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Research Article

The Technique of Infrared Imaging in Medicine

Witthaya Boonsuk[1], Phumin Hongma[2]

[1,2] Department of Information Technology, Nakhon Phanom University, Nakhon Phanom, 48000, Thailand

***E-mail**: [1]witthaya5773@gmail.com, [2]phumin_h@npu.ac.th

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Abstract

The purpose of the study was to develop an algorithm for High-Temperature Patients Using thermal images. This process used spectral intensity analysis to determine the range of spectral intensity. The averaging intensity level of the spectrum of colors emphasized two colors, including red and green. They were applied to analyze the temperature analysis of a thermal camera. The results of the software proficiency gathered from 9 test groups consisted of 5 images per group. The results demonstrated that testing samples of group 1, at 60 °C; group 2, at 55 °C; test group 3, at 50 °C; test group 4, at 45 °C; test group 5, at 40 °C; test group 6, at 35 °C; test group 7, at 30 °C; and test group 8, at 25 °C, can produce an output with an accuracy of 80%. In conclusion, the novelty of this research is to determine the chromaticity of the value retrieved from the image pixel level.

The overview of the developing system proficiency was at a good level. It indicated that the comparison of the spectrum color group was at a considerably precise level. The system was appropriate for further application in the analyzing works.

Keywords: Fever, Infrared, Thermal camera, Spectrum Color, Radiation

Introduction

Nowadays, information technology has the increase of usage in numerous organizations. Infrared thermal imaging has been used in medicine since the early 1960s. In the 1970s computer image processing of thermograms became available, with increased possibilities for quantitation and archiving of images (Ring, 1975). especially, an infrared camera. Initially, it was used for specific users and later used for military purposes. In the late 20th century (Rogalski, 2011). the infrared camera has been used in the medical field to scan thermal images with an average speed of 1 16 frames per second with low spatial resolution. (Ring, 1984). Moreover, the use of infrared cameras increases for both industrial and medical purposes. This resulted in an increased awareness of the need for standardization of techniques. Two publications were initiated by working groups within the European Thermographic Association (now European Association of Thermology) to address this question. The first, 'Standardisation of thermography in locomotor diseases—recommended procedure' (Chan,2004). in the field of medicine Research and development of a screening system for SARS has been widely developed. It assists in remote screening by means of infrared thermometers (IRT) and is widely used in airports for screening cross-border travelers (England, 1979) for medical treatment. Thermography shows the difference in body temperature caused by the heat in the blood flow. which can distinguish the color of the spectrum depending on the body temperature transferred through the camera It is useful for evaluation and analysis in surgery (Okada, 2007). Based on this technique, the researchers used this technique to develop and research a software system that measures patient temperature and automatically alerts.

Because the body has received foreign substances. such as viruses such as colds, influenza Dengue fever, measles, avian influenza, chickenpox, hand-foot-mouth disease Herpes zoster etc. Bacteria such as typhoid fever, jaundice, leptospirosis, whooping cough, cystitis Appendicitis, etc. Inflammation of tissues or various illnesses, the body, etc. or a body temperature greater than 37.5°C

Fever or pyrexia is a condition where the core temperature or dee-body temperature is defined as the temperature of the central organs of the body such as the heart, lungs, abdomen, etc. The temperature

in this area is the actual temperature of the body. body, but in the presence of fever in this area, the temperature is higher than normal. The body temperature is higher than normal or fever occurs. From the benefits mentioned earlier, the researcher studied and designed the spectral conversion system. It converted spectrum values from thermal images to temperature figures. The spectrum of color analysis of infrared camera images could be beneficial for numerous system applications. Recently developed techniques have focused on averaging the sum of the intensity levels and processing them on a single constant. Instead, a newly developed technique divides the intensity level into intensity ranges and then compares the average measured intensity with the range specified in the measuring template.

