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DEPENDENCE OF THE DIGITAL IMAGE OF THE MATERIAL TEXTURE ON THE WAVELENGTH OF THE ILLUMINATION SOURCE

ZÁVISLOSŤ DIGITÁLNEHO OBRAZU TEXTÚRY MATERIÁLU OD VLNOVEJ DĹŽKY SVETELNÉHO ZDROJA

Abstract

The article deals with methodology of measuring the influence of light source spectre on digital image of material texture. Special original measurement system was used for creating special texture images at various lighting conditions. Structure and principle of functioning of the system are described in the article. In the conclusion a relation between the lighting and wave length on the texture quality is examined using a correlation method.

Abstrakt

Článok sa zaoberá metodikou merania vplyvu spektra svetelného zdroja na digitálny obraz textúry materiálu. Na tvorbu špeciálnych obrazov textúry pri rôznych podmienkach osvetlenia bol použitý pôvodný merací systém. Štruktúra a princíp činnosti tohto systému sú v článku popísané. Záverom je korelačnou analýzou skúmaný vzťah intenzity osvetlenia a vlnovej dĺžky na kvalitu textúry.

1 INTRODUCTION

On the basis of chemical consistence as well as production technology, each material has certain basic properties. The properties are of various natures and their relative importance usually depends on the type of information, which we wish to acquire. If the material is analysed by the digital image processing method during the production process (surface control, defects detection), the most important features include: texture and colour.

The term texture refers to a set of local properties, which are constant or regularly changing in the analyzed field. The term texture is simplified into uniformity of local brightness intensities when performing simpler analyses. If they are repeated, patterns are created. These patterns are called visual textures. Basic properties of textures are: roughness, sensitivity, boundedness, directiveness, inequality, regularity.

Colour is a psychophysiologic term. Representation of colour is determined by several colour models. By colour perception, we often encounter the terms: shade, saturation and brightness.

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Shade represents dominant wavelength of the colour, saturation means how far from grey and white the colour is, brightness represents percepted intensity of the luminosity of the surface. Colour is important during material perception, because apart from grey-toned representation, it offers more visual information about the objects and largely simplifies identification and extraction from the image.

2 MATERIAL AND METHODS

Colour of the object

Perception of colour of a certain object is pre – conditioned by a spectral composition of an illumination source radiation, which illuminates the object as well as by spectral reflection factor or transmission of the observed object. The influence of the light source composition on the colour perception of the illuminated objects is characterised by so called colour rendition. Concerning numerical evaluation of the colour quality, colour rendition index is used, representing the degree of compatibility of colour perception of an object illuminated by a considered source. General index of a colour rendition Ra is determined in a relation:

$$R_a = 100 - 4{,}6\Delta E_a \tag{1}$$

Special colour rendition index R_i of the sample I is calculated from S relation:

$$R_i = 100 - 4{,}6\Delta E_i \tag{2}$$

ΔE_a and ΔE_i introduced in the relations (1) and (2) represent:

$$\Delta E_a = \frac{1}{n}\sum_{i=1}^{n}\Delta E_i \tag{3}$$

$$\Delta E_i = \sqrt{(U_{oi} - U_{ki})^2 + (V_{oi} - V_{ki})^2 + (W_{oi} - W_{ki})^2}\ , \tag{4}$$

where:

- U_{oi}, V_{oi}, W_{oi} are trichromatic components describing colour perception of the I sample in the *UVW* framework by the comparison illumination source,
- U_{ki}, V_{ki}, W_{ki} are trichromatic components describing colour perception of the *I* sample in the *UVW* framework by the examined illumination source,
- *n* is a number of used colour samples,
- ΔE is an overall colour differentiation.

For the sake of working with trichromatic coordinates and with regard to colour samples properties it is possible to adjust an equation (4) to the form:

$$\Delta E_i = 800\sqrt{[(u_{oi} - u_o) - (u_{ki} - u_k)]^2 - [(v_{oi} - v_o) - (v_{ki} - v_k)]^2}\ , \tag{5}$$

where:

- u_o, v_o are coordinates of a point describing the light spectrum of the comparison source in a diagram *u*, *V* component,
- u_k, v_k coordinates of the point describing the light spectrum of an examined source in a diagram $u\ ,v\ $.

