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Extracting LED Features from Monitoring Videos in Data Centers

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Abstract: The paper presents a method for LED feature extraction from data center monitoring video. The infrastructures in the data center can be automatically monitored by its LED indicator lamps. The LED feature extraction is the core process to achieve automatic monitoring. Feature data of LED flickering and color are extracted with the proposed method. Detection algorithms will be explained with its details.

Keywords: Data center devices, LED detection, Color estimation, Flickering detection

1. Introduction

The digitalization and outbreak of recent pandemic situation putting many of the traditional on-site services into online services. As the online services grow rapidly, demands of the data centers are continuously increasing. To bear with globally increasing demands of data center, modern data centers need to apply more efficient methods for the operation. One of the most time-consuming tasks of data center management is failure detection of its infrastructures. The sensor-based monitoring methods have been proposed to monitor irregularities of data center devices [1], [2].

2. Background

The main large room within in data center buildings, which is called the machine room, keeps electric devices fully functional at any time around the year where temperature, humidity and measurements are controlled by secure management. There are approximately 2 meters tall metal racks placed in organized rows in the machine room. Each metal rack has multiple device storage units from bottom to top. So electric devices in the data center is kept as stacks of devices. Fig.1 shows the rack placements and devices in the machine room. As shown in the Fig. 1, there are multiple rack rows, and every row has multiple racks. Moreover, frontal side of the devices and mounted devices are visualized in Row 2. On the front side of the rack, we can also observe different types, colors and size of device's Light-emitting Diodes (LEDs).

The data center management mostly prefers to install motion sensor-based room lights in the machine room. So, the room lights only turn on when a daily maintenance or inspection is operated, otherwise the room operates in dark environment to minimize energy usage in the data center.

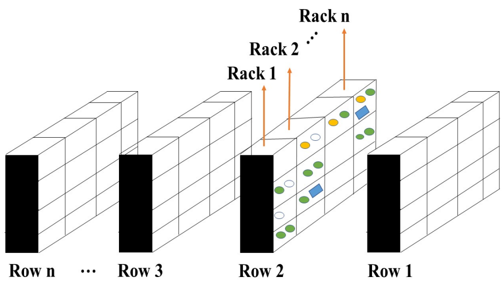

Figure 1. An illustration of the data center rack placement.

In order to detect failures in the machine room, many data centers employ a visual inspection method due to its reliability based on device-to-device inspection. Generally, data center devices have single or multiple LED indicators that represent power, storage, memory or network status. A sample of LED image taken in a data center is shown in Fig. 2. The frontal panel of two devices are captured in two different environments. Fig. 2. (a) represents the device's LEDs in the machine room without lighting. Fig. 2. (b) shows the view of devices during the daylight. The LED lamps have not only the same type and color, but have different types, colors and characteristics.

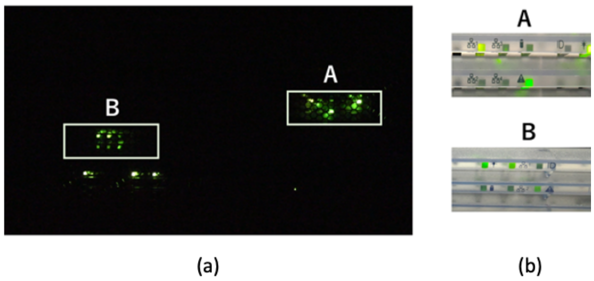

Figure 2. Comparison of frontal side views of same devices in different lighting condition

The data center operator visually inspects each LED multiple times per day. In the visual monitoring method, illusions, flickering frequencies and colors of LEDs will be inspected by the human operators. Typically, frequency changes in flickering LEDs, color changes such as green LED light switched to orange or red color considered as possible irregularity in the device. The data center management currently faces challenges of the human visual inspection method. Longer period of inspection and human-related inspection errors are considered as the biggest challenge of the data center visual inspection method.

An automated systems has proven its efficiency in many fields such as defect detection, quality management and field

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surveillance. Additionally, rapid improvement of hardware devices is enabling more possibilities to convert traditional methods to machine-supported automated systems.

The motivation of this research is to automate the data center human-visual monitoring system using camera-aided technology. To develop an automated monitoring system, it requires data collection, feature extraction and analysis. For the data collection, we cooperated with local data center company to collect the experimental video captures of devices in the machine room.

This paper presents proposed a method for extracting LED features from the monitoring videos captured in the data center machine room.

3. Related Works

Tarkowski *et al*. [2] proposed an algorithm that detects blinking LEDs on the scene, which is one of the very few studies related to detection of LEDs in the data center environment. An experiment of this study conducted in the environment of large university hall with sufficient lighting. The proposed algorithm used background subtraction technique with the Gaussian Mixture model. Comparing to the traditional object detection methods, Tarkowski's method offered computation time efficiency in LED detection on the scene.