Materials and methods

Exploring and analyzing the problem

Recently, auditing and maintaining play an important role in helping business sections and society; they reduce the costs and issues and increase job security.
Besides, it helps elevate the production proficiency. The best technology that serves this kind of business is infrared camera technology. The principles of the infrared camera are to detect infrared radiation from objects. It assists the detection of the unusual phenomenon of the objects as each object has different heat transfer. The infrared wavelength range is between (0.75-1 micrometer) low wavelength (0.78-3 micrometer), medium wavelength (3-6 micrometer), high wavelength (6-15 micrometer). Most infrared cameras have a scanning rate of 30 times per second and capture the heat from -20 to 1,500 °C (Meola,2004). As mentioned earlier, an infrared camera functioned with a face detection system. In organizations and industrial sectors, the face recognition system and face detector detect the unique features of the distinct areas of a human's face. The systems can easily spot the heat on the basic features and unchangeable positions (Yang, 2002). Using this technology shortens the time of the process.

Infrared imagers

An infrared thermogram is an image of temperature distribution of the target. Although the second generation of infrared detectors was in use for military applications in the latter half of the 20th century (Rogalski,2011). (figures 1, 2). Smaller camera units and the use of microbolometers lead to higher mobility and imaging of objects in the perpendicular view i.e. with the camera mounted in the vertical position, which can now be used with modern uncooled equipment. However for very high sensitivity detectors such as the quantum well infrared photodetector, cooling is still necessary.

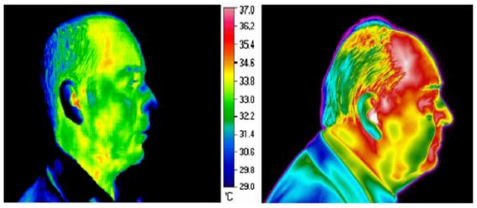


Figure 1 Zoom in Zoom Out Reset image size

Figure 1 (Left) Thermogram of lateral face recorded in 1995 with 320 × 240 pixels; (right) thermogram recorded in 2011 with a new 640 × 480 pixel infrared camera.

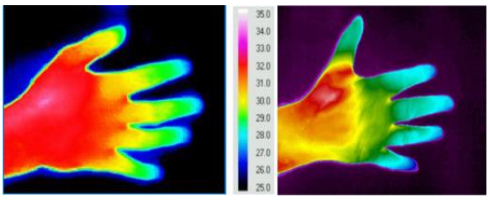


Figure 2 Zoom in Zoom Out Reset image size

Figure 2 Thermograms of dorsal hand (left) recorded in 1990 with 240 × 320 pixels and right recorded in 2011 with modern focal plane array camera with 640 × 480 pixels.

Devices and Instruments

The camera was a Testo 890 made by the German company, with a measuring range of -20 to 350 °C (high temperature measuring of 1200 °C) accuracy of ± 2 °C or ± 2% of market value, resolution of 640 x 480 pixels, an overview of the thermal image of 42° x 32°, and heart reaction speed performed better at 0.05 °C at 30°C, as shown in Figure 1. The program used in the development and design was Visual studio c#. A detecting system of infrared technology detects the heat emission portion and converts it into an electronic signal. There are two types of detectors composed of thermal and infrared photon. The energy from the infrared radiation raises the device's temperature, so the infrared portion is detected. The infrared photon devices that use Cadmium Mercury Telluride (CMT), Anhydride indium, Platinum silicide, and quantum diesel device perform faster than thermal detectors (Willimas,2009), (Alderson,1985).

Research framework

1) Indicate the temperature range: the temperature conversion of the spectrum of colors. In this process, temperature range indication using the analysis of the color intensity of thermal images. The temperature used in this analysis was between 20-60 °C (Kaiser,2016).

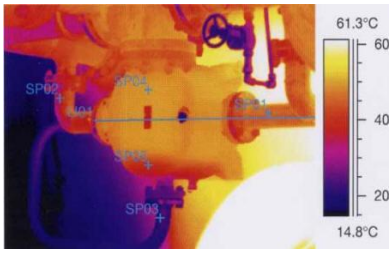


Figure 3 Thermal range used in the experiment

2) Experimental group consisted of 45 samples. The experiment was divided into nine test groups, using five samples in each stage. The samples were tested with the software model to find the precision of the developing software.

