THERMAL-VISUAL DIGITAL SYSTEM IN THE IMAGE OF AREA PHENOMENA

Andrzej Lubecki*, Bogusław Więcek**
* Chair of Photogrammetry and Remote Sensing
Olsztyn Uniwersity of Agriculture and Technology-Poland
**Institute of Elektronics
Technical University of Łódź-Poland

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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 systemcan 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.

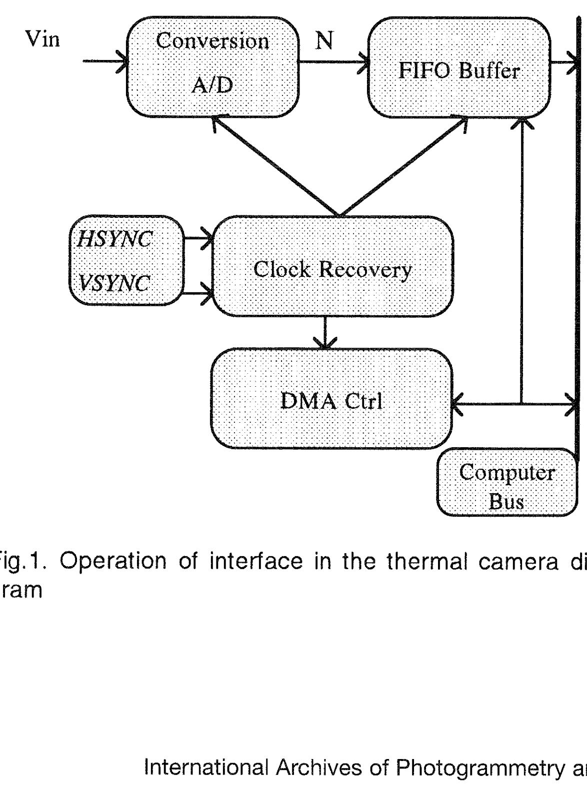

Fig.1. Operation of interface in the thermal camera diagram

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 placedue to rotation of prisms and mirrors. The rate of image generation by the camera is low because rotational speed of the scaning system is limited. A low rezolution data acquiring 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 vertikal 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 butter memory because of the sizeof optical inages. It enables to store one or few full images. The elements of preliminary digital conversion can be additionaly 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 optikal 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 intefacе contains 16-bit graphic processor dedicated for complex video operations.

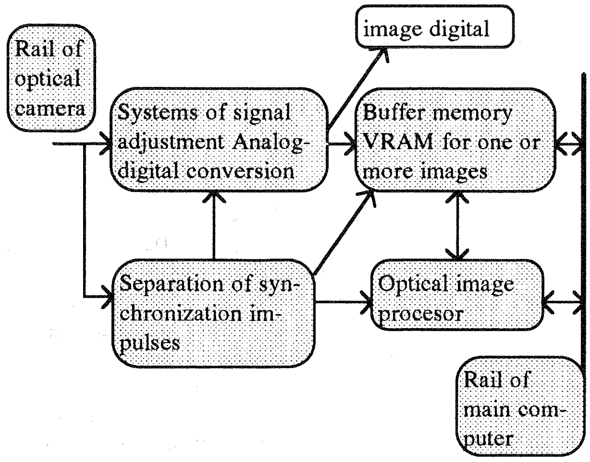

Fig.2 CCD interface block diagram

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) - $t_{min.} = 0,5s$

4. System capacity

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

5. Trigering - *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-interlace)*

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 - *Ivp-p (CVS)*

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

8. Image procesing - *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. Significanterrors resulting from the measurement of energy densityemitted by an object influence temperature measurements. They depend on the error determining several factors which the programme take 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 olifferentiation 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 vectorin 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.

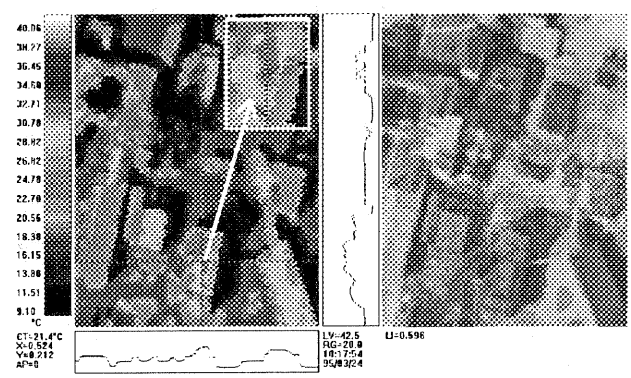

Fig. 3. Enlarging with intersection of minor terrain details and determination of real temperature of the point.

