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Vane Plate Placement Error Detection Using Machine Vision

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Abstract:

The main objective of this thesis is to understand, how machine vision can be efficiently applied to detect the directional placement error of the vane plates in the rotor of the "Vane pump" and also to detect the non-placement error of the vane plate of the rotor. Though the plates can be inserted manually, but many a times due to repetitive operation there might be errors caused which can simply be eliminated by using a simple machine vision system during testing process after assembly of the vane plates in the rotor. This is basically carried out to help the manufacturing industries, solve their simple yet, critical problems easily. Due to which one can easily minimize the loss of cycle time and economy, as a result there would be tremendous increase in the production.

Keywords — **Machine vision, Cognex vision system, Rotor, Vane plate, Lens, Laser sensor**

I. INTRODUCTION

In our country, where most of the manufacturing processes are carried out manually, which is considered to be one of the cost-effective solution. But, many a times due to repetitive tasks, the chances of error occurrence is quite more in manual recognition, when compared to that of the Machine vision system. Machine vision provides innovative solutions in the direction of industrial automation.

Most problems start at the very beginning of a product's journey on the production line. Getting it wrong there can have disastrous consequences. However, with machine vision systems in place, one can instantly improve their production processes so that the products they produce are made at higher speeds, without defects, and at lower cost.

Automation often demands vision. Cognex vision systems perform tasks that are practically impossible for people to do reliably and consistently. The introduction of the automation has revolutionized the manufacturing in which complex operations have been broken down into simple step-by-step instruction that can be repeated by a machine.

In such a mechanism, the need for systematic assembly and inspection has been realized in different manufacturing processes. These tasks have been usually done by the human workers, but these types of deficiencies have made a machine vision system more attractive.

Our expectation from a visual system is to perform the following operations: the image acquisition and analysis, the recognition of certain features or objects within that image, and the exploitation and imposition of environmental constraints.

Machine vision technology improves productivity and quality management and provides a competitive advantage to industries that employ this technology.

The simplest vane pump has a circular rotor rotating inside a larger circular cavity. The centers of these two circles are offset, causing eccentricity. Vanes are allowed to slide in and out of the rotor and seal on all edges, creating vane chambers that do the pumping work.

On the intake side of the pump, the vane chambers are increasing in volume. If the vanes don't seal all the edges creating a vane chamber, then there might be errors in the directional placement of the vane plates in the rotor, due to which there would be increase in the level of noise and pressure.

II. POBLEM STATEMENT

During the assembly of the Vane pump, the rotor needs to be inserted, into which the vane plates are inserted. If the plates are inserted in the wrong direction (one side curved and the other linear) there might be, problem in the mobility of the fluid due to which there will be increase in the level of noise and pressure, which in found during the testing process. This project is carried out, to detect the incorrect, directional placement of the vane plates, at the initial stages. Due, to which one can easily minimize the loss of cycle time and economy, as a result there would be increase in the level of production.

III. OVERVIEW OF MACHINE VISION

Generally, visual inspection and quality control job is performed by human experts. Although human vision is best for qualitative interpretation of a complex, unstructured scene, but machine vision excels at quantitative measurement of a structured scene because of its speed, accuracy, and repeatability.

Moreover, human experts are difficult to find or maintain in an industry, require training and their skills may take time to develop. There are also cases were inspection tends to be tedious or difficult, even for the best-trained experts. In certain applications, precise information must be quickly or repetitively extracted and used (e.g., target tracking and robot guidance).

In some environments (e.g., underwater inspection, nuclear industry, chemical industry etc.) inspection may is difficult or dangerous. Machine vision may effectively replace human inspection in such demanding cases.

A machine vision system built around the right camera resolution and optics can easily inspect object details too small to be seen by the human eye.

IV. ADVANTAGES

Machine vision improves quality and productivity, while reducing manufacturing costs.

TABLE I
BENEFITS OF MACHINE VISION

Strategic goals	Machine vision application
Higher quality	Inspection, measurement, gauging, and assembly Verification
Increased productivity	Repetitive tasks formerly done manually are now done by Machine Vision System
Lower production costs	One vision system vs. many people / Detection of flaws early in the process
Scrap rate reduction	Inspection, measurement, and gauging
Reduced floor space	Vision system v/s operator

V. MACHINE VISION APPLICATION

Typically the first step in any machine vision application, whether the simplest assembly verification or a complex 3D robotic bin-picking, is for pattern matching technology to find the object or feature of interest within the camera's field of view. Locating the object of interest often determines success or failure. If the pattern matching software tools cannot precisely locate the part within the image, then it cannot guide, identify, inspect, count, or measure the part.

