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Automatic Damage Detection of Containers Based on Hierarchical Image Analysis

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Abstract

In this paper, we present a new method for analysing the damage to a logistics container by automatic analysis of its integrity based on parts-zone segmentation and hierarchical image analysis. To achieve this, we use a smart phone or tablet in order to acquire an image from the rear side of the container. The automatic damage detection system consists of three stages: i) dividing the image into small areas as minimum analysis units, ii) calculating the score of the individual units, and iii) summation of the scores for each unit to estimate the degree of integrity. In experiments, we have successfully evaluated the performance of the proposed method with data from a smart phone camera. As such, the proposed method provides automated damage detection which has the advantage of offering a relatively inexpensive and expeditious estimate of container damage.

Keywords: Logistics container, Damage analysis, Zone segmentation

1. INTRODUCTION

In general, the integrity of logistics containers is visually inspected by human experts at gates of container terminals or bonded warehouses. These visual inspections are carried out under adverse conditions such as vehicle fumes or bad weather, and are also based on subjective judgements that depend on the proficiency of the inspection personnel. Therefore, the need for an automated system capable of quantitative analysis is increasing. Recently, techniques for automatically checking damage to containers using 3D laser scanning devices such as the LaseCDI-GATE system (2014), which require fixed facilities including expensive equipment, have been applied. Huang et al (2013) have proposed the system for detecting damages by comparing two images of the containers acquired before and after the transfer using fixed cameras. However, this method only detects changes due to breakage during transport, and cameras of the same specifications should be installed at the departure and arrival points.

In this paper, we propose a method to measure the integrity of a container using only a mobile camera without additional expensive equipment. For this purpose, the rear side image of the container is captured by the camera on a mobile device such as a smart phone or tablet at the container inspection site, it is divided into parts-zones as the analysis units, and quantitative integrity parameters such as a contamination score, decrepitude score, and locking score in each parts-zone are calculated. Finally we can obtain the degree of integrity for the entire container from these integrity parameters.

2. CONTAINER INTEGRITY ANALYSIS SYSTEM

As shown in Figure 1, the proposed container integrity analysis system using the rear side image of the container consists of an input module that cuts out only the rear area of the container with resizing it to a certain size, a parts-zone partitioning module for dividing each component region, a module for analysing integrity parameters for each divided parts-zone, and a module for finally calculating the entire degree of integrity respectively.

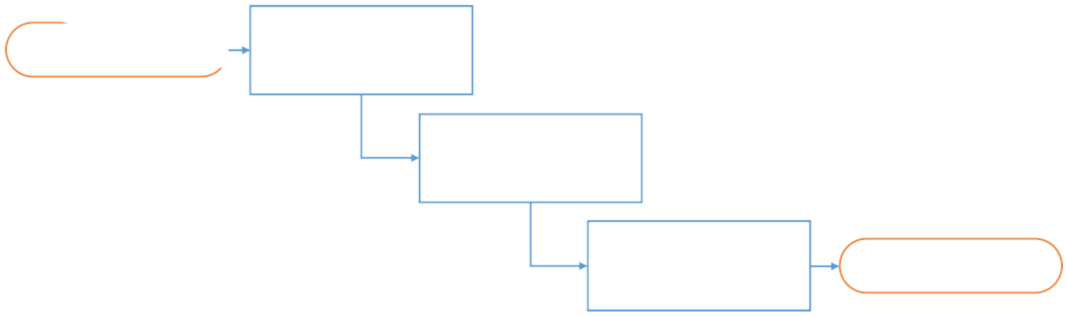

Figure 1. Block diagram of the proposed method

From the image of the container obtained by mobile devices, a square image is extracted by perspective transformation using four corner vertexes of the container area extracted with a manual or semi-automatic method as shown in Figure 2.

Figure 2. Rear side image extraction and size normalization

In order to minimize the influence between each accessory part in analysis, the input image is divided into parts-zone, each of them is analyzed separately, and the results are integrated to estimate the total degree of integrity. These processes will be described in more detail in the following sections.