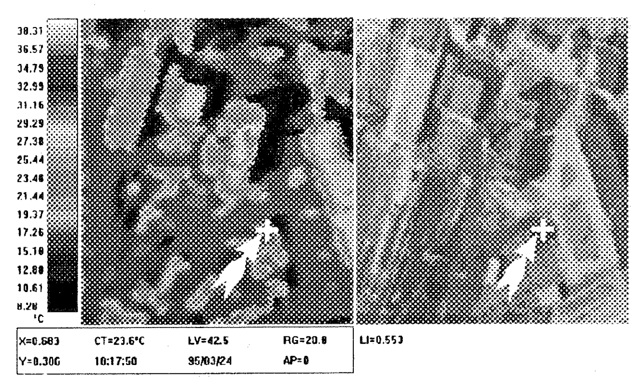

Fig. 4. Thermogram and vision image converted into equal skale (double bearing vector).

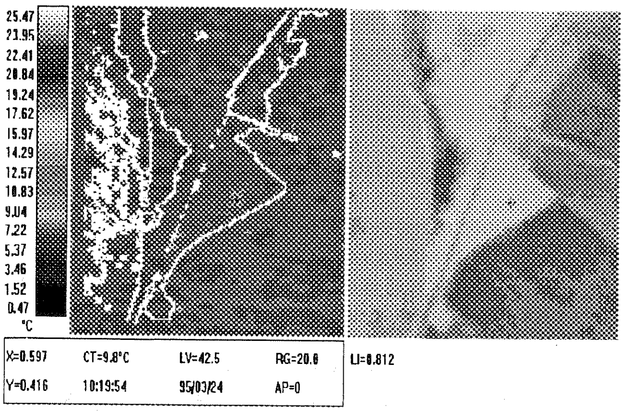

Fig. 5. Thermogram with vision image contour.

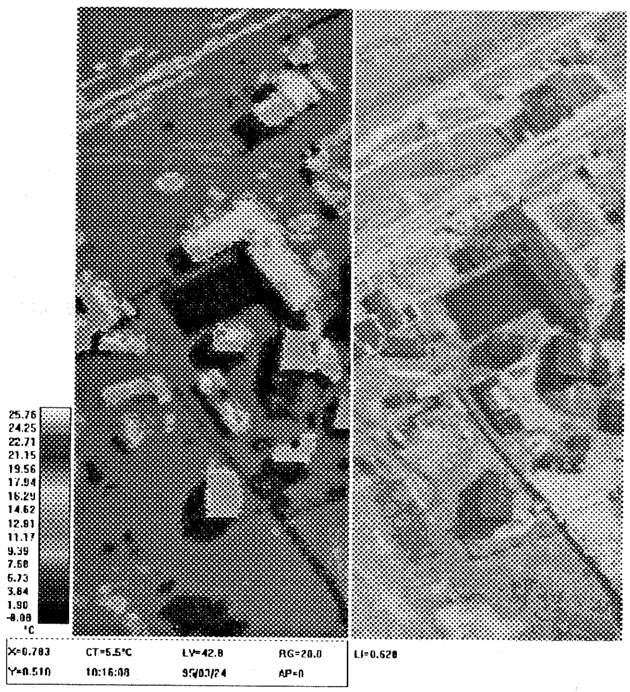

Fig. 6. Converted thermograms and vision images after connection.