Database for the prototype testing using 45 samples

Prototype 1

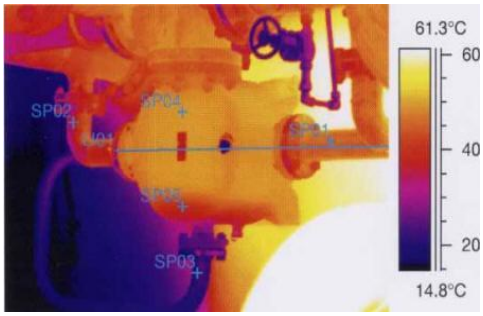


Figure 4 Thermal image of the prototype 1

Prototype 2

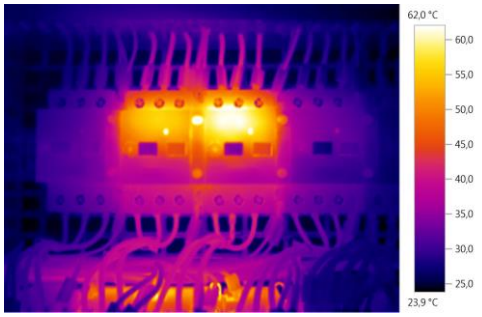


Figure 5 Thermal image of prototype 2

Prototype 3

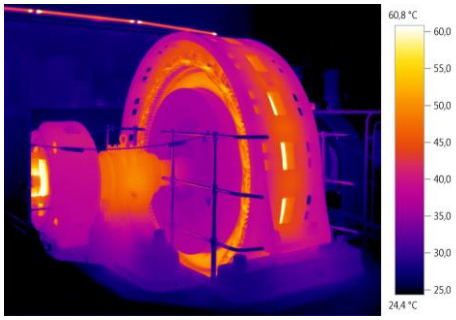
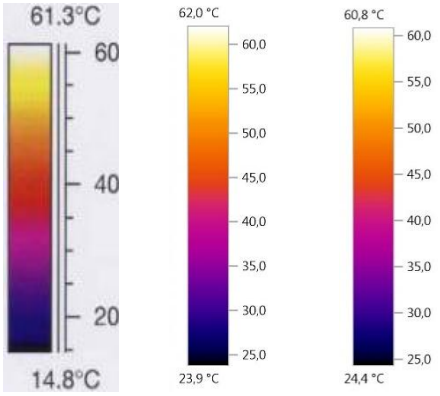


Figure 6 Thermal image of the prototype 3

The spectrum of colors of images was different depending on the manufacturers. There were three model images used in the comparison and analysis. The pictures are shown in Picture 4,5,and 6.

Analyzing the median of the 3 prototypes

1) Graph of thermal range of the 3 prototypes



Prototype 1 Prototype 2 Prototype 3

Figure 7 Thermal graphs of the 3 prototypes and spectral colors

2) Calculation and analysis of the intensity of the spectrum of colors of each scale demonstrating in Figure 5. The camera showed the value level of thermal images. The data were presented in the temperature range only. Color strips had numbers (Alderson ,1995), (Simpson,2008), (Liebel,2012).for the user to use in the analysis. Graph numbers showed the status of the color strips. The temperature range and the spectrum of colors were both analyzed to find the color intensity level. At each level of the graph, presented the temperature of three prototypes covering nine scales, as seen in Tables 1, 2, and 3.

Table 1 The average intensity level of the prototype 1

(thermal image)	temperature °C	Color intensity (Pixel)		
		Red	green	blue
	60	230	232	223
	55	232	222	65
	50	210	158	47
	45	205	93	45
	40	192	47	30
	35	180	30	78
	30	160	25	130
	25	88	17	119
	20	29	16	108

Table 2 The average intensity level of the prototype 2

(thermal image)	temperature °C	Color intensity (Pixel)		
		Red	green	blue
	60	254	245	170
	55	253	200	0
	50	247	133	0
	45	229	72	21
	40	199	15	137
	35	144	0	157
	30	58	0	146
	25	0	0	67
	20	0	0	2

Table 3 The average intensity level of the prototype 3

(thermal image)	temperature °C	Color intensity (Pixel)		
		Red	green	blue
	60	254	250	212
	55	253	212	10
	50	246	141	0
	45	234	80	10
	40	201	18	132
	35	148	0	156
	30	59	0	146
	25	2	0	50
	20	1	0	6

For accurate and precision results, the temperature range was at 20-60 °C. The scope was in nine scales, 5 degrees Celsius each.

3) Color intensity arithmetic mean analysis, from 3 prototypes shown in Table 1,2, and 3, were analyzed to discover the change rate affected the portion of the intensity of spectrum as shown in Table 4. The analysis used graphs to reveal the average changing rate of all three prototypes. Following, selecting steady spectral colors to use as a prototype in the comparison analysis (Alderson,1995), (Simpson,2008), (Liebel,2012).

