RESEARCH REGARDING THE USE OF IMAGE ANALYSIS SOFTWARE FOR IMPROVING THE CONTROL OF BUCKET WHEEL EXCAVATORS

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Abstract: The object of this paper is the design of a image analysis system that can be used for improving the control of bucket wheel excavators. The system uses image analysis cameras that are mounted on the structure of the excavator making real time measurements that can be used by the conductor of the excavator or by the automatic control system in charge of driving the excavator.

Key-words: image analysis system, DVT camera, bucket wheel excavator

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 work 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 × 1024 pixels) with a high-speed DSP processor.

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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 colour. 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.

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

Fig. 1. DVT 554 Vision Sensor

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.).

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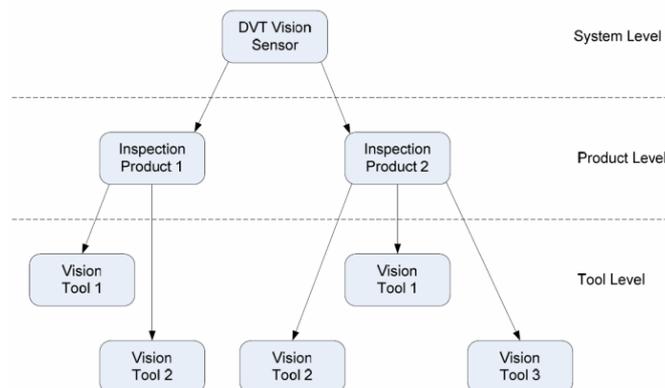

Fig. 2. Hierarchical organization within the vision sensor

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 behaviour 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.

Asynchronous transfers of data happen at a certain rate. In most cases, you select the rate and blocks of data are continuously transferred whether they contain new data or the same data that was already transferred. An example of this method of data transfer is the Modbus master transfer available from Intellect.

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. Using the Intellect user interface, you connect to a Vision Sensor and makes changes to the system files loaded in the Vision Sensor. In order to do this, the Intellect user interface queries the Vision Sensor for images and reproduces in the PC what the Vision Sensor does in its internal memory with those images.

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 [3].

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 remaining toolbar buttons are to duplicate, edit parameters, delete, or access the graphs associated with

the product/Vision Tool selected from the pull down menu.

      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 (Figure 3). 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. In cases where the Vision Sensor is being triggered very fast, the user interface only receives some sample images from the Vision Sensor.
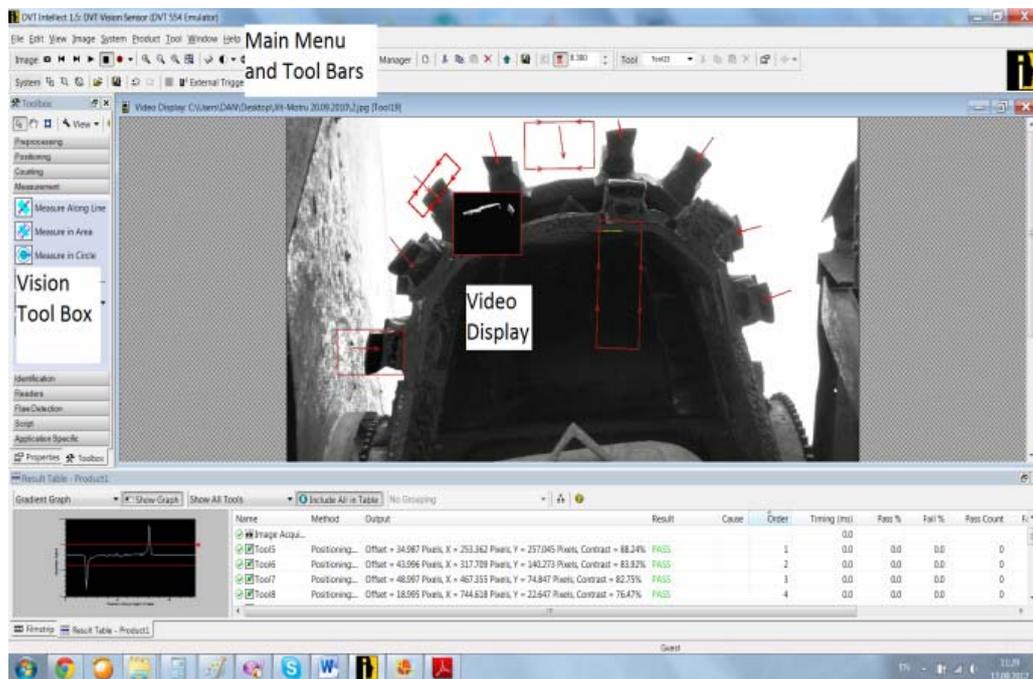
Fig. 3. Intellect user interface

