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DESIGNING AND SHAPING METROLOGICAL FEATURES OF THERMOGRAPHIC SYSTEM

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Abstract

There have been presented the general approach of thermographic system designing problems. Metrological features an infrared thermography equpment have been formed considering various properties and parameters of objects, atmosphere, optics, detection system, electronic and display unit. There have been characterized the synthesis process of the IR thermographic system Algorithm of designing the thermographic system with sequence structure of measuring line with PC, PV or SPRITE IR detectors have been shown.

1. INTRODUCTION

Rapid development of computer techniques made significant changes in the field of general engineering analysis. So, there is the increase of demand for various software necessary to aid the design and therefore the rapid development of computer - aided optical design (CAOD) is observed. In Poznan University of Technology (PUT) there have been designed thermographs that can be applied in medicine, industry and various technical diagnostics (fig. 1). Metrological features of these thermographs have been formed considering various properties and parameters of potential objects, atmosphere, optics [1], detection system, electronic and indication equipment [2]. There have been presented in the paper the general approach of thermographic system designing problems.

2. CREATION OF THERMOGRAPH METROLOGICAL PROPERTIES

In synthesis of thermographic system (TS) there are two problems that can be pointed out.

- simple problem that is based on determination of parameters completely defined TS (in electrooptical meaning; this problem is always solvable).
- reverse problem that is based on searching the parameters characterizing particular ST nodes for given parameters of the whole system. This problem is not solved "explicate" but the results obtained by approximate methods are not stable.

This disadvantageous feature causes that the reverse problem is usually replaced by the set of simple problems with the elements of evaluation of the following results. For such approach it is possible to obtain the solvable result considering all imposed constraints and conditions. Optimal solution according to the imposed criteria, is obtained by means of "test and error" method. Such approach to the TS synthesis problem enabled to prepare the THERMOPT program that is designated to modeling the particular TS nodes as well as to analyzing properties of the whole system.

This repeatable analysis (for various parameters) enables to reach step by step the optimal solution. Applying the THERMOPT program it is possible to model: spectral and spatial filtration of optical system, spatial and frequency filtration of detector, filtration properties of indicator and electronic line, object emission properties and atmospheric attenuation. For given parameters describing particular TS nodes it is possible to determine thermometric

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characteristic, optical and modulation transmission function (OTF, MTF) as well as geometrical and thermal resolution (NEDT) of the system. It seems that generally there is no universal criterion for all thermographic systems, connecting all significant parameters of TS. This is caused by the great dynamics of input data changes. The other factor is the continuos progress in production of multi element and multi color detection structures, progress in production of optical materials for refraction elements, progress in production of coating the anti reflective dielectric layers and so on. All the above facts make impossible to create the stable and universal criterion for all kind of thermographs. Anyhow, such criterion is possible to determine for systems with series structure of measuring line applying point detector as the detection element. In case of the thermographs with series structure of measuring line it is possible to determine the global factor of metrological and using properties (GFMUP) of thermograph. The linking of metrological parameters with using properties is caused by the fact that TS with great dimension optical system are potential of the better resolution parameters than the similar systems equipped with smaller optical systems (for equal values of f - number for both comparable systems) {2],[3],{4}. The GFMUP parameter has been determined by the analysis of influence of various construct factors upon the thermal resolution ΔT and geometrical resolution ΔG with representation "granularity" (determined by number of points in line N_p and number of lines N_l in thermal representation) and by their connection with number of analyzed of images per second n_k and collecting aperture D. Because of the above facts the GFMUP parameter contains the factor with information about the dimension of optical system. In this case the dimensions are represented by collecting aperture of the TS optical system. The GFMUP parameter has been described for the following conditions:

- its value should be approximately equal for each equipment configuration of the given thermograph;
- it should be possible to state what has to be done in construction of given system in order to optimize the chosen parameters (e.g. thermal resolution).