The value of the colour rendition index R_a can be in an interval from 0 to 100. The colours are best perceived by the illumination by heat sources and by the daylight, corresponding to R_a = 100. On the contrary, in the monochromatic yellow light of the low – pressure sodium discharge lamps, the colours are not distinguished at all. Therefore R_a = 0. Nowadays, $R_a \geq 80$, is required in most interiors, even in most of the work spaces according to EN12464. Numerical data representing the colour impulse can be obtained in three ways of measurement:

- spectofotometric measurement,
- comparative colorimeter,
- photometric colorimeter.

Spectofotometric measurements are considered to be the main ones, since the results they provide are the most precise ones. They are also used by etalon determination. Introduced measurements are carried out using monochromators or more precisely spectofotometers with in – built monochromators. Using these devices, spectral characteristics of a colour impulse from observed primary or secondary sources are acquired. Using calculation or an integrator connected to spectrometers, corresponding trichomatic components or more precisely coordinates in a chosen trichromatic system are determined from them. For wood colour characterisation, trichromatic system CIE (International Commission on Illumination) is used based on the fact that by mixing the three basic colour components (red R, green – G, blue – B), we may create a perception of any colour. Each of these components may be described by colorimetric function, which represents a share of these components in the resultant colour.

Measuring system of scanning of digital images of the material texture

Original measuring system composed of Hamamatsu S9706 sensor controlled by microprocessor was used for creation of images for correlation analysis. Flow chart and system arrangement scheme are showed in figure 1 and figure 2.

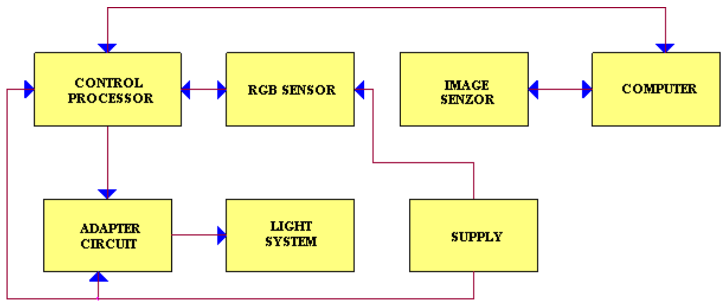


Fig. 1 Sensoric system flow chart.

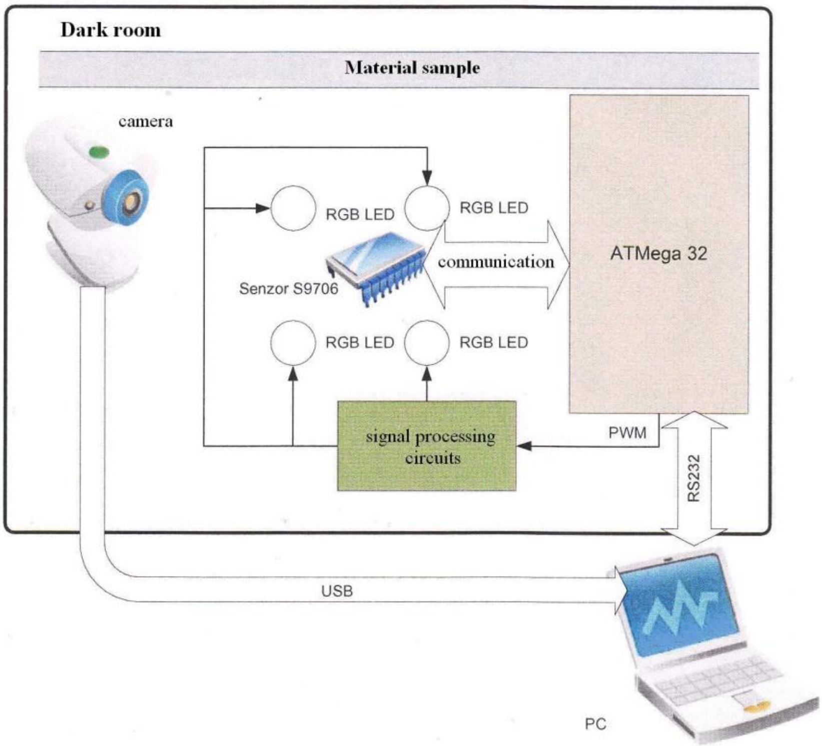
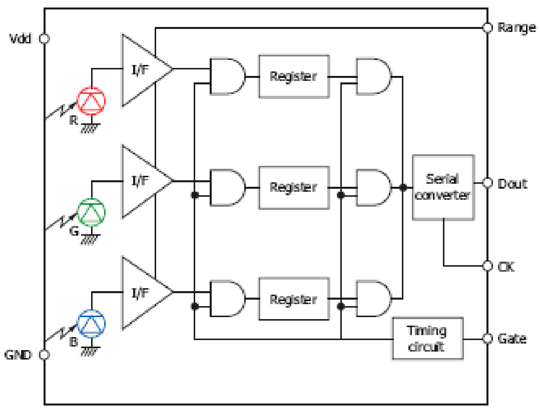


