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DETECTION OF INDOOR AIR POLLUTION ON WET OR MOIST WALLS USING THERMAL IMAGE PROCESSING TECHNIQUE

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ABSTRACT

This paper presents a development of an automatic system that's able to detect indoor air thermal pollution automatically by using thermal image processing technique. This research was proposed to enable civilians to improve the quality of indoor air to ensure the building is well-ventilated and getting rid of air pollutants. Indoor air is more dangerous than outdoor air as civilians spend most of the time in indoor. 255 images are used in this simulation process whereby the images are divided into two categories. The first category has been classified consists of 178 images with the colour changes (pollution detected) while another 77 images showed with no colour changes (no pollution detected). Colour conversion, image enhancement and morphological operation were used in this research in order to process the desired output image. The accuracy of the system was measured for the detection of wet or moist wall that will affect the indoor air quality on polluted data shows 94.94%. While 100% accuracy was achieved for no wet or moist walls detected. The experiment results indicate that this proposed method able to detect indoor air thermal pollution on the differences of moisture area and the wet areas.

Keywords: thermal image, indoor air pollution, morphological analysis, image enhancement.

INTRODUCTION

Image processing analysis has been widely used in the last decade in many applications such as in agriculture engineering, face detection, electrical inspection, thermal imaging, biomedical and car driver assisted (Kamarul Hawari Ghazali, 2008; Kamarul Hawari Ghazali, 2008; Kamarul Hawari Ghazali, 2008; Asiegbu, 2012; Kamarul H. Ghazali, 2013; Sharmiza Kamaruddin, 2013; Ghazali, January 2014; Ahmed M. A. Haidar, January 2012; Kamarul Hawari Bin Ghazali, October 2011; Kamarul Hawari Ghazali, October 2011). All these applications using a vision system includes hardware and software components. Computer vision is a technology for acquiring, processing, analyzing as well as understand the input data which is the images provided to a computer. In the recent years, air pollution is becoming a general term that covers abroad range of contaminants in the atmosphere. The effects of air pollution have focused mainly on human health, but the attention is being directed to environmental quality as well. Air pollution can be classified into primary air pollutants and secondary air pollutants. Primary air pollutant is formed when pollutants are emitted directly into the air. An example of primary air pollution is the carbon monoxide from combustion. The chemical reactions that formed through the reactions in the atmosphere are one of the secondary air pollutants such as the formation of troposphere ozone. Beyond that, air pollution can be categorized into outdoor air pollution and indoor air pollution.

Outdoor air pollution, mainly occurs due to human actions and natural sources. The air pollution that results based on human activities includes the emissions from industries and manufacturing activities such as smoke or fumes that erected from the factories into the air. Besides that, it includes the household and farming chemicals like overused the insect or pest killers as well as the burning of fossil fuels such as the fumes from car exhausts. Generally, indoor air pollution refers to gas or air particles released into a home, business or school by indoor sources. It can be affected by ventilation, heat and humidity. Since the public spends most of the time in indoor areas, in fact the indoor air is more dangerous and toxic than outdoor air (Montgomery and Kalman 1989). Averagely, the survey was conducted amongst of the US residents, showed that, individual spent more time budget of their day inside the buildings by 88% (Robinson 1995). However, the public never realized that air pollution always surrounds at home or office as well as shopping malls. This is due to most people will think of the term of air pollution will be outdoors.

According to (Heseltine and Rosen, 2009), problems of indoor air quality are recognized as important risk factors for human health. The major sources of indoor air pollution consist of wet or moist surfaces, especially walls and floors, bedding whereby it will take place due to the poor maintenance of air conditioners as well as home dust. Beyond that, some other sources of indoor air pollution, including tobacco smoke, household products, pesticides, gases such as radon and carbon monoxide. Due to moisture problem, some microorganism such as mould and bacteria may growth increasingly. This was proved from the researcher in Sweeden, showed that, 65% of 420 building were present vivid microbial growth with microbial or chemical emission from building materials (Wessén, Honkanen et al. 2002). This microbal pollution involves hundreds of species of bacteria and fungi that grow indoors when sufficient moisture is available. This bacterium could be classified as airbone viruses that are harmful to the health of a building's

occupants living or working there which may diminish the indoor air quality of the building.