2.1 Possibility for terrain display

The application of new technologies resulting from technical development often causes excessive pollution of soil. It can be examplified by distribution of large quantities of petroleum for chemical industry and transport. (Lubecki, A., 1995) 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 atributed 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 lokalization the occurance of a given thermal energy as a consequence of environment pollution. Thermovision 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 placeon the area polluted by petroleum. Water permeability of soil is limited about 12 times, potential and effective retention as well as capillary capacity are decreased. The amount of carbon increases 7 times which is a consequence of appearing large quantities of oxidable organic substance, oxidizing-reductive potential of soil changes and its biological efficiency decreases. The amount of potassium and phosphorus available forms decreases several times. Generalnumber of microorganisms particularly oxygen-free increases at the cost of oxygen forms. The changes of spectral brightness on the polluted surface of the soilwith the increase of petroleum origin compounds take place. It was assumed that the leaks petroleum origin substances into soil caused the development of biodegradation of these substancesand they were expressed by the emission coefficient and thermal capacity changes. General so called „tiredness" of environment as a result of permanet presence of fuels in soil helps in capturing the state of environment pollution on the basis of thermal images. The estimations of soil contamination in the terrain was carried out by a probe KVA determining quantitatively general hydrocarbons in the soil air by Kitagawa and Dr□ger's indicator tubes in the range from 100 to 2500 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. Uunderground fuel tanks

An optimal surface thermal moder 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, pre senting 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^{0}C. The direct surrounding of the tanks is covered with grassy plants whereas there is lackof any plants in a further distance. The temperatures on the thermograps themselves are higher and they are placed in the range 24,1 - 26,4^{0}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.

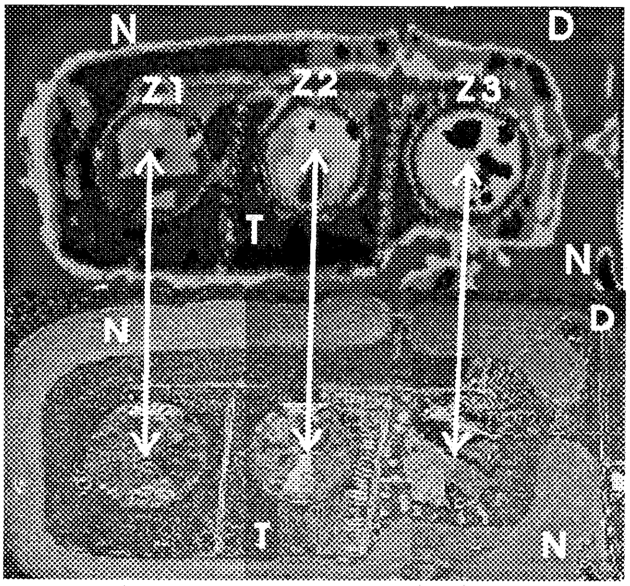

Fig. 7. Thermogram and vision image of the underground fuel tanks. Z1,Z2,Z3-tanks underground, N-area without plants cover, T-grass cover.

2.3. The region of the railway ramp

A wide temperature temperature range from 19,4 to 30,1 is characteristic for the whole area together with the terrain elements. The region of the railway ramp is very rich with technical infrastructure (warehouses, fuel tanks, drafts of furnace fuel and railway siding with standing cistern). Surface tanks used for petroleum products are characterized by lower temperature (20,2 - 21,8^{0}C) because small quantities of fuel are stored in them or there is a lack of it. Higher temperature is typical for the hardened road surface because they contain oil derivatives substances. The zone of railway cisterns and the area of fuel outlet are considered as the sore point of the analysed area. There were 7 cisterns with fuel during the air registration of the thermograms.

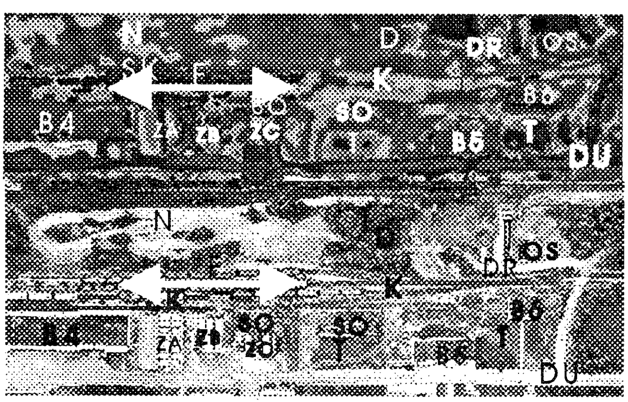

Fig. 8. Thermogram and vision image of the railway ramp.D-trees, N-area without plants cover, DR-non-hardened roads, DU-hardened roads,
T-grass cover, SO-store of fernace fuel, K-rail ways, SK-cistern carriages, ZA, ZB, ZC, ZD-tanks surface, F-front outlet of fuels, B4-oil ware-house, B5-central pump, B6-railway depot.

