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Silviu Marin Nan, Phd Professor; Dan Liviu Dandea, Bogdan Simon

THE MODERNIZATION OF BUCKET WHEEL EXCAVATORS USING INTELLIGENT IMAGE ANALYSIS SYSTEMS

1. INTRODUCTION

This paper presents the design of a image analysis system that can be used for improving the control of bucket wheel excavators. The system uses DVT image analysis cameras that are mounted on the structure of the excavator making real time measurements that can be used by the operator of the excavator or by the automatic control system in charge of driving the excavator.

DVT Vision Sensor works with the Cognex DVT Intellect software that allows the use of sensor's programmable tools to set up inspections that make precise measurements, detect positioning, distances, damage, presence or absence of the excavator parts or defects. These tools provide the flexibility to adapt the sensor to any number of inspection challenges.

2. THE DVT 554 SENSOR CAMERA

The DVT 554 camera is a high-speed, high-resolution image analysis system. It combines a high-resolution CCD (1280 x 1024 pixels) with a high-speed DSP processor.

DVT Vision Sensor works with the Cognex DVT Intellect software that allows you use the sensor's programmable tools to set up inspections that make precise measurements and detect part presence/absence, positioning, defects, or color. These tools provide the flexibility to adapt the sensor to any number of inspection challenges. Figure 1 shows the DVT 554 Vision Sensor and the breakout board with isolation modules.

The PC and Vision Sensor communicate using the TCP/IP and UDP/IP networking protocols.

Vision Sensors functionality. Inspection cameras can take an image and analyze it to determine whether, based on user-defined parameters, is a good image or not. Based on this output from the Vision Sensor, you can take the necessary action (e.g. adjust movement speed, stop the process, measure capacity etc.).

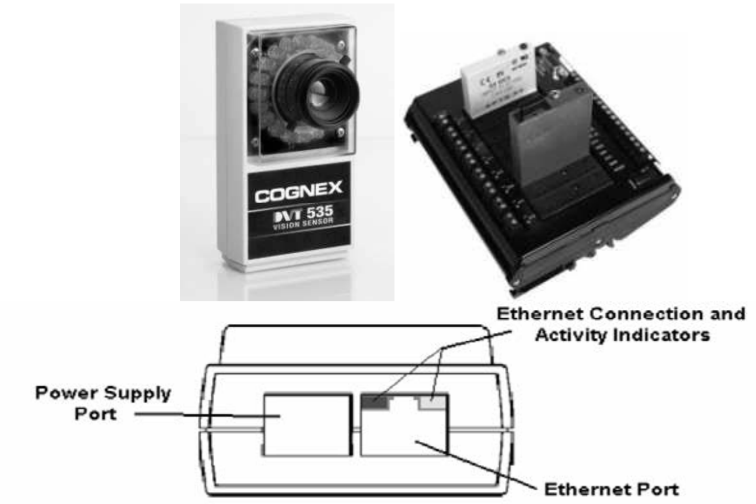

Fig.1. DVT 554 Vision Sensor

System	Speed	Description	Resolution	Ccd size	Ram	Flash
DVT 554	6X	High Speed High resolution grayscale CCD	1280x1024	6.4x4.8 mm	128 MB	16 MB

This section discusses the functionality inside the Vision Sensor. Figure 2 shows the hierarchical tree determined by inner components of Vision Sensors.