Long term staying in polluted indoors will effects in terms of health (Jonathan M. Samet, 1988; Marios. P. Tsakas, 2011; Jonathan M. Samet4, December 1987) . Indoor air pollution can affect human even though they are in a good state of health as they being surrounded by polluted air most of their time. This will lead them to numerous serious health risks such as affecting their respiratory and inflammatory systems. According to a World Health Organization (WHO) classification system, the most of indoor air pollution deaths in Geneva occurred are due to cardiovascular diseases such as heart disease, lung cancer, stroke, COPD and acute lower respiratory infections in children ((WHO) 2014). Indoor air quality often causes discomfort to people due to the poor ventilated dwellings. Thus, in order to improve the air quality in indoor in order to ensure the building or indoor areas are well ventilated and getting rid of air pollutants, the public awareness towards the dangers of Indoor air pollution is increasing. Based on (Wang, Huang et al. 2011), the research carried out by them is based on the detection of air pollution, which is more related towards the colour image processing field and the method is easy to implement. Furthermore, the technique related to colour image processing is done by (Hahn, Hernández et al. 2006).

RGB colour space

A model where colour is represented in terms of intensity value is a colour space. It is a mathematical representation of a set of colour. There are three most popular colour models which are RGB colour model, YIQ, YUV or YCbCr which used in video systems as well as the CMYK which usually used in colour printing. The RGB colour model is implemented in this system for detection of wet and moist walls which lead to indoor air thermal pollution. The RGB colour model is more preferable as it is normally used in computer graphics to display the image.

The red, green, blue (RGB) colour space is widely used throughout computer graphics. It can be used to specify colours based on the mixing of different colour of light. Beyond that, the RGB colour space is defined by three chromatic of red, green and blue additive primaries. Each colour, which is describe and displayed in its RGB components forms a RGB colour cube. The values of red, green and blue can be displayed and represented at each axis of the colour cube in the range of [0,255]. It can be represented by a 3 dimensional, Cartesian coordinate system as shown in Figure-1 below. In the recent years, the RGB colour space is frequently used in image processing.

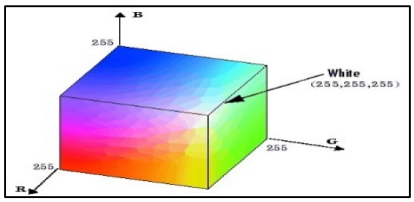

Figure-1. RGB colour cube.

Thermal imaging and its applications

A Thermal Imaging Camera is a type of thermography camera or an infrared camera. A thermal imaging camera forms an image using infrared radiation, which is similar to a common camera which forms images using visible light. In other words, it is a device which used to capture the infrared energy which transfers from an object to its environment and produce a real-time image in a color palette.

Thermal imaging camera had become a common tool in certain industries such as used to verify the building's performances to specifications, determine insulation condition, and verify the structure design as well as to detect some leakage like pipe leakage and gas leakage. In this research topic, the problem with indoor air pollutants is that most are invisible to the eye. This is especially true in the case of particle pollutants. Because the eye detects only particles that are about 30 microns in size, approximately 99 percent of indoor pollutants are almost undetectable. Hence, with the aid of thermal imaging camera, it is able to identify the moisture problem in buildings. Furthermore, a thermal imaging camera is able to determine the areas the differences of moistures area and the heat of drier areas as well as evaporative cooling. Based on the research on Tim C Howell of Energy Loss Evaluations in Thermal Imaging, the dark area indicates the cold or wet area on bedroom ceiling as shown in Figure-2. While based on the Figure-3, it is to show the cold spot around the light fixture. From the thermal imaging camera, it is found that the water dripping onto insulation causing the moist area on ceiling.

