Computer Monitoring of Physical and Chemical Parameters of the Environment Using Computer Vision Systems: Problems and Prospects

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Abstract

The paper is devoted to the initial stages of the developing of a system for computer monitoring of environmental physical and chemical parameters using computer vision systems. The way of using specially designed QR codes as optical identifiers for a set of sensors along with the white standard is shown. A number of materials have been considered for use as an optically active sensor environment for such monitoring system.

Keywords [1]

software, monitoring, environment, physical and chemical parameters, optical sensors

1. Introduction

At the present stage of development, society is facing with new conditions caused by the rapid growth of population mobility. Along with the undeniable advantages of this fact, there is also an increase in negative consequences. One of the most dangerous is the increase in the rate of disease spread and illicit trafficking in dangerous substances. Such negative trends cause the need to amend the regulations on the operation and equipment of transport and medical infrastructure, the operation of emergency services, the deployment of temporary short-term facilities. This is demonstrated in the wearing of protective clothing that needs to be changed frequently, monitoring of physicochemical parameters of workplaces, the imposition of restrictions on the use of wireless data transmission channels.

These factors have led to the almost widespread imposition of industrial video surveillance systems at the aforecited facilities. In this situation, there is a growing need for development of a system for monitoring physicochemical parameters based on optical identification methods.

Optical sensors of physical and chemical quantities will be used as sensitive elements of such systems, in which a change in the detected parameter causes a change in the color of the optically active environment. Changes in the color characteristics of sensors and, accordingly, measuring parameters are expected to be registered using existing video surveillance systems. Such systems have a number of advantages. The low cost of such optical sensors allows them to be placed on disposable objects such as protective suits, packaging of drugs and products, etc. without a significant increase in the total cost. The parameter registration system is based on the existing video surveillance system and requires only the development and installation of additional software. However, the creation of such systems requires solving a number of technical issues. Such

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as the development of a system of optical identification of sensors, improvement of algorithms for determining the color of sensor labels, adaptation of the proposed algorithms to existing video surveillance systems.

2. State of the Art

Existing monitoring systems are mainly based on the use of a stationary sensor system with a radio or a cable data channel. The obtained values are further aggregated and processed by a computing device. This configuration is justified for stationary tasks and is quite expensive. As an example one might mention the products of Particle Measuring Systems Co., which has developed a number of automated solutions for online monitoring of air parameters in clean rooms, such as: concentrations of aerosol and microbiological particles, humidity, temperature, pressure [1]. Another example is "Autonomous system of climate parameters measurement" by a group of authors [2]. Despite the different purpose and cost, projects use the above-mentioned monitoring scheme. The fundamental difference with the approach described in this paper is the monitoring of the premises using stationary sensors. The described below approach focuses on objects (people and equipment) which are indoors and can move freely both in individual rooms and within the complex. In addition, it is possible to replace some protective elements used by the objects. A prerequisite for the creation of optical monitoring systems is the presence of a number of sensors of physical quantities and chemicals agents whose work is based on changing the color of the active environment of the sensor [3–5].

The software part of such optical monitoring system should perform the following main tasks:

- searching for an optical identifier in the picture;
- tag margins searching;
- reading data of optical identifier to determine the category of colored mark;
- determining the white balance and estimating the brightness of outdoor lighting;
- exact determination of the marks color and as a result – information retrieval.

3. Identification of Color Sensors

As mentioned above, the parameter monitoring system is based only on the resources of video surveillance systems, so the identification method can only be purely optical. The small amount of information makes it possible to use both one-dimensional and two-dimensional optical identifiers. However, the use of barcodes such as the European Article Number (EAN) [6] is difficult due to the lack of spatial positioning labels, which complicates their identification in the video frame. Therefore, we chose a QR code as an optical identifier for the discussed monitoring system.

