THERMAL-VISUAL DIGITAL SYSTEM IN THE IMAGE OF AREA PHENOMENA
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ABSTRACT

Thermal-vision digital system (TVDS) was worked out on the basis of a thermal scanner of AGEMA LWB 880 and vision camera CCD. The scanner obtains data in spectrum range 8-12 µm and the camera CCD in the range 0.4 - 0.9 µm. The aim of the system is to register digital data on surface temperatures distribution and their measurements on the examined objects. Generated thermal and visual images are stored in the computer memory IBM notebook type and processed on one monitor in parallel. The system can work on different stands in a laboratory, in a car while driving or in a plane during a flight. TVDS may register thermal images, visual images or both of them: a) as single images, b) as films with given time intervals between registration of particular records, c) in real-time. The registered digital images undergo elaboration taking into account surrounding temperature, emission coefficient and registration distance (atmospheric conditions). The elaboration of thermograms can be carried out in TVDS or outside it. There is a possibility of elaborations in different forms: qualitative or quantitative ones. Graphic image has got a screen form which can be a layer of a vector map. TVDS is an open system and therefore it can be equipped with necessary additional applications.

1. STRUCTURE, FUNCTIONING AND SOFTWARE TVDS

The interface of camera is an essential element of a computer system of processing thermographic images where analog signal carrying information concerning the temperature of an object which is changed into digital form and sent to a computer. The possibility of reciprocal matching of thermal and optical images was applied for faster and easier interpretation of thermograms. Therefore the system was equipped with two cameras: thermal and CCD visual ones. The methods of processing the images concern both thermal and optical parts. However, they differ as far as different amount of information in both images is concerned.

The optical systems of both cameras have got similar parameters and software runs in Windows 3.1 and a computer notebook type-fig.1. The thermal camera AGEMA LWB 880 is an electromechanical device where the process of the image analysis takes place due to rotation of prisms and mirrors. The rate of image generation by the camera is low because rotational speed of the scanning system is limited. A low resolution data acquisition system is recommended. Typically, resolution of 256 pixels/line is quite acceptable. As a result of this resolution the data transmission rate (from camera to the computer) does not exceed hundreds Kbytes per second. Synchronization system, where sampling clock signal is produced, is a very important element of the interface. It is the signal with much higher frequency than horizontal HSYNC and vertical VSYNC deflection frequency. Accuracy of reproduction of sampling clock influences the thermal image being transmitted to a computer (Więcek, B.1993)

Another important element of TVDS is an optical interface of CCD camera. The computer interface of the CCD camera is equipped with large buffer memory because of the size of optical images. It enables to store one or few full images. The elements of preliminary digital conversion can be additionally found in the buffer memory. The image transmitted to the computer is of high stability and quality as the contrast, emission coefficient or environmental conditions are concerned. The interface of the optical camera is presented in picture 2. High power of interface conversion results from high calculation power of optical image processor and the possibility of availability to many image pixels. Low speed information exchange through transmission circuits is limitation of image conversion. Monochrome CCD camera interface contains 16-bit graphic processor dedicated for complex video operations.

Fig.1. Operation of interface in the thermal camera diagram
Some parameters of thermal and visual system:

**Thermal system**

1. **Thermal camera resolution**
   - TVS40TE - 256x60
   - AGEMA 880 - 256x400

2. **A/D conversion resolution** - 4/8 bits

3. **Registration rate**
   - real-time mode (in the memory, TVS40TE) - 1 image/50ms
   - real-time mode (in the memory, AGEMA 880) - 1 image/160ms
   - non real-time mode (on the hard disk) - \( t_{\text{min}} = 0.5s \)

4. **System capacity**
   - real-time mode - 128 images / 1MB of RAM
   - non real-time mode - limited by hard disk capacity

5. **Triggering** - automatic, external, by user

6. **No of colors in thermal diagrams** - 16/64 pallets

**Visual system (for TVS40TE/AGEMA880)**

1. **Visual image resolution** - 512x240 (480- interface)