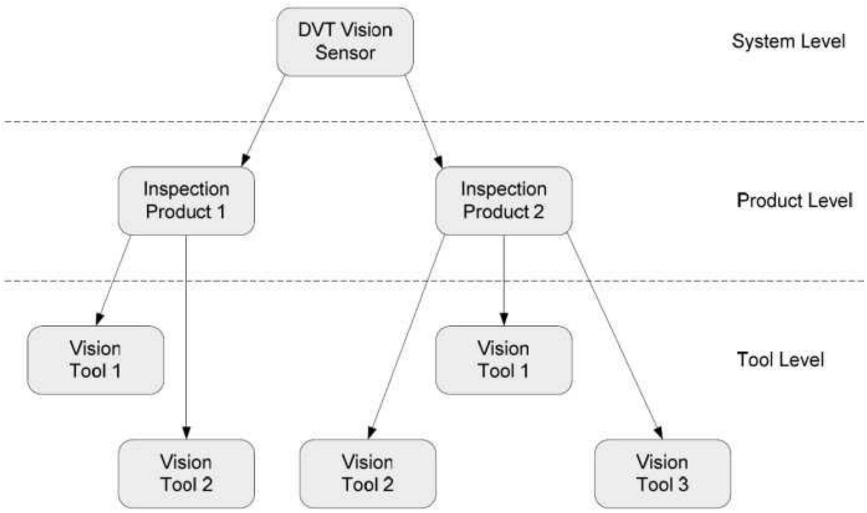

Fig. 2. Hierarchical organization within the vision sensor

At the top level, we find the system parameters. These parameters are common to every inspection that the Vision Sensor performs; they affect the overall behavior of the Vision Sensor rather than that of a certain inspection. Next, at the next level, you can change parameters that affect a specific inspection (such as illumination). Product parameters affect only one of the inspections that the Vision Sensor is performing. Finally, at the Tool level, you can set some Tool parameters. Each Tool performs part of an inspection; here is where all the pieces of every inspection are defined. Vision Tools are associated with inspection tasks.

DVT cameras implementation is made taking in consideration the timing of a data transfer. Information about an inspection needs to arrive in a certain way for the receiving system to interpret it correctly. There are two ways to transfer data: synchronous and asynchronous.

Synchronous transfers of data happen after every inspection. There can be the data to be transferred and that data is sent out after every inspection. This ensures the receiving system that new data is transferred as soon as it becomes available. The methods of communication that support synchronous transfers are the digital I/O (discussed under system parameters), and DataLink.

DataLink is a built-in tool used to send data out of the system and even receive any terminal commands from another device. This tool is Product specific, that is, every product has its own DataLink that can be configured depending on the inspection and the Vision Tools being used (figure 3). DataLink consists of a number of ASCII strings that are created based on information from the Vision Tools. By default, the datalink string is sent out after each inspection; however you can define a set of rules under which those strings are to be sent out. Once the conditions are indicated, the strings need to be created.

In order to read the data sent out from DataLink, there needs to be established an Ethernet connection using TCP protocol to port 3247. DataLink output can also be sent in XML format. In this case the names of the tags and overall format are hard-coded. Additional meta-data is provided beyond what DataLink's regular format provides so as to make parsing easier. For example, the parameter's name and format (int, float, etc.) is given, as well as the associated Product name.

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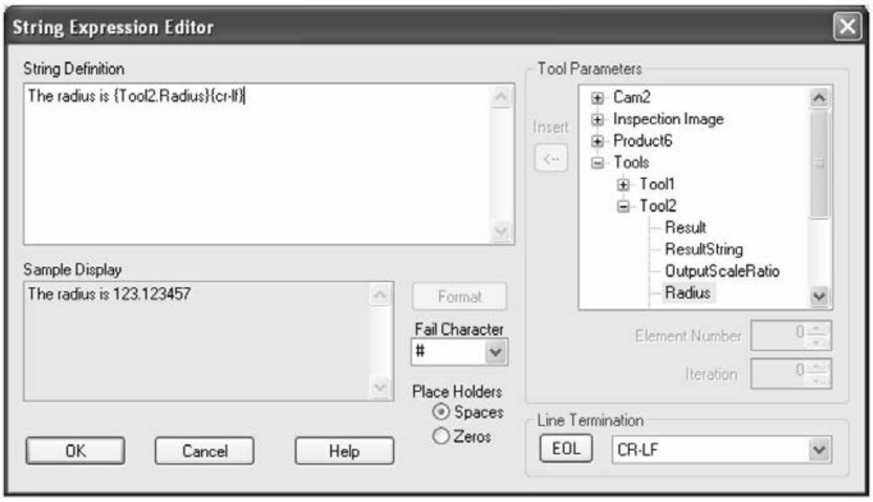

Fig. 3. Data link setup.