While finding a part sounds simple, differences in its appearance in actual production environments can make that step extremely challenging. Although vision systems are trained to recognize parts based on patterns, even the most tightly controlled processes allow some variability in a part's appearance.

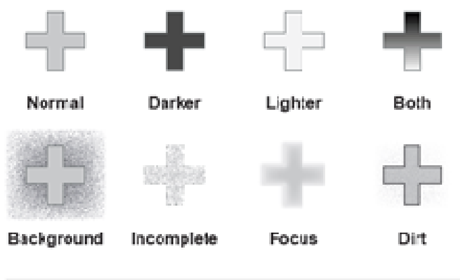

Fig 1: Appearance changes due to lighting or occlusion can make Part location difficult

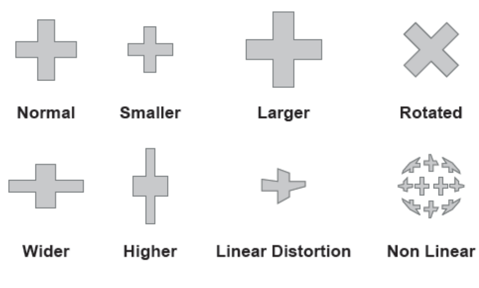

Fig 2: Part presentation or pose distortion effects can make Part location difficult

To achieve accurate, reliable, and repeatable results, a vision system's part location tools must include enough intelligence to quickly and accurately compare training patterns to the actual objects (pattern matching) moving down a production line. Part location is the critical first step in the four major categories of machine vision applications. The categories are:

- Guidance
- Identification
- Gauging and
- Inspection

VI. ESSENTIAL COMPONENTS OF MACHINE VISION

The major components of machine vision system include the lightening, lens, image sensor, vision processing, and communication. Lighting illuminates the part to be inspected allowing its features to stand out so that they can be clearly seen by camera. The lens captures the image and presents it to the sensor in the form of light. The sensor in a machine vision camera converts this light into a digital image which is then sent to the processor for analysis.

Vision processing consists of algorithms that review the image and extract required information, run the necessary inspection, and make a decision. Finally, communication is typically accomplished by either discrete I/O signal or data sent over a serial connection to a device that is logging information or using it.

The following are the key components of a machine vision system including:

- Lighting
- lenses
- vision sensor
- image processing
- vision processing
- communication

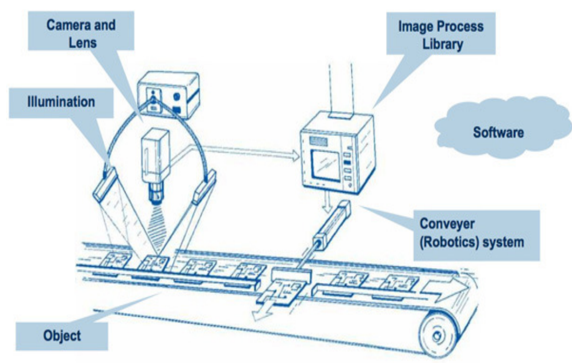

Fig 3: Main components of a machine vision system

A. Lighting

Lighting is one key to successful machine vision results. Machine vision systems create images by analyzing the reflected light from an object, not by analyzing the object itself. A lighting technique involves a light source and its placement with respect to the part and the camera. A particular lighting technique can enhance an image such that it negates some features and enhances others, by silhouetting a part which obscures surface details to allow measurement of its edges.

B. Lenses

Lens captures the image and delivers it to the image sensor in the camera. Lens will vary in optical quality and price, the lens used determines the quality and resolution of the captured image. Most vision system cameras offer two main types of lenses: interchangeable lenses and fixed lenses. Interchangeable lenses are typically C-mounts or CS-mounts.

The right combination of lens and extension will acquire the best possible image. A fixed lens as part of a standalone vision system typically uses autofocus, which could be either a mechanically adjusted lens or a liquid lens that can automatically focus on the part. Autofocus lenses usually have a fixed field of view at a given distance.

