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Image Based Surface Visualization Method for the Defects Detection

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ABSTRACT

Defects detection on the final product of camera module is a major issue in the visual inspection industry. This paper is about the study of surface visualization for foreign material detector or abnormal lens surface between IR filter and lens in camera module. With the purpose of making filter surface noticeable, it extracts background image assumed as polynomial expression in input image and then generate the differential image of input image. Also, it accentuates flexuosity of surface, applying median filtering with high precision, after it smoothes a set of pixels that has recursively similar brightness value based on coarse-to-fine strategy known as bilateral filtering. Performance of the proposed method has been evaluated on some sample images captured in the white light. As a result of the experiment, we verified that surface condition is visualized and surface defects such as foreign substance is identified distinctly. And this method is expected to be used widely in the machine vision industry for automated or manual visual inspection of defects system.

KEYWORDS: Surface Visualizations, Defects Detection, Background Estimations, IR filter, Bilateral filter, Camera modules

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1. Introduction

The demand for equipment technology using mini camera increases in IT technology area. Request for a visual inspection for defects contained in the camera module using the image processing technique according to the increase of the production line, and related products may also increase. Camera module is generally as <Figure 1>. FPCP(Focal Plane Cold Plate) is embedded with CCD sensor, and on it, IR filter and lens module are combined with lens holder. This camera module goes through discovery test to see if there is foreign material between lens and CCD sensor or IR filter and lens, after assembling work. At this time, foreign material detection work is performed through image information from CCD sensor, by filming white light that illuminates uniform light into camera module. If there is foreign material between CCD sensor and IR filter, black or white point appears in the acquired image, and this detection can be performed by comparing each pixel value in image. However, foreign material between IR filter and lens is relatively difficult to be distinguished because of irregular pattern with low-contrast and non-uniformed brightness. Thus, this thesis suggests the method focusing surface visualization that applies to preprocessor stage and offers the surface image for visual examination and automatic examination [1~4].

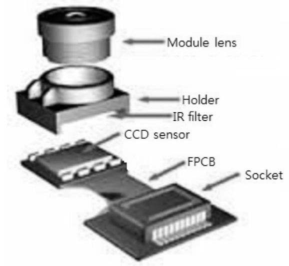


그림 1. 카메라 모듈의 구조
Figure 1. The Structure of the camera module

[5] shows the study for defects detection about low-contrast image through multiple resolution analysis, and [6] shows the defects detection with algorithm based singular value decomposition and reconstruction process. [7] is mura defects detection through two-pass process using surface fitting and visual perception model. However, these study performs preprocess premising automatic defects detection, and there is a lack of research which visualizes so effectively that surface condition is possible for visual examination.

This paper proposes the method focusing surface visualization that applies to preprocessor stage and offers the surface image for visual examination and automatic examination.

This paper is organized as follows. In Section 2 details the algorithm for surface visualization. Then experimental results are presented and discussed in Section 3. Finally, Section 4 concludes the paper by briefly summarizing the main points and proposing future work.

2. Surface Visualization

This chapter is about the technology that is applied to surface visualization process. The overall process of surface visualization completes visualization, performing rotationally coarse-to-fine recursion that includes high-pass filter and diplex filter after background image estimation and differential image formation.

2.1 Background Estimation

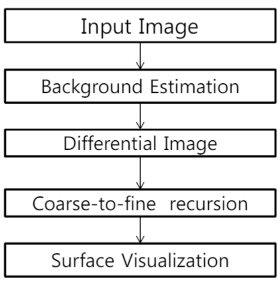


그림 2. 제안하는 표면 시각화의 전체 과정

Figure 2. Overall procedure the proposed surface visualization

To make surface condition noticeable, background image(C) is estimated from input image g. Background image(C) should be constant in all pixels in ideal condition. In practice, however, there has uneven background as lens aberration. Background is set as second-order polynomial model [1].

$$C(u,v) = k_0 + k_1 u + k_2 v + k_3 u^2 + k_4 uv + k_5 v^2 \qquad (1)$$

Based on background pixels of the observation image, $g_c(u,v)$, we have the following over-determined linear system.