Table 4 The average intensity level of the 3 prototypes

Temperature °C	The average intensity level of the 3 prototypes (Pixel)		
	Red	green	blue
60	246	242	201
55	246	211	25
50	234	144	16
45	223	82	25
40	197	27	100
35	157	10	130
30	92	8	141
25	30	6	79
20	10	5	39

4) Analysis of a steady trend of color, the color intensity of spectrum on the changing temperature of the 3 prototypes. It acted as a primary model to use in the comparison (Metz,1978).

Graph prototype 1

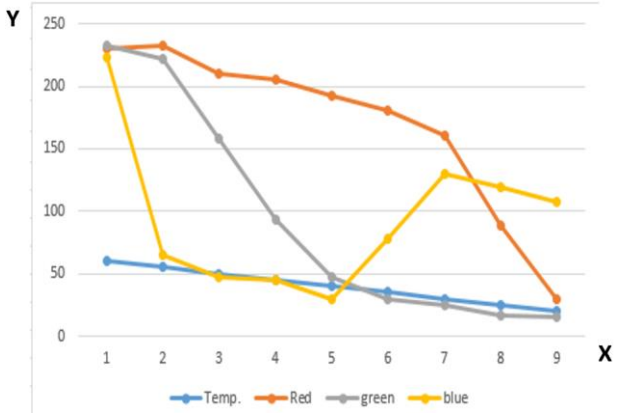


Figure 8 Graph of the color intensity at increasing temperature of the prototype 1

Graph prototype 2

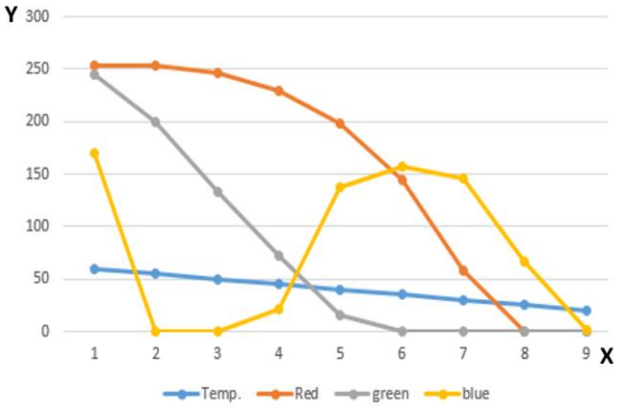


Figure 9 Graph of the color intensity at increasing temperature of the prototype 2

Graph prototype 3

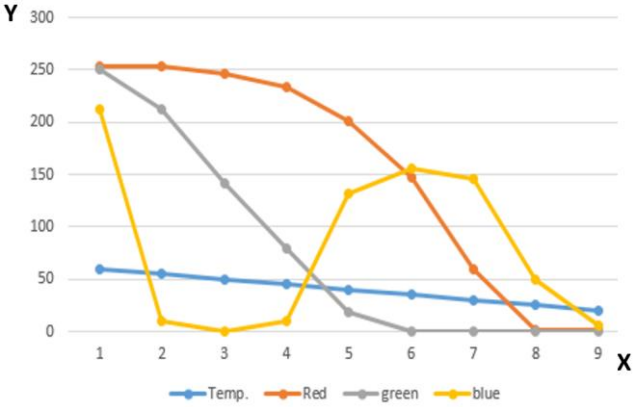


Figure 10 Graph of the color intensity at increasing temperature of the prototype 3

The average graph of the 3 prototypes

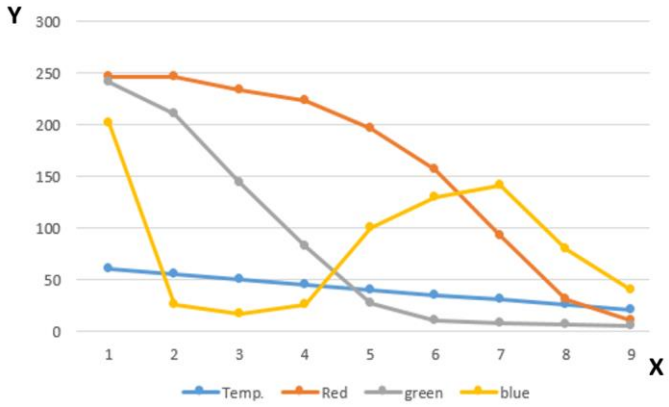


Figure 11 Graph of the color intensity at increasing temperature of the 3 prototypes

The graphs in Figures 9-11 showed the primary colors included red, green, and blue. When the temperature increased from 20 °C to 60 °C, the red and green graphs were at a noticeably steady level. As can be seen that the green and red figures had a stable trend, which these two graphs would be as primary data for the comparison.

