Bilinear Interpolation Method on 8x8 Pixel Thermal Camera for Temperature Instrument of Combustion Engine

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Abstract. Measuring the temperature of the combustion engine is very much needed. Both from the use of tuning, research, and learning. The problem with the syringe when measuring the temperature of the combustion engine is that the measuring device must be attached to the combustion engine body and there is a time delay for measuring the temperature. In this paper the focus is on the interpolation method for an 8x8 pixel thermal camera. The image data will be created in a graphical user interface (GUI) so that the image looks very clear. Images that have a resolution of 16x16 and 32x32 resolutions. The Sehigga object on the thermal camera reading looks clearer and more detailed. In the GUI, it allows data to use both ordinary images and videos. There are 3 sample images that have been interpolated. The results of the research on paper show the conditions of the interpolated results from images 8x8 to 16x16 and 32x32. The time it takes to display the image is 0.5 seconds.

1. Introduction
The use of temperature measurement instruments for automotive is of course important. Judging by technological developments that are increasing every time, it requires that each measuring instrument has high enough precision and accuracy. If you look at the aspects of using measuring instruments, especially thermometers, of course, it will be very closely related to temperature measurement in the automotive or medicine sector [1].

It should be noted, the use of sensors to measure combustion engine parameters is very much. The temperature measurement that is still commonly used is the thermometer which is always attached to the body of the vehicle. Whereas each vehicle manufacturer certainly uses the bolt nut model in placing the temperature sensor. Certainly, different models and sizes. This is adjusted to the combustion engine model issued by the factory. So that the temperature measurement on the combustion engine between factories requires using a temperature sensor that has been recommended.

Several studies have been carried out in the use of temperature sensors of various types and sizes. However, when placing the physical temperature sensor there is an air gap that causes the measurement results to be less than optimal. Moreover, physical contact that causes heat delivery requires a response time so that the flowing temperature can be measured. It becomes a problem if the measurement results are used for temperature control on the engine.

This paper discusses the use of a thermal camera to measure engine temperature. Thermal cameras include contactless temperature sensors. Where the temperature measurement is carried out without the sensor touching the body of the engine. The advantage of using a thermal camera is that the number of measuring points is more and the time delay caused by heat propagation between the body and the sensor can be avoided. The thermal camera has a resolution of 8x8 measurement points. So
that the resulting image pattern on the thermal camera looks mosaic. In order to refine the image quality on a thermal camera, the image resolution is increased using the interpolar method [2]–[5]. Where between pixels are made sparse, and between these pixels is the middle value.

2. Literature study
2.1 Thermal camera
Table 1 shows the technical specifications of the thermal camera.

| PARAMETER          | DESCRIPTION                     |
|--------------------|---------------------------------|
| Type               | AMG8833                         |
| Pixel number       | 64 (8x8 matrix)                 |
| Applied voltage    | 3.3 V                           |
| Temperature object | 0-80 °C / 32-176 °F             |
| Communication data | I2C (fast mode)                 |
| Frame rate         | 10 fps (type 10) / 1 fps (type 1)|
| Thermistor output resolution | 0.0625 °C / 32.1125 °F |

Where the type of thermal camera used is AMG8833, the working voltage of the thermal camera is 3.3V. The temperature that can be measured using this thermal camera is from 0-80 °C or 32-176 °F. The speed of the thermal camera in capturing images is 10 fps when using type 10 and 1 fps when using type 1.

The concept of temperature measurement in a thermal camera is to measure the heat radiation captured by the chip sensor. Because the thermal camera only captures heat radiation, this camera has a certain distance measurement. The measuring distance between the object and the thermal camera is 7 meters.

The number of chip sensors is 64, so there is a selector used to switch between chip sensors. There is a signal amplifier that amplifies the transducer on the sensor chip. The results of the signal amplification are compared with a thermistor, then the signal is processed using an analog to digital converter (ADC). In the control process, ADC result data is sent to another integrated circuit (IC) using inter-integrated circuit (I2C) communication.

2.2 Bilinear Interpolar
Linear interpolation is a technique for getting a value between two values based on a linear equation [2], [3], [7]. Linear interpolation also includes methods for determining the value of a linear equation function based on the law of proportionality.

Figure 1 shows the interpolar method in an image. The interpolar bilinear method shows that the interpolar results are obtained based on the meeting of 4 values of the upper right, lower right, upper left, and lower left corners. Equation (1) shows the bilinear interpolar equation between pixels pixel $x_0$, $x_1$, $y_0$, and $y_1$. 

