RESEARCH OF FOREIGN MATERIAL DETECTION ON TEMPERED GLASS FOR AUTO-CLEANING SYSTEM USING SIFT ALGORITHM

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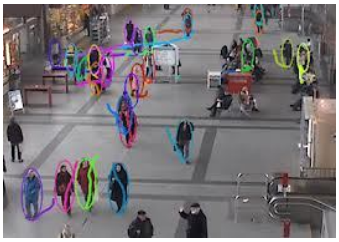
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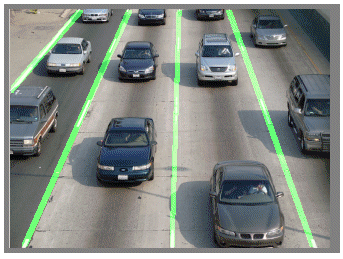
Abstract- Development of computer vision technology has been recently carried out rapidly. Nowadays, many computer vision technologies are applied to machine vision technology. In this paper we research the detection of foreign material on the tempered glass of the digital display based upon SIFT algorithm. The SIFT algorithm is used to detect the feature points of foreign materials for auto-cleaning system. By using this detection system, we can improve the reliability of the auto-cleaning and reduce the time and expenses.

Keywords- SIFT, DoG, Foreign Material Detection, Tempered Glass, Computer vision.

I. INTRODUCTION

Recently computer vision technology has been widely used for image processing like image recognition and object recognition on robot, mobile, security system and other fields. Especially, the object recognition, a subfield of image processing, has been mostly used for industry and military purpose from the past. The examples of various computer vision technology applied for object recognition are shown in Figure 1.





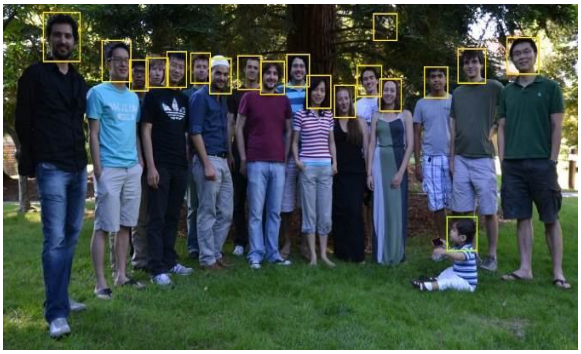


Fig. 1. Various computer vision technology

Nowadays, many computer vision technologies are used for machine vision technology. The primary uses for machine vision are automatic inspection and industrial robot guidance. Other machine vision applications include:

- Automatic PCB inspection
- Wood quality inspection
- Final inspection of sub-assemblies
- Engine part inspection
- Label inspection on products
- Checking medical devices for defects
- Final inspection cells
- Robot guidance and checking orientation of components
- Packaging Inspection
- Medical vial inspection
- Food pack checks
- Verifying engineered components

In this paper, we research the detection of foreign materials on tempered glass of digital displays. The SIFT algorithm as one of feature point detection technologies is suitable to find and locate foreign materials easily. The SIFT algorithm is used to detect the feature points of foreign materials for auto-cleaning system. By applying this technique, auto-cleaning system determines automatically whether to clean the glass again or proceed to clean the next glass after checking for the foreign material detection. The reliability of the tempered glass cleaning system can be improved by our vision system.

II. SIFT ALGORITHM

SIFT(Scale-invariant feature transform) is an algorithm in computer vision to detect and describe local features in images. The algorithm was published by David Lowe in 1999. Applications include object recognition, robotic mapping and navigation, image

stitching, 3D modeling, gesture recognition and video tracking.

A. Detection of Scale-Space Extrema

As described in the introduction, we will detect keypoints using a cascade filtering approach that uses efficient algorithms to identify candidate locations that are then examined in further detail. The first stage of keypoint detection is to identify locations and scales that can be repeatably assigned under differing views of the same object. Detecting locations that are invariant to scale change of the image can be accomplished by searching for stable features across all possible scales, using a continuous function of scale known as scale space. The scale space of an image is defined as a function, L(x, y, σ), that is produced from the convolution of a variable-scale Gaussian, G(x, y, σ), with an input image, I(x, y), as in (1).

$$L(x,y,\sigma) = G(x,y,\sigma) * I(x,y) \quad (1)$$

Where * is the convolution operation in x and y, as in (2).

$$G(x,y,\sigma) = \frac{1}{2\pi\sigma^2} e^{\frac{-(x^2+y^2)}{2\sigma^2}} \quad (2)$$

To extract feature points, SIFT algorithm makes Gaussian images by filtering masks that have different values of variance as shown in Figure 2. Then Gaussian pyramid is established as shown in Figure 3.