Fig. 2 Sensoric system arrangement scheme.

Sensor S9706 by Hamamatsu Company was a scanning element of the measuring system used for creation of special images with the modified scene illumination. It is a digital sensor with maximal sensitivity of the red element with wavelength λ=615 nm, green element with wavelength λ=540 nm and blue element with wavelength λ=465 nm. Inner structure as well as the sensor itself is showed in Fig. 3.



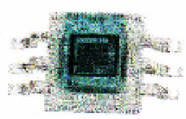


Fig. 3 Flow chart and sensor S9706 [Hamamatsu, 2008].

Photodiodes set on the given sphere of the spectrum are the scanning components. In the measurement mode, signal of each photodiode is amplified and modified to the form 12 – bit digital output word. Photodiodes are arranged into a measuring field. Scanning elements' and sensitivity spheres' arrangements are shown in Fig. 4.

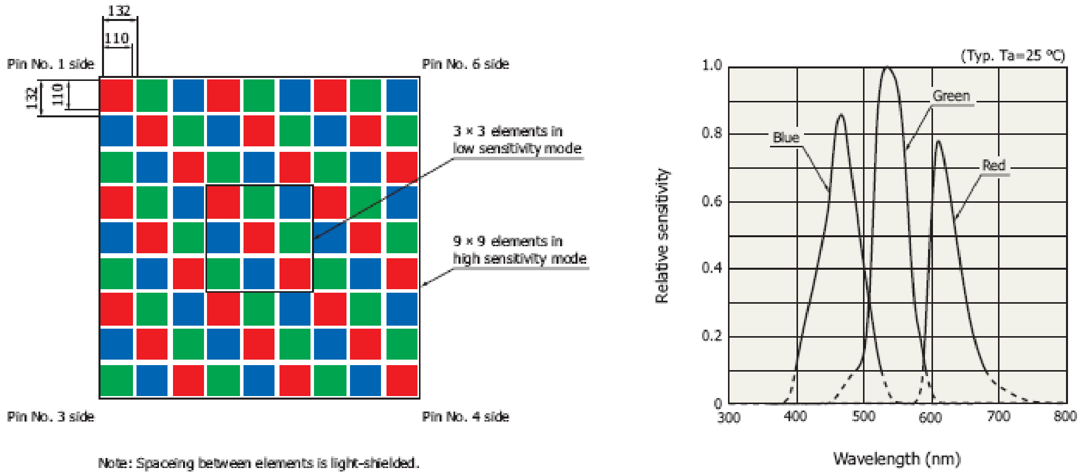


Fig. 4 Scanning elements' and sensitivity spheres' arrangements S9706 [Hamamatsu, 2008].

Sensor communicates with the microcontroller through the use of instructions sequence, as shown in Fig. 5. CK signal is generated by microcontroller timer and general in – out terminals ATMega 32 are used for watching levels of other needed.

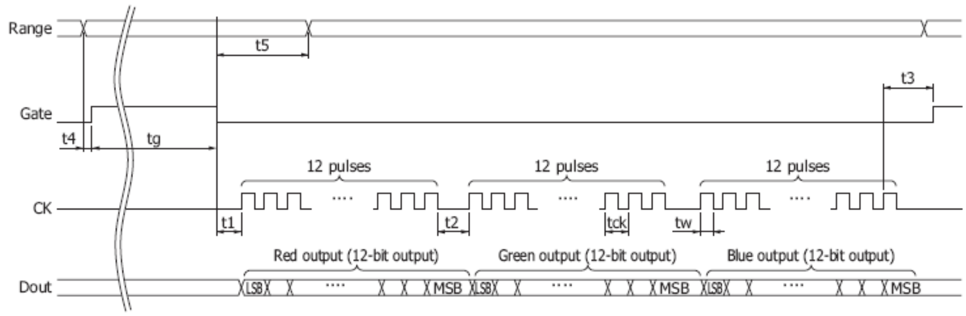


Fig. 5 Communication of sensor with microcontroller [Hamamatsu, 2008].