Table 5 The average color intensity level of each temperature range. From the analysis, red and green were appropriate for the application, as shown in the table.

Temperature °C	Color intensity (Pixel)	
	Red	**green**
60	246	242
55	246	211
50	234	144
45	223	82
40	197	27
35	157	10
30	92	8
25	30	6
20	10	5

Finding the temperature range prototype

The intensity level of spectral colors was the average of the three prototypes, and the steady graphs included green and red. The system revaluated the graph values for a more precise rate. It increased the scope of the temperature range, as shown in Figure 12.

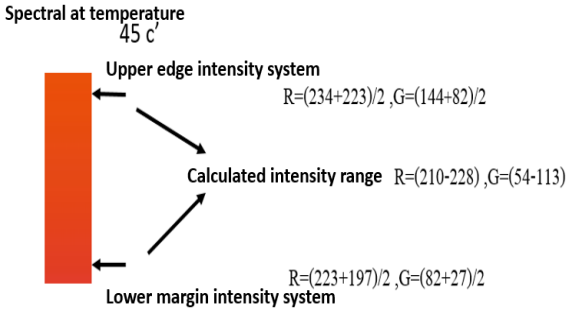


Figure 12 Analysis principle of the upper edge and lower margin color intensity of spectral heat

Table 6 The level of spectral color intensity implemented in the primary database, used in the upper edge and lower margin analysis

Temperature °C	Color intensity	
	Red	Green
60	246-255	226-255
55	240-246	177-226
50	228-240	113-177
45	210-228	54-113
40	177-210	18-54
35	124-177	9-18
30	61-124	7-9
25	20-61	5-7
20	1-10	1-5

As presented in Table 6, the data used as the primary data of comparison for the analysis. The data yielded the averaging temperature in each range of the color intensity of the thermal images. Besides, there were only two colors implemented; the spectrums of red and green.

