A Machine Vision Application for Industrial Assembly Inspection

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***Abstract*—Today's high speed, complex manufacturing systems require the development of automation technologies that can be efficiently integrated into the systems and used in manufacture floors. This article presents a successful industrial application of machine vision technology for medical syringe assembly. The developed vision inspection station with ten cameras that was integrated into an assembly line has a capability of inspecting 5 syringes per 250 million seconds for a total production rate of ranging from 300 to 600 parts per minute.**

Keywords-Machine Vision; Inspection; Automation; Syringe Assembly

I. INTRODUCTION

To remain competitive in an increasingly competitive world, businesses must boost operational efficiency wherever possible. Today's high-speed, complex manufacturing systems require the development of automation technologies that can be efficiently integrated into the systems and used in manufacture floors. For medical syringe manufactures, to ensure the safety of patients and caregivers, manufactures need to maintain high levels of quality while maximizing productivity to deliver their products at a competitive price.

Machine vision has been widely recognized as an innovative automation technology for quality inspection, measurement and control in different industrial sectors. Jia *et al*. (1990, 1993) investigated the feasibility of using machine vision technology to locate corn plants and inspect seed corn quality. Wen and Tao (1999) developed a rule based machine vision inspection system for apple sorting. Wang *et al*. (2007) developed a vision inspection system for film. Bazin *et al*. (2006) described a novel method for industrial inspection of ophthalmic contact lenses.

Syringes offer many challenges for visual inspection. Very stringent quality demands must be met and the shape and translucent materials of the syringe offer its own visual challenges. In order to ensure the syringes meet the most stringent quality demands, for syringe manufactures, machine vision technology is logic choice for their manufacturing floor considering the programmability of a vision system and consistent and repeatable measurement results the technology can provide. The advantages of using machine vision technology are that the machine vision system can be integrated into manufacturing system for the measurement, inspection, verification of geometrical dimensions, and part integrity and providing many quality and visual information during the operation for quality controls.

This paper introduces an industrial development of inspecting medical syringe assembly with machine vision technology. The vision inspection system hardware, user interface and implementation of vision inspection tools are presented.

II. MATERIALS AND METHODS

A. Vision System Description

The syringe assembly vision inspection system consists of two Checkpoint vision processors installed in a computer, ten monochrome cameras with 16 mm lens and two LED back-lighting panels. Each processor is connected to five cameras. First vision processor named as board # 1 inspects the needle end (Side A) of five syringe assemblies while second processor named as board #2 inspects the thumb end (Side B) of five syringe assemblies at a time. Since each Checkpoint processor has only four camera ports, a multiplexer is required for each processor. This allows the required five cameras to be connected to each processor.

As showed in Table 1, each camera at position 1 (marked as # 1A or # 1B) is connected to port 1 of channel A of a multiplexer. Each camera at position 2 (# 2A or # 2B) is connected to port 2 of channel A of the multiplexer, each camera at position 3 (# 3A or # 3B) to port 3 of channel A, and each camera at position 4 (# 4A or 4B) to port 4 of channel A. Each camera at position 5 (# 5A or # 5B) is connected to port 1 channel B of the multiplexer. Each vision processor has discrete I/O connections to the PLC that controls the assembly process. The vision computer is connected to and communicated with the PLC via Ethernet. This allows vision results to be transferred to the PLC. The vision PC uses Visionlinx software from Cognex and Rslinx from Rockwell Software to communicate with the PLC.

The sequence of the operation of a vision inspection is as follows. The assembly process indexes five assembled syringes into the vision inspection station and lifts the parts to present them to the ten cameras. The assembly PLC sends

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a discrete trigger signal to each of two vision processors. The duration of this signal is 0.25 seconds. After the 0.25 seconds the parts can be indexed out of the inspection station and five new parts presented to the cameras. When each vision processor receives the trigger signal, the following operations of a vision processor take place. The multiplexer is switched to channel B first. Two images for the needle end and the thumb end of a syringe are acquired from the cameras 5A and 5B. The vision tools are executed and evaluated for this image. The multiplexer is then switched to channel A. Eight images are acquired simultaneously from the cameras at positions 1A to 4A and the cameras at positions 1B to 4B of the two processor boards. At this point, the parts can begin indexing out of the station. During this time, the vision tools are executed and evaluated from the four images of each of the two processors. Once all vision tools have been evaluated, the inspection results are written to the PLC data table. Each vision processor sets a discrete signal to the PLC that the data has been sent. Once the PLC receives the data and the signal, it sets a discrete signal to the vision system acknowledging receipt. This completes the vision inspection and the vision inspection can start inspection for the next group of syringes that have been indexed into the station.