4. LED Features

According to the data center inspection manual, most LEDs are monitored by the core features of its illumination, flickering or colors. Including the manual into our research, we focus on extracting core features to evaluate the automatic methods with human work.

4.1 Region of LED

Practically, it is more convenient and efficient to monitor multiple devices at the same time. To locate every LEDs on the frame images is one of the main challenges in our research.

4.2 Flickering of LED

Assuming that single LED is observed from the recording, the LED shows characteristics of either stable illumination or flickering. Fig. 3 shows the illustration of the LED and flickering. A video recording consists of sequential frame images. If there is

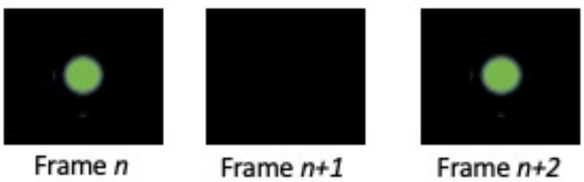

Figure 3. Circle shaped green object represents the LED.

a flickering of the target LED, we will observe only dark region as *Frame n+1* in the Fig. 3. So, the LED illumination changes such as fading out and reappearing are considered as LED flickering.

4.3 Color of LED

LED lamps used in the electric devices can have different types and colors. Also, LED can change its color when there is an irregularity situation in the devices as shown in the Fig. 4.

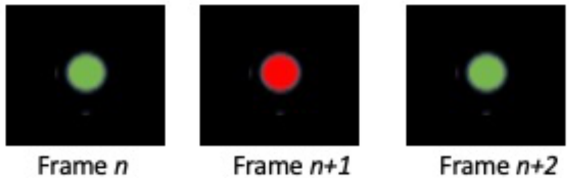

Figure 4. An illustration of LED color change within frames.

5. LED Features Extraction

5.1 Overview

An overview of the proposed LED feature extraction flow is shown in Fig. 5. Firstly, a video collection method is proposed. After the collection of video data, the LED region is detected. Based on the extracted LED region data, features of the LED states (ON or OFF state) and color are extracted. Details of each method are discussed in the following subsections.

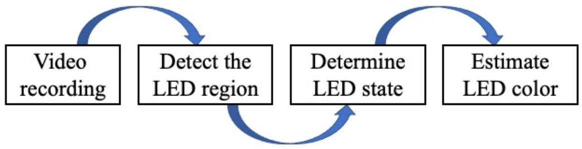

Figure 5. The LED feature extraction flow

5.2 Video recording

Considering to not interrupting daily maintenance or other works in the machine room, an appropriate position of taking a video recording is fixing monitoring camera on top of the opposite rack where the target devices are observed entirely. A camera setup is shown in the Fig. 6. The distance and angle between the camera and the monitoring devices are fixed on top of the opposite rack.

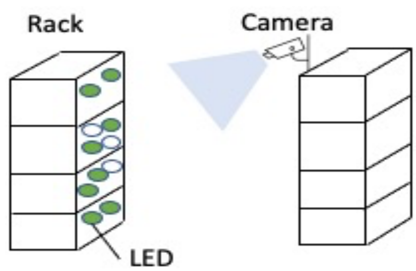

Figure 6. An illustration of camera setup

5.3 LED region detection

LED region detection on a frame is the basis process of LED feature extraction. The proposed method loads a frame from recording at a time. The algorithm of LED region detection is described as shown in the Fig.7. A frame from video recording which is in RGB color space is converted to grayscale image. Then, binary thresholding and background subtraction with Gaussian Mixture Model (GMM) [3] methods are applied to the grayscale image separately. The binary thresholding method is used to detect the stable illuminating LED candidate regions. With the background subtraction method candidate regions of flickering

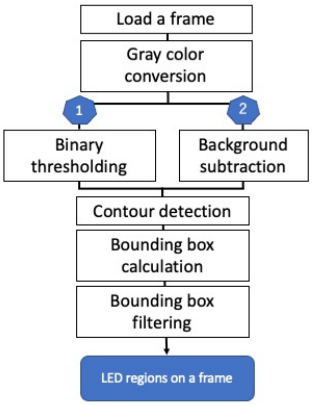

Figure 7. The LED region detection flow

LED are detected. Those candidate regions are also called blobs. To estimate appropriate region of the LED, we apply contour detection and bounding box calculations. At the end, less than 2 by 2 pixel sized bounding boxes will be removed due to prevent from possible noises from recording. Results of LED region detection are kept for the next feature extraction.

