# ADVANCED SPATIO-TEMPORAL THERMAL ANALYSIS OF ELECTRONIC SYSTEMS

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**Summary** - The article gives a brief review the of diagnostics and analysis possibilities by a spatio-temporal approach into electronic system in infrared bandwidth. The two dimensional image grabbed by the thermovision camera provides information about the surface temperature distribution of an electronic system. The main idea is based on the analysis of the object which consists of a temporal sequence of a spatial thermal images. Advanced analysis is achieved by morphological image gradient spatio-temporal model . The mentioned method provides a total temperature system evaluation as well as it allows separate analysis in the chosen determined temperature area.

**Abstrakt** – Článok poskytuje prehľad o možnostiach diagnostiky a časovo-priestorovej analýzy elektronických systémov v oblasti infračerveného pásma. Dvojrozmerný obraz zachytený termovíznou kamerou poskytuje informáciu o rozložení povrchovej teploty elektronického systému. Hlavnou myšlienkou je teplotná analýza časo-priestorového objektu, ktorý pozostáva z časovej sekvencie zosnímaných termovíznych 2D obrazov. Precíznejšia analýza vychádza z vytvorenia časovo-priestorového objektu vytvoreného zo sekvencie morfologických gradientov termovíznych obrazov. Uvedená metodika poskytuje komplexné posúdenie teplotných pomerov v elektronickom systéme, ako aj čiastkovú analýzu vo zvolenej teplotnej oblasti.

## 1. INTRODUCTION

In a time where miniaturization of electronic systems develops quickly and the density assemblage of electronic elements and circuits on the board increases fast, the thermal problems become really serious and important. Thermal monitoring and a special test design need to be basically established as a common tool for the electronic systems analysis.

Infrared imaging is a sensitive technology that is specifically used in several industrial technologies. Thermal imaging systems show invisible thermal patterns of the surroundings of objects and recognize them according to different temperatures.

## 2. IMAGE ANALYSIS

In analysis each image element is a function of the original degree of grayness, to which the point transformation adds a new degree of gray. It is possible to correct the image contrast (linear, exponential, logarithmic), and it is possible to create a binary image using threshold levels, as well. The local transformation utilizes the results of the output brightness of the additional points around the input point of the image. The filtered image can be included into the local transformation, depending on the selected matrix of the kernel K (3x3, 5x5, 7x7). Convolution filters have an important role during the image transformation.

The field of image analysis provides applications in the diagnosis of electronic circuits and electronic systems (Fig.1). The main reason for these operations is to obtain representative data about the surveyed process. The methods of image preprocessing and their results are used to improve the image quality from the aspect of the subsequent processing. It is important to know that, if it is loose, reduce or increase any of the gained information, results are desolated and not used for the development of the process.

The process of analysis is a heuristic one, and through a combination of possibilities which are provided by the system important information is gained. But there is no single algorithm that would guarantee a successful solution, whichever character the image has. To deal with a particular problem an experimental approach is required.

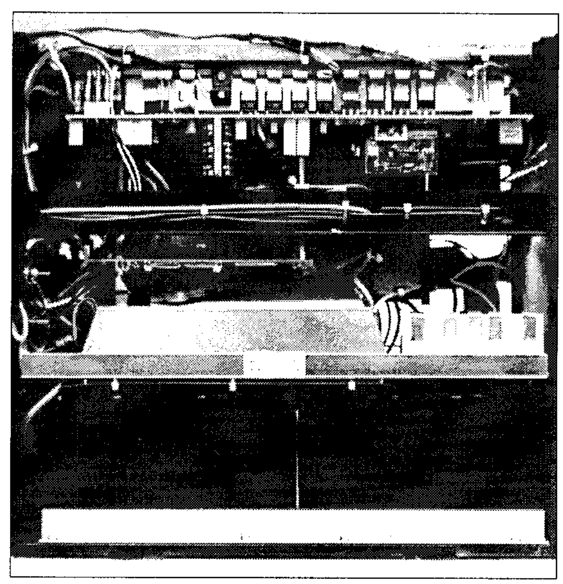


Fig.1 Electronic system in visible spectrum

The camera for infra-red imaging converts the thermal radiation of objects into a visible picture that allows their processing in a similar way as it is possible with images from standard camera.

