

INFRARED IMAGE PROCESSING IN MEDICINE

Andrew Stanchev Andreev

Centre of Biomedical Engineering “Prof. Ivan Daskalov”,
Bulgarian Academy of Sciences Acad.G.Bonchev str. Bl.105, 1113, Sofia, Bulgaria, mobile:
+359 88 7526408, e-m@il: andrew.andreev@binnetix.com

The infrared thermography is a technique for remotely measuring the temperature of objects. The modern thermograph cameras are providing great opportunity to observe consequently surfaces. The generated image result can be processed for additional analytical purposes.

The current research and development demonstrates how an independent digital image processing can identify the object temperature directly from the source without having specialized hardware. It shows also different techniques for image enhancements, three-dimensional representations and effective batch processing of operations for compression analyses.

Keywords: thermal infrared image processing

1. INTRODUCTION

1.1. Practical Issues

The first documented application of Infrared (IR) imaging in medicine was in 1956 [4], when breast cancer patients were examined for asymmetric hot spots and vascularity in IR images of the breasts. Since then, numerous research findings have been published and the 1960s witnessed the first surge of medical application of the IR technology with breast cancer detection as the primary practice. However, IR imaging has not been widely recognized in medicine nowadays, largely due to the premature use of the technology, the superficial understanding of IR images, and its poorly controlled introduction into breast cancer detection in the 70s [5].

Recently, advances in a couple of related areas have pushed forward series of activities to reappraise the role of IR imaging in medicine. These advances, including the development of the new-generation infrared technology, smart image processing algorithms, and the pathophysiological-based understanding of IR images, will provide a cost-effective, non-invasive, non-destructive, and patient-friendly approach to health monitoring and examination, as well as to assisting diagnosis [3].

In this article is discussed the software implementation of the following issues:

- A. Thermogram temperature measurement.
- B. Thermal histogram aggregation.
- C. Creation of 3-Dimensional temperature model.
- D. Thermal images comparison and batch processing.

1.2. Temperature Calculation Background

[6] Generally speaking, the total received power radiation W_{total} captured by the thermo camera can be examined on three groups:

- Object radiation
- Reflected Radiation
- Atmosphere Radiation

The object temperature in terms of thermograph output signal can be represented as follows (1):

$$T_{obj} = \frac{1}{\varepsilon\tau} \cdot T_{total} - \frac{(1-\varepsilon)}{\varepsilon} \cdot T_{refl} - \frac{(1-\tau)}{\varepsilon\tau} \cdot T_{atm}$$

where:

- T_{refl} : temperature produced by reflection radiation
- T_{atm} : temperature produced by atmosphere radiation

The coefficients of object emittance ε and atmosphere transmittance τ may vary in diapason (0, 1]. The total temperature T_{total} fully depends on the temperature range of the measurement: $T_{total} \in [T_{min}, T_m]$.

The influence of the reflected emission is removed when $\varepsilon = 1$ (100% absorption of pure black body).

The influence of the atmosphere emission is removed when $\tau = 1$ (vacuum).

2. IMPLEMENTATION

2.1. Restore the temperature information from Thermogram

The general concept of thermographs, in accordance with the Theory of Three Primary Colors, is to represent the temperature by coloring the image in the visible spectrum [2]. The following color chain can be identified: Black, Blue, Green, Yellow, Orange, Red, Violet and White. Therefore the possible color transitions are 6. The algorithm preliminary accepts that any of those transitions are possible. It follows the rule of sequential natural color transitions described in *Figure 1: RGB Color Star*.

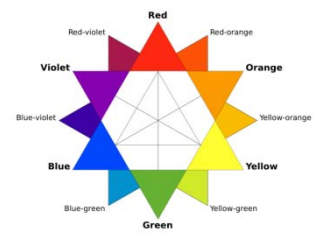


Figure 1: RGB Color Star

Phase 1: Regeneration of Thermal Color Palette. The fluent transition from one color to another is possible by reproducing the missing values for each color channel by increasing or decreasing in range of 0 to 255. The reverse-engineering process of the specific palette information requires color rearrangement for each recognized transition because of the 3-channel digital image encoding. Therefore it requires different logical approach. For example the comparison for the Black-Blue transition is represented by the following Boolean expression (2)[6]:

$$Res = \frac{C1.G + C1.R}{2} < \frac{C2.G + C2.R}{2}$$

where Res is TRUE when $C1$ (Color 1) < $C2$ (Color 2). The green and red channels are represented as G and R . Comparison (9) is simple because Blue channel is always raising and because the digital representation of the Left transition color (Black) is very simple – 0 (zero for each channel). The complexity of comparisons for the rest of the transitions becomes polynomial.