C. Image sensor

The camera's ability to capture a correctly-illuminated image of the inspected object depends not only on the lens, but also on the image sensor within the camera. Image sensors typically use a charge coupled device (CCD) or complementary metal oxide semiconductor (CMOS) technology to convert light (photons) to electrical signals (electrons). Essentially the job of the image sensor is to capture light and convert it to a digital image balancing noise, sensitivity and dynamic range.

The image is a collection of pixels. Low light produces dark pixels, while bright light creates brighter pixels. It's important to ensure the camera has the right sensor resolution for the application. The higher the resolution, the more detail an image will have, and the more accurate measurements will be. Part size, inspection tolerances, and other parameters will dictate the required resolution.

D. Vision processing

Processing is the mechanism for extracting information from a digital image and may take place externally in a PC-based system, or internally in a standalone vision system. Processing is performed by software and consists of several steps. First, an image is acquired from the sensor.

In some cases, pre-processing may be required to optimize image and ensure that all the necessary features stand out. Next, the software locates the specific features, runs measurements, and compares these to the specification. Finally, a decision is made and the results are communicated.

E. Communications

Since vision systems often use a variety of off-the-shelf components, these items must coordinate and connect to other machine elements quickly and easily. Typically this is done by either discrete I/O signal or data sent over a serial connection to a device that is logging information or using it. Discrete I/O points may be connected to a programmable logic controller (PLC), which will use that information to control a work cell or an indicator such as a stack light or directly to a solenoid which might be used to trigger a reject mechanism.

Data communication by a serial connection can be in the form of a conventional RS- 232 serial output, or Ethernet. Some systems employ a higher-level industrial protocol like Ethernet/IP, which may be connected to a device like a monitor or other operator interface to provide an operator interface specific to the application for convenient process monitoring and control.

VII. EXPERIMENTAL SETUP

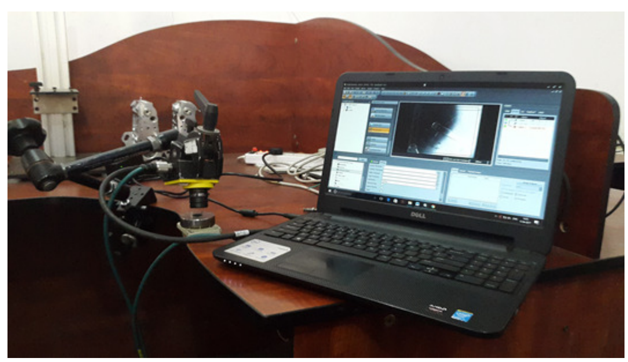

Fig 4: Experimental setup for Vane plate placement error detection

A. Materials required:

Materials required to conduct this experiment are as follows:

1. Cognex camera (Insight-IS7400)
2. Lens (6mm,16mm)
3. Insight explorer 5.4
4. Communication cables(Ethernet or RS-232 , Power and I/O Breakout Cable)
5. Rotor
6. Vane plates

B. *Connection:*

1. Connect the Ethernet cable's M12 connector to the vision sensor's Ethernet connector.
2. Connect the Ethernet cable's RJ-45 connector to a switch/router or PC, as applicable.
3. Verify that the 24V DC power supply being used is unplugged and not receiving power.
4. Optionally, connect the I/O or serial wires to an appropriate device (for example, a PLC or a serial device)
5. Attach the Power and I/O Breakout cables, +24V DC (Red wire) and GROUND (Black wire) to the corresponding terminals on the power supply.
6. Attach the Power and I/O Breakout cable's M12 connector to the vision sensor's Power, I/O and RS232 connector.
7. Restore power to the 24V DC power supply and turn it on if necessary.

C. *Working:*

1. The part is kept at the inspection station.
2. Sensor detects part and sends a trigger to the vision system.
3. Strobe is flashed to illuminate part.
4. Vision System acquires the image from the sensor
5. Software algorithms running on vision system performs image processing and/or image analysis on acquired image
6. Vision system sends signal along a discrete output line which activates a diverter if the part is bad and the result displayed is fail (Red).

