A New Approach Based on Image Processing for Detection of Wear of Guide-Rail Surface in Elevator Systems

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***Abstract*— In this study, a system based on image processing has been developed in order to prevent wear on guide-rail surface in elevators. In the proposed method, real-time condition monitoring is performed by cameras using built-in system. The images of elevator guide-rail surface are captured via four digital cameras fixed onto elevator cab. The image-processing methods are applied on the images captured by cameras and hence the wears on the surface of guide-rails are detected. The surface of guide-rail is firstly detected in the proposed method. Then, image segmentation and mathematical morphology are applied on the image of guide-rail surface and the wears on the surface of rail are detected. The failure extent of the wear failures detected are calculated. By processing the images captured by four cameras during movement of elevator, the results for surface of guide-rails are obtained. Using these results, reporting is performed. An elevator prototype has been created in order to carry out tests for development of the proposed method. The tests have been conducted by fixing the built-in system and cameras onto this elevator prototype. It is considerably advantageous to detect the failures on elevator guide-rails through image-processing methods. Following a literature review, it is seen that the proposed method is a new approach.**

***Keywords*— Elevator Systems, Fault Detection, Image Processing, Image Segmentation**

I. INTRODUCTION

Elevators ensure transportation of people inside buildings and increase their life quality. High-rise buildings whose number is increasingly going up today has one or more elevator cabs to provide vertical transportation. A great number of people use elevators in many buildings such as business centres, hotels, hospitals and shopping centres daily. It is highly essential for the elevators used by many people daily to operate constantly. In the event of sudden failure of elevators during operation, people inside them face with a tough situation. Also, people have difficulty during the maintenance-repair period of elevators. Elevator system has counterweight system in order to balance the weight of elevator cab. A guide-rail system has been developed to limit the movements of elevator cab and counterweights on horizontal axis. When an elevator system is operational, cab and counterweight system move reversely. The common failures in elevators are usually seen in the components such as elevator guide-rail system, ropes and motors.

Today, when we take multi-storey buildings as an example, the fact that the elevator becomes out of service negatively affects the life of users and reduces the quality of life. In this study, it is aimed to repair the small failures that may occur in the elevator line without causing major failures through early detection. Thus, elevator companies will bring quality service to the elevator systems by gaining customer satisfaction. A elevator company with such a system will be preferred more by its customers. In this way, the fact that users are stuck in the elevator cages and the system becomes out of service will be prevented by eliminating the failures that may occur suddenly in elevators.

Today, most of the multi-storey buildings have elevator systems. Elevator systems are excessively used in the daily life. Elevators are used not only in buildings but also in dangerous places such as mines. In this study, a system has been proposed for the early detection of failures that may occur in the rail line, which is the most important component of the elevator. In the proposed system, it is aimed to produce accurate results by using digital cameras with image processing techniques without being affected by the environmental conditions. Elevator rail is fixed to the elevator shaft and is a unit which facilitates movement of the elevator. In the elevator system, the guide rails are used for the purposes of guiding the cage and counter weight separately in the vertical movements, minimizing its horizontal movements, protecting the vertical directions of the cage and counter weight and preventing its rotation. In this study, methods have been developed for the early detection of failures that may occur in the rails during the movement of the elevator cage.

The general structure showing the sample elevator system is given in Figure 1.

It is seen that similar studies are not available when a literature review is performed for the proposed method. When national theses are analyzed, we see how important the elevator guide rails are [1-4]. In the master's thesis, Serhat [1] carried out a thesis study about the stress analysis of guide rail consoles by mentioning the importance of the elevator guide rails. When we analyze the studies which have been carried out until today, studies have usually been carried out by elevator control and elevator component analysis [5].

