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A concept of a method of remote determination of the air temperature along a sight line of surveying instruments

The author presents a concept of a method of remote determination of temperature along a sight line of surveying instruments. It has been assumed that the environment influences a laser beam propagated in space; as a result of this influence the laser beam is distorted and weakened. It has been decided to make advantage of such situation and to read information concerning the medium of light beam propagation from the change of the structure of the laser beam. The paper presents a laboratory method of readouts of atmospheric factors of the air from images of the face of the laser beam. Initial experiences have been promising and confirmed assumptions made by the author.

INTRODUCTION

Results of surveying measurements are influenced by an ''internal'' inaccuracy of surveying instruments and by an inhomogeneous measuring medium along a sight line, i.e. by an ''external'' inaccuracy, which determination is very difficult.

Conditions of the measuring medium are influenced by many meteoparameters; the most important of them are the air temperature and its gradient. Mathematical formulae and diagrams, which allow to calculate appropriate corrections of results of levelling, distance or angular measurements are widely presented in professional literature and users' manuals [1, 2, 3].

Methods of elimination or partial reduction of negative influences of external factors on the final results of surveying measurements performed with the use of optical sight lines have been also developed. However, total elimination of the influence of the air temperature on propagation of electromagnetic waves and on refractive deformation of a sight line is very difficult in practice [4, 5, 6].

Variations of temperature along the sight line plays an important role in forming optical density of the atmosphere and it results in generation of a varying factor of the air refraction. Point measurements of the air temperature, pressure and humidity are mostly performed in

order to determine the refractive factor of the air. Such measurements are performed with the use of liquid and electronic thermometers (temperature), Assmann psychrometers and special electronic sensors (humidity), and a precise aneroid (atmospheric pressure). The discussed meteorological parameters may considerably vary along a sight line; therefore even representative, multi-point determination of their values, with division of a measured sections into parts corresponding to a uniform land cover or altitude of the sight line above the ground, does not necessarily allow to introduce appropriate corrections.

1. *Outline of the discussed method*

Continuous development of laser technology, which has been observed since the seventies, contributed to wide utilisation of lasers in various sectors of science and technology. LIDARs (Light Detecting And Ranging) allow for remote sounding of the atmosphere and, in particular, for specification of types and amounts of pollution as well as of many other parameters of the atmospheric air. Measurements performed with the use of lidars consist of emission of a light beam into the atmosphere and on analysis of its optical echo. A lidar is a laser coupled with a telescope equipped with a photomultiplier. A light beam emitted by a lidar scans the investigated area and light reflected by even small objects returns to the telescope and is focused by the lens on the photomultiplier; then its directional analysis is performed. Lidars have not been widely applied for the needs of surveying.

Besides photography, which is commonly used, one of the main means of recognition, basing on analysis of images of investigated environment, are television systems [7]. They allow to monitor the environment, with simultaneous, real-time spatial processing of a reflected light beam and vision electric signals. CCD matrices are one of basic subsystems in this case. Operating as converters, they allow to convert the light beam into the electric signal. Utilisation of fast microprocessors, analogue/digital converters and operating memories allows for real-time digital processing, spectral analysis and visual presentation of information. Particular advantages of television systems are:

- reaction not on the total light beam, by on a static and dynamic distribution of light in the image field, in time and space,
- high speed of acquisition of information characterised by high resolution,
- possibility of comparing acquired images.

In order to determine the continuous distribution of temperature along the given sight line, the author proposes to apply a method of remote sounding the air [8], with the use of laser technology, a CCD camera and a microcomputer system of data recording and processing. It is assumed that the environment influences the laser beam propagated in the space and that it carries information about the air temperature. Assumptions of this concept have been investigated at the laboratory base located in the basement of the Department of Geodesy and Photogrammetry of the Academy of Agriculture in Wrocław. Besides the author, Mr Krzysztof Kowalski has considerably contributed to the discussed experiment [9].

