Gas Leakage Detection Using Thermal Imaging Technique

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Abstract — Gas leakage is one of the hazards that can cause major incidents to human injuries, fires as well as high impact on economic. To avoid such situation, a preventive inspection is paramount important. Since gas leakage is unseen by naked eyes due to the energy that are emitted by gas are too small to simulate by eyes, thermal imaging technology is used to detect and evaluate the severity level of the leakage. This paper presents a method for detecting gas leak using infrared image analysis. Through an image filtering technique, the target region of interests is enhanced and segmented to extract the leaky regions. The image feature is extracted to identify the leakage. From the experimental result, it shows that this system is effective in detecting the presence of gas leakage in real industrial problem.

Keywords—infrared image; gas leakage; image processing;

I. INTRODUCTION

Thermal camera is one of the tools that can be used as the inspection tools. This is an infrared technology that uses the principle of infrared radiation (IR) to measure the temperature and the radiant energy of the object. Detection of this thermal camera that has been developed in recent decades is a new type detection technology, and its main feature is non-contact measurement, not change the temperature distribution field of the measured object, to measure the temperature of moving objects and the charged objects, and with the advantage of wide temperature range, high sensitivity, fast response time, high precision, low power consumption, long life, easy operation, safe and reliable [1]. Since, the gas leakage cannot be seen by naked eyes, but can be read by thermal images, so the thermal camera is used to detect the gas leakage.

As we all already know, gas is the matters that are freely moving. Gas can exist in the liquid state or solid because it can be compressed within a high pressure. During the transportation operation, maybe some problem will happen, such as, pipeline leakage, the corrosion of the pipeline or anything else. Realize the dangerousness, an automated detection system has to be developed by which the gas leakage can be detected earlier and faster. Thermal camera is used in order to monitor the. This thermal camera produces an image to indicate the condition of the situation due to the change of the colour of the image.

This paper proposes a method of detecting gas leakage by analysing their thermal image. The remainder of this paper is organized as follows: Section II briefly review the related works of detecting gas leakage. The proposed method of this research is presented in Section III. Experimental results and discussions are given in Section IV and finally concluding remark appears in Section V.

II. RELATED WORK

Before the invention of sensor, gas leaks were detected by using human senses. However, with the advance technology nowadays, lots of sensors have been created in order to reduce hazards and health problems. There are a lot of gas sensors available in the market, but some of them very costly to be implemented. For example, the optic cable sensor can be used as the gas leak detection [2]. Although this technique has a very fast response, nevertheless, the installation cost is too high to be implemented. Besides, another sensor that is available in the market nowadays is soil monitoring. This type of sensor worked by dragging the instrument along with surface above the pipeline [3]. But this sensor cannot detect the leaks from the pipeline that are exposed. In addition, it's also because it need trace chemical that have to continuously add to the gas.

During the gas leak due to significant speed of the gas extension, the temperature of the pipe around the crack is rapidly cooling [4]. Compare to the normal temperature, the drop of temperature of the leak hole is according to expanding of the gas. This is because the frequency of the atomic collision of the gas is decreased. Recently, infrared imaging has been used in the oil and gas industry as a method to detect potential leakage in the pipeline, components and equipment [4]. Thermal imaging is the one of the accurate method of detection for the gas leakage [5]. This method is widely used for the gas leakage detection because the thermal image can detect the radiation of the gas pipeline by displaying the image on the thermal camera.

The algorithm of image processing, divided into three main parts which are pre-processing, Feature extraction and classification [6]. For leak classification, decision has to make whether the leak is present or not. The thermal imaging technique can be applied to detect breast cancer. Thermal imaging records skin temperature distribution of the body and thus, provides insight in thermal dysfunction associated with breast cancer and pain [7]. Besides, in surveillance, thermal image processing is used in monitoring and detection. According to a research paper, gas also can be detected by using a thermal image processing because every object will emit heat whether in the hottest or in the coolest situation. In the gas leakage, as long as the gas leak, it will emit heat.
III. METHODOLOGY

For this project, there are five stages of methodology which are data acquisition, image pre-processing, image processing, feature extraction and classification decision. Data acquisition is the process whereby how the data were acquired. In this step, the tools are used in order to get the data. Image pre-processing can be defined as the process that we want to enhance and improve the original image to be used in next process which called image processing. There are lots of image processing technique can be used in this step like edge detection, colour thresholding compression and so on. Image processing is an important stage in methodology because at this stage the image will be analysed and digitized in order to get the desired image. Generally, feature extraction is the process of creating features to be used in the classification. Classification process is the process to make decisions based on test and analysis done on the image.

A. Data Acquisition

For this project, data were acquired by using a thermal camera and save AVI (Audio Video Interleaved) file. Thermal camera used for this project is A615 FLIR type that has IR resolution 640 x 480 pixels. After recording the video of the gas situation, that video was converted into image in JPEG (Joint Photographic Experts Group) image format by using Matlab coding. The video was taken about 22 second and after converted with 1 frame per second the image was extracted to become 530 images.

