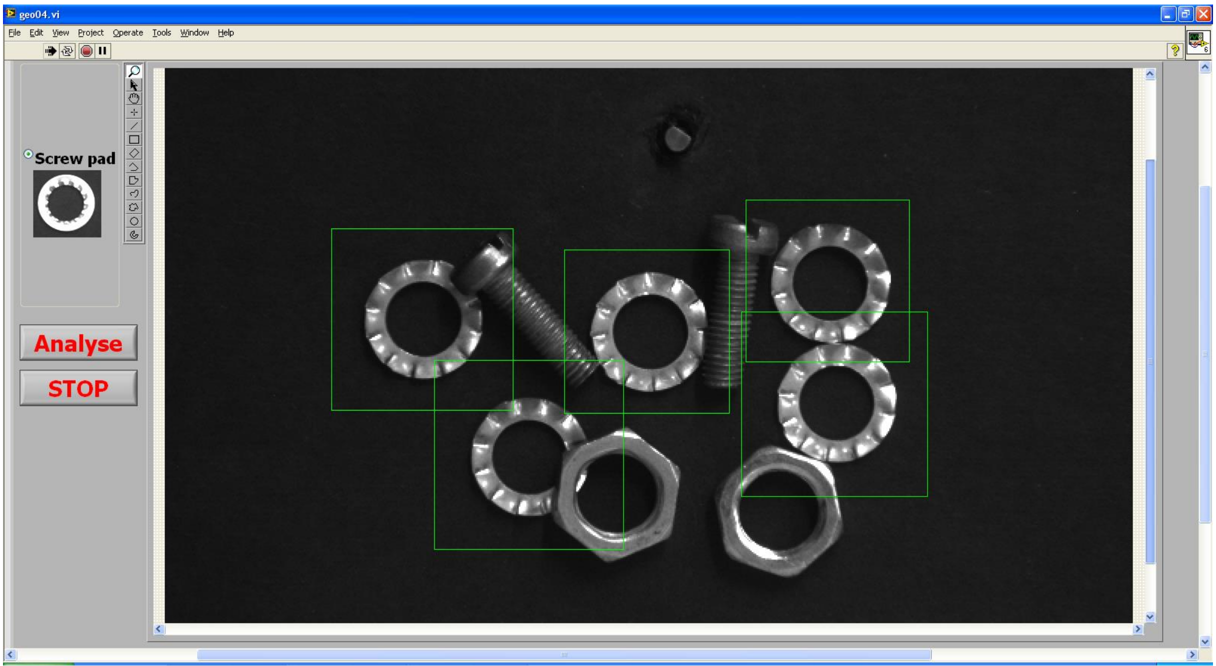

Fig. 8 Result of video inspection for screw pad

Conclusions

In this paper were presented two models, which can be used in mechatronic applications or on the other hand the models can be used in teaching process. The first model present possibility of virtual instrumentation in real time applications. The industry PC implemented in cRIO and CAN interface was described in case of visualization of processes during control of vehicle. The simulation panel contains components which is used in real cars and the software created through virtual instrumentation can control these components. Another mode of software is visualization of the components state based on CAN protocol.

In the second model is shown possibility of virtual instrumentation exploitation in video inspection applications. The presented system was designed for detecting of selected components and determination of numbers of these components.

Acknowledgments

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