VIII. RESULTS

8.1 Detection of non-placement of the vane plates in the rotor

Specifications:

1. Camera -Insight IS7400
2. Lens -16mm
3. Working distance -150mm
4. Field of view -50mm X 50mm

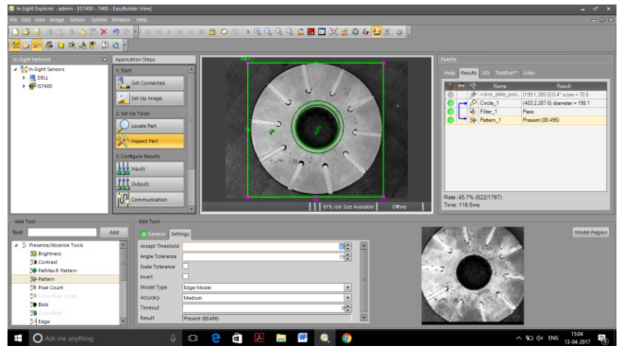

Fig 5: Green signal indicates that all the vane plates are present

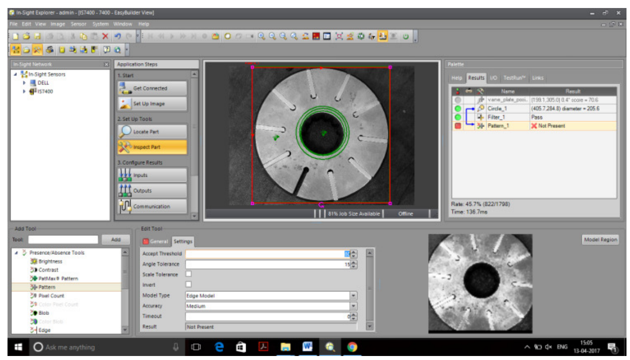

Fig 6: Red signal indicates error (i.e. one of the vane plates absent)

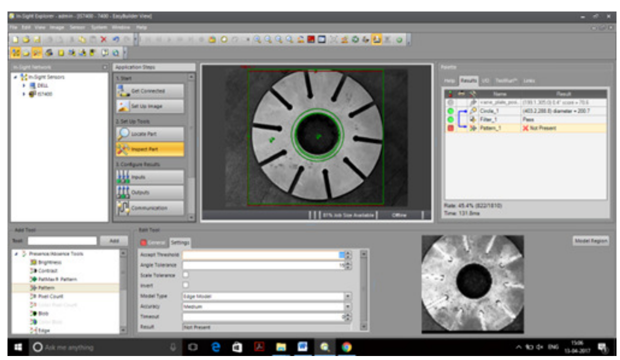

Fig 7: Red signal indicates error (i.e. all the vane plates absent)

8.2 Detection of directional placement error of the vane plates in the rotor (Horizontal placement of rotor)

Specifications:

1. Camera -Insight IS7400
2. Lens -6mm
3. Working distance -30mm
4. Field of view -15mm X 20mm

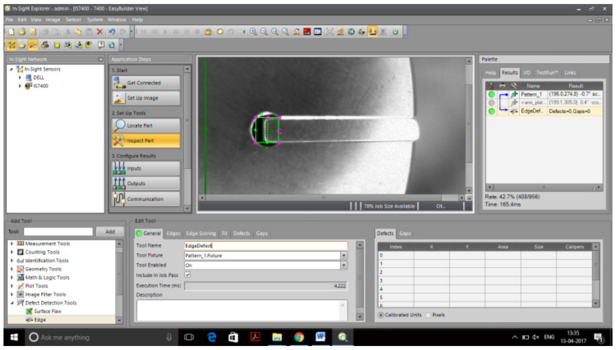

Fig 8: Green signal indicates that the plate is correctly placed

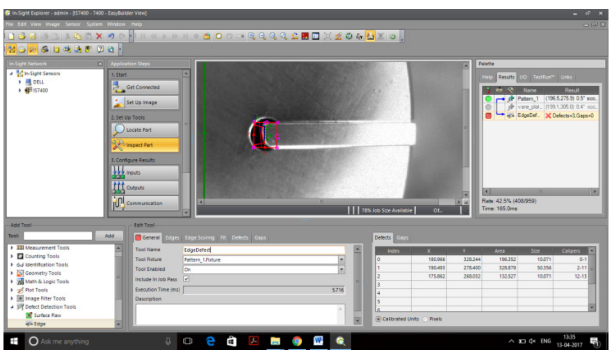

Fig 9: Red signal indicates an error (i.e. vane plate directional placement incorrect)