TABLE 1.

Needle End Inspection (Processor Board #1 – Side A)		**Thumb End Inspection (Processor Board #2 – Side B)**	
Camera Number	Multiplexer Port # (Channel A or B)	Camera Number	Multiplexer Port # (Channel A or B)
1A	1 (A)	1B	1 (A)
2A	2 (A)	2B	2 (A)
3A	3 (A)	3B	3 (A)
4A	4 (A)	4B	4 (A)
5A	5 (B)	5B	5 (B)

B. Vision System Components

The components used on the vision inspection system are listed in Table 2.

C. Camera and Light Setup

The initial camera and lens set-up were as follows. Two spacers are inserted between each camera and lens. Each lens aperture setting is set to a specified value. Camera focus is adjusted to give the sharpest image of the part when it is raised to the inspection position. For both end inspection cameras, the height from the base of the camera lens to the surface of the part in the inspection position is set to a specified value accordingly.

The two customized designed LED back-lighting panels, one for needle end inspection and another for thumb end inspection, are controlled by two programmable power supplies separately. The light levels are controlled through the main operator interface (RSView) on the machine. The values are set to a percentage of full scale as allowed by the PLC. The light level for the needle end and the thumb end back lights were set at different specified values at machine set-up.

TABLE 2.

Quantity	**Manufacturer /Supplier**	**Components**
1	Advantech	IPC-6908 Industrial PC - PCA 6179 Single Board Computer PIII 733 MHz
1	Rockwell Software	RSLinx OEM Software
1	Cognex	VisionLinx Software
2	Cognex	Checkpoint 900 Deployment System
2	Cognex	CMX-900 MUX - 8 port camera multiplexor
10	Cognex	15’ camera cables
10	Sony	XC-55 camera (1/3”)
10	Tamron	23FM16 lens (with two 1mm spacers)
2	CCS America	Customized designed red LED back light panel
2	CCS America	24V DC digital programmable power supply
2	CCS America	5 m extension cables

III. RESULTS AND DISCUSSION

A. User Interface Description

User operation interface consists of following operation panels:

- Main Panel
- Camera and Program Setup panel
- Bypassing Inspection panel
- Camera Setup and Monitoring panel
- Camera calibration Panel

During machine operation and assembly, each vision system will show a main screen panel (Figure 1). The last processed image with associated vision tools will be shown on this panel. The "**Setup**" pushbutton is for an operator to perform individual camera set-up, change program parameters or conduct trouble shooting. It is important to note that the vision system will be in an offline mode and stop to accept inspection commands from the PLC if the "**Setup**" pushbutton is selected and running in a camera set-up mode.

In order to perform camera set-up or conduct trouble shooting from a specific camera, an operator can select the desired camera pushbutton (Figure 2). The colour of an indicator beside the button will appear in green colour if a corresponding camera was chosen; otherwise, it is in red. The "**InspectionBypassPanel**" button is used for selecting or changing which inspections are included in the result for statistics purpose. Select the "**Run**" button to return normal operation.

When starting the vision program, all inspections are enabled in default and marked with an "X" (Figure 3). To bypass an inspection, select the inspection to be bypassed. If an inspection was bypassed, select the inspection again will enable the inspection. Select the "**Return**" button to return to the set-up panel.