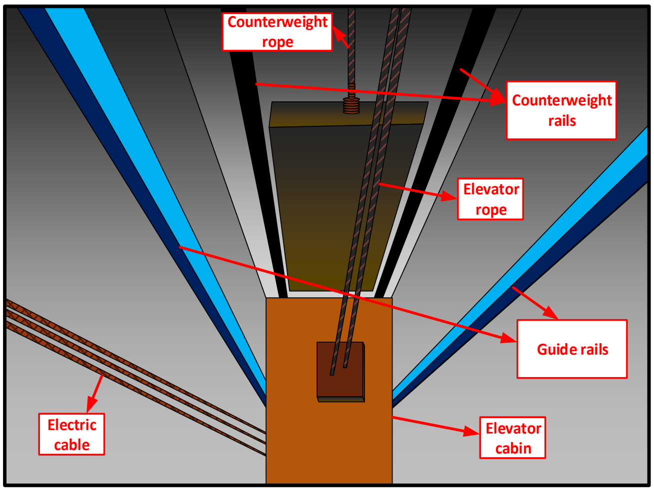


Fig. 1 The general structure showing the elevator system

Landaluze et al. [6] proposed the active noise control application for the elevator cages. They received results from the proposed algorithms by creating a sample experimental environment. Peiliang et al. [7] proposed wavelet packet algorithm and fuzzy neural network based methods for the elevator brake systems. The proposed algorithms were applied for the different failures that occur in elevators. As a result of the experimental studies, successful results were achieved for the detection of the elevator braking failures. Zhang et al.[8] proposed a method based on failure detection in elevators. They created an information system for the failure events by explaining the elevator door failures. Zeng et al. [9] developed a elevator door control algorithm based on image processing. They created a system with a micro processor having camera on it, and they used it in the control operations of the elevator doors. Zhao et al. [10] carried out a study for detecting the failure in the elevator systems. They proposed a method for the detection of the failures by explaining the failures occurring in the elevator systems and the reasons for the emergence of these failures. Jiancan et al. [11] proposed a signal processing-based failure detection method for the detection of the failures in elevator machines. They performed failure detection by applying spectrum-based methods to the signals received from the elevator system. Hu et al. [12] developed a real-time knowledge-based detection system by using PLC controlled production systems. In the thesis study, Yimou [13] conducted elevator inspection and market research. Yimou developed a system for measuring the inspection and quality of the elevators in Deyang, China. In addition, various studies have been carried out in the elevator systems such as quality control, failure detection, inspection and condition monitoring. [14,15].

When the websites of the major elevator companies such as ThyssenKrıpp, Kleemann, Otis, Kone and Schindler as well as the scientific studies in the literature were analyzed, it was seen that studies similar business idea were not available. When the existing studies in the literature are analyzed it is seen that the failure detection, control and condition monitoring methods are very important in the elevator systems. In this study, failure detection is performed by image processing techniques by developing much more different methods than the literature.

II. Proposed Method

In the studies carried out in recent years, about 152 thousand elevators have been inspected and nearly 63% of these elevators could not pass the quality level. These types of elevators often fail while using, endanger the life of users and lead to the disruption of their daily life. In the elevators used in hospitals, the lives of emergency patients are put at risk as a result of the failures that may occur while handling emergency patients. Besides, the failure of the elevators used in large businesses such as mines leads to disruption of the works and the people's lives are put at risk [16,17]. Early detection of the failures that occur in the elevators is very important to avoid such problems. In the proposed method, it is aimed to reduce the maintenance and repair costs by condition monitoring system, to prevent the major failures that may occur and to eliminate the user victimization. In addition, it is aimed to ensure energy saving by preventing the frictions that may occur in the rails as a result of monitoring the rails structures in the elevator lines by cameras. Sample images for the elevators rails are presented in Figure 2.

