EZVISION® VISION SENSOR

APPLICATION DESCRIPTION

Application: Multiple

Industry: Pharmaceutical

Product: Syringe

1 BACKGROUND

A leading manufacturer of liquid filling equipment is considering the integration of a smart camera product into one of their machine designs. They have written a preliminary specification, to serve as a guide to evaluating the smart camera's ability to provide solutions to the required inspections. This document addresses that specification line by line. In order to evaluate the vision application for feasibility with any vision system, the application engineer needs to consider a number of alternatives with regard to lighting, optics, part presentation and a general work cell layout. Accordingly, suggestions for part placement, fixture design, etc. may accompany the discussion of a particular inspection methodology.

Eleven inspection system requirements have been outlined. They are the ability to:

1. Scan a 1D and/or 2D barcode
2. Verify print content (Optical Character Verification)
3. Detect the color of a syringe (clear or amber)
4. Measure the diameter of a range of syringe sizes
5. Detect fill level in syringes
6. Provide remote approval in event of questionable inspection results
7. Store a visual record of certain inspections
8. Measure fill volume within the syringe

9. Detect voids in the liquid

10. Detect the presence of the cap on a syringe

11. Verify legibility and information on text (text quality).

Provided were 16 sample syringes with caps, eight each clear and amber with diameters ranging in size from approximately 5mm to 30mm and lengths ranging from approximately 65mm to 122mm. Each sample was evaluated within the context of the part population so as to attempt to arrive at a common inspection methodology. This was not always feasible and is noted where applicable in this document.

Because this tester did not receive samples of bar codes and text, those evaluations were not performed. Instead, this report will discuss in general the capabilities of smart cameras to perform those respective inspections.

The conclusions drawn from the study performed are that:

1. Certain 1D and/or 2D barcode can be scanned

2. Certain print content can be verified either with Optical Character Verification (OCV) or Recognition (OCR)

3. The color difference between clear and amber syringes is detectable

4. The diameters of the syringes provided is measurable

5. Fill level in syringes is detectable at the meniscus

6. Remote approval in event of questionable inspection results is achievable with the incorporation of a network device

7. Storage of a visual record of certain inspections is achievable with the incorporation of a networked device

8. Fill volume within the syringe cannot be repeatably measured

9. Voids in the liquid cannot be repeatably detected

10. The presence of the cap on a syringe can be detected

11. Certain text can be verified for legibility (quality) and information (OCR)

2 Laboratory Setup

Figure 1 is a picture of the laboratory setup for the syringe inspection. Testing was performed using a smart camera with a 0.3 Megapixel sensor. Working distance was approximately 110mm. This smart camera has an internal light source and fixed focal length lens. Figure 1 illustrates the back light configuration that is used on certain inspections. Additionally, front lighting using the sensor's internal light source and oblique lighting was also employed. These lighting schemes are discussed as applicable below.

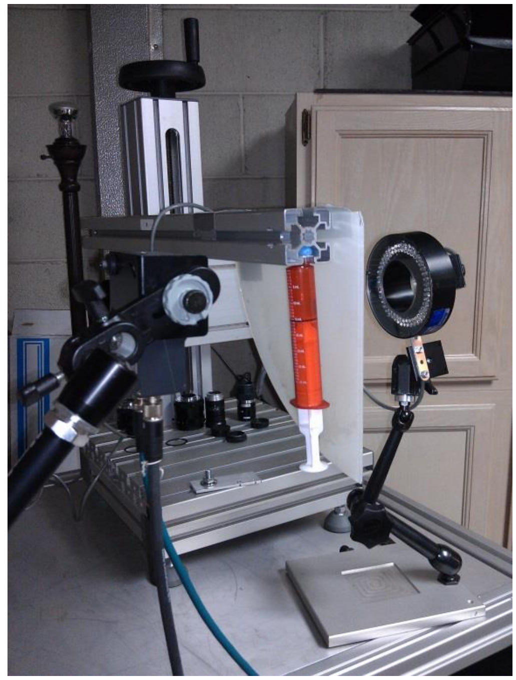

FIGURE 1: LABORATORY SETUP

The smart camera setup and configuration are performed with a Windows-based computer over an Ethernet connection. Once configuration is performed, the camera operates stand-alone and the computer is not required. Up to 255 configuration recipes ("jobs") can be stored on the sensor. The smart camera has 5 digital inputs and 5 digital outputs. These are used for such functions as image acquisition, job selection, part reject, etc.