The QR code symbol is a square array consisting of some square modules (Fig. 1). It contains an encoding area and a functional area (includes search patterns, delimiter symbols, coordination patterns, and alignment patterns). The function area should not be used to encode data. The surrounding area of a QR code symbol is an empty space. The finder template (which includes three recognition templates) located in three corners of a code is intended to help searching the position, size, and tilt of the code. As a module, there are delimiters between each recognition pattern and the encoded data area. They all consist of light modules. The functions of the coordination templates are to determine the density and version of the QR code symbol and to provide a starting position that can determine the coordinates of the modules. A significant advantage of the selected identifier is the presence of well-developed processing algorithms [7–9]. The following steps are needed for recognition of a QR code:

1. Binarization – the conversion of an image into black and white;
2. Obtaining an approximate area of the QR-code and applying rough positioning using recognition templates;
3. Obtaining accurate positioning using alignment templates;
4. Calculation of the angle for rotating the QR-image and straightening the image;
5. Obtaining the version number of the QR-code and using self-adaptive sampling;

6. Decoding of the code using the corrected image and created standard 2D-matrix.

To build the system of optical monitoring of physical and chemical environmental parameters, we chose ver. 1 QR code with a size of 21x21 pixels and error correction level Q. An example of such a code is shown in Fig. 2. The body of the code contains an information of the form "A01B22C30", where letters indicate the order of color sensors and numbers stands for their color palette. Besides there is a white square in the center of the code. The purpose of which will be discussed later.

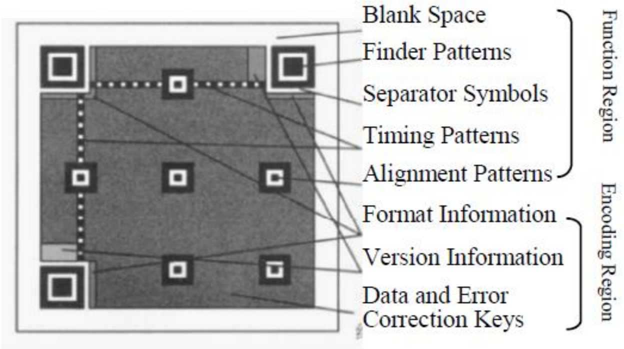

Figure 1: The structure and elements of a QR code

Figure 2: An example of the generated QR code for identification of color sensors along with the frame part with its image.

Studies of the QR code model with linear dimensions of 90x90 mm have shown that the range of stable code recognition by standard means is 0.3–3.5 m at the angle of the image to the horizon of 0–45 deg. However, this distance depends on the characteristics of the camera of the scanning device, so it is better to operate with the size of the code image in the frame. In our case, the minimum size was 90 pixels.

4. Types of Color Sensors

The basis of the monitoring system are color sensors, the principle of operation of which is to change the spectral characteristics of the optically active medium under the influence of the detected factor, physical quantity, or chemical compound. The physical nature of color formation in such structures is based on two physical principles. The first is the absorption of a certain part of the visible spectrum by molecules of an optically active substance. Usually such materials have several absorption areas. The visible color of such materials significantly depends on the spectral characteristics of lighting. Another principle is that the color source is a special type of diffraction on periodic structures. In such structures the part of the radiation of a certain wavelength is reflected from the sample. The reflection spectra of such materials have the form of one explicit maximum. In this case, the effect of surrounding lighting on the color of the sample is not so critical.

The spectral characteristics of composite PVA – PANi films are given in Fig. 3 [3]. These films belong to the first mentioned class of color formation substances. As can be seen from the presented dependences, the spectrum consists of several absorption areas and as a result the color of such material is formed by mixing radiation of different wavelengths.

Fig. 4 shows the spectral characteristics of the cholesteric liquid crystalline mixture KET90600 at different temperatures [4]. This kind of liquid crystal is an example of the mentioned periodic structures which color is formed as a result of the light diffraction. On the spectral dependence in Fig. 4 there is one distinct peak, the position of which changes with the temperature of the sample. In case of such materials the spectral characteristics of the lighting in the room will have less effect on the color of the sensor. However, materials with supramolecular periodic structure are mainly in the liquid state, which requires additional measures when using them as an optically active sensor environment [10, 11].

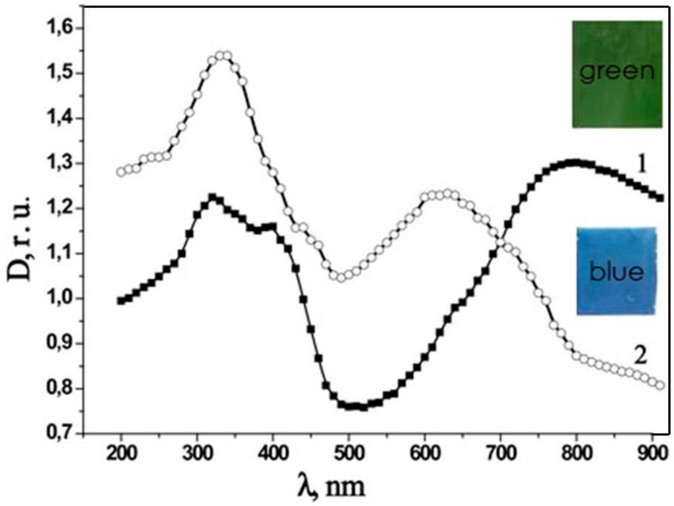

Figure 3: Absorption spectra of free standing composite films PVA– PANi: 1 – on air, 2 – in ammonia environment (h ¼ 1.4 kPa). Thickness of the film is 0.15 mm. PANi content in composite is 7.2 % [3].