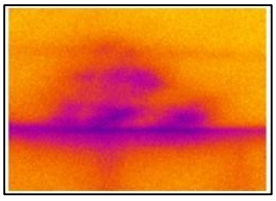

Figure-2. Cold or wet area on bedroom ceiling.

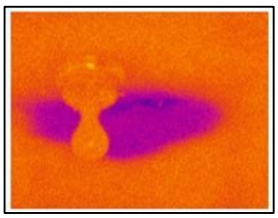

Figure-3. Cold spot around light fixture.

Other than that, another research on moisture detection is done by (Hopkins October 2010) on the dampness in old houses. Figure- 4 shows the gypsum plasterboard is dabbed onto bare bricks and no apparent problems were noticed in this home. On the other hand, thermal image of wall, in Figure-5 shows the purple spot which a colder area where plasterboard dabs are transmitting heat to outside.

Figure-4. Image of wall using a night vision camera.

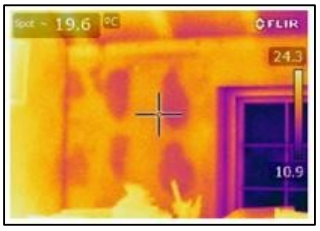

Figure-5. Thermal image of wall using a thermal imaging camera.

A thermal imaging camera provides an easy solution, clearly revealing which piles are heating up fastest and need to be processed as well as a rapid scanning of a surface. This can be seen through a defect is able to detect in a short duration and this is able to reduce the troubleshooting time and preventative maintenance. There are 3 factors that need to be considered using a thermal imaging camera, including the detection, recognition as well as identification

METHODOLOGY

The methodology consists of five major stages, as shown in Figure-6 below, for each thermal image. The stages including data acquisition, image pre-processing, image processing, feature extraction as well as the classification.

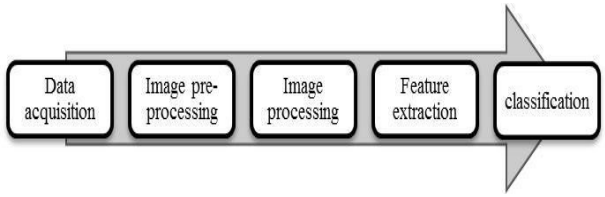

Figure-6. Methodology of thermal image analysis.

Data acquisition

In this project, about 250 thermal images of walls in the surrounding of indoor area are captured by using a thermal imaging camera. After the collection of thermal images, the images are transferred into a computer. Then the image is converted and stored in Joint Photographic Experts Group (JPEG) due to it is readable by the computer as picture.

Image pre-processing

The next phase is the image pre-processing stage where the objective of this phase is to improve the image quality for enhancement of important features of interest. Thus, the images from the entire databases are implemented by using the image processing technique in Matlab 2010a. The images taken from the database are in different dimensional size. Hence, the image is loaded into the system through the use of *imread* function and displayed it into window by using *imshow* function in Matlab. Generally, each original image has the combination of three components of the colour arrays where each pixel value in the image is represented by RGB (Red, Green, and Blue) components. From the original image, the image is converted to 255 level grayscale using *rgb2gray* function. A grayscale image is an image whereby the value of each pixel is in the category of single sample per point, in which it carries the intensity of information. Image is defined with grayscale level, which means the number of pixels in an image is stored 8-bit integer to represent colour from black to white.

Image processing

In this stage, by using a threshold value enables users to obtain the region of interest which is the purple spot in the image. The threshold value is set throughout the analysis of a set of images. Furthermore, thresholding is employed in this operation in order to form a binary image. Threshold value set in the project is shown as below in Table-1. The pixels with a value out of range of the threshold are set to logic 0 while the pixels with a value in the range of the threshold are set to logic 1.