2. **A/D conversion resolution** - 8 bits

3. **Sampling rate** - 15MHz (Quartz-controlled PLL)

4. **Graphic processor clock** (TMS34010) - 40MHz

5. **Life-Video mode** - on the computer screen

6. **Visual input** - lvp-p (CVS)

7. **System capacity** - limited by hard disk capacity

8. **Image processing** - filtering, edge enhancement, mixing, noise cancelling

9. **Graphics** - 16/256 SVGA

2. **TVDS UTILIZATION FOR TERRAIN DISPLAY**

Accurate determination of real temperature in a given point and the borders of isotherms between temperatures on the examined area or spacial object is a significant problem in thermo-vision measurements. Significant errors resulting from the measurement of energy density emitted by an object influence temperature measurements. They depend on the error determining several factors which the programme takes into consideration i.e.: emission coefficient, distance influence camera-object (atmospheric conditions), environment temperature and the process of image conversion. Identification of details on the examined objects where there is a little differentiation of temperature is also a very important problem. Vision image CCD with the possibility of its contour and then contour extraction on thermogram of the examined object prior to scaling both images is very useful as shown in figures 3-6. Double bearing vector in both image windows at scaled images enables to show mononual points. Having worked out generated images they are connected into the whole investigated object or in its greater parts. Then edition with legend and onomatology is carried out.

![Fig. 3. Enlarging with intersection of minor terrain details and determination of real temperature of the point.](image)

![Fig. 4. Thermogram and vision image converted into equal skale (double bearing vector).](image)
2.1 Possibility for terrain display

The application of new technologies resulting from technical development often causes excessive pollution of soil. It can be exemplified by distribution of large quantities of petroleum for chemical industry and transport. (Lubecki, A., 1996) Damages of pipelines sending petroleum take place more often. The present bases of fuel with tanks of few thousand tons capacity do not belong to a young generation. It all happens in a given nature environment and it causes its potential hazard. Some phenomena attributed to the hazard may be directly localized but it is necessary to analyse polluted areas in non-contact way particularly in inaccessible, dangerous and large areas or incase when they cannot be investigated by other methods. Thermal system equipped with additional vision channel which enables the determination of ranges of contaminating substances influence can be used for localization the occurrence of a given thermal energy as a consequence of environment pollution. Thermo vision allows registration of thermal anomalies on the terrain surface and their interpretation when technical state of objects is concerned.

The subject of undertaken investigations concerns the areas over tanks and in their neighbourhood which were registered on thermograms. The images underwent computer processing which allows the analysis of situation in different temperature ranges. It has already been pointed out that numerous unfavourable changes take place on the area polluted by petroleum. Water permeability of soil is limited about 12 times, potential and effective retention as well as soil air by Kitagawa and Dr.tiger's indicator tubes in the range from 100 to 1500 ppm. Thermal vision of fuel base together with its surrounding was made on 24th July, 1994 at night hours from the height of 500m. The whole area was visualized in three series. The option of gaining thermal images as a film was used for its presentation.

2.2 Underground fuel tanks

An optimal surface thermal model of underground tank was made after detailed computer processing of thermal images of three underground tanks filled with fuel. Such model should present:

- inside circle with highest temperature
- outside concrete ring with lowest temperature
- outside area of the ring with lowest temperature, presenting cooling zones of a tank

Three tanks have got the shape of circles with equal area and capacity. The temperature on thermograms range between 18.6 and 26.4°C. The direct surrounding of the tanks is covered with grassy plants whereas there is lack of any plants in a further distance. The temperatures on the thermograms themselves are higher and they are placed in the range 24.1 - 26.4°C. Analysing them it was stated that the tanks Z1 and Z2 correspond to the above thermal diagram. However, the tank Z3 differed from the model which was a consequence of its weaker cooling (Lubecki, A., 1996) - fig. 7.
The temperatures of these cisterns reached 27.9°C. The zone of the outlet front reached the highest temperatures which proves the presence of fuel inside it. It is clearly indicated by colours typical for the highest thermograms (28.6 - 29.3°C). The area of railway ramp where the fuel is reloaded, due to its systematic utilizations, is exposed to fuel leakage from cistern and pipeline valves into soil - fig.8. It was proved by KVA sounding of the second serate at the depth from 1m to 1.64m presented in table 1.