System design
Context Diagram of the system

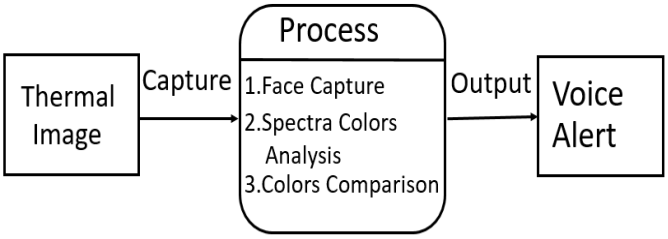


Figure 13 Overview of context diagram of the system

System components

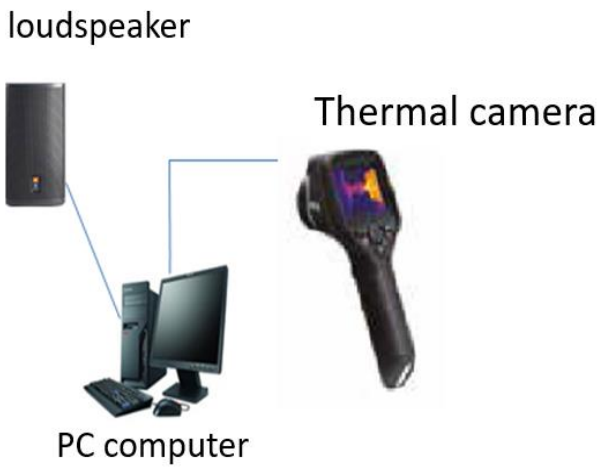


Figure 14 System components

System process

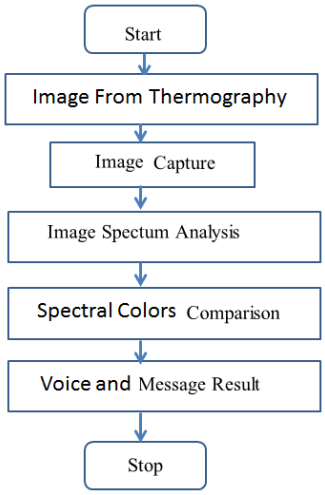


Figure 15 System process

Color intensity spectroscopy system used to measure fever

Temperature °C	Color intensity	
	Red	Green
60	246-255	226-255
55	240-246	177-226
50	228-240	113-177
45	210-228	54-113
40	177-210	18-54
35	124-177	9-18
30	61-124	7-9
25	20-61	5-7
20	1-10	1-5

Figure 16 The level of spectral color intensity

Which controls heat to maintain body temperature at about 36-37 degrees Celsius or 98.6 Fahrenheit (Fahrenheit) because the average body temperature is approximately 36.8 ± 0.4 ° C (98.2 ± 0.7 ° F), or a body temperature greater than 37.5 ° C in the morning and greater than 37.7 ° C in the evening. If the body has a higher temperature than that, it means "fever" This is where we focus on processing temperatures above 37.5°C. The temperature range 35-40 is the red spectrum (177 + 124) / 2 = 150 and the green spectrum (9 +18) / 2 = 14.

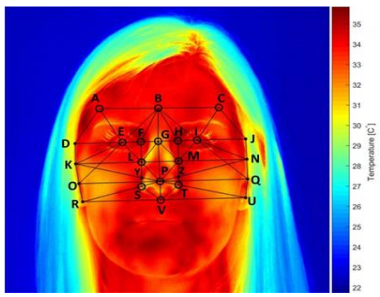


Figure 17 Thermal screening of a woman's face. University of Nottingham 2018. Courtesy university of Nottingham

Algorithm System

```
imgCapture.Image = imgVideo.Image;
Bitmap bmap = newBitmap(imgCapture.Image);
Color c;
for (int i = 0; i<bmap.Width; i++)
{
   for (int j = 0; j <bmap.Height; j++)
    {
  c = bmap.GetPixel(i, j);
 byte chk_R = (byte)(c.R );
 byte chk_G = (byte)(c.G );
    if ((chk_R > =246) && (chk_G > =226))
            {
             Celcias=60;
            text1 = "The  temperature is 60";
            }
     Else  if ((chk_R > =240) && (chk_G > =177))
         {
              Celcias=55;
              text1 = " The  temperature is 55";
        }
     Else  if ((chk_R > =228) && (chk_G > =133))
        {
              Celcias=50;
              text1 = "  The   temperature is 50";
        }
     Else  if ((chk_R > =210) && (chk_G > =54))
        {
              Celcias=45;
              text1 = " The   temperature is 45";
                  }
     Else  if ((chk_R > =177) && (chk_G > =18))
              {
              Celcias=40;
              text1 = " The  temperature is 40";
                  }
     Else  if ((chk_R >= 150) &&(chk_G > =14))
            {
             Celcias=37.5;
             text1 = "You are fever and  temperature is Very  high";
            }  (Northam, 2014), ( US Army Natick Soldier RD&E Center, 2007).
     Else  if ((chk_R > =124) && (chk_G > =9))
              {
                  Celcias=35;
                 text1 = " The  temperature is 35";
                  }
     Else  if ((chk_R > =61) && (chk_G > =7))
                   {
                  Celcias=30;
                text1 = " The  temperature is 30l ";
                    }
      Else  if ((chk_R > =20) && (chk_G > =5))
                   {
                  Celcias=25;
                 text1 = " The  temperature is 25 ";
                    }
```

```
    Else  if ((chk_R > =1) && (chk_G > =1))
                    {
                    Celcias=20;
          text1 = " The temperature is 20; ";
                     }
   }
}
        SpeechSynthesizer synthesizer = new
        SpeechSynthesizer();
        synthesizer.Volume = 100;
        synthesizer.Rate = 0;
        synthesizer.Speak(text1);
```

System design and system development

This study developed the prototype system to convert the temperature of any object from an infrared camera. Visual C# program was as a tool to design the prototype and the user interface. A webcam was a receiving device for capturing images from a camera as the data for the analysis.