2.1. Parts-zone partitioning

In analyzing the damage to the container through the general image processing techniques, various shapes of parts in the container may be mistaken for damage factors, which may affect the accuracy of the analysis. In order to solve this problem, the container image is divided into the areas of parts as analytic units named parts-zones to calculate the integrity parameters (contamination score, decrepitude score, locking score, etc.) by specialized algorithms for each areas. To do this, zone grids are first set up to divide the rear side image of the container into zone areas. The zone grids are lines to divide in which the relative positions are predefined based on a container standard specification template to distinguish each parts area in the size-normalized image as shown in the left of Figure 3. At this time, if the zone grids do not exactly match the container image due to the camera direction or distortion, an automatic adjustment function using the matching method of the LBP (Local Binary Pattern) mask may be performed to move the position of each zone grid within a certain range. After the zone has been determined by the zone grid, those are recombined to form the parts-zones as shown in Figure 3.Here, the parts-zones of door panel, door seal, and locking handle which are closely related to the life of the container, are selected as the parts-zone of interest for analysis.

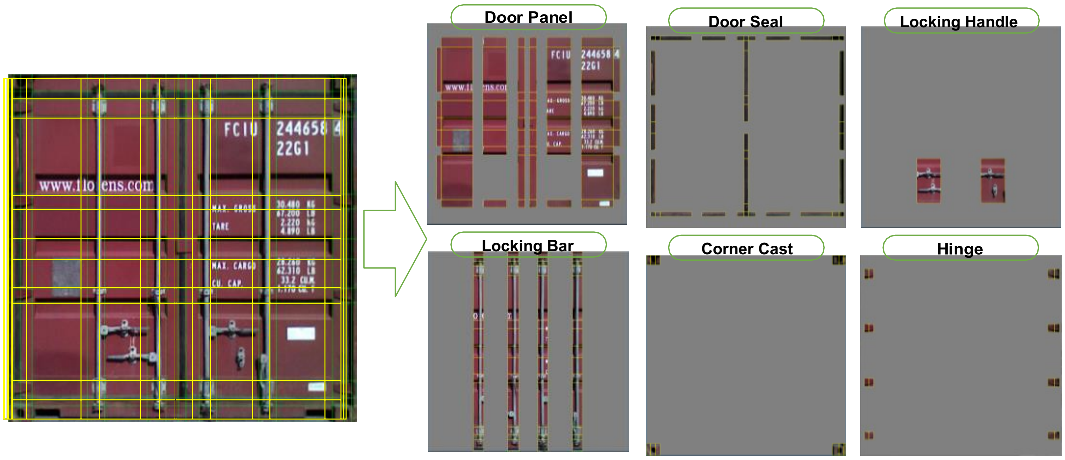

Figure 3. Parts-zone partitioning

2.2. Estimation of integrity parameters in each parts-zone

For each parts-zone, the integrity parameters are defined according to the major damage types expected in it. The contamination score for the door panel, the decrepitude score for the door seal, and the locking score for the locking handle are defined and calculated as these parameters. To compute these values, we applied a specific procedure for each parts-zone by combining color, edge, and frequency analysis methods properly as follows.

First, the contamination analysis procedure of the door panel is shown in Figure 4. The hue channel is extracted from the parts-zone of the door panel and the standard deviations of each zone in the parts-zone are calculated. If this value is above a certain threshold, it can be said that the zone contains contamination. The total contamination score of the door panel is calculated as a weighted average of the standard deviations multiplied by the size of each zone. Because various labels such as symbols or characters may act as noise components, the label masking step which extracts and removes the label area using thresholding and morphological operations of the gray image is performed.