A very efficient way to share data among DVT Vision Sensors or between a Vision Sensor and an external device is to perform a Modbus transfer. Modbus transfers, as implemented in the Intellect user interface, take a number of registers from one system and copy those registers into another system. Using this procedure, one Vision Sensor can make a decision based on the result from other Vision Sensors or gather data from other Vision Sensors and send it out to an external device. In a Modbus network there are master devices and slave devices(figure 4). The Modbus Master initiates the connection and decides the type of operation to perform (write data to the slave or read data from it).

The final output of the inspection is made available to an external device using either Modbus or some other type of communication. It could even be a single I/O line indicating a PASS or FAIL result. The external device has direct access to the internal memory of the Vision Sensors so it can easily query the individual inspection results from each.

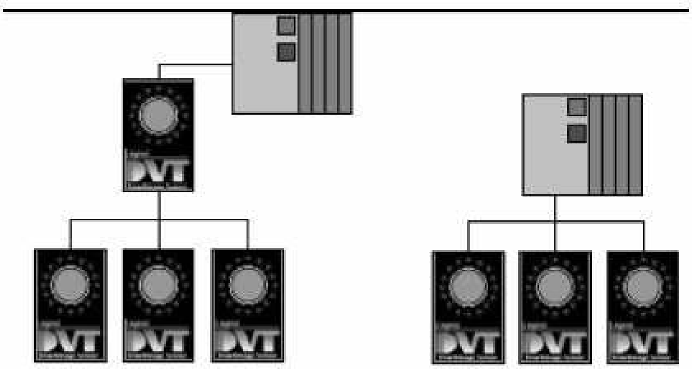

Fig. 4. Modbus transfer method.

3. THE INTELLECT SOFTWARE.

The Intellect software consists of two main parts. One of them is the Intellect firmware which resides in the Vision Sensor. The Intellect firmware is responsible for all the computations that happen inside Vision Sensors. You can control the firmware by programming the user interface, which translates everything for the firmware to execute. The second part of Intellect is the software. The Intellect software consists of the Intellect user interface and the Vision Sensor hardware emulator. You can only access the components that reside in the PC: the Intellect user interface and the hardware emulator. The Intellect User Interface is a Microsoft Windows® application used for the configuration of Vision Tools. The main areas of the interface are the main menu, the toolbars, the Vision Tool toolbox, the Video Display, the result table, the properties window and the status bar.