Although a computer is not required for the smart camera to function, certain requirements in the specification require the transmission and manipulation of data. In this case, the camera acts as a stand-alone vision sensor transmitting inspection data and images to the work cell controller.

3 EZVISION® SOFTWARE: IMAGE ACQUISITION, SOFTWARE TOOLS AND COMMUNICATION

EZVision® is machine vision software that is available for PCs running either Linux or Windows operating systems. It provides both an easy-to-use prototype environment and a flexible run time solution environment. Its comprehensive vision algorithm set is accessed through a series of drop-down menus, slide bars and point-and-click buttons. EZVision®

FIGURE 2: EZVISION(R) INTERFACE

1). Adjust Image (Lighting, Focus, Calibration, etc.);

2). Check Features (Select appropriate software tool);

3). Configure Interfaces (digital I/O, data)

4). Activate VeriSens® (download configuration to the sensor, which runs the inspection)

FIGURE 3

3.1 Step 1

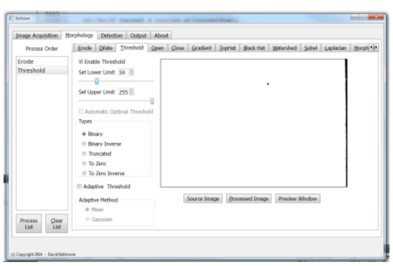

FIGURE 3

Step 1 is to establish proper part positioning and lighting. For the inspection to be successful, the web *must be repeatable with respect to location* in order to maintain proper angles from light source to part to image sensor.

Because the material is reflective, a UV line source applied at a low angle was selected. This resulted in good fluorescence yield from the catalyst, but also some unexpected results described below. Figure 2 also illustrates in the image window the image result using UV light. For comparison, Figure 3 is an image captured with diffuse ambient light. Note the contrast differences between the two.

3.2 Step 2

Step 2 is to select the appropriate software tool to perform the inspection. For this application the "Feature Comparison, Area Size Tool" was selected. This Tool performs a count of pixels at or above a gray scale threshold within a Region of Interest (ROI). The result will detect voids

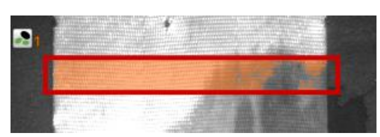

FIGURE 4

within the coating as well as at its extents, thus fulfilling both inspection requirements. Figure 4 illustrates an ROI detecting the absence of coating represented by the area shaded in orange.

3.3 Step 3

Step 3 is to configure the digital outputs and select data for transfer over the Ethernet connection. Because this is a web, there are no discrete parts to reject when an inspection fails. Therefore, a digital output shall be assigned to provide an operator alert when the inspection fails. Data and images shall be sent to a user-provided computer for review. Also, if the sensor is connected to the appropriate network, a web browser may be used to monitor the sensor operation and process.

4 INSPECTION

4.1 SPECIFICATION

Each item in the specification is addressed by number, below.

1. *Establish and maintain a "Reference Point" to be used for all syringes.*
2. *The reference point shall be just below the syringe tip and at the intersection of top of the syringe body.* For purposes of this evaluation, a custom fixture was not produced. Figure 5 illustrates the use of a cap to suspend the syringe within an extruded aluminum frame. In this arrangement, the clearance between the frame and the syringe does not permit the vision system to reference the tip/ body intersection, except on larger parts.

FIGURE 5

However, there is a potential issue with using the vision system to reference upon the part. Figure 6 illustrates two parts; one large and one small. Note that on the large part, the specified referenced area on the part may be found on the slight shoulder of the tip (Arrow 2) or on the top of the syringe body (Arrow 1). A slight difference in the presented angle of the part to the camera could result in a different reading. It must also be mentioned at this time that the tester observed that some syringes exhibited a slight curvature. It is not known whether or not this is a normal occurrence.

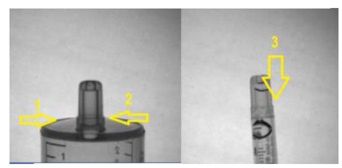

FIGURE 6

An additional possible issue is with small parts. Note that in order to detect the shoulder at Arrow 3 the vision tool must be precisely located. Additionally, this location is different for every part diameter.

A simpler solution may be to assign the reference point to the part fixture. Either a hard stop or a sensor within the fixture could serve to provide a reliable reference point.

Conclusion: there is probably a better way to establish the reference point than with the vision system.