Signals on the DOUT contact are an output of currently scanned data from the sensor. They are conducted to the entrance of microprocessor and consequently processed. Requesting of the measured data is carried out by changing the logical level of the signal transmitted from the microprocessor to the Gate sensor contact. Changing the logical level on the Gate contact must be accompanied by Clk signal generating from the microprocessor reader.

Firmware of the microcontroller can be described by following flow diagram (Fig. 6).

Individual sample illuminations are carried out by RGB LED diodes in dark chamber. With a help of PMW modulated signal, which is adjusted by signal processing circuits on the processor output, a microcontroller sets values of brightness of red, blue and green emitted by LED diodes. Scanning element S9706 is separated from the radiation sources by a shade, so that only radiation reflected by a sample creates a light incidence on the scanning surfaces. It is possible to do a setting of a new value of emitted light by a service program running on connected PC. This request activates disconnecting from USART channel of microcontroller.

Controlling application created in C++ program environment and running on the connected PC serves for setting the luminance in particular coloured LED diodes (Fig. 5). Thanks to installed camera in the dark room, there are visualization and archiving of scanned images available. It is also possible to change intensity settings of red, green and blue components of light spectrum by using the program. Communication of a connected PC and microprocessor takes place through the means of bus RS232. Firstly, setting values of PMW modulation for RGB luminance components of LED diodes are transmitted. In the next step, a start of measurement characteristic is transmitted and 36 currently scanned bits of RGB luminance components are being received. Then, microcontroller awaits new PWM modulation settings, however if it receives start of measurement characteristic, it sends currently scanned values. Flow chart representation of the communication protocol microcontroller – connected PC is in the Fig 7.

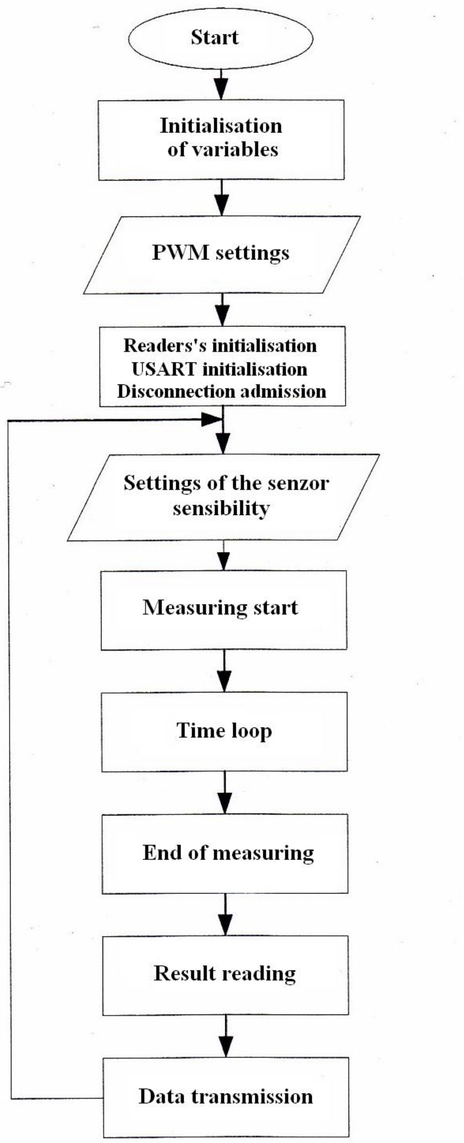


Fig 6 Flow diagram of algorithm implemented in controlling microcomputer.