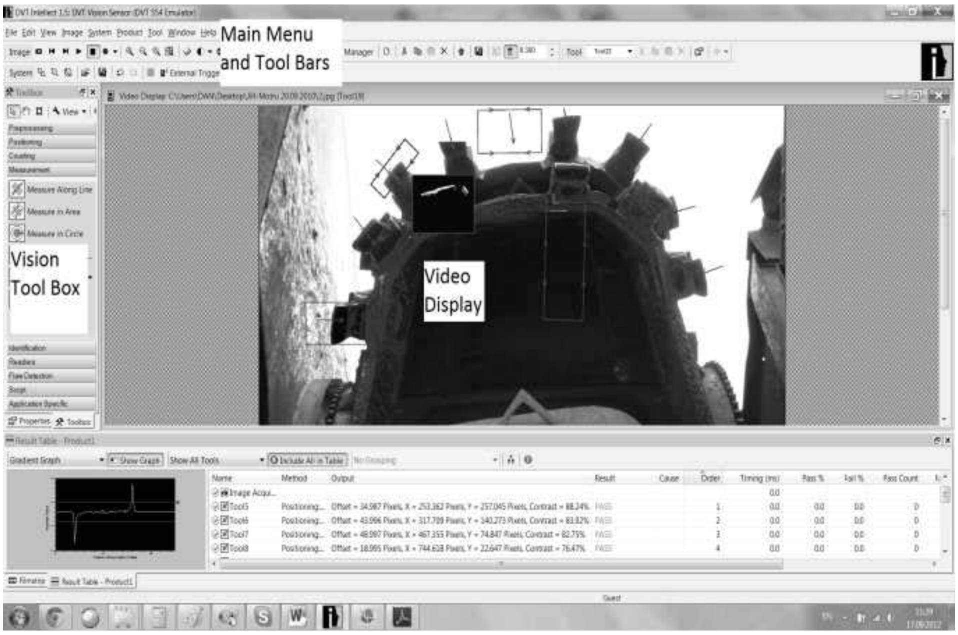

Fig. 5. Intellect user interface.

The Product toolbar and the Tool toolbar contain similar functionality for products and Tools. For products it offers the extra options of showing the result panel, creating a new product, and saving a product to flash memory.

The Video Display is where the images obtained from the Vision Sensor are displayed. Not every image from the Vision Sensor is transferred to the user interface. For the Vision Sensor the number one priority is to run inspections. After that, and depending on processor usage, it sends images via Ethernet to the user interface.

The Vision Tool toolbox is where all Vision Tools are available. This toolbar represents a shortcut to most options available under the Vision Tool menu of Intellect.

Every type of Vision Tool serves a specific purpose, and the combination of the Vision Tool results represents the overall result of the inspection. The main groups of Vision Tools are Filters, Positioning, Counting, Measurement, Identification, Reader, Flaw Detection, Script, and Application Specific Vision Tools. Positioning Vision Tools help locate parts to be inspected.

4. APLICATION

In order to give examples for what we have presented in the paper we will design an inspection system that can verify the state of wear or damage of the bucket wheel excavator EsRc 1400.

Fig. 6. DVT Vision sensor positions on the bucket wheel excavator

The position of the image cameras (fig. 6) is very important because a high contrast is needed for the image analysis. An optimum position could be right above the cutting wheel of the excavator and the base structure.

This positions confers good illumination, protection from damage and an easy routing of the networking cables that feed information to the central control system and the operator.

Using the large array of image analysis tools we could check the condition of the cutting teeth and in case of excessive wear, damage or missing teeth.

For each cutting tooth there were assigned measurement tools for measuring wear in area, (figure 9) for a total of 8 image verification tools.

Position along line tool (fig. 7. tool 1) measures the cutting edge of the cutting tooth. Position along a line locates the absolute position of an element in an image in cases where that element's position changes between inspections.