3. *The reading shall be taken from the "Reference Point" downward to the seal ring of the plunger.* If, as discussed in (2) above, a reference point is a fixed point determined by the part location on the clamp, then that value can be stored for later use. As illustrated in Figure 7, a common locater tool may be applied across the centerline of all parts to obtain the vertical location of the plunger ring.

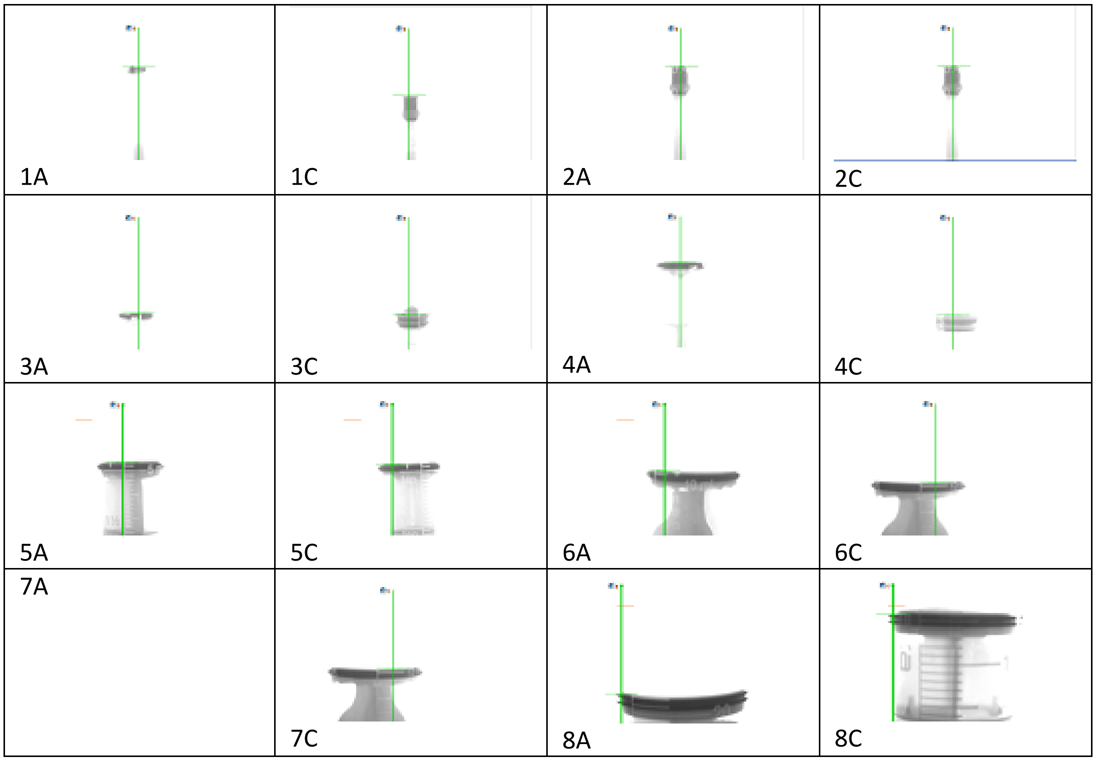

FIGURE 7

In the above images, the parts were assigned arbitrary designation for size (1-8) and color (“A”- amber; “C”- clear). All clear parts were inspected using the same lighting set point and all amber parts were inspected using the same set point (but different from the clear parts). The set point is an adjustment made in software and may be changed “on the fly”.

By knowing the location in “Y” of the Reference Point and by inspecting for a repeatable feature on the plunger seal, a mathematical comparison may be made between the two to obtain a distance measurement.

4. *A reading shall be taken as a numerical dimension for the specific syringe size and relative to the prescribed dose. The reading will be compared to a pre-determined number associated with both the syringe size and every increment on the syringe. For example: a 10ml dose is prescribed. Our database recommends a 20ml syringe if properly filled, the dimension will read 32.75mm or 1.29”.*

   Because the system knows the dosage and syringe size ahead of time, it is able to

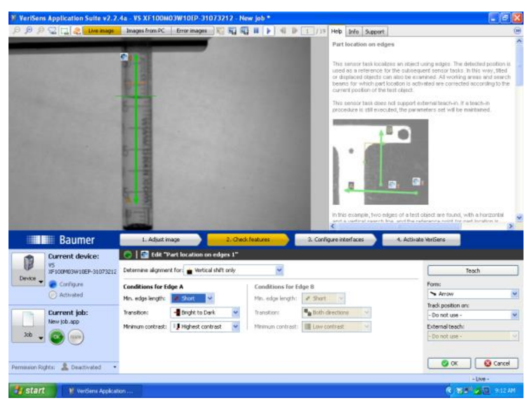

FIGURE 8

increment the camera on a vertical servo axis to the appropriate location to perform the measurement, thus optimizing the lighting and camera angle for maximum accuracy. The absolute measurement value is either pixels or calibrated world space units and is exported to a controller for comparison to the Reference Point.