![Figure 1. Bilinear Interpolation Method](image)
\[ y = y_0 \left( 1 - \frac{x - x_0}{x_1 - x_0} \right) + y_1 \left( 1 - \frac{x_1 - x}{x_1 - x_0} \right) \] (1)

Where the pixels that become interpolar objects will adjust to the interpolated value. The interpolated value of \( y \) shows the value between pixels \( x_0 \) and \( x_1 \) and pixels \( y_0 \) and \( y_1 \). Note that the \( y \)-values will not be greater than the values for \( x_0, x_1, y_0, \) and \( y_1 \). This equation is used as the basis for forming a color pattern that will be used on a thermal cam.

Figure 2. Interpolar Method

Figure 2 (a) shows the results of the thermal camera readings with black and white output. Whereas in Figure 2 (b) shows the results of the interpolation between black and white. It can be seen that the interpolar bilinear in the picture shows the image composition between the white and black color patterns separated by the gray color pattern.

The image displayed on the thermal camera temperature reading will be shown with a color pattern. The formation of color patterns can be seen from equations (2) and (3).

\[ C_n = (T_n - T_{min}) \times Res \] (2)

\[ Res = \frac{(T_{max} - T_{min})}{255} \] (3)

Where, \( C_n \) pixel color, \( T_n \) temperature reading in the 1-pixel thermal camera, \( T_{min} \) is the lowest temperature, \( T_{max} \) is the highest temperature. Res value is the resolution between the maximum temperature and the minimum temperature divided by the number of color resolutions.

2.3 Overlay

The overlay is a method of combining 2 images so that the 1st and 2nd images can be seen in 1 image. This overlay method disguises the top image so that the image on the bottom layer will be visible [8]–[10].

Figure 3. Overlayer on the thermal camera

Figure 3 shows the overlay result on a thermal camera. Where an image on the camera will be superimposed with the camera's thermal reading. The red color shows the high-temperature conditions on the object. The equation below shows an overlay of 2 images.

\[ C_0 = \alpha_a C_a + (1 - \alpha_a) C_b \] (4)
Where \( C_0 \) is the color of the overlay result image, \( C_a \) is the color of image 1, \( C_b \) is the color of image 2, \( \alpha_a \) is the level of image transparency between 0-1. The greater the \( \alpha_a \) value, the lower the \( C_b \) color. Meanwhile, when the \( \alpha_a \) value decreases, the \( C_a \) color value will increasingly dominate.

3. Methodology

3.1. Research Scheme

Figure 4 shows the research scheme in the paper carried out.

![Research schematic](image)

Figure 4. Research schematic

It can be seen that the research scheme shows the stage of taking pictures using both a digital camera and a thermal camera. When a digital camera takes a picture, the thermal camera measures the heat in the object captured on the digital camera. A thermal camera with a resolution of 8x8 will form a color pattern based on the amount of temperature values [11]. By using the bilinear interpolation method, the measurement results with a resolution of 8x8 were expanded to 57x57. The resulting image is shown on a graphic user interface (GUI).

3.2. Study case

There are 2 case studies to be carried out in this research, namely: interpolating the data from the sensor readings into an image with an image pattern and overlaying the image of the interpolation pattern with the object image.

3.2.1 Mono color (red)

Case study of temperature reading using a thermal camera with a 1 color pattern [12]. The color used is red. The coding below shows the method of making an image pattern using 1 color.

3.2.2 Overlay

After interpolating the red color, the interpolation result will be combined with the object image [9]. Where the interpolated colors are stacked on top of the object image.

4. Result and discussion

Table 2 shows the readings from the thermal camera. The output on the thermal camera shows the temperature measurement results with a total of 64 measurement data.

| Table 2. Data Temperature |
|---------------------------|
| 40.75 | 41.50 | 44.00 | 52.75 | 38.25 | 38.75 | 36.75 | 35.75 |
| 45.75 | 54.25 | 40.50 | 42.50 | 54.25 | 75.50 | 60.00 | 45.25 |
| 37.00 | 57.00 | 50.50 | 50.50 | 58.75 | 68.00 | 79.25 | 73.75 |
| 31.00 | 40.25 | 37.75 | 56.25 | 73.00 | 58.25 | 72.25 | 40.00 |
| 42.75 | 40.75 | 52.75 | 61.75 | 59.75 | 47.50 | 44.00 | 47.25 |
Figure 5 shows the results of taking pictures with a digital camera. Figure 6 shows the results of taking temperature data on a thermal camera. The image that is used as the object is the combustion engine after operating. Where Figure 6 (a) shows the conversion of temperature data into color patterns. White color indicates a higher temperature, while black indicates a lower temperature. The overlay results in Figure 6 (b) shows a fairly large pixel so that when the temperature reading image with the image from the digital camera is overlaid, a very wide temperature determination pattern will be formed. This will increase the temperature reading error at a certain point on an object.