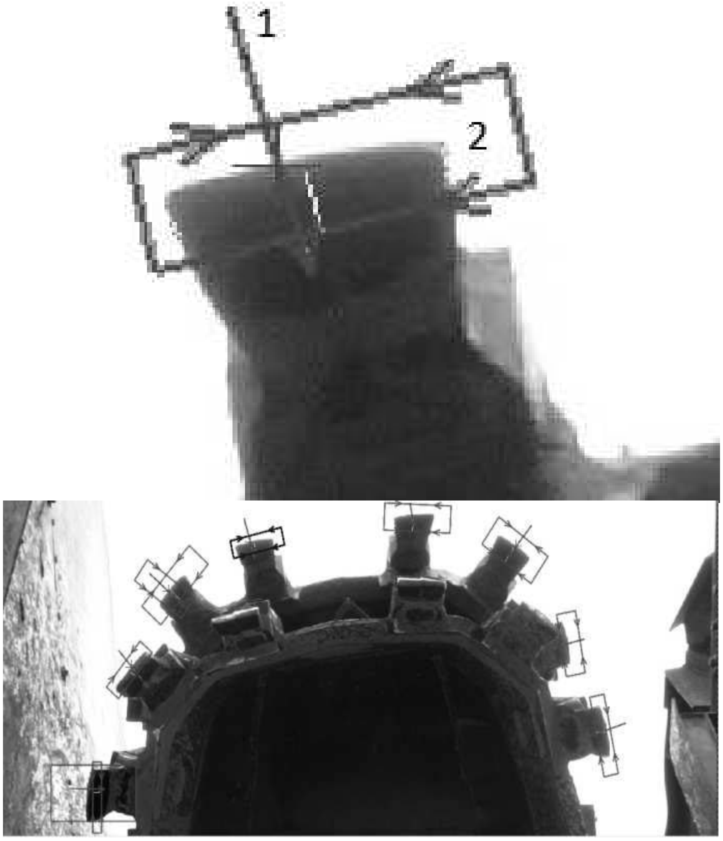

Fig. 7. Teeth measurement tools

This type of Vision Tool reports the distance from the origin of the Vision Tool. It searches the pixels from the origin in the direction of scanning (set by the direction in which the Vision Tool was drawn). When it finds the edge/pattern that is indicated, it reports the distance from the origin of the Vision Tool to the location of the edge/feature in pixels.

Sensor Type = Position_Sensor; Sensor Name = Tool7; Sensor Description =

Sensor ID = 7; Threshold Value = 50.00 %; Sensor Shape = 3 (Line Segment); Sensor Shape Learn Region % = 0.100000, 0.900000; Algorithm Type = 1; Edge Type = 0; Edge Index = 0 ;Edge Width = 5; Pass Minimum Contrast = 1500; Pass Minimum Offset = -1.000000; Pass Maximum Offset = -1.000000

After the measurements of a new installed tooth the resulting pixel offset was Offset = 38 Pixels. If this value is ≅ 38 pixels then the cutting tooth is in good condition. If the measurement is ≅ 41 pixels the tooth needs to be scheduled for replacement. High wear can be a consequence of hard material excavation. A value above 46 pixels means that an tooth is badly damaged or is broken and needs immediate replacement.

Table 1. Teeth measurement pixel values

Wear state	***Pixel measurement cutting edge***	***Pixel measurement side wear***
Low wear	38	66
Medium wear	41	56
High wear	45	47
Damaged tooth	≥46	46≤

The next measurement is the wear on the sides of the cutting teeth. Thickness measurements can be performed using an area Vision Tool (fig. 7 tool 2). In both cases the Vision Tool can scan inside out or outside in (just like using a caliper). The scanning lines start scanning from the ends of the Vision Tool or from the center until they find the specified characteristic. This characteristic could be a peak value in the gradient graph (when using gradient computation) or a specific type of edge. The output of the Vision Tool is the distance in pixels between the edges of the part.

The measurements reveal that a good no wear tooth measures ≅ 66 pixels. The values of wear are presented in table 1.

Verifying the position of the excavators boom on the vertical axis can be used to assure a flat working plane. A flat working plane prevents a series of problems that the excavator can encounter in its working regime. The biggest problem is that the excavators structure can lean to one side and the excavator can overturn causing high damage to the machinery and endanger the workers life.