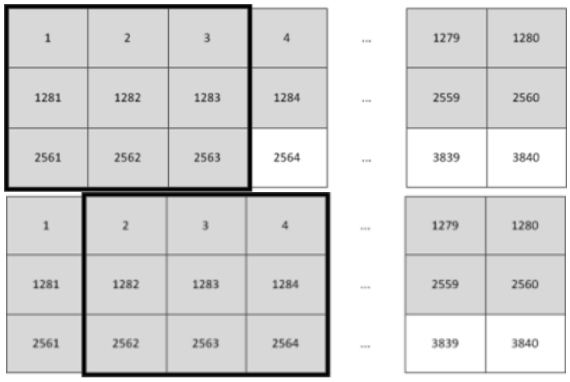


Fig. 2. Gaussian mask

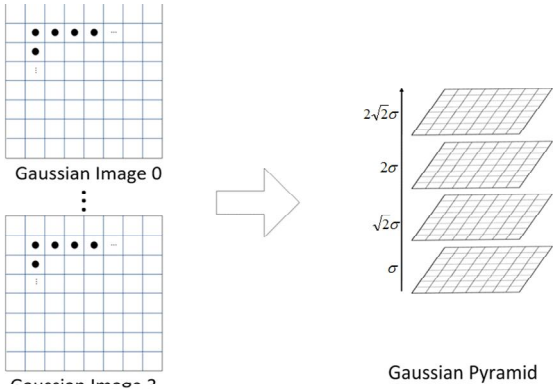


Fig. 3. Process of Gaussian pyramid

B. Difference-of-Gaussian

To efficiently detect stable keypoint locations in scale space, we use scale-space extrema in the DoG(Difference of Gaussian) function convolved with the image, D(x, y, σ), which can be computed from the difference of two nearby scales separated by a constant multiplicative factor k, as in (3).

$$D(x,y,\sigma) = (G(x,y,k\sigma) - G(x,y,\sigma)) * I(x,y) = L(x,y,k\sigma) - L(x,y,\sigma) \quad (3)$$

As shown in Figure 4, when the generated images have different variance, images are blurred differently at edge. After that, edge-based images are generated.

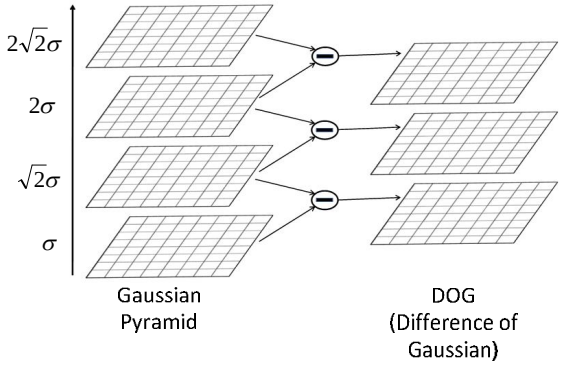


Fig. 4. Generating DoG

C. Detect Scale-Space Extrema

Maxima and minima of the difference-of-Gaussian images are detected by comparing a pixel to its 26 neighbors in 3x3 regions at the current and adjacent scales. Detect Scale-Space Extrema is shown in Figure 5.

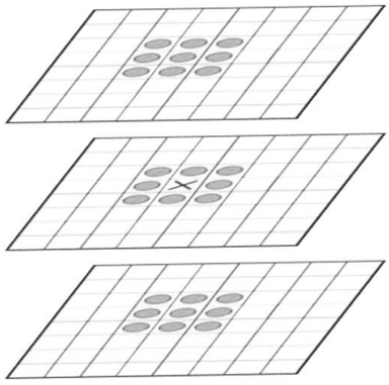


Fig. 5. Detect Scale-Space Extrema

D. Accurate keypoint localization

Scale-space extrema detection produces too many keypoint candidates, some of which are unstable. The next step in the algorithm is to perform a detailed fit to the nearby data for accurate location, scale, and ratio of principal curvatures. This information allows points to be rejected that have low contrast or are poorly localized along an edge. The new approach calculates the interpolated location of the extremum,

which substantially improves matching and stability. The interpolation is done using the quadratic Taylor expansion of the Difference-of-Gaussian scale-space function, D (x, y, σ) with the candidate keypoint as the origin. This Taylor expansion is given by, as in (4).

$$D(x) = D + \frac{\partial D^T}{\partial x} x + \frac{1}{2} x^T \frac{\partial^2 D}{\partial x^2} x \qquad (4)$$

If the offset x is larger than 0.5 in any dimension, then that's an indication that the extremum lies closer to another candidate keypoint.

E. Discarding low-contrast keypoints

To discard the keypoints with low contrast, the value of the second-order Taylor expansion D(x) is computed at the offset x. If this value is less than 0.03, the candidate keypoint is discarded.

III. FEATURE POINT DETECTION

We can detect the feature points using SIFT algorithm. Feature point detection is shown in Figure 6, 7.

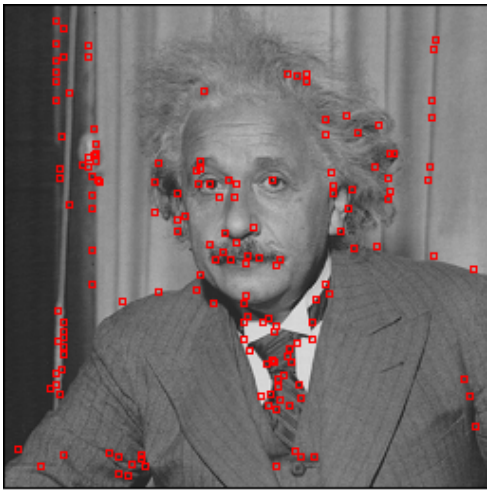


Fig. 6. Feature point detection



Fig. 7. Feature point detection

And we tested using test image for detection of foreign material detection on tempered glass. Feature point detection is shown in Figure 8 and 9.