![Figure 5](image_url)

**Figure 5.** Results of Capturing Images Through the Camera

![Figure 6](image_url)

(a) (b) (c) (d)

**Figure 6.** Temperature and Overlay Readout Coloring Results

![Figure 7](image_url)

(a) (b)

**Figure 7.** 15x15 Interpolation Results and Image Overlay
In Figure 7 (a) shows the results of bilinear interpolation from a resolution of 8x8 to 15x15. Figure 7 (b) shows the overlay result of 15x15 biliary interpolation with Figure 5. When the 15x15 biliary interpolation shows the formation of a finer pattern. In Figure 8 (a) shows the results of bilinear interpolation from a resolution of 15x15 to 29x29. Figure 8 (b) shows the overlay results of the 29x29 biliary interpolation with Figure 5. When the 29x29 biliary interpolation shows the pattern, formation is smoother than before. This shows, the greater the inter polarization that is carried out, the smoother the formation of image and color patterns on temperature readings with a thermal camera.

In Figure 9 (a) shows the results of bilinear interpolation from a resolution of 29x29 to 57x57. Figure 9 (b) shows the overlay result of the 57x57 biliary interpolation with Figure 5. When the 57x57 biliary interpolation shows the formation of a finer pattern. The results using the 57x57 inter polarization get very good results. When the overlay shows the heat radiation of the combustion engine in a clearer image.

5. Conclusion

From the research results, it can be seen that the pattern of numbers from the reading of the thermal camera will form an image. The image forms a pattern with the size 8x8. So that the use of the biliary interpolation method causes the image pattern to be refined from 8x8 to 57x57. By using the overlayer method on the results of the interpolation, the image can show the measured temperature conditions on the object image and can determine the heat radiation that occurs.

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7. References

[1] Rajmanova P, Nudzikova P and Vala D 2015 Application and Technology of Thermal Imagine Camera in Medicine IFAC-PapersOnLine 28 4 pp 492–497
[2] Parsania P P S and Virparia D P V 2015A Review: Image Interpolation Techniques for Image Scaling Int. J. Innov. Res. Comput. Commun. Eng. 02 12 pp 7409–7414
[3] Patel V and Mistree K 2013 A Review on Different Image Interpolation Techniques for Image Enhancement Ijetae 3 12 pp 129–133
[4] Abdullah D et al 2018 Application of Interpolation Image by using Bi-Cubic Algorithm J. Phys. Conf. Ser. 1114 1
[5] Armas Vega E A, González Fernández E, Sandoval Orozco A L and Garcia Villalba L J 2020 Image Tampering Detection by Estimating Interpolation Patterns Futur. Gener. Comput. Syst. 107 pp 229–237
[6] Panasonic 2017 Infrared Array Sensor Grid-EYE (AMG88) p 6
[7] Getreuier P 2011 Linear Methods for Image Interpolation Image Process. Line 1 pp 238–259
[8] Schaefer G, Tait R and Zhu S Y 2006 Overlay of Thermal and Visual Medical Images using Skin Detection and Image Registration *Annu. Int. Conf. IEEE Eng. Med. Biol. - Proc.* pp 965–967

[9] MOBOTIX AG 2018 *Technical Specifications MOBOTIX M16A Thermal/M16A Thermal TR* p 9

[10] Schaefer G, Tait R, Howell K, Hopgood A, Woo P and Harper J 2008 Automated Overlay of Infrared and Visual Medical Images *User Centered Des. Med. Vis.* pp 174–183

[11] Best C 2018 How To Build An Eight-Bit Thermal Imaging Camera [Online] Available: https://www.fierceelectronics.com/components/how-to-build-eight-bit-thermal-imaging-camera [Accessed: 02-Sep-2020]

[12] Flir 2017 Understanding Color Interpolation [Online] Available: https://www.flir.com/support-center/iis/machine-vision/application-note/understanding-color-interpolation/ [Accessed: 02-Sep-2020]