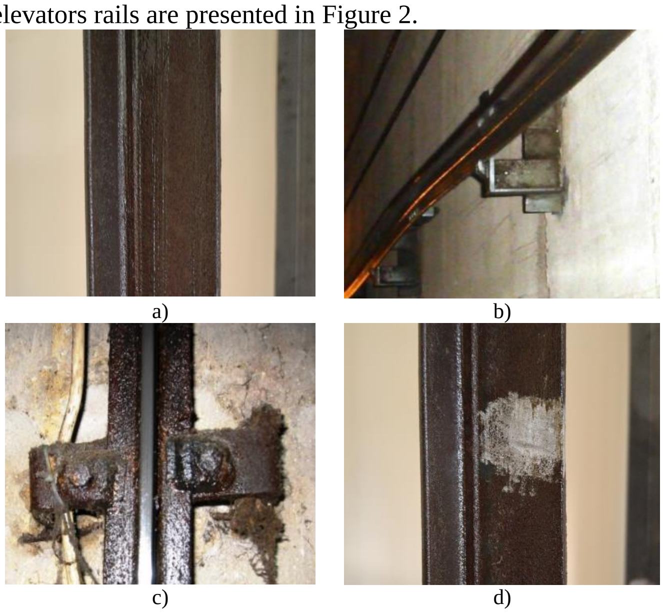


Fig. 2 Sample elevator rail images a) Robust rail image b) Curved rail image c) Rusty rail image d) Worn rail image

The robust, curved, rusty and worn rail image samples are presented in Figure 2. In this study, the detection of the failed parts of the worn ray images is performed. A sample elevator prototype was formed to detect the failed parts by image processing. The cameras were fixed on the elevator cage to monitor the rails on this prototype. The cameras fixed on the elevator cage are seen in Figure 3.

The images were taken by placing 4 cameras on the elevator cage as in Figure 3. The wear failures that occur on the elevator rails are detected by applying the proposed method on the image taken. A general flow chart of the proposed method is presented in Figure 4.

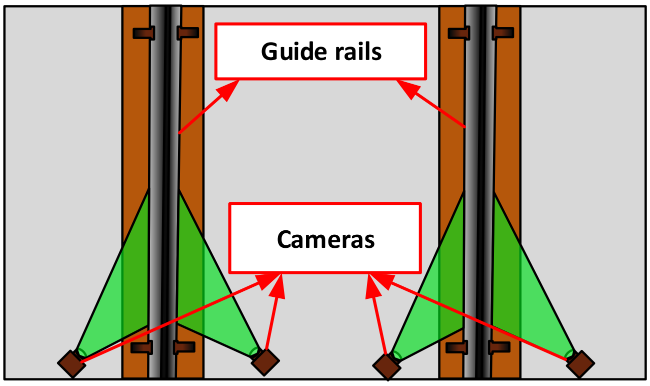


Fig. 3 Cameras fixed on the elevator cage

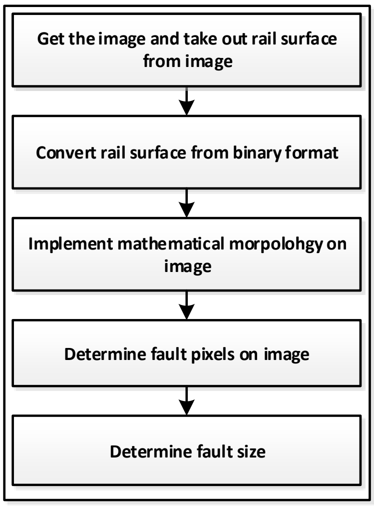


Fig. 4 Flow chart of the Proposed Method

The flow chart of the proposed method is seen in Figure 4. Firstly, the rail surface is extracted as preprocessing on the image taken from the camera. A section with a size of 480x200 is taken from the image taken in 480x640 size. This section taken involves the rail surface image. The rail surfaces represent the same pixels on the continuous image because the cameras are fixed over the elevator cage. Therefore, the pixels belonging to rail surface are extracted in 480x200 size from the image. The obtained RGB rail surface image is transformed into gray format and then binary format [18,19]. The image was transformed into binary format by using a specific threshold value. This threshold value was determined through the tests performed. The opening operation was performed as the mathematical morphology operation on the binary image. The mathematical expressions of the basic binary morphological operations are defined in equations 1,2,3 and 4 [20].

$$X \oplus B = \{p \in Z^2 : p = x + b, x \in X, b \in B\} \text{(dilation)} \quad (1)$$

$$X \Theta B = \{p \in Z^2 : p + b \in X, \forall b \in B\} \text{(erosion)} \quad (2)$$