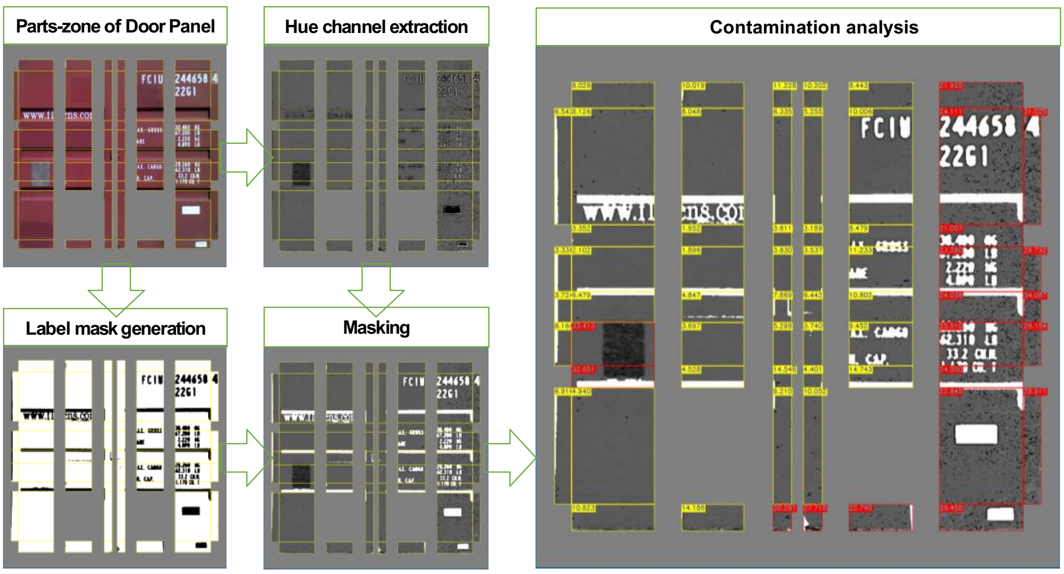

Figure 4. Integrity analysis for each parts-zone (I): Contamination score of door panel

Second, the decrepitude analysis procedure for the door seal as shown in Figure 5, uses the intensity channel extracted from the parts-zone image of the door seal. Through frequency analysis of the intensity image, the noise values of each zone constituting the parts-zone are obtained. The weighted average of the standard deviation with respect to the area size is calculated as the decrepitude score of the door seal.

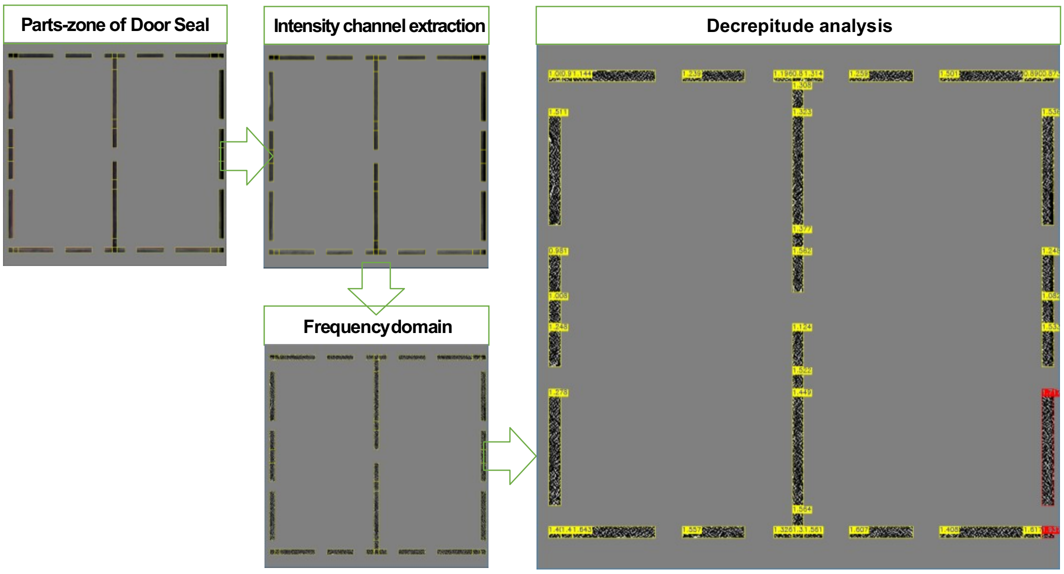

Figure 5. Integrity analysis for each parts-zone (II): Decrepitude score of door seal

Finally, Figure 6 shows the procedure for analyzing the locking score that indicates whether the locking handles are properly locked. If the Locking Handle is in the normal locked state, it is arranged in the horizontal direction. Therefore, we can obtain the locking score by extracting the horizontal edge components in the parts-zone of locking handle, performing appropriate noise removal, and calculating the average intensity of the edge.