5. *Any voids or bubbles shall be interpreted as a mixed pixel count in either light or dark depending on the opacity of the medication from our database. In the event of a +/- 2 ½% or greater mismatch of pixel color or shading, within the fill zone the Pharmacist will make a decision to either pass or fail the filled syringe. Compounded medication solutions will not be applied to the Vision System unless bulk quantities are being produced.*

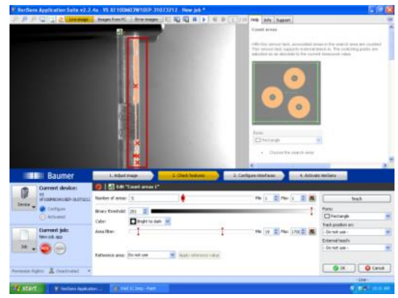

FIGURE 4

The tester used water as the measured liquid for fill volume (see Figure 10).

6. *An optional feature for digital photographing of the filled syringe should be considered when designing the operational software.*

Because the vision system is acquiring images of only portions of the syringe, individual images can be acquired and "stitched" together with 3rd party software. Figure 10 is an image captured (.bmp format) at a given location. As the camera increments own the servo-driven additional images may be acquired and stored. These images can be assembled and stored on the cell controller.

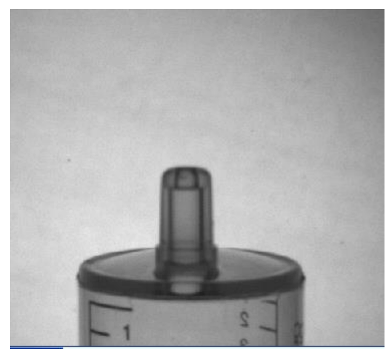

FIGURE 5

7. *The system must be able to determine if the syringe is "short filled". The 'back light' should be able to confirm differences in shading, and thereby indicate that the fill has voids in it. Similar to the above mentioned bubbles.*

Short fills and voids are problematic for two reasons: the low transmittance of the amber syringes and the increments and text that is applied to the syringes. The images in Figure 7 are deliberately overexposed in order to eliminate the effects of the increments and text on the syringes. Similarly, bubbles and voids cannot be differentiated from these markings by the camera. If the part is front lit, the markings appear in the foreground; if the part is backlit, the markings appear in the background. In either event, there is no separation in the image between "voids" and markings.

Figure 12 illustrates the application of an Edge Locate tool in the vertical axis. Note that, although the meniscus is found in this particular case, the presence of the increment lines along the part are definite noise factors. By definition, short fills must be able to locate the meniscus. Therefore, the lighting must be such as to highlight the meniscus while reducing noise in the image.

In Figure 10 this was accomplished with a clear syringe through the use of oblique lighting. Note the highlights above and below the meniscus. The presence of more than one of these indicates one type of short fill, an air pocket near the syringe plunger.

Figure 8 illustrates oblique lighting as applied to an amber syringe. Note the absence of highlights. This is due to the difference in optical properties from the clear syringe. Meniscus detection for this part is achieved using the Edge Locate tool. This tool may be configured to detect the meniscus at either the top or the bottom of a void.

FIGURE 6

8. *Once the system satisfies all the parameters and effectively can deal with all syringe sizes and colors no adjustments nor changes nor use of change parts shall be acceptable.*

As discussed previously, the number of variables (size, color, defects) dictates an inspection methodology unique to each part. Brightness and tool selection differences are primarily associated with the differences in optical characteristics between clear and amber syringes. Although a large number of configurations may be stored on the smart camera, it may be advantageous to store configuration recipes on the work cell controller with other parameters associated with the part to be inspected. Additionally, the concept of maintaining a smaller Field Of View and repositioning the image sensor increases the flexibility while reducing the inspection variables.