$$\begin{bmatrix} \vdots \\ g_c(u,v) \\ \vdots \end{bmatrix} = \begin{bmatrix} \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ 1 & u & v & u^2 & uv & v^2 \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \end{bmatrix} \begin{bmatrix} k_0 \\ \vdots \\ k_5 \end{bmatrix} \qquad (2)$$

and denote it as

$$g_c = Ak \qquad (3)$$

To estimate the polynomial coefficient vector k from equation (3), we need to know the background pixels , but the background pixels are unknown until the segmentation is done. To handle this dilemma, we treat all observed pixels as background pixels (i.e. $g_c \leftarrow g$) and estimate by a least-square solution

$$k = (A^T A)^{-1} A^T g \qquad (4)$$

We could refine this background estimation after we obtain the restoration and segmentation result and reiterate the processes. However, based on our experiments, there is no obvious improvement gained from the iterative process, because we estimate from an over-constrained system (e.g., for a 1000 × 1000 image, we have 1 million equations to estimate 6 coefficients in equation (2). Therefore, we use all pixels in an observed image for background estimation without iterative refinement. Given an observed image, we compute the background as $C = Ak^*$, and remove it from the observed image, i.e. $g = g - C$.

Background image of final two-dimensional image is estimated; background estimation process as the above explanation is alternately applied to transverse, one-dimensional pixel, and then to longitudinal, one-dimensional pixel as shown in <Figure 3>. And <Figure 4> is the background-input difference image example.

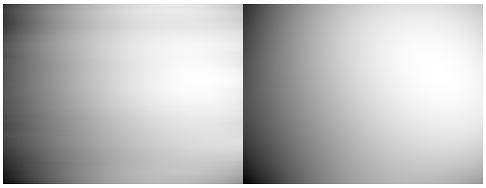


그림 3. 수평 스캔 이미지(왼쪽), 수직 스캔 이미지(오른쪽)

Figure 3. Horizontal scan image(left), vertical scan image(right)

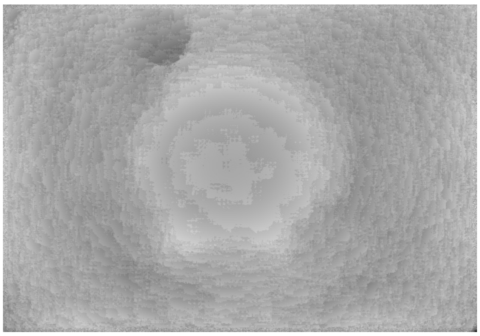


그림 4. 배경 - 입력 차분 영상

Figure 4. Background- Input Difference Image

2.2 Visualization using coarse-to-fine recursion

Visualization in the surface that is brought out by the difference of background image and original image is completed by coarse-to-fine recursion. Recursion process is performed recursively with high pass filtering and bilateral filtering[9][10].

Typical bilateral filter is nonlinear filter that preserves outline and edge in original image and smoothes image noise. pixel $Q(m,n)$ that is estimated by bilateral filter is

$$Q(m,n)=\sum_{l=-N}^{N}\sum_{k=-N}^{N}H(m,n;l,k)P(l,k) \quad (5)$$

P(l,k) is input pixel, and H(m,n;l,k) is nonlinear combination between pixel (l,k) in local window and center pixel in local window. Nonlinear combination of local window is

$$H(m,n;l,k) = \begin{cases} \omega_{m,n}^{-1}\exp-\frac{(l-m)^2+(k-n)^2}{2\sigma_d^2} \times \exp\frac{P(l,k)-P(m-n)^2}{2\sigma_r^2} & \text{if}(l,k)\in A_{m,n} \\ 0 & otherwise \end{cases} \quad (6)$$

$$A_{(m,n)}=(l,k) : (l,k)\in(m-N,m+N)\times(n-N,n+N) \quad (7)$$

where $A_{m,n}$ is pixels in local window, σ_d and σ_r is standard deviation for the domain filter and range filter respectively.

$$\omega_{m,n}=\sum_{l=m-N}^{m+N}\sum_{k=n-N}^{n+N}\exp(-\frac{(l-m)^2+(k-n)^2}{2\sigma_d^2} \quad (8)$$

where $\omega_{m,n}$ is normalize factor represented by equation (8). As a nonlinear filter, we adopted low pass Gaussian filter in domain filter and range filter. Thus, domain filter increase weights of pixels that is spatially close to center pixel, and range filter increase weights of neighbor pixels that has similar pixel value with center pixel. <Figure 5> is the result example image of bilateral filtering.