## 3. INFRARED ANALYSIS

The intended solution of the imaging camera system produces a temperature map. Each point on the map represents a number that corresponds with the local temperature of objects. Next processing the temperature map there are two possibilities. The first possibility is to create a gray image where warmer objects are shown in lighter gray and colder ones in darker gray. The shades of gray from black to white represent the whole temperature scale (Fig.2) and correspond in that way with local temperatures. Basically a particular camera should be calibrated and adjusted.

Fig.2 Electronic system in infrared spectrum

The second way to use the thermal analysis efficiently is the creation of a colored image, where particular colors correspond with quantitative temperature levels.

As mentioned earlier, the thermal camera produces a data flow representing a time sequence of IR radiation maps. In principle there are two basic ways for the interpretation of this data flow. One way is based on the visualization of these maps, giving the possibility to post-process the captured static images. The other way uses real time signal processing in order to extract some specific features from the time sequence of the radiation maps. This is necessary when a position of an object has a specific temperature or a dangerous trend of inspected processes is monitored.

To guarantee the maximum reliability and safety of electronic systems, their thermal processes needs to be regularly supervised under the use of special technological equipment according to a defined time schedule. Frequently the equipment that is needed for the supervision of the processes is rarely accessible.

## 4. SPATIO-TEMPORAL 3D MODEL

The next technological procedure is the diagnosis and analysis of an electronic system in infrared bandwidth by a three dimensional (3D) spatio-temporal model. The two dimensional (2D) image grabbed by an infrared camera provides information about the surface temperature distribution (Fig.2). The time sequence of a 2D infrared image provides the fault detection and localization.

The whole process is based on the analysis of a 3D object consisting of temporal series sequence of 2D infrared images (Fig.3). The third dimension is the time domain.

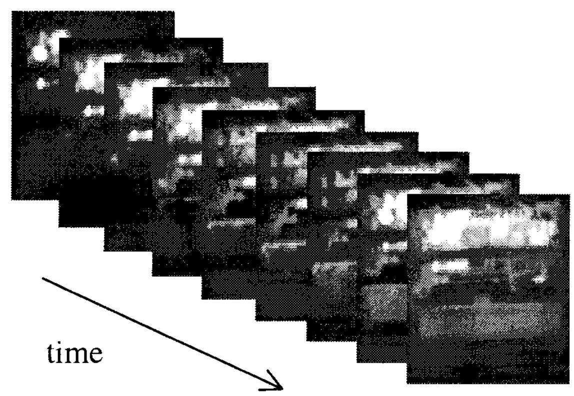



Fig.3 Temporal sequence of 2D infrared images

After multi-threshold level operation of all the 2D infrared images (Fig.4) a spatio-temporal model with discrete temperature areas is obtained (Fig.5).

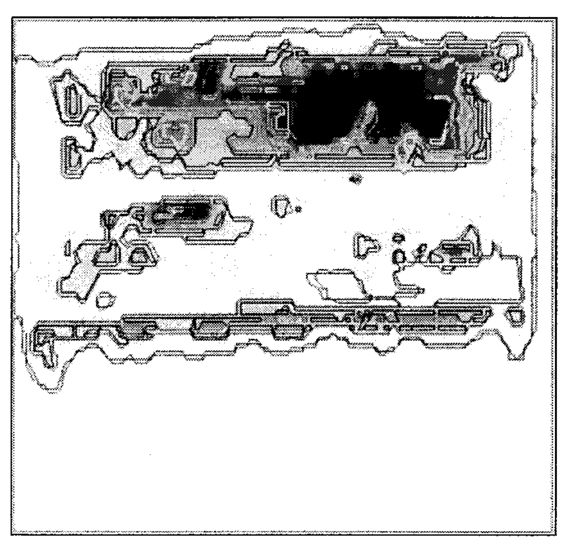


Fig.4 Electronic system with discrete temperature areas

Each shade of grayness has a certain temperature range. Transparency or non-transparency rendering can be adjusted.

Another possibility is the rotation of the object in the three rectangular planes, Fig.6. This approach provides more detailed analysis and evaluates the thermal conditions.

In case there are more detailed inside analysis, it is possible to create a cross-section of the 3D spatio-temporal model, Fig.7.