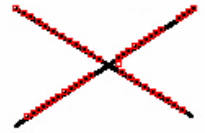


Fig. 8. Feature point detection

Fig. 9. Feature point detection

Figure 10, 11 shows the feature point detection of foreign material detection on tempered glass

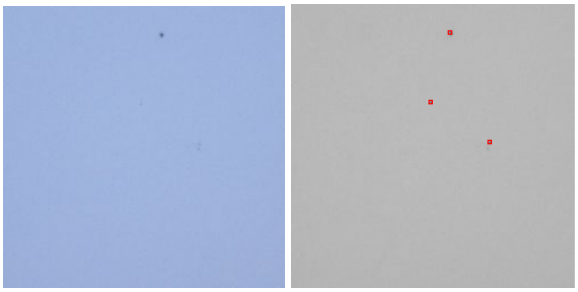


Fig. 10. Original image and Feature point detection image

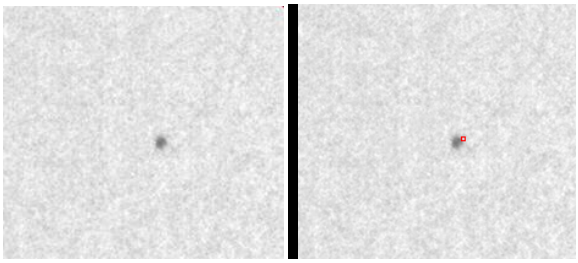


Fig. 11. Original image and Feature point detection image

Feature point detection using SIFT algorithm can detect foreign materials properly in spite of many noise or reflection of light.

IV. AUTO-CLEANING SYSTEM FOR TEMPERED GLASS

Auto-cleaning System for tempered glass checks the tempered glass after cleaning. It is a way to improve the reliability of the cleaning. The auto-cleaning system is shown in Figure 12.

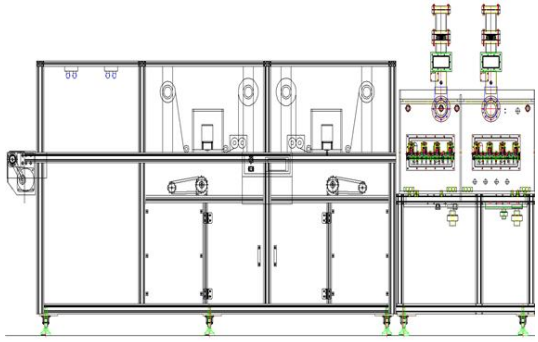


Fig. 12. Auto-cleaning system for tempered glass

The flowchart of auto-cleaning system is shown in Figure 13.

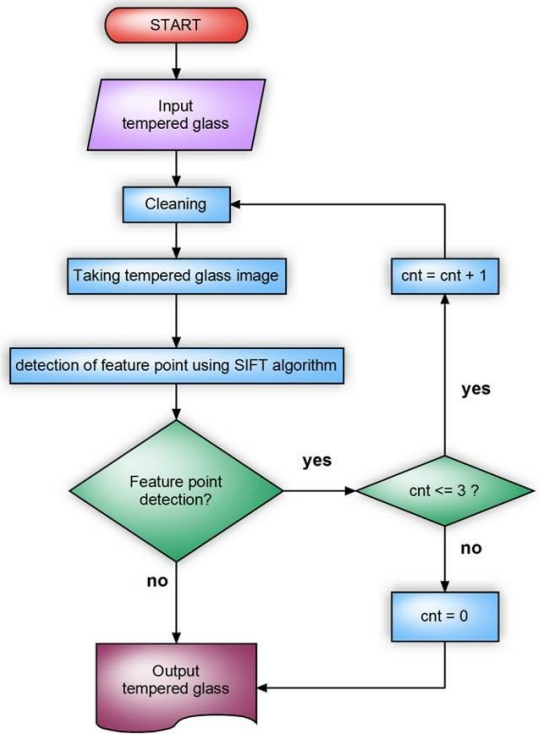


Fig. 13. Flowchart of auto-cleaning system for tempered glass

Auto-cleaning system determines whether to clean the tempered glass again or continue to proceed for another glass after checking for the foreign material detection. When the tempered glass is not clean after three times cleaning, the tempered glass is classified as a faulty.

CONCLUSION

We researched foreign material detection on tempered glass of digital display using SIFT algorithm. We applied the feature point detection system which is implemented in FPGA to the cleaning system. Feature point detection using SIFT algorithm can detect foreign materials properly in spite of many noise or reflection of light. Therefore the feature point detection system can improve the reliability of the cleaning and reduce time and cost due to the automation.

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