Table-1. Threshold value for colour processing.

Colour	Digital image representation
Red	180-230
Green	0-50
Blue	80-150

Feature extraction

At feature extraction stage, it is to make quantitative measurements from the image. It is a process which needs to represent the output of the image by image processing technique. After the region of interest is obtained in the image processing stage, the threshold image is converted to binary image by using the *im2bw* function. After the binary image is obtained, the features that determine the analysis by suppressing

undesired distortion referred as ''noise'' or by the existence of wet or moist walls that will causes the indoor air thermal pollution can be now extracted. However, some pixels in the binary images might have wrong binary value. Thus, morphological operation is carried out in order to handle this problem. In this case, to set a value of 0 in pixels, the value must be below than the threshold. On the other hand, the pixels with a value greater than the threshold is automatically set to 1. The morphological operation that used in this project includes erosion, dilation, filling as well as closing.

Classification

From the results of image analysis, the classification of image can be done by getting the area of wet or moist surfaces on the wall based on the total number of pixel values in the image. The function of region props is used to identify the area of the wet or moist walls. In addition, bounding box(s) that will ease the classification decision process is drawn on the area of the wet or moist walls that will lead to indoor air thermal pollution.

RESULTS AND DISCUSSIONS

The simulation of this project was applied in the computer vision toolbox in Matlab 2010a. 255 images are used in this simulation process whereby the images are divided into two categories. Based on the thermal images of walls captured, the observation of changes in colour is carried out. Hence, the first category has been classified consists of 178 images with the colour changes while another 77 images showed with no colour changes. However, the system should achieve a 90% effectiveness for an acceptable usability.

Colour detection

1) Pollution detected: The methods or process of thermal image analysis is carried out in detecting the indoor air thermal pollution on wet and moist walls to analyze the polluted data. For the polluted data, there is changes in color whereby there is purple spot(s) existed.

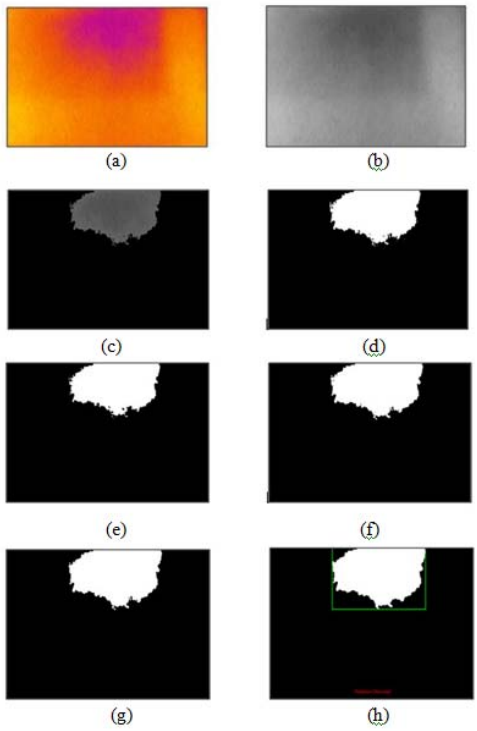

Figure-7. (a) Original image, (b) Grayscale image, (c) Threshold image, (d) Image after binarization, (e) Eroded image, (f) Dilated image, (g) Filled image, (h) Closed image.