<table>
<thead>
<tr>
<th>Sounding number</th>
<th>Depth of sounding [m]</th>
<th>Type of detector tube</th>
<th>Hydrocarbons [ppm]</th>
</tr>
</thead>
<tbody>
<tr>
<td>S5</td>
<td>1.0</td>
<td>Kitagawa**/</td>
<td>242</td>
</tr>
<tr>
<td></td>
<td>1.0</td>
<td>Dräger**</td>
<td>180</td>
</tr>
<tr>
<td>S6</td>
<td>1.64</td>
<td>Kitagawa</td>
<td>&gt; 1400</td>
</tr>
<tr>
<td></td>
<td>1.40</td>
<td>Dräger</td>
<td>&gt; 2500</td>
</tr>
<tr>
<td>S7</td>
<td>1.70</td>
<td>Kitagawa</td>
<td>&lt; 50</td>
</tr>
<tr>
<td>S8</td>
<td>1.70</td>
<td>Kitagawa</td>
<td>&lt; 50</td>
</tr>
</tbody>
</table>

*/ Kitagawa - General Hydrocarbon Detector Tube (50 - 1400 ppm)

/** Dräger - Petroleum Hydrocarbons 100/a n-octan (100 - 2500 ppm)

2.4. Municipal wastes dump

There is a great danger of spontaneous ignition or fires to people who work on large waste dumps. The wastes stored on large areas are the mixture of organic and non-organic materials which decompose into methan, carbon dioxide and others during physico-chemical and biological processes. About 91% of methan originates from cellulose wastes, about 8.4% from nitrogen organic compounds and 0.6% from sugars. Biogas is used in some dump wastes but unfortunately not in all. There fires can take place in the places with high concentration of methan. TVDS can be applied for detection of such places. The images are taken from a plane or a helicopter. The temperature increase is immediately noticed by a scanner and registered in the computer memory. Therefore we can warn much earlier about the danger. This situation is presented in fig. 9.

2.5 Monitoring of lake pollution

Continuous penetration of lake shores and river banks in order to localize the sources of pollutions by farms and
holiday resorts is a significant problem in environment protection. It happens that they have got so called "wild" outlets by pipes under the lake bottom several meters from the shore. It is very difficult to identify it from the shore. It is necessary to penetrate the area from a plane at night when the wastes are being let into the lake or after a short period of time when the procedure took place. Only then is it possible to pick out the activity. Inflow of warmer polluted substances than water in the reservoir enable its registration on thermograms fig. 10.

Fig. 9. Thermogram and vision image municipal waste damps, A-burning spot.

26.89
26.49
26.09
25.68
25.28
24.87
24.46
24.05
23.64
23.23
22.81
22.40
21.98
21.56
21.13
20.71

LI=0.039 CT=21.7°C LV=46.7 RG=5.0
Y=0.480 21:47:26 94/07/12 AP=0

Fig. 10. Thermogram of a part of a lake with contaminated water surface. A-place of contamination.

3. Conclusion

TVDS is a system of different applications with the possibility of digital processing. As the system is open there is a wide range of working it out in different programmes. The results may be presented in a qualitative or quantitative way. Percentage histogram in each thermogram can be used for the determination of its thermo-area. Four different contouring filters in the programme give the possibility of their regulation and obtaining a required contour of an analysed object. Coordinates of bearing vector enables precise localization of discussed elements of the terrain. Using the possibilities of the programme, having a thermal image there is a possibility of obtaining real temperature of the investigated object or determination its emission coefficient. Colour scale of temperature registered at each thermogram is given with accuracy of 0.01°C for programme calculations and the accuracy of determining temperature by means of TVDS is 0.1°C. There is still lack of automatic radiometric and geometric correction of the image. At present TVDS can be used for non-topographic research or for investigations with lower accuracy of point mapping.

BIBLIOGRAPHY