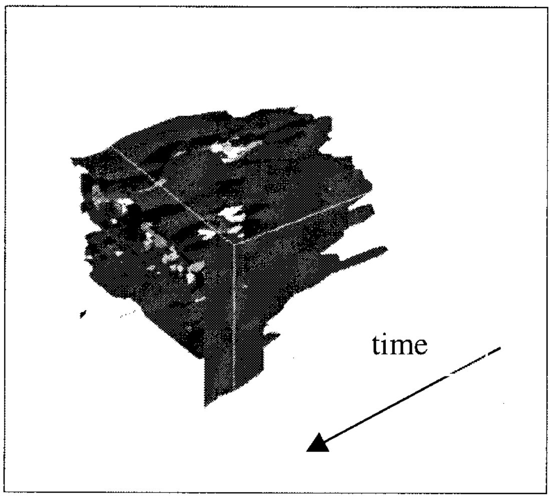



Fig.5 Spatio-temporal temperature model with discrete ranges

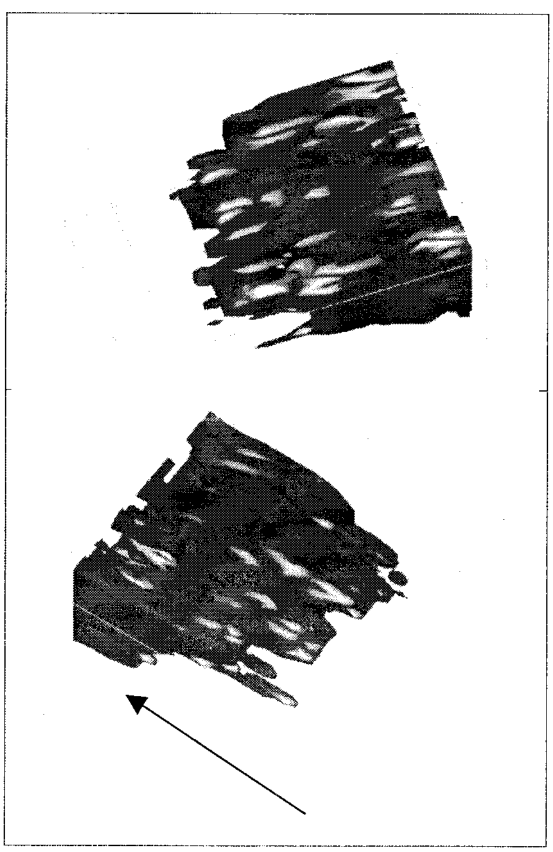


Fig. 6 Rotated spatio-temporal model one of the thermal range

## 5. ADVANCED THERMAL ANALYSIS

The commonly used method of differentiation in the image processing applications is the use of the gradient procedure. The value of the gradient is proportional to the difference in the shades and value of gray between adjacent pixels in image (Fig.7). The gradient assumes relatively large values for prominent edges in an image, and small values in regions that are fairly smooth. Zero is only found in regions which have a constant gray level.

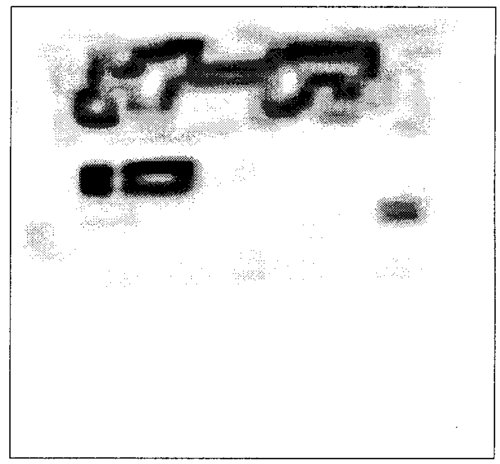


Fig.7 Gradient image (inverse form)

If the value of grayness corresponds with the temperature, it is possible to obtain more detailed trend analysis of the surface temperature distribution. Generally, areas with a large temperature difference correspond to higher grayness values, and areas with a small temperature difference correspond to lower grayness values. Areas with no temperature changes are black. (The example gradient image of Fig.2 is displayed in an inverse form in Fig.7.)