For Camera and Program Setup panel screen, a live image for the selected camera will be displayed (Figure 4). The camera number is shown on the upper right corner of the display with green colour indicating which camera you are working on. Select "**Inspect**" button to perform an inspection, this will capture an image and evaluate the vision tools for that image. An operator can use this function for testing and troubleshooting purpose. The indicator beside an "**inspect**" button will be in green if a captured image is displayed. To display a live image, select "**Live**" button. At any time, if a live image is being displayed, the indicator beside the "**Live**" button will be in green. To check camera calibration, select the "**Calibrate**" button. To check the light intensity of the image, select the "**Light Intensity**" button. The current value of light intensity will be displayed in a continuous manner until the "**Light Intensity**" button is selected again. This function can be used for monitoring the light intensity of an LED back-lighting panel while adjusting the light intensity level from a power supply. Select the "**Return**" button to return to the set-up panel

In order to enter the camera calibration screen a password is required. Once the correct password is entered the calibration screen will appear as in Figure 5. A camera calibration plate was specifically designed for easily use under a manufacture condition. The camera can be calibrated by following the calibration instruction on this panel.

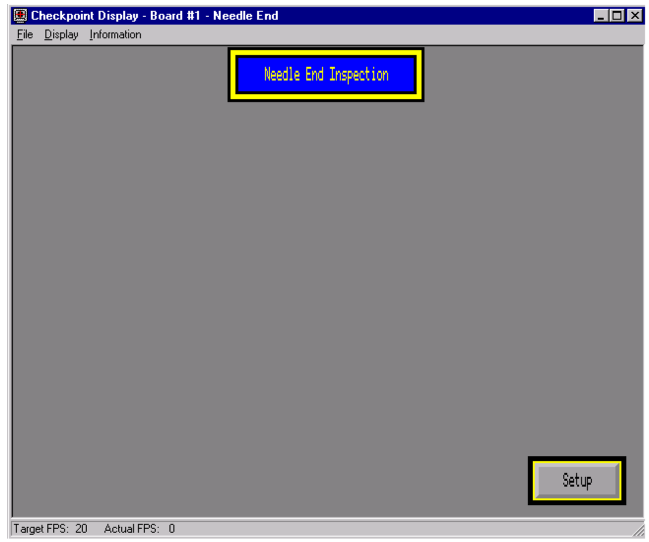

Figure 1 - Main Screen Panel (Needle End Main Panel)