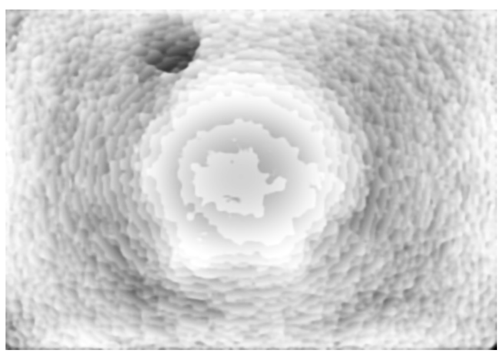


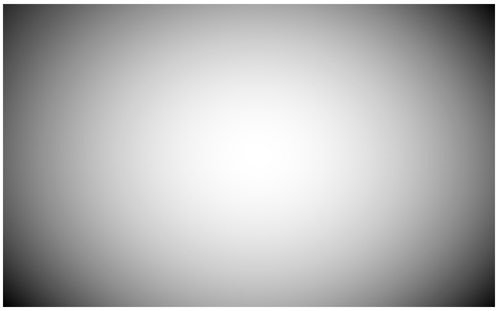
그림 5. 양방향 필터링 결과

Figure 5. Bilateral filtering results

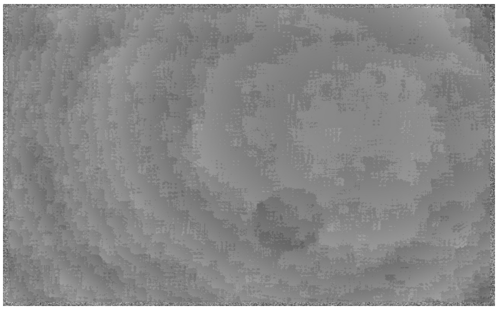
3. Experimental Results

Performance of the proposed method has been evaluated on some sample images captured in the white light. As a result of examination with defects surface image using the proposed surface visualization method, surface condition was visualized and surface defects was definitely distinguishable as shown in <Figure 6>.<Figure 7>. <Figure 6>(a) image is an input image containing surface defects. Due to the very low contrast of the visually distinct shows an image of a defective area is almost impossible. <Figure 6>(b) is a second-order polynomial background image is estimated from the input image. The brightness of the outer portions and the central portion can be confirmed that the effect is formed as the brightness difference between the white light for inspection. <Figure 6>(c) is an intermediate difference image of the visualization. Second-order polynomial model estimated by the background image and the input image to the difference image of the surface defects is shown set off a verifiable level only rough. Finally, <Figure 6>(d) image is largely a result of the image visualized by the coarse-to-fine recursion method. The image shows the resulting surface is visually represented in more detail. <Figure 7> show some resulting images of the experimental images. The top nine images are the ones that contains the defects. The bottom nine images are the normal surface state ones.