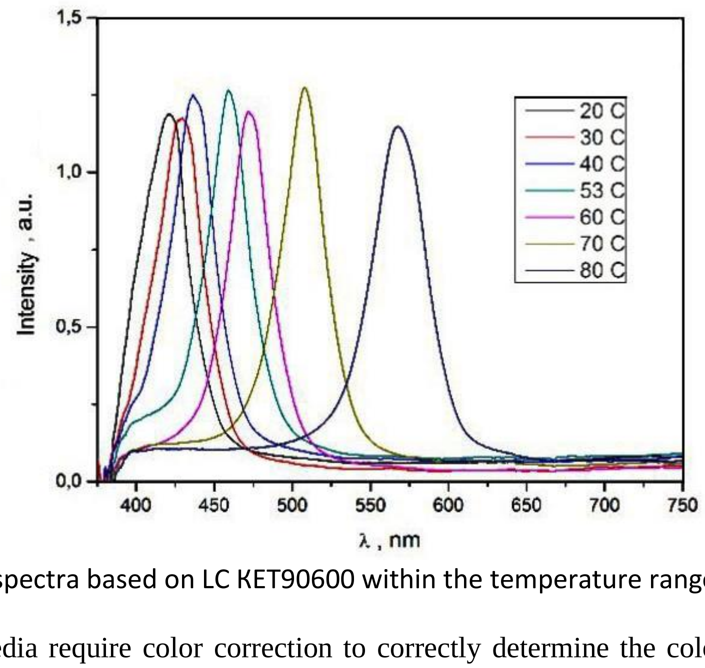

Figure 4: Reflection spectra based on LC KET90600 within the temperature range 20-80 °C [4].

Both types of media require color correction to correctly determine the color of the sample and compare it with the palette. The white spot correction algorithm [12, 13] can be used for this purpose. The White Patch Retinex Algorithm [14] is a simplified version of the Retinex algorithm. This algorithm uses a white spot somewhere in the image to assess the light source. The idea is that if there is an unfilled spot in the field of view or an unpainted part of the layer in the field of view, then this spot transmits the maximum light possible for each color channel. As mentioned above, the proposed in this paper optical identifier (QR code) contains a white square in the center, which we use as a white standard. Fig. 5 shows a sketch view of a set of sensors along with an optical identifier for a mobile placement.

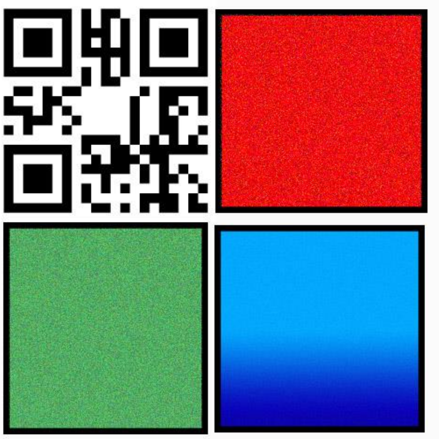

Figure 5: Sketch of a sensor set with an optical ID for mobile placement.

5. Conclusions

This paper discusses the optical monitoring system for monitoring of physical and chemical environmental parameters. The proposed system allows monitoring of physical quantities and chemicals at 0.3–3.5 m, which satisfies the indoor conditions. The significant influence of spectral characteristics of light sources on detection of color characteristics of optical sensors is revealed. The proposed system allows one to monitor moving objects using an existing video surveillance system by developing and installing additional software while the sensors with optical ID are developed to be suitable for mobile placement.

The relative cheapness of the set of proposed sensors and the method of monitoring their parameters allows them to be placed on single-use facilities, such as packaging of drugs and equipment with special requirements for storage and transportation, chemical and bacteriological protection of people, etc. The need for such systems increases in case of emergencies during the deployment of temporary medical infrastructure.

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