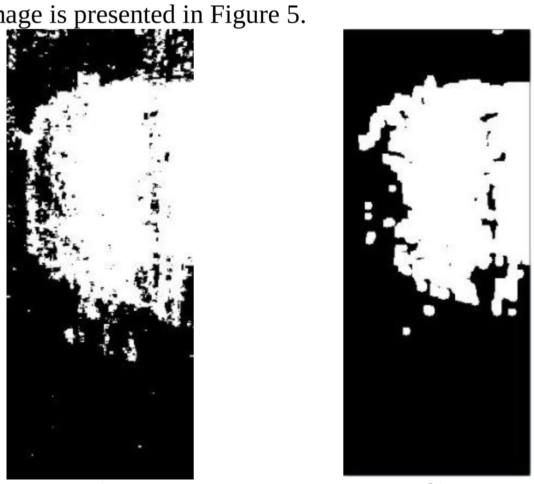
$$X \circ B = (X \Theta B) \oplus B (opening) \quad (3)$$

$$X \bullet B = (X \oplus B) \Theta B (clo\sin g) \quad (4)$$

The opening operation is obtained as a result of applying the dilation processing right after the erosion processing on the image. The objects within the image and the gaps between objects are cleaned according to the size of the structural element. The mask matrix used for the opening operation in the proposed method is presented in equation 5 [20].

$$\begin{bmatrix} 0 & 0 & 1 & 0 & 0 \\ 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 \\ 0 & 0 & 1 & 0 & 0 \end{bmatrix} \quad (5)$$

The opening operation was performed using equation 5. The realization of the opening operation on a sample elevator rail image is presented in Figure 5.



a) b)

Fig. 5 Application of the opening operation on the sample image a) Normal image b) The image administered with opening operation

The image in Figure 5.b was obtained by applying the opening operation to the normal image in Figure 5.a. In Figure 5.b, it is seen that small asperities on the rail surface were disappeared and the real failures appeared more clearly. After the opening operation, the failure detection and the size of the failure are estimated by taking into account the number of white pixels on the image. The code particle given in Figure 6 is used for the estimation of the failure detection and the size of the failure.

```
if whitepixels < 3000:
    print "HEALTLY"
else:
    print "FAULT RATE= %.2f " %(whitepixels/( 480*200 / 100))
```

Fig. 6 The code particle used for failure detection and the size of the failure

III. Experimental Results

Raspbbery pi card having the features of "Broadcom BCM2836 ARMv7 Quad Core SOC (Quad-Core), 900 MHz processor speed and 1 GB RAM" was used in this study. The image processing was performed with "OpenCV" libraries by using "python" programming language on the Raspberry pi card. In addition, 4 cameras with 24 FPS speed were used to take the images. First of all, an experimental setup was developed to take the images and perform the test procedure. The developed experimental setup is presented in Figure 7.