2. *Description of the experiment*

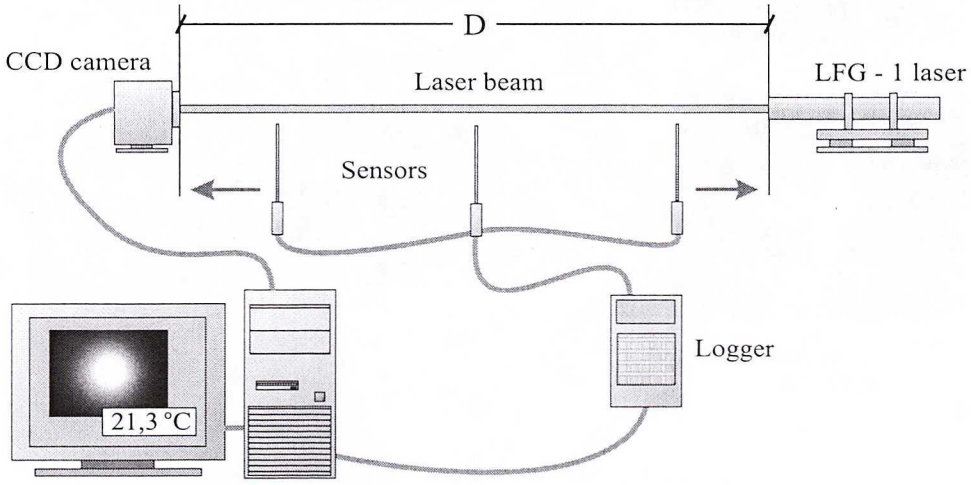
During the test measurements, atmospheric conditions at the room were stable for the relative humidity and the atmospheric pressure and they were equal to: 74.5% ± 0.5% of the air relative humidity and 999.5 hPa ± 0.5 hPa, respectively. The initial temperature equalled to 20.7 °C and then it was artificially raised along the sight line, with the use of portable electric heaters.

It has been assumed during completion of experimental tools, that the laser beam used for sounding should be continuous and non-modulated. The author considered that the LFG-1 direction indicator of Carl Zeiss Jena would meet such requirements. It is a surveying laser instrument, which operate at the wavelength of 633.7 μm, with the basic mode TEM_{00}. The minimum diameter of the laser beam, at the output from the emitting telescope of the instrument equals to approximately 1 cm. LFG-1 is characterised by the high stability of location of the beam as the function of time.

The CCD TC 3102/03A camera has been used as the receiver of the laser beam. This camera is characterised by the sensitivity of 0.05 lx. It is equipped with an AV cable, which allows for transmission, recording and digital processing of images.

Meteorological conditions along the path of the laser beam were determined by means of the electronic Logger SF12 set, of the following parameters and accuracy:

- temperature: resolution: 0.1°C, accuracy: ± 0.3°C (0 ÷ 70°C), ± 0.4°C (-20 ÷ 0°C), ± 0.6°C (above 70°C),
- humidity: resolution: 0.1% of relative humidity, accuracy: ± 3%,
- pressure: resolution: 1 mbar, accuracy: ± 5 mbar.