It is possible to prove that the adequate parameter, fulfilling of condition can be described by the following equation.

$$GFMUP = \frac{(n_k \cdot N_l \cdot N_p)^{\frac{1}{2}}}{\Delta T \cdot \Delta G \cdot D} \tag{1}$$

The thermograph is better for smaller ΔT, ΔG and D values and for greater n_k, N_p and N_l values. So the GFMUP value should be as great as possible. The GFMUP parameter has been determined in order to connect the values describing the resolution properties, the speed of creation the thermal representation and (indirectly) camera dimensions from one side, and to connect the value of this parameter with values describing the construction of image analysis system from the other side. This parameter is connected with construction of image analysis system by the dependence:

$$GFMUP = \frac{(k_V \cdot k_H)^{1/2} \cdot I}{2\pi^{1/2} \cdot \xi} \tag{2}$$

$$I = \int_0^\infty \tau(\lambda) \cdot D^*(\lambda) \frac{\partial\, m(\lambda, T)}{\partial T} d\lambda \tag{3}$$

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where:
k_V, k_H - coefficients of screen efficiency in vertical and horizontal direction,
λ - wave length,
$\tau(\lambda)$ - spectral coefficient of optical system transmittance,
$D^*(\lambda)$ - spectral detectivity of the detector,
T - absolute temperature,
$m(\lambda,T)$ - emitance,
ξ - coefficient describing aberration properties of optical system.

Due to equation (1) it is possible to evaluate the construction of thermographica equipment that is available on the market. Equation (2) and (3) are important for thermographic equipment designers as they point out how to improve the resolution properties of the thermograph for given camera dimension and frequency of frame analysis. Additional conclusions from equations (2) and (3) are:

- detectors with the highest detectivity should be used (e.g. BLIP detectors);
- spectral transmittance characteristic of optical system should be properly formed in order to chose such characteristic of descriptive function for which it is possible to find the maximum of functional I. Generally, the designing process of thermographic equipment should be carried on properly in order to fulfill all the demands that have been imposed considering the technical and economical aspects. Basic requirements concerning the metrological, technical and usability, properties are determined by ΔT, ΔG, n_k, N_l, N_p parameters (fig. 2). As it has already been stated the maximal acceptable, for given construction, diameter Dmax of the objective entrance pupil can be as the constraint concerning the thermograph dimension. While creating the preliminary concept of thermograph construction the following aspect should be considered:
- operational spectral band (proper criteria are given in literature);
- kind of optical system (refractional, reflexive, mixed);
- type of scanner (plane mirror, refractional polyhedrons, reflexive polyhedrons, wedge filters);
- kind of detectors;
- technical constraints;
- economical requirements.

After selection the applicable solution in new thermograph it is necessary (basing on the chosen scanner type) to estimate coefficients k_V and k_H. Next step is connected with determination of spectral transmittance for optical system. In case of refractional systems it is possible to assume single layer coatings (they are cheap). Next, it is necessary to assume the value of f/number N for optical system. It is recommended to assume at the very beginning N = 1,8 (for smaller N values it is more difficult to correct optical system and to assure dimensions of aberration spot as smaller than effective surface of the detector). Then, for imposed metrological parameters and assumed construction constraints,
it is necessary to determine the diameter D of the objective entrance pupil. In case, the calculated D value is greater than Dmax so it is necessary to enlarge the functional value I. For refractional or mixed systems there is the necessity to apply the multi layer anti reflection coatings. When the condition D<Dmax is not fulfilled so it is necessary to use scanner with better coefficients k_H and k_V. When this action is of the unsatisfied results so the value of N has to be decreased (in practice the N is seldom smaller than 0.9). When condition D<Dmax is still not fulfilled it is necessary to change the metrological parameters or camera dimensions. When the condition D<Dmax is finally fulfilled it is necessary to calculate:
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3. CONCLUSIONS

. The paper shows the general procedure connected with creation of TS properties with series structure of the measuring line. In case of thermographs with series structure of measuring line it is possible to determine the global factor of metrological and using properties of thermograph. There have been characterized the synthesis process of the thermographic system with application of IR point or SPRITE detector. The characteristic features of the thermographs equipped with this kind of detectors have been discussed. It seems that generally there is no universal criterion for all kinds thermographic systems, connecting all significant parameters and features of TS.