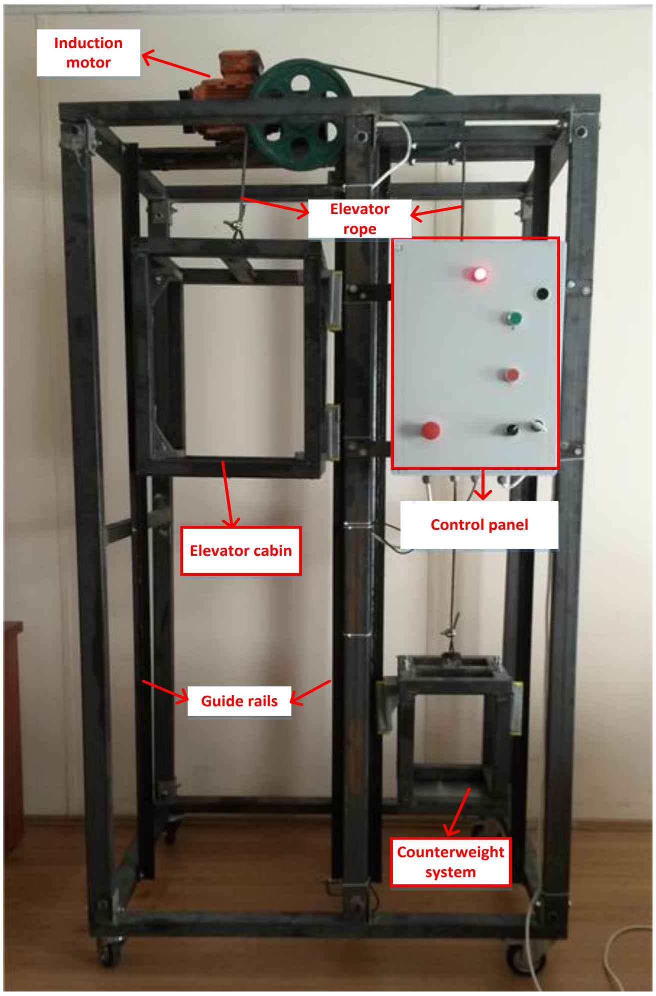


Fig. 7 Development of the experimental setup

A system which was similar to a normal elevator structure was developed in Figure 7. This elevator structure has rails, ropes, elevator cage, counter weight system, control panel, asynchronous motor and sensors. The cameras were fixed over the elevator cage to take the images in the developed experimental setup as shown in Figure 8.

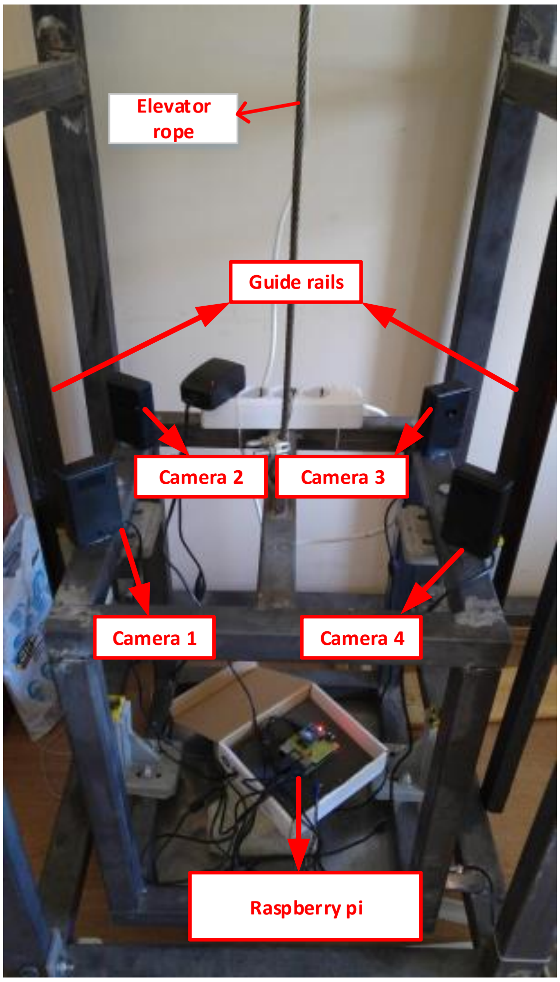
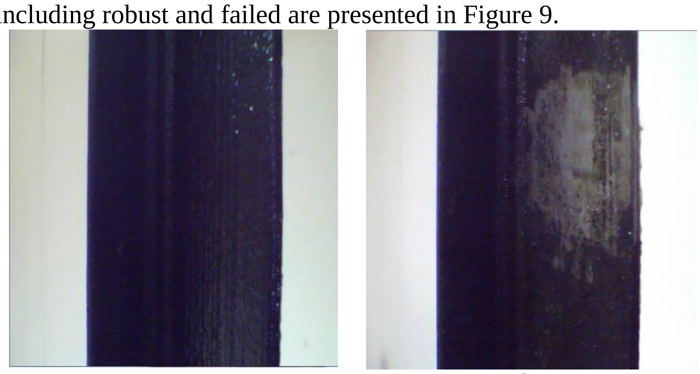


