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Portable device for on-site, non-contact normal emissivity estimation in cultural heritage monitoring applications

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Abstract

The paper presents the developed portable device enabling on-site emissivity estimation in non-contact manner. It is based on reflection intensity analysis in long wavelength infrared spectral band. It enables determination of emissivity and reflection factor for non transparent surfaces. Those are important parameters for thermal imaging, but also may be correlated with the type of analysed surface. It may be used to determine the type of material or its condition in different applications, where it is not recommended (or not possible) to heat up the surface for measurement. It is often the condition in case of underground built heritage.

1. Introduction

Emissivity is the key parameter for thermal imaging purposes. It influences the amount of power radiated by a surface in a certain temperature, according to the Stefan-Boltzmann formula for graybody radiators. In the same time, for non transparent surfaces, the lower is the emissivity coefficient value, the higher is the reflection coefficient value. Furthermore, for certain materials one can expect specific values of emissivity coefficient. Let us take an example of polished metals with near-zero emissivity. On the other hand, porous materials as rubber or skin may exhibit emissivity values close to 1.

1.1. State of the art

The simplest approach for emissivity estimation is to use tables with already measured values for different materials. One may take [1, 2, 3] as examples. The limitation here is that one needs to know the material type to find its emissivity in the table. In practice, for certain materials, e.g. rocks, that are often found in case of underground built heritage [4], there may be different emissivity for different types of rock. According to [5], it may vary from 0.89 to 0.99 for sedimentary rock group, 0.89 to 0.99 for metamorphic and 0.83 to 0.98 for igneous categories. Hence there is a need for emissivity measurement, which in practice may be carried on with different methods. The approach presented in [5] requires heating up the sample and using an adhesive tape (as a reference) to partially cover its surface. Thus on-site usefulness of this method may be limited. In such cases, another technique may be applied, which can work without affecting the samples in any way. It is based on analysing the reflection appearing in the surface of the sample, coming from a known source of infrared radiation. Devices using this principle may exhibit very good accuracy and repeatability [6, 7, 8]. Other techniques for emissivity measurement are presented in [9].

1.2. Proposed solution

The idea behind this paper is to propose a simple technique for normal emissivity measurement by measuring reflectance of infrared radiation from the sample surface at a near normal angle of incidence. In this case, a single source of infrared radiation may be used together with a single infrared detector. To maintain the required angle of measurement, additional distance sensors are used to guide proper alignment of the measurement head. The advantage behind such approach is the ability to perform the measurement in a non-contact manner, from a certain distance (typically a few centimetres) from the sample. For recalculating normal emissivity into hemispherical one, it is possible to use formulas discussed in [9].

2. Measurement method

The proposed solution uses commercially available infrared thermometer MLX90614ESF-DCI by Melexis Technologies NV. It is single zone, digital non-contact temperature sensor in TO-39-4 metal can enclosure. With the remote sensing temperature range -70°C ~ 380°C and narrow field of view 5°, it is well suited for capturing the reflection of infrared illumination coming from an emitter. For this purpose, IR-43 infrared emitter with reflector by HawkEye Technologies, LLC is used. It may operate up to 600°C at 14 Volts, but for this application lower voltages may be sufficient (especially for samples with low emissivity), resulting in lower emitter temperature. With maximum power 1.3

Watts, it may be battery powered, what makes it suitable for a portable device. Those two elements are placed in proximity, with thermal insulation between them, in a configuration ensuring near parallel optical axes. It together make measurement (sensing) head, which may be directed towards a measured sample surface. To ensure near normal angle of incidence, additional distance sensors are integrated with this head to guide its proper alignment versus the sample and distance from it. For driving the emitter, reading the sensor data and displaying the information to the user, microprocessor platform is used. The configuration of the above described elements is shown in Fig. 1. Illumination pattern at the sample surface is similar as it would be in case of heating by a deposited resistor [10]. Exemplary thermogram of this illumination is shown in Fig. 2, where white paper (emissivity 0.93 [1]) is illuminated by the emitter powered with 9 Volts, with the distance about 3 cm between radiating element and paper surface.

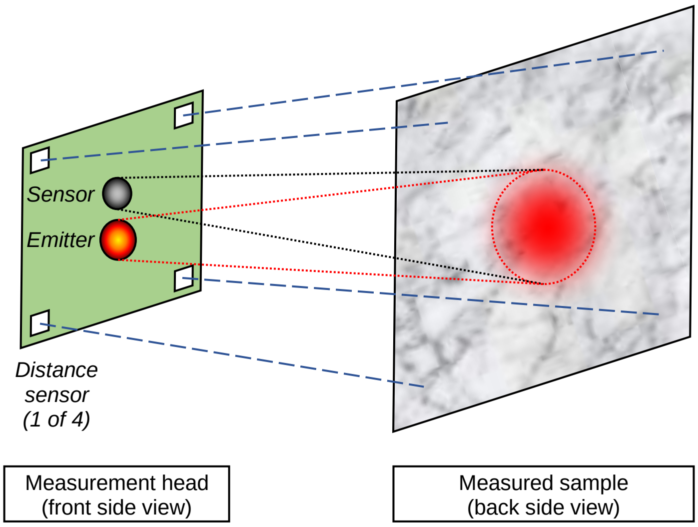

Fig. 1. *The proposed principle of operation for emissivity*

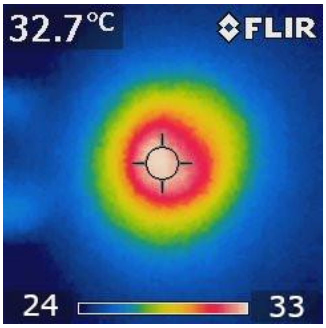

Fig. 2. *Illumination thermal image*

3. Conclusion

This paper presents the design of portable device for normal emissivity estimation with infrared radiation emitter and sensor. Proper measurement head alignment is facilitated by distance sensors. Due to the idea of measurement based on reflectivity, it can be performed in non-contact manner, what may be important in case of cultural heritage monitoring. Testing of the prototype is to be performed i.a. in underground built heritage sites with the support of the COST Action CA18110 - Underground Built Heritage as catalyser for Community Valorisation [4].

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