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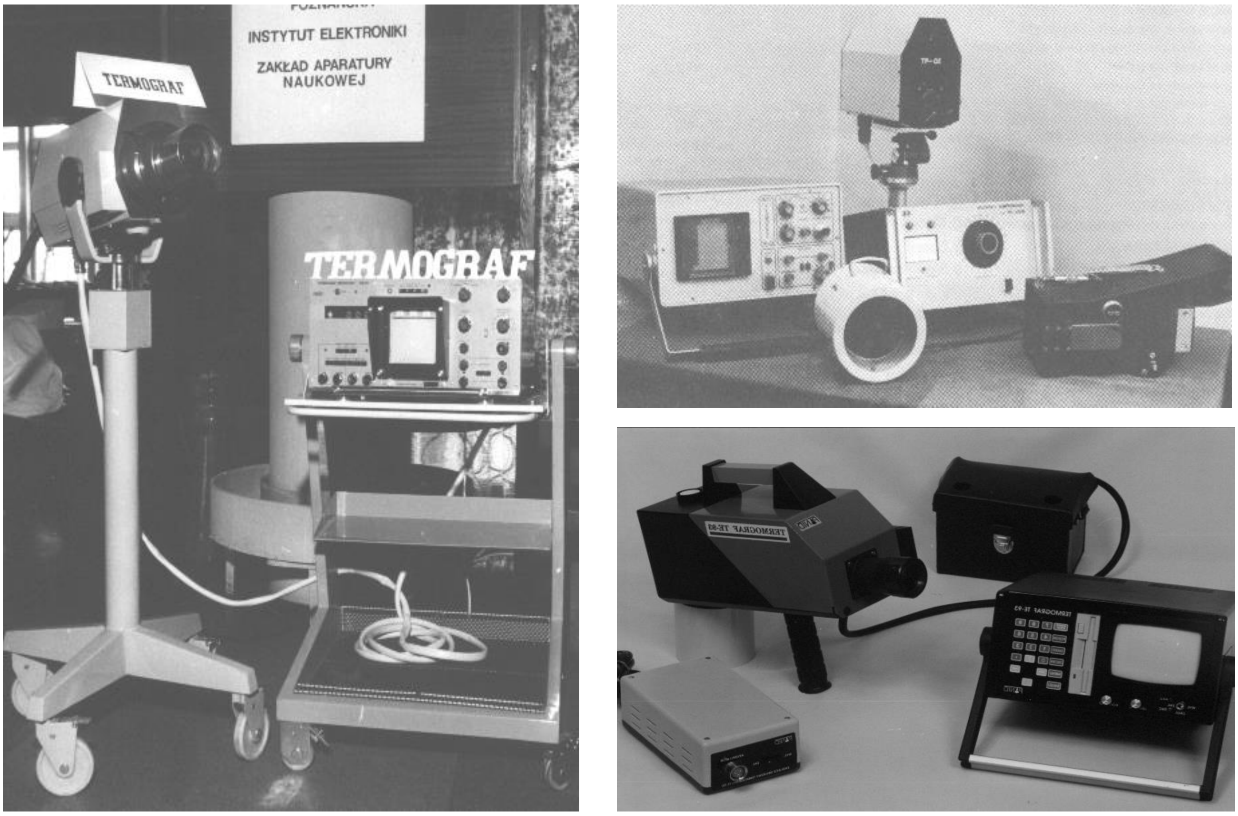

Fig 1. IR thermographs designed in PUT

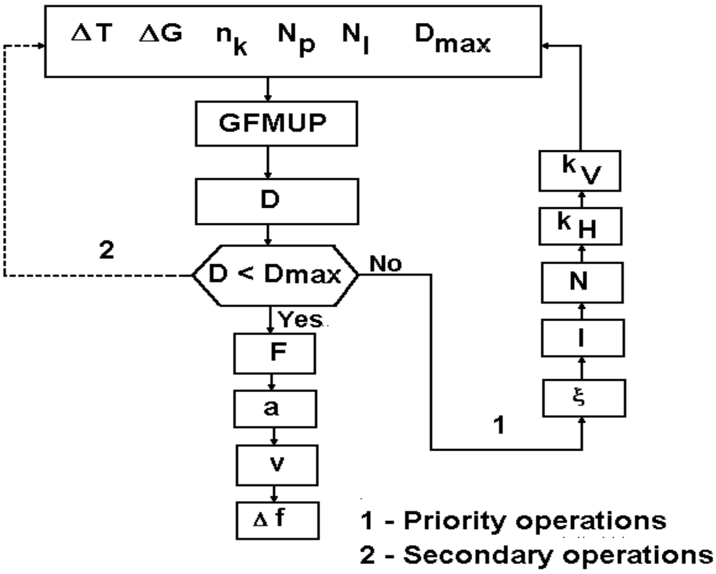

Fig. 2 Algorithm of designing the thermographic system