Fig. 8 Fixing of the cameras and the preparation of the test environment

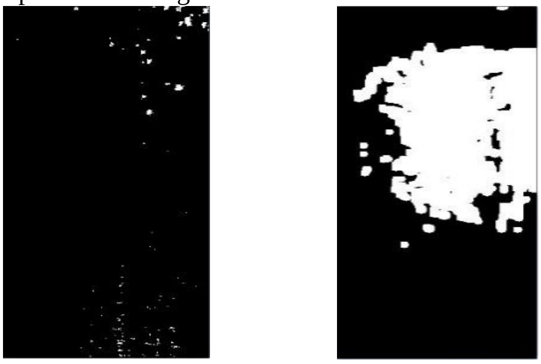
As it is seen in Figure 8, the images are taken from the cameras fixed over the elevator cage. The erosion failures that occur on the rail surface are detected by applying the proposed method on the images taken. Two rail surface images including robust and failed are presented in Figure 9.



a) b)

Fig. 9 Sample rail surface image a) Robust rail surface image b) Failed rail surface image

The robust and failed rail surface images are presented in Figure 9. The proposed method was applied to the robust rail surface image in Figure 9.a, and the obtained result is presented in Figure 10.a. The proposed method was applied to the failed rail surface image in Figure 9.b, and the obtained result is presented in Figure 10.b.



a) b)

Fig. 10 Application of the proposed method to the rail surface image a) Robust rail surface image b) Failed rail surface image

In Figure 10.a, it is seen that the rail surface is robust and there is not any erosion failure. In Figure 10.b, it is seen that there is an erosion failure. The proposed method was tested for 4 cameras and the erosion failures on the rail surface were detected. The speed of the developed elevator prototype is about 0.60 m/sec. When the speed of the elevator was taken into account, the real time operation of the proposed method was evaluated as appropriate and it was seen that it was working successfully as a result of the tests performed. The real-time rail surface is monitored in the "Python Sheel" environment while the elevator is working. As in Figure 11, the size of the failure is monitored by performing failure detection in the "Python Sheel" environment while the elevator is working on a sample rail with erosion failure on the rail surface.

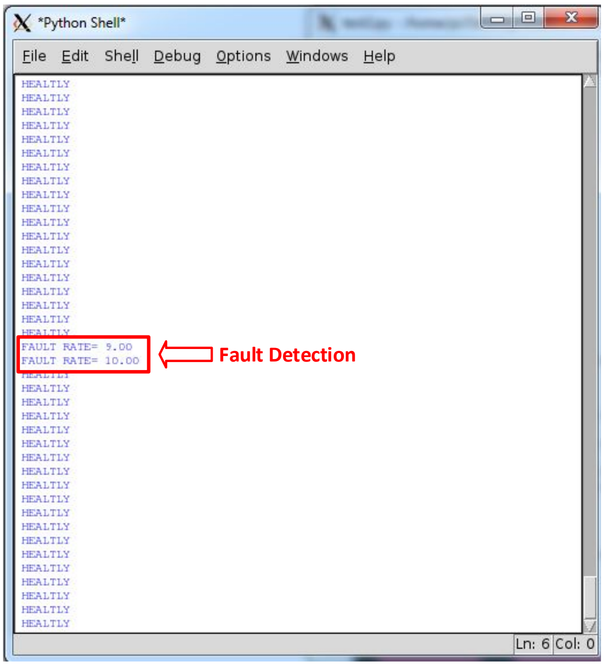


Fig. 11 Real-time operation of the proposed method and its monitoring in the "Python Sheel" environment

IV. Conclusions

Elevator systems have become an indispensable part of people in our day. Elevators are the means of transport which are beneficial to people regarding the transportation of loads and people. The fact that elevators are failed while working is one of the undesirable events. In particular, the fact that elevators are failed while people are using them reduces the quality of life. A new image processing-based method for the prevention of the elevator failures has been proposed in this study. The rail surface erosion failures that may occur on the rails, one of the critical components in the elevator systems, are detected. In this study, a sample elevator system was created and 4 cameras were fixed on the elevator cage. Whether the rail surface was robust or failed was detected and the size of the failure was estimated if it was failed, by applying the proposed method on the images taken from the cameras. When the proposed method is compared with the studies in the literature, it is seen that it is a new study and it can operate in real time. This study provides a basis for the future studies, and it is aimed to detect the erosion, cracking, warping and corrosion on the elevator rails in the future studies.

Acknowledgment

This study was supported under the Teknogirisim project of the Ministry of Science, Industry and Technology. Project No: 0684.TGSD.2015.

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