The temperatures of these cisterns reached 27,9^{0}C. The zone of the outlet front reached the highest temperatures which proves the presence of fuel inside it. It is clarly indicated by colours typical for the highest thermograms (28,6 - 29,3^{0}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 serie at the depth from 1m to 1,64m presented in table 1.

Tabel 1.
Results of KVA sounding

Sounding number	Depth of sounding [m]	Type of detec tor tube	Hydrocarbon s [ppm]
S5	1.0 1.0	Kitagawa*/ Dräger**/	242 180
S6	1.64 1.40	Kitagawa Dräger	> 1400 >2500
S7	1.70	Kitagawa	< 50
S8	1.70	Kitagawa	< 50

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

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

2.4. Municipal wastes damp

There is a great danger of spontaneous ignition or fires to people who work on large waste damps. 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 celulose wastes, about 8,4% from nitrogen organic compounds and 0,6% from sugars. Biogas is used in some damp 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 warm much earlier about the danger. This situation is presented in fig. 9.

2.5 Monitoring of lake polution

Continuous penetration of lake shores and river banksin order to localize the sources of pollutions by farms and holiday resorts is a significant problem in environment

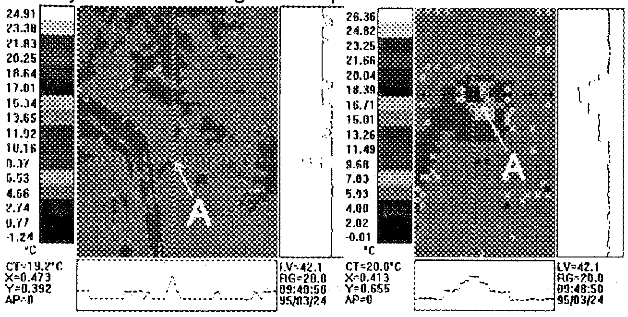

Fig. 9. Thermogram and vision image municipal waste damps, A-burning spot.

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 s-hore. 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 pla-ce. Only then is it possible to pick out thes activity. Inflow of warmer polluted substances than water in the reservoir enable its registration on thermograms fig. 10.

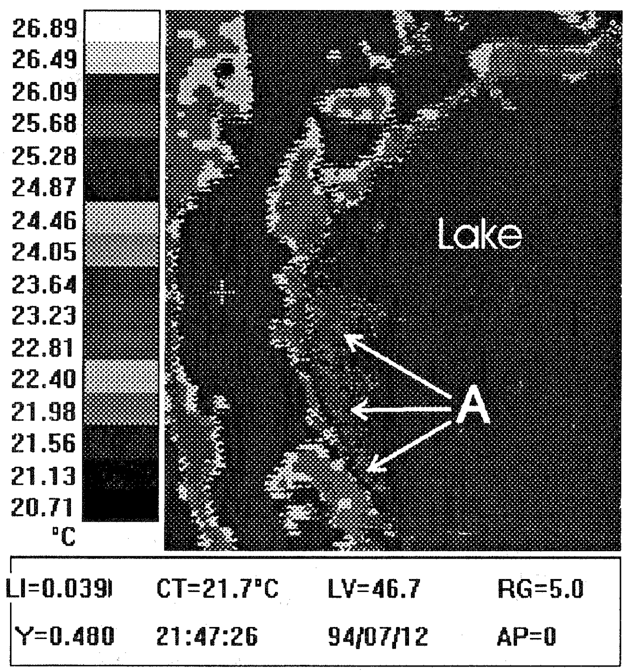

Fig. 10. Thermogram of a part of a lake with contamina-ted water surface. A-place of contamination.

3. Conclusion

TVDS is a system of different applications with the po-ssibility 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 quantita-tive way. Percentage histogram in each thermogram can be used for the determination of its thermo-area. Four different contouring filters in the programm give the po-ssibility of their regulation and obtaining a required con-tour of an analysed object. Coordinates of bearing vektor 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 re-gistered at each thermogram is given eith accuracy of 0,01^{0}C for programme calkulations and the accuracy of determining temperature by means of TVDS is 0,1^{0}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.

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