5.4 Determining LED flickering feature

In order to determine LED flickering, LED region data which are accumulated in the previous method are referenced. The overlapping bounding boxes of LED region data are merged to single region. So, the absolute position of LEDs is estimated. Then the LED region box and absolute LED positions are compared to determine LED illumination states. We assume that LED illumination has only two states which are ON (1) and OFF (2). The LED illumination state sequences can be collected through iterating on frame images. An example of the single LED state sequence is shown in the Def. (1). An *L* represent LED that is currently observed. The values of 0 and 1's show that illumination states of the LED within the frame sequences. One or more state value change in LED state sequence is considered as flickering of LED illumination.

$$L = [\ 1\ 0\ 1\ 0\ 1\ 1\ 1\ \ldots.] \qquad \text{Def. (1)}$$

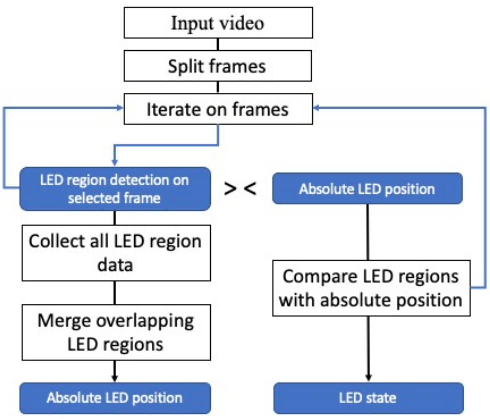

Figure 8. The LED flickering detection flow

5.5 Determining LED color feature

The absolute position of each LED that is estimated in the previous step represents Region of Interest (ROI) of monitoring LEDs. So, we convert those ROI to HSV color space to apply color estimation [4]. Then, we calculate an average pixel value of only the hue channel as it defines more characteristics of color. Def. (2) shows the pre-defined range values to determine LED color based on the average pixel value. The color value ranges are defined heuristically with the observation of frame images of LED and HSV value chart.

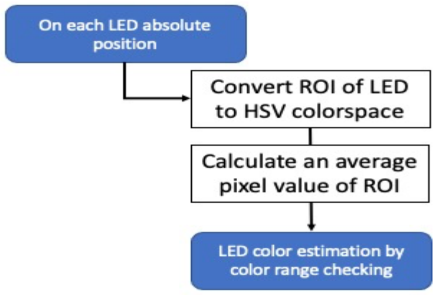

Figure 9. The LED color detection flow

$$\begin{cases} Red \quad if\ avg(p) > 161\ and\ avg(p) < 179 \\ Green \quad if\ avg(p) > 25\ and\ avg(p) < 102 \\ Blue \quad if\ avg(p) < 103\ and\ avg(p) < 126 \end{cases} \qquad \text{Def. (2)}$$

6. Experiment and Results

The proposed method has been implemented with C++ programming language and OpenCV 4 image processing library. A real data center monitoring video recording is used for the evaluation of the proposed method. In the experiment, a video was captured at 15 frames per second (fps) and 15 seconds long. The absolute position of LEDs detected on the experimental video is shown in Fig. 10. Fig. 11 shows that LED flickering and color feature detection results. In Fig. 11, the column of "Id" represents index of the LED. In the column of "Sequence", "点滅 – flickering", "点灯 – stable illumination" notations are used. In column of "Color", "['G'] - Green, ['B'] - Blue, ['R'] - Red, ['色変化'] – Color change if color has changed within frames" notations are used to represent results.

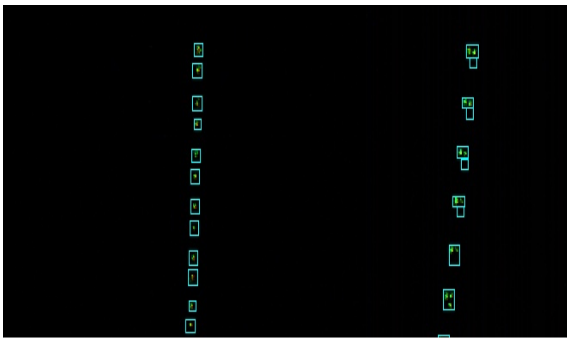

Figure 10. A part of the detection result has shown in this figure due to smaller size of LEDs.

Id	Sequence	Color
0	点灯	["G"]
1	点灯	色変化
2	点灯	色変化
3	点灯	色変化
4	点灯	色変化

Figure 11. A sample results of LED feature detection.

7. Conclusion

In this paper, we proposed a method to extract the flickering and color features of LEDs from the data center monitoring video data. Experimental data were collected in a real-world data center environment. Coding implementation has been done accordingly the proposed method description. The proposed method was evaluated with the experimental data and the results have proven its availability for LED features extraction.

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