Based on the process of colour detection, there is a wet or moist wall detected as shown in the output of the image as shown in Figure-7(h). This process begins in pre-processing stage where original image. Figure 7(a) is converted into a grayscale image as shown in Figure 7(b). After the pre-processing stage, the image is undergoing the process of image processing whereby it enables us to obtain the region of interest of the project as shown in Figure 7(c). Followed by the stage of feature extraction, morphological operation such as erosion, dilation, filling as well as closing took place by using the function such *as imerode, imdilate, imfill and imclose*. This can be seen in Figure 7(d), 7(e), 7(f) and 7(g). Furthermore, a suitable structuring element is required for each operation in order to obtain better output. The morphological operation is important as it able to remove the "noise" in the image. However, before the process of morphological operation, the image must be converted into a binary image so that the features of the existence of wet or moist walls can be extracted and determined. By identifying the area shown in the bounding box by using the function of *regionprops* that's shown throughout the process, in a polluted data, the output would be likely as shown in Figure 7(h). Furthermore, the text "Pollution Detected" is displayed if wet or moist walls existed.

2) No pollution detected: The same methods or process that carried out in detecting the indoor air thermal pollution on wet and moist walls are repeated in order to analyze the non- polluted data. The non-polluted data initially determine, based on there are no changes in colour as well as there is no purple spot exists. During the analysis of non-polluted data is carried out, the same threshold value and structuring element set in the process of feature extraction during analyzing the polluted data are used.

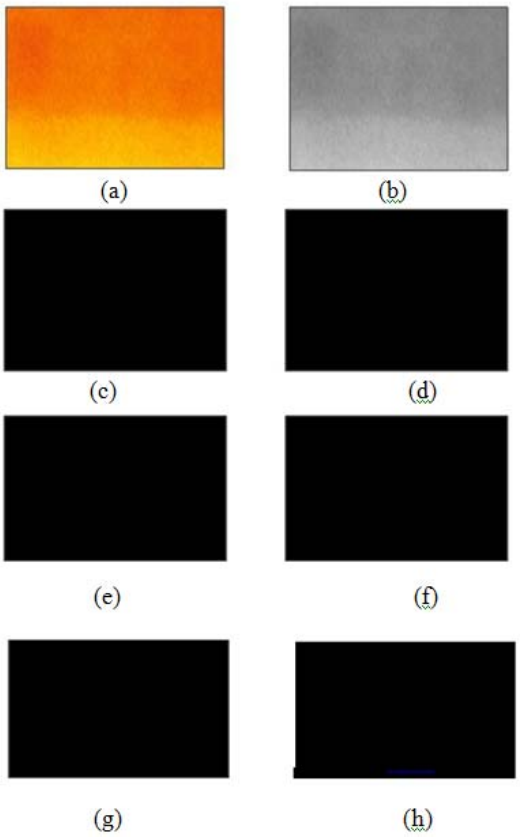

Figure-8: (a) Original image, (b) Grayscale image, (c) Threshold image, (d) Image after binarization, (e) Eroded image, (f) Dilated image, (g) Filled image, (h) Closed image.

In pre-processing stage, the original image Figure-8(a) is converted into a grayscale image and as shown in Figure-8(b). Then, the image is undergoing the process of image processing whereby it enables us to obtain the region of interest of the project as shown in Figure-8(c). In the stage of feature extraction, morphological operation that took place can be seen in Figure 8(d), 8(e), 8(f) and 8(g). However, the same structuring element is used in the detection of non-polluted data to show there are no wet or moist walls detected due to no colour changes. Since no area is identified in the bounding box, thus, it can be concluded that the image is a non-polluted data whereby the wall is not wet or moist. Beyond that, the text "No Pollution Detected" is displayed as shown in Figure 8(h).

Graphical user interface (GUI)

A Graphical User Interface (GUI) is designed and created in this project because it aids the user to obtain the output easily by inserting or choose any desired input. Due to there are lots of images need to be analyzed, hence, the GUI is developed in order to obtain the results or outputs instead of analyzing the image one-by-one. Figure-9 shows the GUI where there is a wet or moist wall detected, whereby indoor air pollution existed. However, in Figure-10, it is the GUI of no wet or moist wall detected, hence no pollution detected.