The algorithm passes on three stages:

- *Pass 1*: The pixels in the image are sorted in *transition groups*. Special evaluation function calculates a relative weight for each pixel in for each group;
- *Pass 2*: Groups are optimized by removing the duplicated colors;
- *Pass 3*: Modified QuickSort algorithm is executed for each group using the calculated relative weight from Pass 1. Depending on the transition group this modification of QuickSort is working in ascending or descending mode.

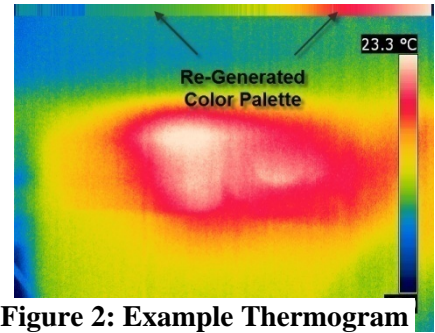


Figure 2: Example Thermogram

Phase 2: Temperature Calculation. The modern thermographs encode the temperature levels and the parameters of measurement while capturing the IR image. Normally the result is saved in specific to the camera file format. Later these files are distributed as a standard image file formats like JPEG (compressed) or BMP. However during this process the information necessary for any further analyses is lost. In this case the most important issue for the IR imaging is to restore the temperature information for each pixel in source image. In order to solve this issue the minimal T_{min} and maximal T_{max} temperature levels detected by the camera must be provided as external parameters.

After Phase 1 the color palette is already sorted – the first unique color is the coolest one, the last color is the warmest.

The temperature value T_c is distributed for each unique color in the palette as follows (3)[6]:

$$T_c = T_{min} + \sum_0^{C_T-1} \frac{abs(T_{max} - T_{min})}{C_T - 1}$$

where $C_T = C - G$, C is the count of all unique colors from the palette, C_G is the count of the garbage colors. Temperature *calibration* can be performed in accordance with Formula (7) where T_{total} have to be replaced with T_c .

The full calculation process over 400000 pixels takes less than 10 second.

2.2. Create Thermal Histogram

In terms of the theory of colors the *Thermal Histogram* shows the IR image *color density* for a specific temperature range. From practical point of view the Histogram provides quantitative information how warm or cold is one IR image. The aggregation process of the histogram is a global operation and, therefore, does not depend on the IR image geometrical parameters.

Consequently, the *Thermal Histogram* is an excellent tool to compare two different IR

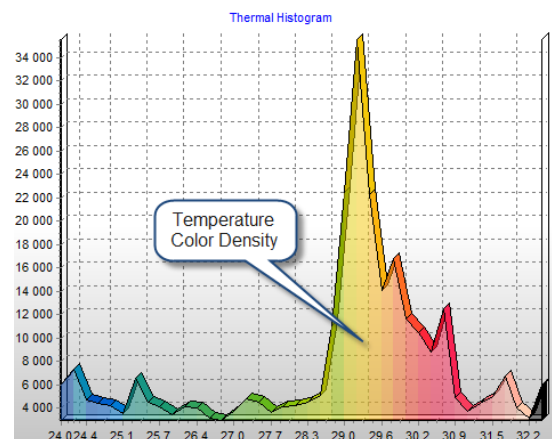


Figure 3: Thermal Histogram

images. It helps also when analyzing the temperature changes on specific object.

The data required for the Histogram is acquired by calculating the occurrence of each pixel from the source image vs. each unique color from the thermal color palette. The algorithm complexity is $\phi(\chi^2)$.

The number of calculations could be significant if the algorithm is not working with color probes. These probes are selected automatically. The histogram color density values are approximated to the nearest color probe. For example on *Figure 3: Thermal Histogram*, the temperature density is graphically represented by 40 unique color probes within temperature range 17.9 °C – 23.3 °C. For better view each probe is colorized in accordance with the *thermal palette* of the IR image.

The Histogram preparation time is very fast – assuming that the thermal palette is already create over 400000 pixels then the Histogram is generated for a second.