9. *The accuracy of fill should be +/- 5% of target. The bubble void percentage will remain at +/- 2 ½%.*

+/- 5% is achievable if fill accuracy is determined by location of plunger seal.
Bubble void percentage of 2 ½% has not been demonstrated to be achievable. Testing performed with water demonstrated the ability to detect large voids that produce a meniscus. Fluids were not available to test for bubbles. Until those fluids are available for testing is is expected that the optical noise from the syringe markings will preclude the detection of bubbles.

5 Conclusion

The variety of part size, colors and textures requires that each application be considered on its own. The lighting and software methodology will need to be developed for each inspection. Changeover from one part to another using the same mechanical/ lighting configuration will not be feasible in most instances. All inspections across the sample set can be performed using the software tools available on most vision systems, but the number and variability of inspections to be performed suggest the use of a PC-based vision system.

6 Operation

Operational parameters to be specified as the design process matures.

7 DELIVERABLES (AS DESCRIBED FOR INSPECTIONS DESCRIBED HEREIN)

A typical system would consist of the following:

- 1 High-performance computer with multiple GigE ports
- Multiple GigE cameras
- Multiple light sources
- Multiple lenses
- Electrical controls including switches, lights, etc.
- Engineering and documentation
- Installation and training

Assuming a four camera system the budget estimate for an inspection station such as this is <$20,000 US plus installation.

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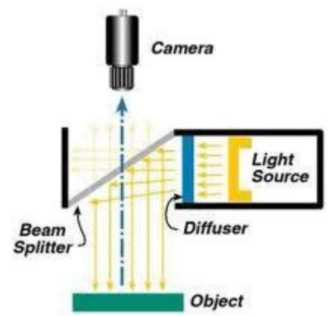
GLOSSARY

Back Lighting Lighting technique in which the light source and the camera are on opposite sides of the part to be inspected.

Contrast Measured in grayscale (Black = 0; white = 255). A minimum contrast must be present in order to differentiate a feature from its background.

BACKLIGHT

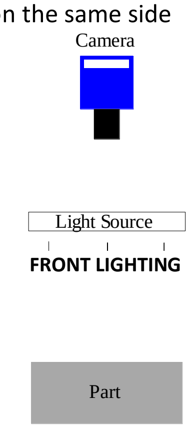


Dual On Axis Light (DOAL) On Axis illumination uses beam splitting techniques to enable the illumination to be positioned between the camera and the object so that the camera is situated behind the light. **Note:** Due to light loss in the beam splitter the unit generally needs to be positioned as close as possible to the object.

Edge Detection A software tool that calculates the gradient location across a pixel matrix based upon the difference between the grayscale values. Typically, a nearest line fit is calculated across several pixels within the maximum gradient and this line is determined to be the edge.

Feature Extraction The ability of machine vision software to separate a feature from its background and determine some attribute (area, brightness, *etc.*)

Front (or Top) Lighting Lighting technique in which the light source and the camera are on the same side of the part to be inspected.



Gray Scale In an 8 bit monochrome system, black =0 and white = 255 with values between depicting varying shades of gray.

Optical Character Recognition (OCR) The ability of machine vision software to determine the value of a string of previously unknown characters.

Optical Character Verification (OCV) The ability of machine vision software to determine whether or not the value of a string of previously taught characters matches the current image.

Resolution Measured in Units of measure per pixel.

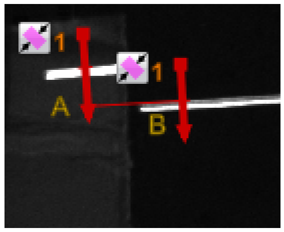
Field of View ÷ minimum number of pixels on the sensor.

For example, a 1" FOV with a VGA sensor has a resolution of approximately .002"

Resolution = FOV/pixels Resolution = 1"/480

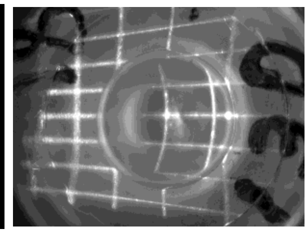
Resolution =.002"/ pixel

Structured Lighting Lighting technique whereby the illumination source has a defined geometry: line, grid, pattern, etc. It is often employed to obtain geometric information about a part that is inspected. The vision system measures attributes of the light pattern in order to obtain information about the part. Below examples are: (1) Line used to determine vertical displacement on a paper feed; (2) three line pattern used to count crayons in a box; (3) Grid used to detect 3D contour information.



PAPER VERTICAL DISPLACEMENT

CRAYON COUNT



GRID PATTERN

Threshold (Gray Scale) With binary algorithms**,** the gray scale value above or below which the pixel values will be recognized.