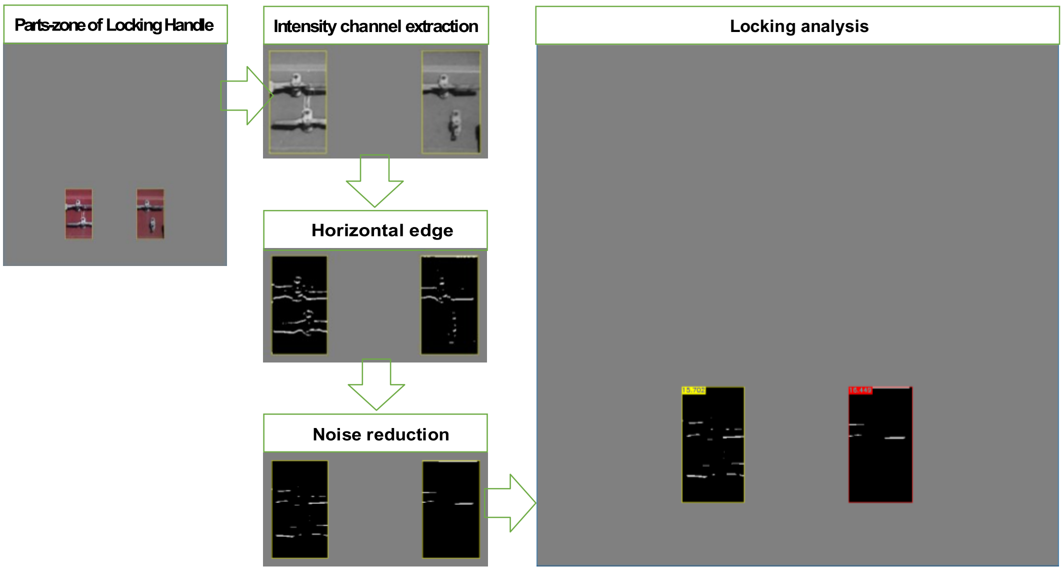

Figure 6. Integrity analysis for each parts-zone (III): Locking score of locking handle

2.3. Calculation of total degree of integrity

Through the procedures described above, result images showing the locations of the zones in which the damage exceeds a certain criterion are provided to the user, and the degree of integrity for the entire container is finally calculated by the weighted sum of the integrity parameter values from each parts-zone. If the degree of integrity does not meet a certain threshold, we can decide that this container is damaged enough to need repair.

3. EXPERIMENTAL RESULTS

Table 1 shows the results of the integrity analysis by proposed method for the six sample container images shown in Figure 7.

(a) ID-CON1 (b) ID-CON2 (c) ID-CON3 (d) ID-CON4 (e) ID-CON5

Figure 7. Sample images used in container integrity analysis

The contamination score of door panel (CDP), decrepitude score of door seal (DDS), and locking score of locking handle (LLH) as the integrity parameters for each rear side image of container had been calculated and the total degree of integrity (DOI) had been calculated by weighted sum of them. In some case, the CDP had been inaccurate due to the lighting conditions such as sunlight reflection on the door panel at the time of photographing, but the reasonable total DOI had been obtained by adjusting the weights.

Table 1. Results of integrity analysis with the sample images

Container ID	CON1	CON2	CON3	CON4	CON5
CDP	97.4	86.6	83.4	83.6	95.3
DDS	92.2	83.6	80.9	79.6	79.2
LLH	100.0	75.0	75.0	50.0	0.0
Total DOI	95.3	82.8	81.3	74.9	68.2

4. CONCLUSIONS

The container integrity analysis system proposed in this paper had divided the rear side image of the container photographed using a mobile camera into predefined parts-zones based on the container standard specification and applied an independent image processing algorithm for each parts-zone to measure the integrity parameters related to the container life. It then had calculated the degree of integrity for the entire container with these parameters.

The proposed system is inexpensive because it uses only the camera of the mobile device instead of additional expensive equipment. In addition, when run concurrently with a container management ledger computerization system, it is possible to provide more objective container integrity analysis results to stakeholders through photography alone without additional processes.

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