2.3. Create Thermal 3D model

The thermal 3-Dimensional (x, y, z) model visualizes the flat IR image into as a function of the temperature, where:

- X-axis and Z-axis represent the 2D pixel matrix of the IR image
- Y-axis represents the temperature level
- All “garbage colors” are kept in order to preserve the geometrical proportion of the image. Anyway, they are set as zero Y-axis value and are colorized in light gray.

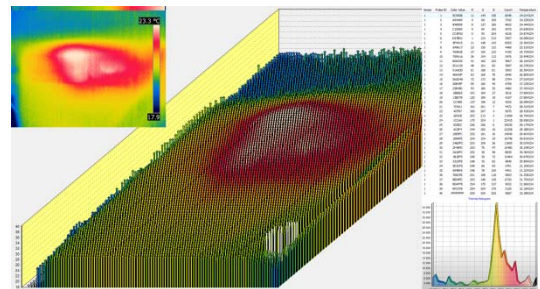


Figure 4: Thermal 3D Model

Unlike the *Thermal Histogram*, this model is geometrically dependent. Therefore it can be used to visualize and to magnify different intersections from the IR image. This option is very useful when hot and cold intersection areas have to be compared.

The *Figure 4: Thermal 3D Model* demonstrated how the algorithm visualizes the IR image shown on *Figure 2: Example Thermogram*. The current software implementation allows also selecting a graphical region for generating the 3D model and for supplying the following statistical information:

- Regional temperature levels, incl. minimal, maximal, average values etc.
- The relative temperature deviation between the absolute and calibrated temperature level (locally or globally for the IR image)
- Color pollution measurement

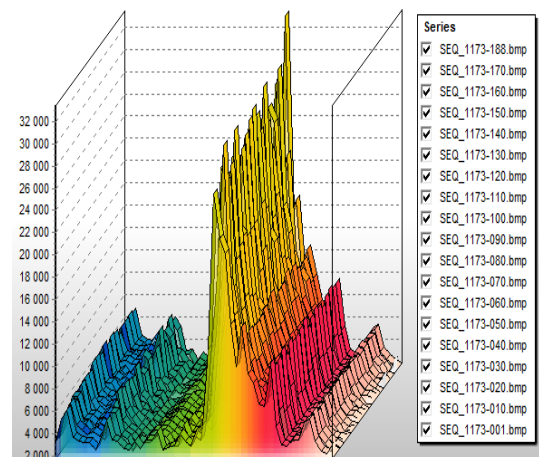


Figure 5: Batch Processing

2.4. Compare IR images as a bundle

In Section 0 was clarified that the *Thermal Histogram* is geometrically independent and therefore could be extremely useful tool to compare two or more IR images.

Figure 5: Batch Processing demonstrates the real behavior of relay which temperature is increased fluently for a certain period of time. The *Thermal Histogram* calculation uses 10% of about 200 serial images. Most of the surface of the object remains unchanged except those pixels marked in yellow.

The complete process of batch processing is shown on *Figure 6: Batch Processing Implementation*:

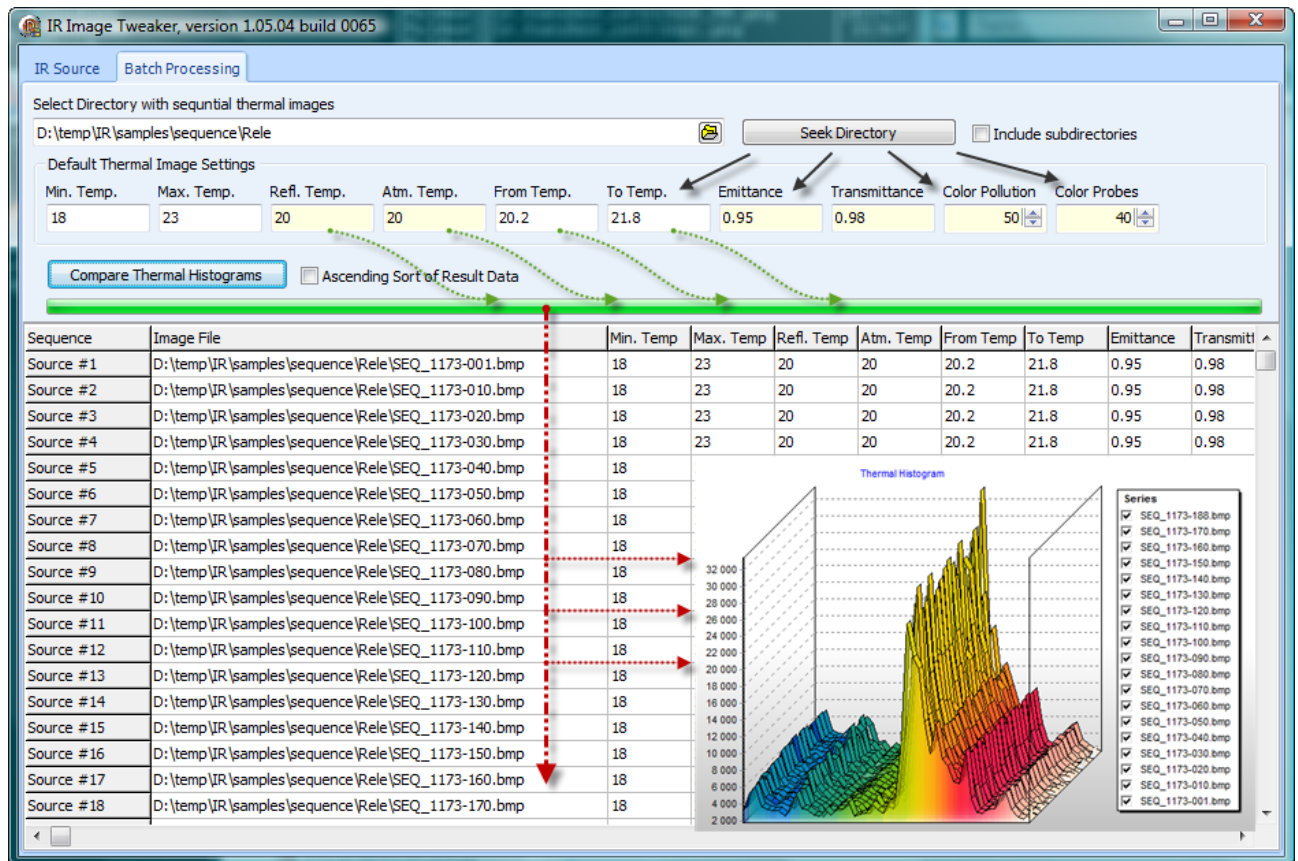


Figure 6: Batch Processing Implementation

- Step 1: All IR image files are collected and scanned for errors
- Step 2: The IR image bundle is normalized by applying different image point and local operations like contrast equalization, noise reduction, affine transformations, smoothing operations etc.
- Step 3: The normalized bundle is processed by applying the reverse-engineering method described in *Section 2.1*. All input parameters for this step are gathered from common thermal list of settings for each IR image.
- Step 4: The aggregated thermal histogram is created using the intermediate information gathered from the above steps.

3. CONCLUSION

The paper shows that the temperature information can be effectively restored using the IR image as the only source. This functionality helps IR images to be analyzed from different sources or cameras. The image calculations are working fast with high precision and large amount of data.

The calibration of color transition during thermal palette generation has to be improved in cases when the image color pollution is high or when there are too many color transitions gaps.

Namely over the above written issues my future work in research is ongoing.

4. ACKNOWLEDGMENT

The authors would like to thank to the support of Ministry of Education – Scientific Investigations Fond under which contract 1-854/2007 “Thermal Management of Microelectronic Systems (MC) – TEMC”, the present work was conducted.

5. REFERENCES

- [1] FLIR Systems, *Technical Specification Issue*, 1558550, Rev. a174, pp 243-244, 2005
- [2] Robert Fisher, Simon Perkins, Ashley Walker, Erik Wolfart. *Digital Image Processing*, HIPR2, John Wiley, 2004
- [3] Hairong Qi, Nicholas A. Diakedes, *Infrared Imaging in Medicine*, Article, Book 3, pp. 108-113, 1998.
- [4] R. N. Lawson. *Implications of surface temperature in the diagnosis of breast cancer*. *Canad Med Assoc J*, 75:309-310, 1956.
- [5] J. R. Keyserlingk, P. D. Ahlgren, E. Yu, N. Belliveau, M. Yassa. *Functional infrared imaging of the breast*. *IEEE Engineering in Medicine and Biology*, pages 30-41, May/June 2000.
- [6] Andrew Andreev, Anna Andonova, *Measurement of IR Temperature Deviation in Bio-Medicine*, Proceedings of CEMA, Athens, Greece, November, 2008 (to be printed).