GUI system design

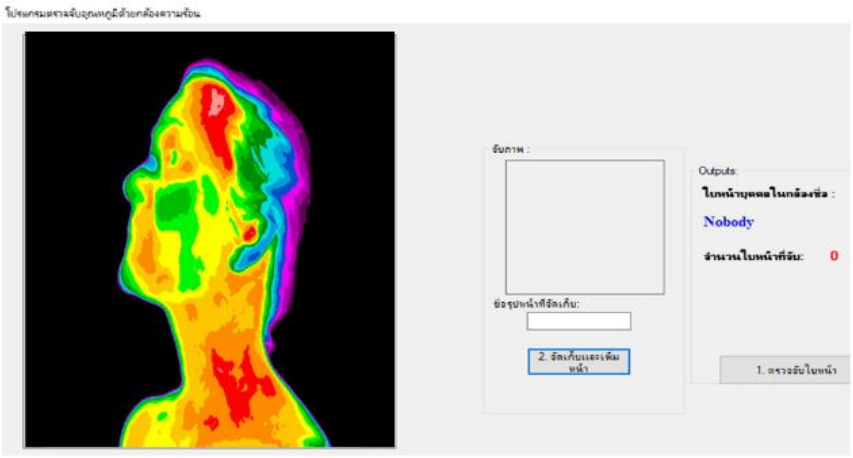


Figure 18 Overview of GUI system

As seen in Figure 13, the context diagram of the system acted as a system overview. It received images from an infrared camera and converted the heating value. Then, informed the user of the temperature value by a voice message.

System testing

Assessment of the accuracy and precision: using accuracy assessment. This method is a means to evaluate the accuracy of the imaging analysis in the database. The system considered the number of the sample images that were accurate compared with the primary pictures in the database, as shown in the equation (Bonnett,2006), (Sefton,2010), (Holey,2011).

$$\%\text{Accuracy} = 100 - \%\text{Error}$$

$$\text{Relative error} = \left| \frac{x_{mea} - x_t}{x_t} \right|$$

$$\%\text{Error} = \text{Relative error} \times 100$$

When X_{mea} equals measure value

X_t equals true value ISO Definition (ISO 5725)

Results

System development

Graphic User Interface)

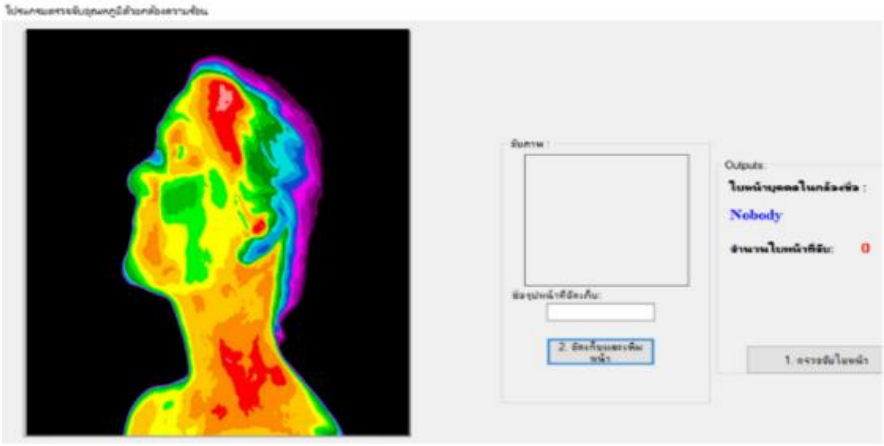


Figure 19 User interface

Other applications have shown that monitoring stent insertion sites and peripheral circulation with thermal imaging is an efficient means of assessing the need for revision of the arterio-venous fistula. Thermal imaging is now increasingly used for imaging different physiological reactions induced by non-drug treatments such as massage [21]. (Wu, 2009). or manual therapy (Mori H, 2004). Temperature distribution of the skin during and after physical exercise has been reported (Zontak A ,1998), (Ferreira,2008), (Merla A,2010)

System proficiency testing:

for temperature measurement of the software using images from the infrared camera. Pictures from the test groups showed in quantitative and qualitative means. Data retrieved from 9 test groups, 5 per group, 45 images in total. The following step: the software analysis to find the precision proficiency and acceptance test by the user.