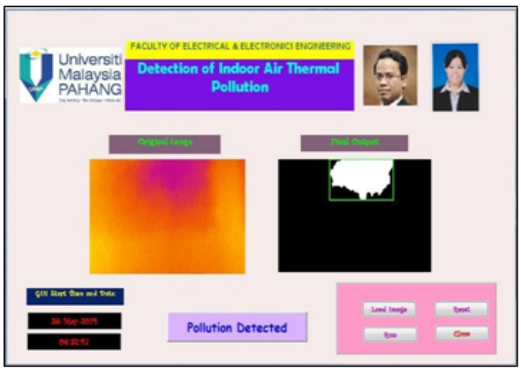

Figure-9. GUI for pollution detected.

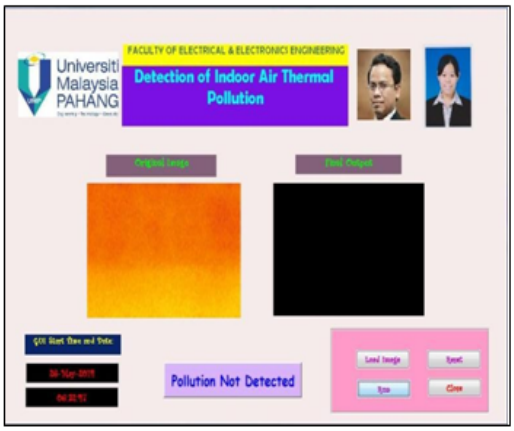

Figure-10. GUI for no pollution detected.

Analysis data accuracy

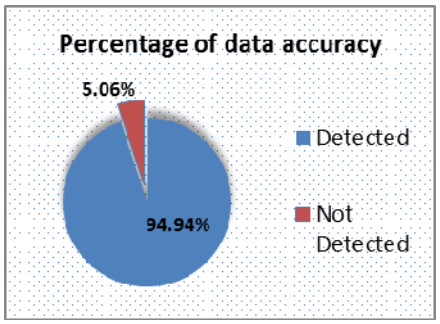

Figure-11. Data accuracy of wet or moist walls detected.

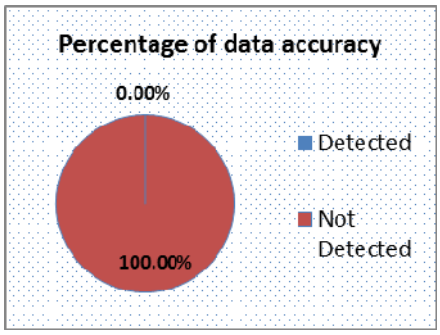

Figure-12. Data accuracy of no wet or moist walls detected.

The accuracy of data is one of the most important elements in researcher field. However, the data obtained during the stage of image acquisition needs to be sufficient in order to validate the accuracy of the system. Hence, based on the threshold value that had been set as shown in Figure-1 1 , the accuracy of the system for the detection of wet or moist wall that will affect the indoor air quality on polluted data shows 94.94% . In other words, it means that, due to the changes of colour in the thermal images of polluted data, out of 178 images, 9 images that have changes of colour are not able to detect by using the threshold value. On the other hand, for the non-polluted data as shown in Figure-12, since there are no colour changes shown in the thermal images and no detection appear by using the same threshold value, hence, the system achieved 100% accuracy.

CONCLUSIONS

In this paper, a detection of indoor air pollution on wet or moist walls using thermal image processing technique were presented. To fulfill the image processing system process, a combination techniques of colour thresholding and morphological operation have been implemented. Herein, the detection technique to detect wet or moist wall has proven successfully. This is proved from the accuracy result, showed that, 94.94%. Accuracy of wet or moist wall were detected While 100% accuracy for no wet or moist walls has been detected. Even though there some error occurred regarding to unsuccessfully wet or moist detected, but this system reliability is above 90% from the validation results. Hence, thermal imaging camera could be a suitable tool since it's able to detect indoor air thermal pollution on wet or moisture problem in buildings.

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