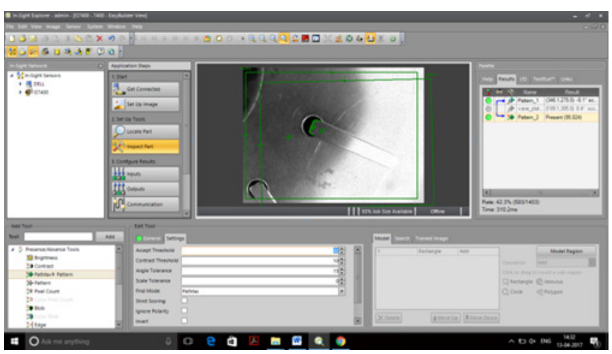

Fig 10: Green signal indicates that the plates are correctly placed

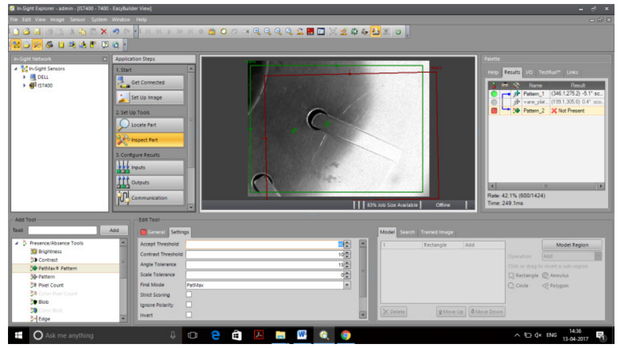

Fig 11: Red signal indicates an error (i.e. Vane plate directional placement)

8.3 Detection of directional placement error of the vane plates in the rotor (Vertical placement of rotor)

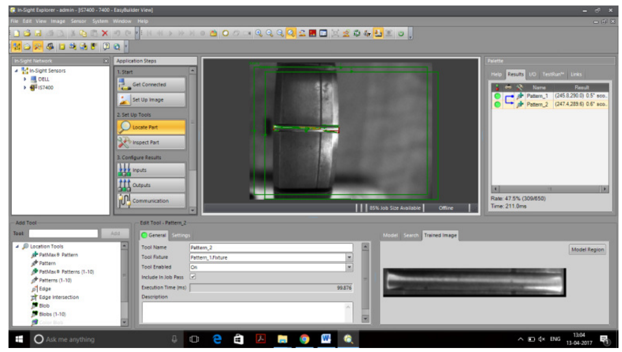

Fig 12: Green signal indicates that the plates are correctly placed

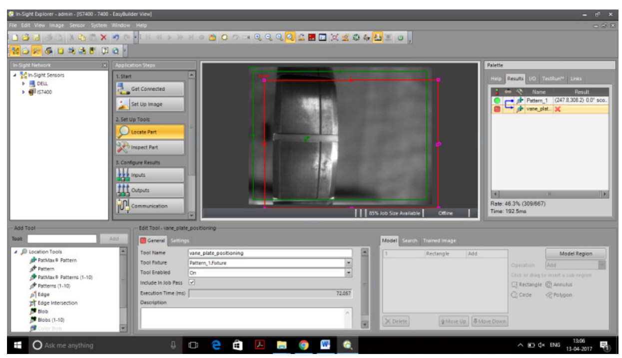

Fig 13: Red signal indicates an error (i.e. Vane plate directional placement incorrect)

IX. CONCLUSIONS

There are two types of error which occurs while testing of vane plates:

1. Non-placement of Vane plates in the rotor (i.e. absence of vane plates in the rotor)
2. Directional placement error of the vane plates in the rotor.(One side curved while other linear: curved to be placed outward, while linear one inside)

Both, the errors are successfully detected using Machine vision system, usually the time taken to manually test the vane plates placement error detection is about 25-30 seconds .While, in case of a machine vision system it takes 0.4 - 0.6 seconds.

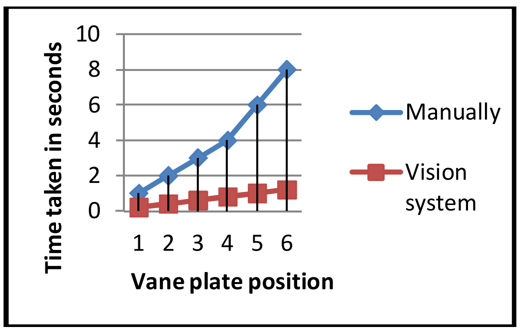

Chart -1: Graphical representation of time cycle

From this thesis, the conclusion drawn is that the machine vision can be successfully adopted on the manufacturing floor, where the repetitive tasks are performed several times. Hence, machine vision can be used in order to minimize the cycle time, default and increase the production.

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