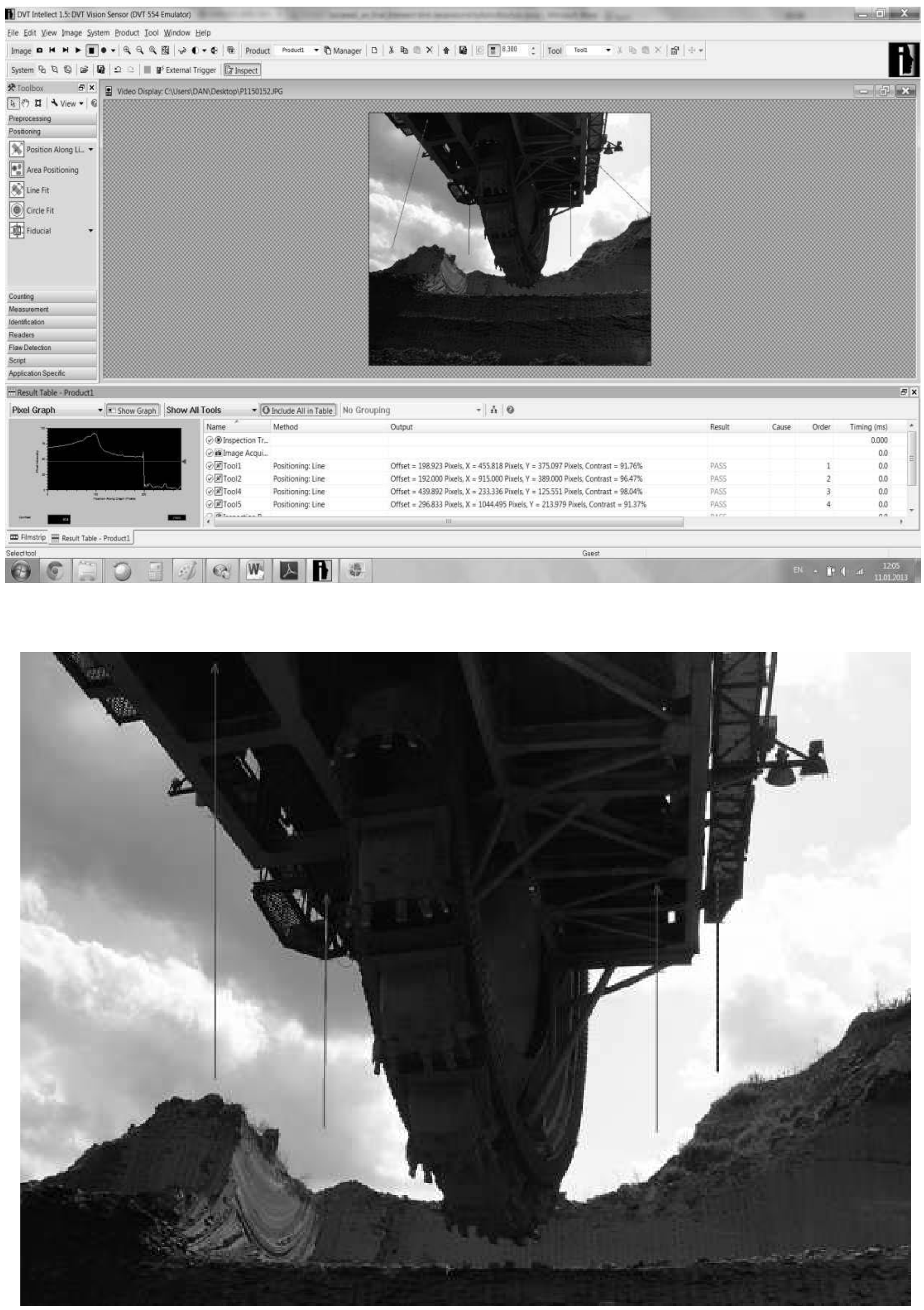

Fig. 8. Vertical axis boom position measurement tools

Experimental measurement of the position of the boom using the image inspection tools gave an minimum and maximum values for the pixel offset, tool1 = 196/65, tool 2 = 192/60, tool 3 = 311/180, tool 4 = 177/45 corresponding to top and bottom position of the boom. If the boom travels to a lower position than the one measured with the vision sensors the bucket wheel may cut in the working plane.

4. CONCLUSIONS

The used concepts and ideas in the design of the image inspection system presented in the paper may be used and developed for other types of measurements on the structure of the bucket wheel excavator as well.

Because of the real advantages of the image analysis system the productivity and the maintenance of the bucket wheel excavator are greatly increased and reduce the exploitation costs. We may say that implementing and using the system is a real advantage.

REFERENCES

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2. Nan M.S.: Excavation process parameters of the bucket wheel excavators, Petrosani, Universitas Publishers House, 2007

3. *** Intellect software help.