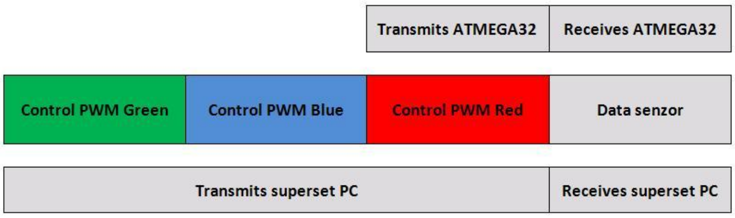


Fig. 7 Communication protocol of microcontroller and personal computer interconnection.

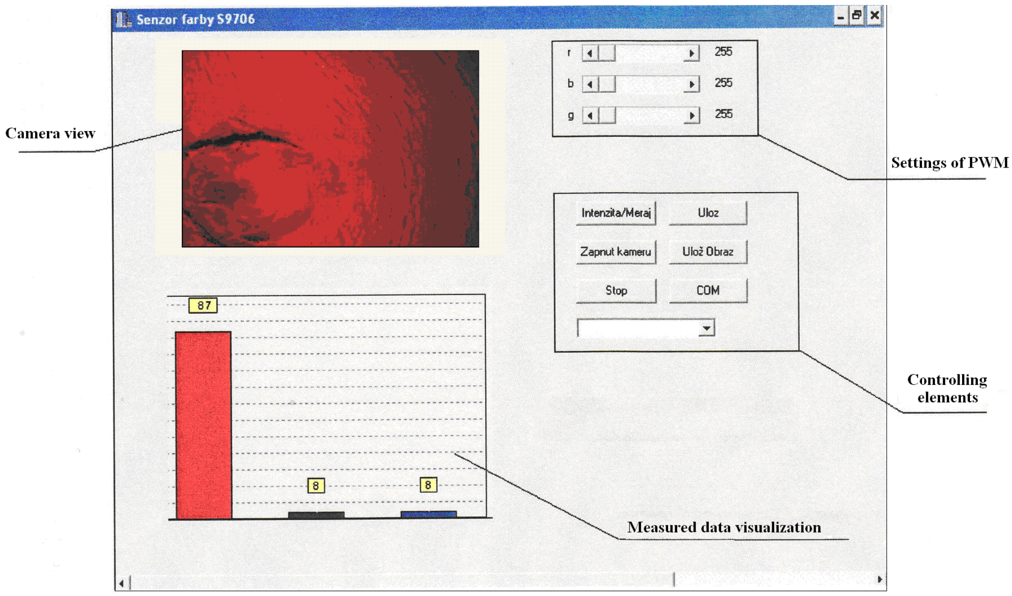


Fig. 8 Controlling application window.

3 RESULTS

Experiments were carried out on the materials with the distinctive texture, on the wood. Special images of wood texture were created from beech prisms, which contained various defects, e.g. bumps, cracks, false hardwood, decay or traces of cutting equipment. Examples of these images are in Fig. 9. Samples were chosen on the basis of diversity, from the view of: defects of wood, wood colour, different kinds of wood patterns etc. In the measuring device through the means of controlling program, these samples were illuminated with different levels of red, green and blue components of the light spectrum, or eventually by their combination. Acquired images were processed to uniform resolution of 256x256 pixels.

Fig. 9 Examples of images with various wood samples.

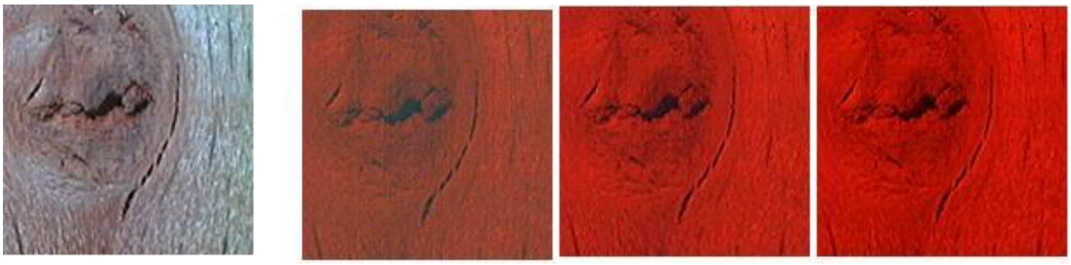


Fig. 10 Examples of illumination with various levels of red component.