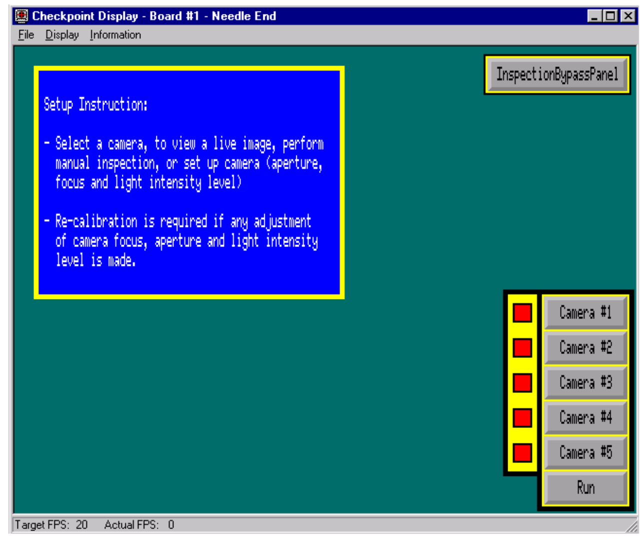

Figure 2 – Camera and Program Setup Panel

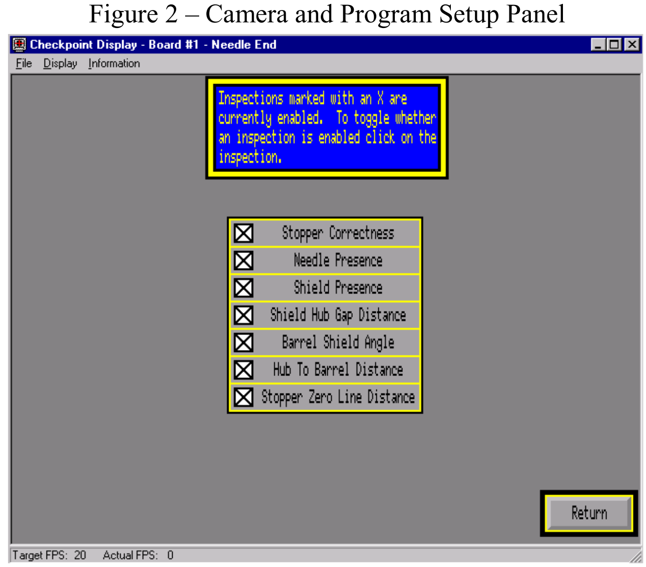

Figure 3 – Bypass Inspection Panel

Figure 4 – Camera Set-up and Monitoring Panel

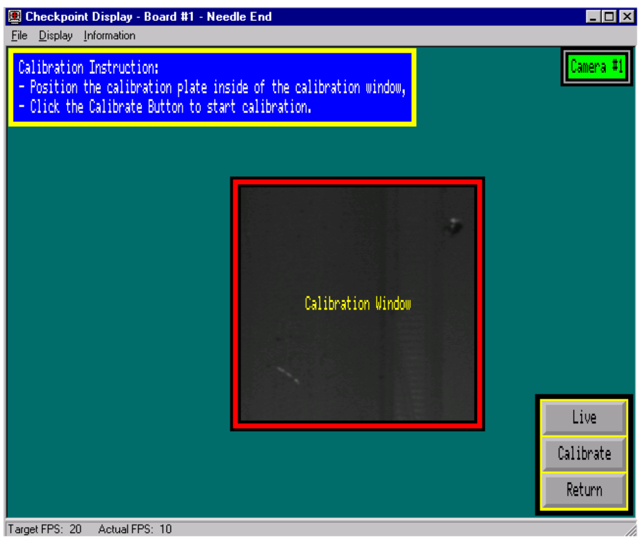

Figure 5 – Calibration Panel

B. Vision Tools for Needle End Inspection

The inspection of the needle end of a syringe is shown by the graphics drawn on the image in Figure 6. The graphics for vision tools that pass the inspections are shown in green. Vision tools that fail inspection have graphics drawn in orange. The graphic showing a picture of tools (hammer and screwdriver) is shown in green if all inspection tools for the needle end pass. If any of the included tools fail, the graphic will be shown in orange. As an example, on the image in Figure 6, the inspection for needle presence has failed and showed in orange since needle is not present.

The inspections performed by the vision tools are listed as follows.

1. Barrel fixture location
2. Stopper fixture location and presence measurement
3. Barrel Centre line location
4. Stopper shape measurement
5. Needle presence measurement
6. Needle shield presence measurement
7. Shield to hub gap measurement
8. Needle shield angle measurement
9. Hub to barrel interface distance measurement
10. Stopper to zero line distance measurement

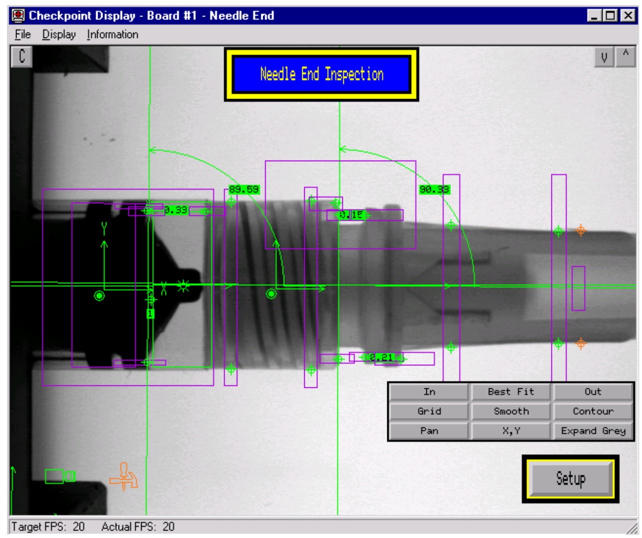

Figure 6 – Sample Image of Needle End Vision Inspection Tools

C. Vision Tools for Thumb End Inspection

The inspection of syringe thumb end is shown by the graphics drawn on the image in Figure 7. The graphics for vision tools that pass the inspections are shown in green. Vision tools that fail inspection have graphics drawn in orange. The graphic showing a picture of tools (hammer and screwdriver) is shown in green if all inspection tools for the thumb end pass. If any of the included tools fail, the graphic will be shown in orange.