Shown in Fig. 2 below are samples of three state of gas image after extracting using the Matlab code. There are three states of the leakages which are before leakage, during leakage and after leakage. As we can see, the gas leakage is clearly appeared. The colour of the surrounding change as the gas was released. Compared with digital camera, the changes of the surrounding colour cannot be seen. The hole of the leakage is also invisible, so that is the main reasons why the thermal camera is more preferred for this project compared to the normal digital camera.

![Figure 1. Methodology of the systems](image)

![Figure 2. Sample of thermal image (a) before leakage, (b) during leakage, (c) after leakage.](image)

B. Image Enhancement

Image enhancement is the process that lies on the image pre-processing steps. This step is important in order to remove noise from the original image because most of the original image are unclear and blurred. Through this process image becomes clearer in appearance compared to the original one. Fig. 3 shows the step of the image enhancement technique from an original image. Image (a) in (Fig. 3.3 (a)) is the original image of the gas leak which is in RGB format. Since, the RGB image consists of three colour arrays which are red, green and blue. So this colour arrays needs to be converted into grayscale as shown in Fig. 3 (b). Then the image is enhanced by image filtering and noise removing. The result of filtered image is given in Fig. 3 (c). There are several types of filter were tested in order to find the most suitable filter. However, the unshared filter was found to be the most suitable filter to be employed for all images.

![Figure 3. Steps of image enhancement (a) Original image, (b) Grayscale image, (c) Filtered image](image)

C. Image Thresholding

Referring to the image depicted in Fig. 4, the image (a) is the original image from the thermal camera. Image (b) is the filtered image that undergoes the rgb2gray process. Then, by using the threshold value that has been set, the coolest region of the image is detected (the blue colour) as shown Fig. 4(c). Then the image undergoes the binarization process to be easy in the analysis. Finally, classifications of the image are based on the pixel value in the eroded image (d). The figure below shows the result of the colour detection.

![Figure 4. Image thresholding (a) coolest region detected, (b) detected region](image)

The arrows show in Fig. 4 point the area that undergoes the thresholding process. The blue colours of the coolest region for the leakage are detected. After the coolest region was detected, the image is once again converted into a grayscale image in order to enhance the coolest region. Table I shows the summary of maximum and minimum histogram value from the three conditions of the image. Out of 530
images, three images were chosen. These digital image representations are actually based on this histogram value of these three images.

<table>
<thead>
<tr>
<th>Condition</th>
<th>Image No.</th>
<th>Red x</th>
<th>Red y</th>
<th>Blue x</th>
<th>Blue y</th>
<th>Green x</th>
<th>Green y</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before</td>
<td>1</td>
<td>225</td>
<td>16</td>
<td>40</td>
<td>19</td>
<td>68</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td></td>
<td>251</td>
<td>16</td>
<td>91</td>
<td>2</td>
<td>103</td>
<td>11</td>
</tr>
<tr>
<td>During</td>
<td>287</td>
<td>226</td>
<td>32</td>
<td>41</td>
<td>260</td>
<td>69</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td></td>
<td>248</td>
<td>88</td>
<td>31</td>
<td>103</td>
<td>114</td>
<td></td>
</tr>
<tr>
<td>After</td>
<td>483</td>
<td>210</td>
<td>18</td>
<td>32</td>
<td>13</td>
<td>44</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td></td>
<td>249</td>
<td>59</td>
<td>118</td>
<td>6</td>
<td>113</td>
<td>7</td>
</tr>
</tbody>
</table>

Next, the image was threshold using the threshold value that has been set. This threshold will detect the coolest region on this image that indicates the blue colour. Table II shows the threshold value in the digital image representation. In this thresholding process, the pixel value that is in the range in the Table II will be remain maintained, while the pixel value that's out of the range will set to 0. From this, the desired image region will appear.

<table>
<thead>
<tr>
<th>Colour</th>
<th>Digital image representation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Red</td>
<td>100-250</td>
</tr>
<tr>
<td>Green</td>
<td>10-160</td>
</tr>
<tr>
<td>Blue</td>
<td>90-210</td>
</tr>
</tbody>
</table>

For the normal condition image, a video is recorded using A615 thermal camera and then it was abstracted to be an image. Here, 100 images were abstracted using specific coding in MATLAB. Above are overall outputs of the normal condition image. A sample of thermal image has taken to test with the systems. After going through the process, there are not white region on the eroded image. Fig. 5 (a) shows the original image of the normal gaseous condition. First, the original image is converted to a grayscale image. The filtering process takes part. After that, the thresholding process, binarization process using im2bw also are applied, but there has no change to the image. The output of that image is not visible. So we can conclude that the gas leakage does not exist for this image.