A system for data recording and processing analysing images of the beam's face

Fig. 1 Position of surveying instruments during the experiment

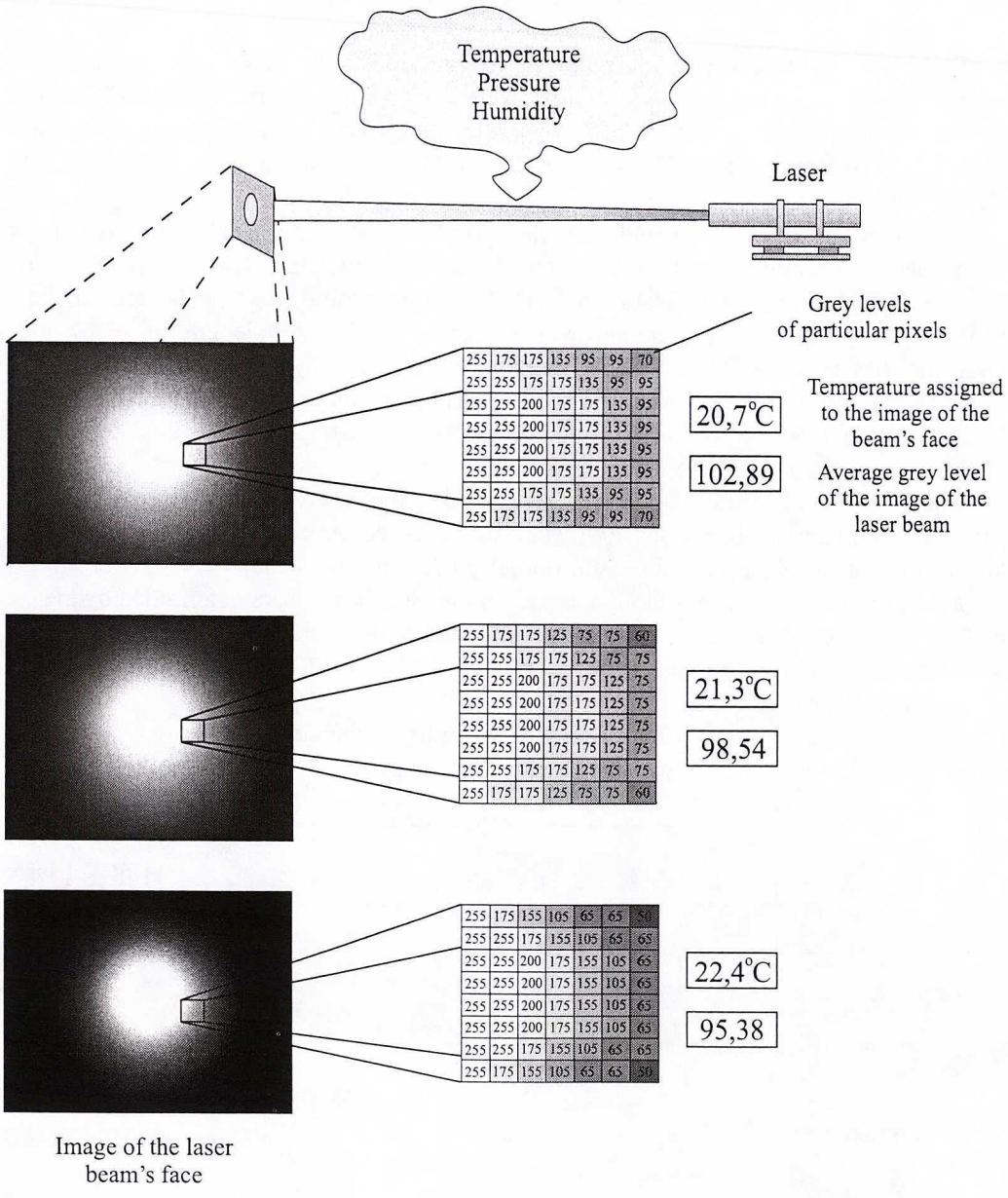


Fig. 2 Examples of results of the experiments

The proposed method of remote determination of the air temperature will consist of readouts of the representative value of this factor for the path of the laser beam, from images of its face.

The performed experiment consisted of emission of the laser beam within one hour in the space of observation of the laboratory base and on reception of images of its face with simultaneous recording of meteorological factors (temperature, pressure and humidity). Figure 1 presents settings of measuring instruments during sounding tests within one hour, for 1-minute interval of recording.

The laser beam was distorted while it was passing through the artificially modified atmosphere (changes of temperature by means of heaters). Changes of the structure of the laser beam, resulting from variations in temperature, were observed on images recorded by the CCD camera. Appropriately measured values of atmospheric factors were assigned to these images.

As a result of performed experiment, visible relations between the image of the face of the laser beam and atmospheric factors were noticed. Figure 2 presents examples of extreme results of the experiment; it also specifies assigned grey levels of images with respect to recorded values of temperature. The grey level of images was assumed as the arithmetic average calculated for grey levels of particular pixels, considered for the scale 0 – 255 (0 – black, 255 – white). Influence of variations in pressure and humidity may be determined in a similar way.

CONCLUSIONS

The presented concept of remote determination of the air temperature along the sight line of surveying instruments requires complete, experimental verification of a model of a sounding set. Results of experiments will allow for specification of a formula describing the influence of temperature, humidity and atmospheric pressure on the laser beam propagated in the given space, as main elements, which influence variations of the coefficient of the air refraction. Conclusions from testing the sounding set should answer questions concerning:

- the scope and range of operations of instruments,
- functions describing investigated relations,
- dimensions and weight of the model,
- ergonomics and measurement techniques.

Precise surveying measurements of unanimated natural and engineering objects, in difficult field conditions, requires support in the form of various types of auxiliary equipment and untypical technology. Besides increase of accuracy and efficiency of measurements, the presented measuring set may also contribute to increase of the level of safety of the measuring team (e.g. measurements of atmospheric conditions of dangerous production processes).

In the case of positive verification of results of experiments, the discussed sounding set may become a useful tool used in works aiming at improvement of levelling, distance and angular measurements, performed in varying meteorological conditions.

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Koncepcja metody zdalnego określania temperatury powietrza wzdłuż celowej realizowanej instrumentami geodezyjnymi

Streszczenie

W artykule przedstawiono koncepcję metody zdalnego określania temperatury wzdłuż celowej instrumentów geodezyjnych. Założono, że wiązka laserowa propagowana w przestrzeń ulega wpływom środowiska czego wynikiem jest jej zniekształcenie i osłabienie. Postanowiono wykorzystać ten fakt, i ze zmiany struktury wiązki odczytać informację o ośrodku propagacji wiązki światła. W artykule przedstawiono laboratoryjną metodę odczytania czynników atmosferycznych powietrza z obrazów czoła wiązki światła laserowego. Wstępne doświadczenia przyniosły obiecujące rezultaty i potwierdziły założenia autora.

Казимеж Цмелевски

Концепция метода дистанционного определения температуры воздуха вдоль визирной линии геодезических приборов

Р е з ю м е

В статье представлена концепция метода дистанционного определения температуры вдоль визирной линии геодезических приборов. Принято, что распространяемый в пространство лазерный пучок подвергает влиянию среды, чего результатом является его деформация и ослабление. Решено использовать этот факт и на основе изменения структуры пучка вывести информацию о среде распространения пучка света. В статье представлен лабораторный метод определения атмосферных факторов воздуха из изображений фронта пучка лазерного света. Предварительные эксперименты дают многообещающие результаты и подтверждают принятые автором положения.