The inspections performed by vision tools are listed as follows.

1. Barrel fixture location
2. Thumb tab fixture location
3. OPR to IPR coupling
4. Barrel centre line location
5. Flange left bend angle measurement
6. Flange right bend angle measurement
7. Thumb tab to shroud distance measurement

8. Thumb tab bend angle measurement

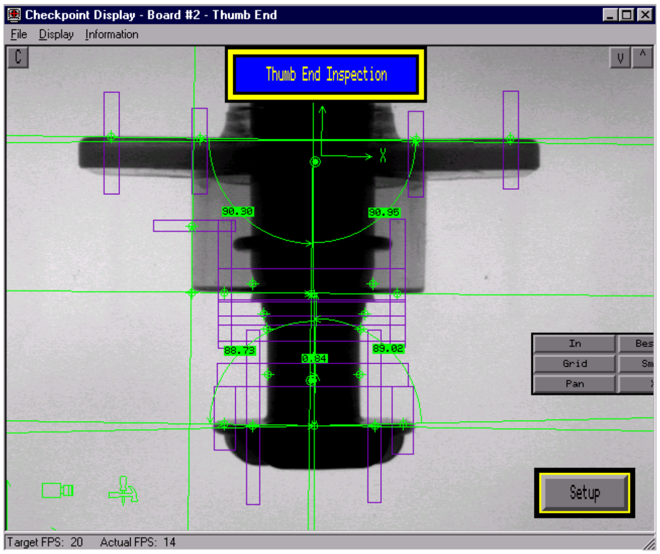

Figure 7 – Sample Image of Thumb End Vision Inspection Tools

The tolerance values for all measurements were set and are adjustable based on manufacture specifications. If only one specification is not met based on vision measurement, the part will be reject into a reject/recycle bin by an air nozzle after the five syringes move out the inspection station. The PatMax pattern matching and other measurement tools from the Checkpoint vision system were used to locate features and to measure the dimensional and angular characteristics from a syringe and approved to meet the challenge for this project. User interface and programs developed using different vision tools from this project were also found to be useful for syringe quality control purpose.

IV. CONCLUSIONS

A machine vision inspection system for syringe assembly, which operated at a higher production rate while providing 100% inspection to ensure the product quality of every unit, was developed and presented. The advances of machine vision technology in both academic and machine vision industry during the last decade have been successfully providing and supporting technical progresses of different industrial sectors in manufacture and production automation. Another important factor for this project success is also relied on the design and chose right illumination or light technique and method which are especially important for machine vision inspection of a translucent material.

REFERENCES

[1] J. Jia, G. W. Krutz, and H. G. Gibson, “Corn Plant Locating by Image Processing,” Proc. SPIE, Optics in Agriculture, Boston, MA, USA, Nov. 1990, Vol. 1379, pp. 246-253; doi:10.1117/12.25095.

[2] J. Jia, “Seed Maize Quality Inspection with Machine Vision,” Proc. SPIE, Computer Vision for Industry, Munich, Federal Republic of Germany, June, 1993, Vol. 1989, pp. 288-295; doi:10.1117/12.164872.

[3] Z. Wen and Y. Tao, “Building a Rule-Based Machine Vision System for Defect Inspection on Apple Sorting and Packing Lines,” Expert Systems with Application, Vol. 16, No. 3, pp.307-313(7), 1999.

[4] A. Bazin, I., T. Cole, B. Kett, and M.S. Nixion, “An Automated System for Contact lens Inspection,” Lecture Notes in Computer Science, Vol. 4291, 2006

[5] J. Wang, *et al.*, “Machine Vision Inspection System for Film,” Sensor Review, Vol. 27, No. 3, Pg. 212-216, 2007.

[6] J. Jia, “Machine Vision System Development for Syringe Assembly Inspection,” Unpublished Technical Report,