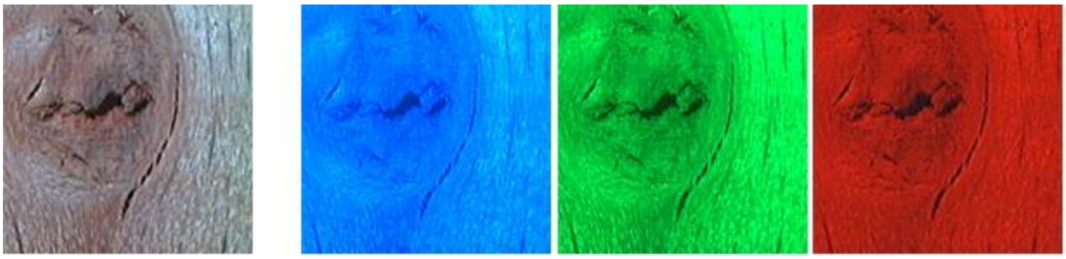
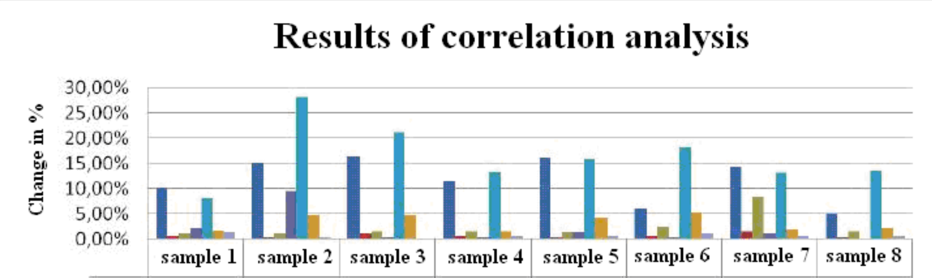


Fig. 11 Examples of illumination with various colour components with the same level of intensity.

Even subjective look at the given examples reveals differences of the same wood sample in different images. E.g. by the green component illumination, a defect in the centre of the image is more visible, as well as lines, which are a part of wood texture, are more clearly defined. For objective results, special images evaluated by correlation analysis were acquired. Images of particular samples were compared to reference samples. Acquired values were converted to percents, which express magnitude of influence of illumination by particular light spectrum components and various intensities of the components. Results are shown in the Fig. 12.

From the reached results, it can be stated that illumination of the samples with various light spectrum components and their combinations caused greatest changes in image when using red light spectrum and combining red and blue light spectrum. These changes were of dual nature. In the first case, wood texture lines, eventually wood defects in the sample were more intensive and clearly defined. In the second case some of the less striking features of the wood texture were suppressed. This fact has a great importance when concerning the wood sample image segmentation and consequently its further evaluation either by determining the wood defect occurrence and its kind or by recognising the wood type on the basis of texture.



	sample 1	sample 2	sample 3	sample 4	sample 5	sample 6	sample 7	sample 8
r	10,08%	15,13%	16,31%	11,44%	16,06%	5,81%	14,37%	5,03%
g	0,47%	0,38%	1,20%	0,43%	0,37%	0,59%	1,50%	0,24%
b	1,15%	1,17%	1,53%	1,53%	1,35%	2,22%	8,33%	1,55%
rg	2,06%	9,45%	0,24%	0,28%	1,31%	0,37%	1,08%	0,18%
rb	8,10%	28,19%	21,05%	13,26%	15,91%	18,16%	13,20%	13,51%
bg	1,61%	4,80%	4,80%	1,54%	4,13%	5,21%	1,96%	2,05%
rgb	1,26%	0,38%	0,18%	0,40%	0,56%	1,10%	0,60%	0,47%

Fig. 12 Results of correlation analysis.

4 CONCLUSION

The aim of the design of the measurement workplace with Hamamatsu S9706 sensor was to prepare an environment, where it would be possible to carry out a wood analysis from the viewpoint of colour, texture and faultiness. Special wood images database was created in this workplace, by doing experiments realised through the means of the controlling program. For the evaluation, correlation analysis method was used. It showed an influence of the sample illumination by various intensities of light spectrum colour components and their combination on the final image. Emphasising the wood features, which are important for its further processing may be achieved by an optimisation of illumination. On the other hand, by realising suitable illumination settings, we may achieve suppression of the details that are usually a source of inaccuracies in the process of image evaluation. These results may be applied by material defects determination and materials recognition and classification.

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