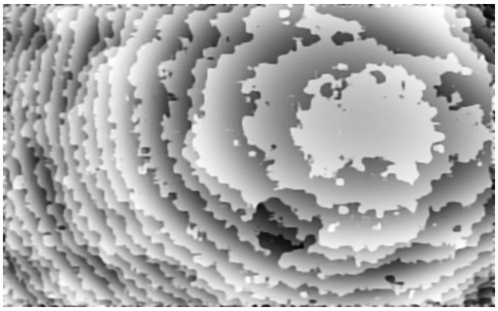
(a) Input image



(b) Second-order polynomial background image



(c) Intermediate difference image



(d) Final result image

그림 6. 입력 영상에 결과 영상

Figure 6. Visualization result images for the input image

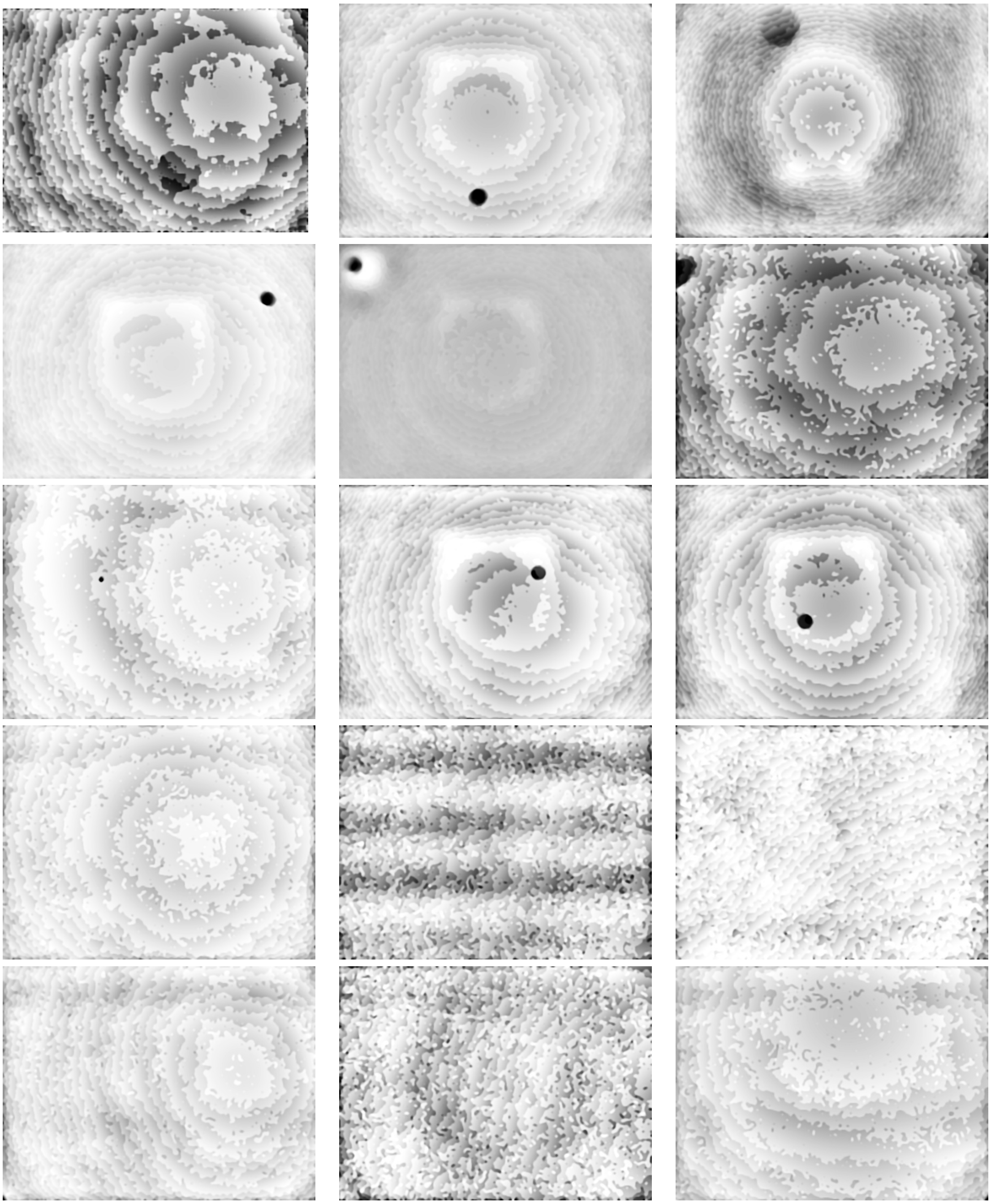


그림 7. 표면 시각화 결과 영상들 (상단 9개 영상:결함 포함, 하단 6개:정상 상태)

Figure 7. Surface Visualization result images (Top 9 images :Defects Included, Bottom 6 images : Normal State)

4. Conclusions

This paper suggests the methods for visualization of surface defects. Surface visualization for defects detection is performed by grouping adjacent pixels through high-pass filter and coarse-to-fine recursion method in result image from background estimation result that is estimated as second-order polynomial function of one-dimension pixel. According to the result of real image examination, we could verify that surface visualization was remarkable and efficient defects detection was possible in automatic detection.

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결함 검출을 위한 영상기반 표면 시각화 방법

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요 약

카메라 모듈의 최종 생산품에 대한 결함 검출은 시각 검사 산업에서 중요한 문제이다. 본 논문은 카메라 모듈에서의 IR 필터 상단 이물질 검출 혹은 비정상적인 렌즈 표면에 대한 표면 시각화에 관한 연구이다. 필터 표면을 두드러지게 하게 하기 위한 목적으로 입력영상에서 다항식 표현으로 추정된 배경 영상과 입력 영상의 차분 영상을 추출한다. 그리고 높은 정밀도를 가진 메디안 필터링을 적용하여 재귀적으로 유사한 밝기 값을 가진 이웃 픽셀 집합을 평활화하여 표면의 굴곡 상태가 시각적으로 두드러지게 한다. 제안

하는 방법의 성능은 백색광하에서 획득된 샘플 영상으로 평가되었다. 실험결과 표면의 상태가 시각화 될 뿐만 아니라 이물질과 같은 표면 결함이 확연히 식별 가능하게 표현되는 것을 확인하였다. 그리고 이 방법은 수동 및 자동 결함 검출 시스템에 널리 사용될 것이라 예상된다.

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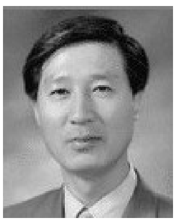

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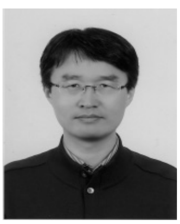

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