Fig. 6 shows the process of colour detection one sample of abnormal condition image when the gas leakage detected. From the beginning, the region of interest (ROI) of the leakage point can be seen clearly using this thermal camera. Original image from Fig. 6 (a) is converted to the grayscale image and filtered by using ‘imfilter’ function to remove the noises. The filtered image yielded a better view leak region as shown in Fig. 6 (c). From this enhancement process the image was thresholded to get the coolest region. Then the image undergoes the binarization process to be easy in the analysis. The classifications of the image are based on the pixel value on the eroded image.

Figure 5. Overall output for normal condition. (a) Original image, (b) grayscale image, (c) filtered image, (d) coolest region detected, (e) Grayscale image of coolest region, (f) BW image, (g) BWfill image, (h) BWnobord image, (i) Erosion image

Figure 6. Overall output for abnormal condition. (a) Original image, (b) grayscale image, (c) filtered image, (d) coolest region detected, (e) Grayscale image of coolest region, (f) BW image, (g) BWfill image, (h) BWnobord image, (i) Erosion image

D. Feature Extraction and Decision

Feature extraction to be extracted in this process is the value of the eroded image which is in binary value. Based on it feature, the image will tell that the leakage happened or not. After getting coolest region of the image, the image needs to convert to binary to easy analysis. Finally, the
morphology technique was used in order to achieve the desired output. The closing and erosion operations are used. In this project, the image was classified based on the pixel value that we extract in the eroded image. The pixel values of the 530 erosion image of abnormal situation and 100 erosion images for normal situation is presented in Fig. 7.

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![Figure 7. Graph of gas leakage analysis](image)

This graph shows that gas leakage analysis that has been tested. From the graph, the x-axis of the graph is the number of image and y-axis of the graph is the number of pixels of erosion image. Roughly, image number 0 until 146, number pixel of the image is 0. Then, numbers of pixel start increase at the image 156 and above. This indicated that this system stated detecting the leakage and shows the warning at the image number 156. The higher number of pixels in this graph is 295 which in the image 432 and the lower pixel number are 6 at the image 154. The separation function chosen are y=16. This is because, the detection of gas leakage starts with that pixel number. If the pixel value less than 16, the leakage is not detected, but if the number pixel is bigger than 16, the leakage is detected. Therefore, the final threshold value for colour processing is presented in Table III.

<table>
<thead>
<tr>
<th>Situation</th>
<th>Pixel Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Leakage</td>
<td>&lt;16</td>
</tr>
<tr>
<td>Gas Leakage</td>
<td>&gt;16</td>
</tr>
</tbody>
</table>

This system was tested with two types of situation which is gas in normal situation and gas in an abnormal situation. For the normal situation, about 100 images were tested and the accuracy is shown in Fig. 8. From the pie chart above, 95% of the images are detected when tested with the systems and only 5% of the images are in error. There are 5 error image of this data. The error may be due to the unclear image during it is being captured. Although during the process the image has passed through the image enhancement process, but the noise is still there. Out of 530 images, 22 images represent 4% are error. 508 images represent 96% can read by the systems. Here, we can conclude that some error still happened to the systems weather it had been using normal condition gas or abnormal condition gas.

![Figure 8. Data accuracy of normal gas](image)

![Figure 9. Data accuracy of abnormal gas](image)

Fig. 10 shows the entire design of the GUI before any image is loaded. This part will explain about the way how the GUI runs for the user. There are four buttons on this GUI which are ‘Load’ button, ‘Stop’ button, ‘Reset’ button and ‘Close’ button. These buttons have their own function which is to load the image to be analysed, the stop button is used to stop the system or interrupt the system during the process, reset button is used to reset the system and the last is close button is to close the systems. Besides, this GUI also has three panels that show the result of the analysis. First is a thermal image panel. This panel will show the thermal image. Next is analysis panel. This panel shows the eroded image that the classification is applied. This panel only shows a black and white image. Lastly the condition panel show the result of the image that has been analysed. If the leakage is detected the result automatically show that leakage location.

<table>
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IV. RESULT AND ANALYSIS

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V. CONCLUSION

As the conclusion, the system successfully fulfils the objective. The system was designed by technique of image processing which are data acquisition, image pre-processing, image processing, feature extraction and classification. The system finally success to recognize two types of gas condition, which are normal and abnormal condition. This system is able to classify the situation when we need for maintenance. The warning given indicates that the situation is in danger. Further study is needed to achieve a clearer image, thus decreasing the error detection. The higher resolution of camera is needed if want to achieve higher
accuracy. The system can automatically detect the condition instantaneously without the need to bring to the laboratory. In addition, this system also can be used to detect any type of gas and can be applied in various types of the petrochemical industry.

![Figure 10. GUI when leakage detected](image)

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REFERENCES