      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. In most applications, this type of Vision Tool becomes the key to a successful setup because they locate the part to be inspected and pass an internal reference to the remaining Vision Tools indicating the location of the part. Counting Vision Tools are often used for Presence/Absence applications were the application is to detect features. Specific measurement Tools, math tools, colour Tools, identification, flaw detection, spectrograph for colour analysis, and programmable Tools.

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 teeth EsRc 1400 [2].

The position of the image camera (fig. 4) 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. This position confers good illumination, protection from damage and an easy routing of the networking cable that feeds information to the central control system and the operator.

Fig. 4. DVT Vision sensor position on the bucket wheel excavator

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 2 measurement tools: position along line (1) and measure in area (2), figure 5 for a total of 16 image verification tools.
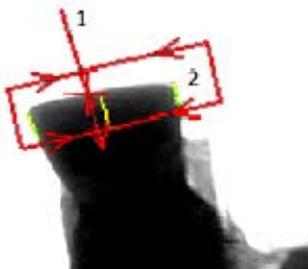
Fig. 5. Teeth measurement tools

After the measurements of a new installed tooth the resulting pixel offset was Offset = 38 Pixels. If this value is $\cong$ 38 pixels then the cutting tooth is in good condition. If the measurement is $\cong$ 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 a tooth is badly damaged or is broken and needs immediate replacement. The values of wear are presented in

table 1.

Sensor description:
- Sensor ID = 7
- Sensor Active Flag = 1
- User Output Bits = 1,0 (Pass, Fail)
- Maximum Inspection Time = 2000 (ms)
- Maximum Training Time = 5000 (ms)
- Image Reference = -1
- Local Marking Mode = 1
- Threshold Type = 1 (Intensity - Percent of contrast along path)
- 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

Table 1. **Cutting edge wear**

Wear state	Pixel measurement
Low wear	38
Medium wear	41
High wear	45
Damaged tooth	≥46

The second set of tool measures the wear on the sides of the cutting teeth. Thickness measurements can be performed using an area Vision Tool. In both cases the Vision Tool can scan inside out or outside in (just like using a calliper). The scanning lines start scanning from the ends of the Vision Tool or from the centre 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.

Sensor description:
- Sensor Type = Mes_LineFit_Sensor
- Sensor Name = Tool46
- Sensor ID = 46
- Sensor Active Flag = 1
- User Output Bits = 1, 0 (Pass, Fail)
- Maximum Inspection Time = 2000 (ms)
- Maximum Training Time = 5000 (ms)

- Threshold Type   = 32 (Gradient - Fixed)
- Threshold Value   = 10.00
- Sensor Shape   = 7 (Rectangle)
- Edge Width   = 4
- Which Edge   = 0
- Minimum Contrast   = 1500
- Minimum Straightness   = -1.000000
- Min/Max Offset   = -1.000000, -1.000000
- Min/Max Angle   = -100.000000, -100.000000

The measurements reveal that a good no wear tooth measures $\cong$ 66 pixels. The values of wear are presented in table 2.

Table 2. **Side edge cutting wear**

Wear state	Pixel measurement
Low wear	66
Medium wear	56
High wear	47
Damaged tooth	46$\leq$

5. 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.

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