The assessment system evaluates the proficiency of information technology systems and software. There are four parts of the system as follows:

1. Function Requirement Test
2. Function Test
3. Usability Test
4. Security Test

In this experiment, the process focused on the system or software proficiency, so only a function test was used. Thermal images were applied in the preparation stage, retrieving from the Thermoscan camera in *.jpg consisting of 45 thermal images. The pictures were divided into 9 test groups, containing five images per group, as presented in Figure 20.

Test group 1: 5 thermal images at 60 °C
Test group 2: 5 thermal images at 55 °C
Test group 3: 5 thermal images at 50 °C
Test group 4: 5 thermal images at 45 °C
Test group 5: 5 thermal images at 40 °C
Test group 6: 5 thermal images at 35 °C
Test group 7: 5 thermal images at 30 °C
Test group 8: 5 thermal images at 25 °C
Test group 9: 5 thermal images at 20 °C

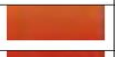
Group Test	Data set 1	Data set 2	Data set 3	Data set 4	Data set 5
1.Thermal image at 60 degrees Celsius					
2.Thermal image at 55 degrees Celsius					
3.Thermal image at 50 degrees Celsius					
4.Thermal image at 45 degrees Celsius					
5.Thermal image at 40 degrees Celsius					
6.Thermal image at 35 degrees Celsius					
7.Thermal image at 30 degrees Celsius					
8.Thermal image at 25 degrees Celsius					
9.Thermal image at 20 degrees Celsius					

Figure 20 Group tests of the thermal spectrum

Implementing and assessing the system

Table 7 The precision comparison of 45 images of the test groups

Test group	Amount of data	Accurate readable information	Relative Error	% Error	%Accuracy
1.Thermal image at 60 degrees Celsius	5	4	1	20%	80%
2.Thermal image at 55 degrees Celsius	5	4	1	20%	80%
3.Thermal image at 50 degrees Celsius	5	4	1	20%	80%
4.Thermal image at 45 degrees Celsius	5	4	1	20%	80%
5.Thermal image at 40 degrees Celsius	5	4	1	20%	80%
6.Thermal image at 35 degrees Celsius	5	4	1	20%	80%
7.Thermal image at 30 degrees Celsius	5	4	1	20%	80%
8.Thermal image at 25 degrees Celsius	5	4	1	20%	80%
9.Thermal image at 20 degrees Celsius	5	4	1	20%	80%
Total	45	40	9	20%	80%

From Table 7, the proficiency assessment using to test the precision of the analysis of temperature of thermal image spectrum. The samples consisted of 9 test groups, five images each, 45 images in total. The results are as follows:

Test group 1 had the precision of 80%
Test group 2 had the precision of 80%
Test group 3 had the precision of 80%
Test group 4 had the precision of 80%
Test group 5 had the precision of 80%
Test group 6 had the precision of 80%
Test group 7 had the precision of 80%
Test group 8 had the precision of 80%
Test group 9 had the precision of 80%

The average precision of the system was 80%, considered as an excellent level. As seen in Table 7, the precision evaluation using the thermal images of 9 test groups, 5 per group, 45 in total. The finding revealed that the precision was 80%, considered excellent. The suggestions for more precise results include the proximity should be less than three meters between the thermal detectors and the objects; the room should be entirely closed without airflow because it will cool off the object's heat. Moreover, the refrigerating rooms are not suitable for the system analysis because the heat radiation will be inaccurate. Lastly, a camera should be of high quality for accurate results.

Discussion

The findings of the research consisted of the results from two sources of data. The first source was from a system precision assessment using the thermal spectrum of the developing software. The other source was thermal images of 9 test groups. The results show that the averaging precision was 80%, considered a good level. Recently developed techniques have focused on averaging the sum of the intensity levels and processing them on a single constant. Instead, a newly developed technique divides the intensity level into intensity ranges and then compares the average measured intensity with the range specified in the measuring template.

Conclusion

The developing software was preferably precise at 80%; however, the temperature range illustrated in each scale was not. Temperature data presented in 5 degrees instead of 1 degree, considered as not precise. In the future, the development of an algorithm to show the data in the one-degree is a must. Prospectively, there should be a comparison with other systems or related research; to reach the desired precision. Later on, the system can be valuable in analyzing systems and temperature screening works. In conclusion, the novelty of this research is to determine the chromaticity of the value retrieved from the image pixel level.

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