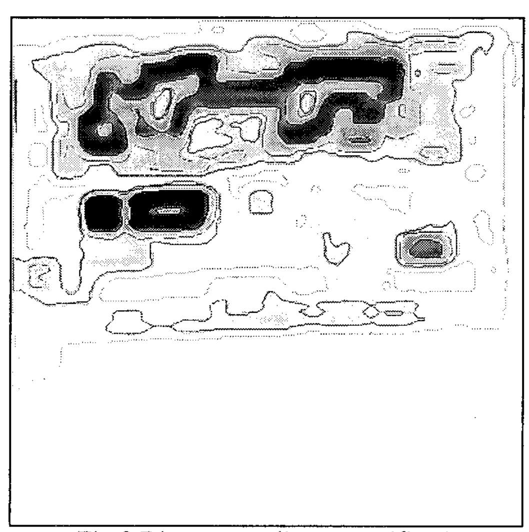


Fig.8 Discrete gradient quantification

The next step is the segmentation of the gradient images. The gradient image with the discrete gradient quantification (temperature changes) is useable for temporal presentation (Fig.8).

The spatio-temporal model consisted of the 2D gradient images sequence is possible to create by the same mentioned method.

It is possible to display spatio-temporal dependence only one range of gradient value (Fig.9).

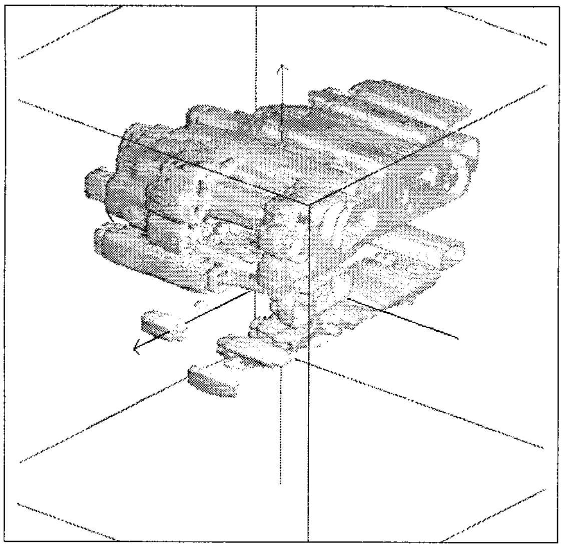
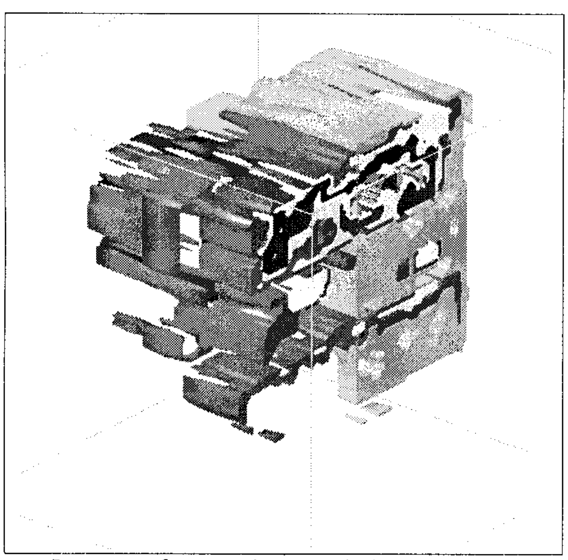


Fig.9 Spatio-temporal image gradient model



In case of general appreciation it is possible create a sum of complete spatio-temporal gradient ranges for the whole object (Fig.10).

Fig.10 Sum model of complete spatio-temporal gradient image ranges

## 6. Conclusion

The mentioned method provides a complex temperature evaluation system as well as it allows the separate analysis in the selected determined temperature range, as well as in the cross-section temperature layout.

The analysis of the spatio-temporal thermal model provides several possibilities: shifting in defined direction, three planes rotation, zoom-in, zoom-out, and contrast adjustment.

The spatio-temporal thermal model created by a sequence of gradient images provides the analysis of more details (location, time) and trends of the surface temperature distribution on electronic systems.

The results of the analysis are: the temperature profiles, the temperature gradients, and the thermal propagation in the temporal dependence. They manifest thermal overloaded areas and predict the area and the moment of a possible failure in the system.

The spatio-temporal thermal analysis controls the thermal processes of technological equipment. It is a non destructive testing and failure predicting or failure detecting method that may be applied in the manufacturing and in the quality control, and it is a thermal navigation and security system for the localization of hot and cold objects.

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