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MEASUREMENT DIMENSIONS OF THE OBJECT IN PRESENCE OF INDUSTRIAL EVAPORATION USING TECHNIQUES OF DIGITAL IMAGE PROCESSING

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Abstract. *This paper analyses the influence of industrial vapours on the measurement of physical dimensions of an object. Basic models of the vapours are analysed and adequate real system, for dimension measurements of an object, is proposed. Behaviour of the system is analysed using a high symmetry object.*

Key words: *Industrial evaporation, measurement*

1. INTRODUCTION

Industrial vapours have become an influential component of some technological processes. In addition, vapours are a great obstacle in the realization of all the processes that are required for good visibility. By applying the techniques of digital image processing, it is possible to obtain better information about the dimensions of the objects under some unfavourable circumstances. These, for realisation, relatively simple methods can be used to improve significantly the problem of moving object detection and distance estimation. Therefore the possibilities of determining the exact dimensions of the object increase.

Smoke is the main product of combustion and a significant part of industrial gases and vapors. Its composition is very similar to that of a cloud. The process of complete combustion is the ideal case and can be difficult to achieve in real terms. In this process, besides the products of complete combustion, there are some toxic components which are dominant, such as:

1. Carbon monoxide **(CO)**
2. Hydrocarbons **(HC)**
3. Nitrogen oxides **(NO_x)**

The creation of these components is a consequence of the conditions in which the combustion process is realized. Carbon monoxide is a product of incomplete combustion.

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Hydrocarbons occur as a product of incomplete combustion. Nitrogen oxides occur as a product of oxidation of nitrogen from the air.

For the purpose of realization of the process of measuring dimensions of the object in the presence of smoke, the process of light transmitting through the smoke must be known. Knowing this provides an opportunity for the development of techniques for the elimination of interference in order to achieve reliable results.

Remooving the influence of the smoke can be realised by using the modified Koschmieder theory [1]. He noticed that remote objects merge with air, and found a simple relation between the distance d object, the intrinsic luminance L_0 and apparent luminance L:

$$L = L_0 \, e^{-kd} + L_f(1 - e^{-kd}), \tag{1}$$

where L_f denotes the luminance of the sky, and k the extinction coefficient of the atmosphere. Smoke attenuates the light in the sense of absorption and diffusion. Because of that disappearance, coefficients are equal to the sum of diffusion coefficients and absorption coefficients. In this relation the phenomenon of diffusion is the dominant light that turns from the initial path. Based on this research, Duntley [1] has brought the law of atmospheric attenuation contrast:

$$C = C_0 \, e^{-kd} \tag{2}$$

Here C indicates the contrast to the pseudo-distance d, and C_0 essentially a contrast object in relation to the background. This law is applicable only to uniform illumination atmosphere. In order for the object to be only barely visible, the value of C must be equal to contrast threshold ε. International Commision of Illumination (CIE) [5] adopted the average value of $\varepsilon = 0{,}05$ for the contrast threshold. It gives possibility to define a conventional distance, called "meteorological visibility" V_{met}, as the greatest distance at which the black object ($C_0 = 1$) of appropriate dimensions can be seen on the horizon.

$$V_{met} = -\frac{1}{k}\ln(0.05) \cong \frac{3}{k}. \tag{3}$$

From the image processing point of view, the influence of industrial vapors and smoke can be seen primarily in the degradation of local contrast, so the restoration and improvement of image contrast can be realized in different methods.

Narasimhan and Nayar [6] suggested the method of image restoration which applies Koschmieder's law for modelling degradation in the contrast depending on the distance.

Bush and Debes [7] proposed the calculation of the contour in the image based on wavelet transformation and based on this, we can measure the distance of the further pixels that are still running in the contrast greater than 5% in accordance with the recommendations of CIE. Pomerlau [8] estimated visibility contrast attenuation measurements.

Light through the clouds and fog and visibility of objects in different assessment methods was the domain of the studies by Nicolas Hautiere, [3] Raphael Labayrade, Jean-Philippe Tarel and Jean Lavenant [4].

The main objective of the research carried out by J. E. Hall and J. D. Awtrey [9] is to modify the local contrast to obtain authentic local features. The analysis of the images obtained in the presence of smoke assumes that the regions covered by smoke have increased local lighting, as a result of reflection of light from the smoke layer, and reduced contrast due to local reduction of light intensity signals originating from light sources. Improving the quality of the images implies the inverse process i.e. the increase of local contrast and the reduction of local brightness.

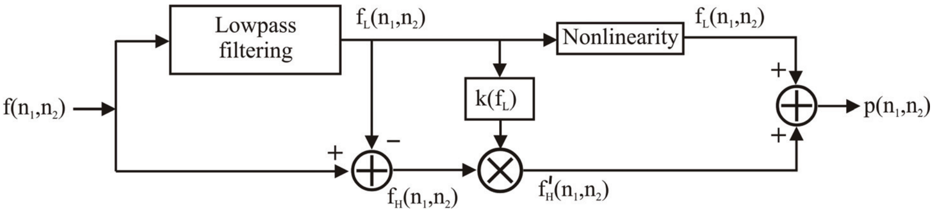


Fig. 1. Block diagram of the system for suppression of industrial vapours

Based on the consideration of the existing systems, the system in Fig.1 is suggested for the restoration and improvement of image quality. This system can be viewed as a special case two-channel processing where the processed image has two components: local luminance mean and local contrast. The components are modified separately and they form the processed image by combining results.

Modifications in the existing system are done primarily in nonlinearity and $k(f_L)$. This system modifies the local contrast and the local luminance mean. In the figure, $f(n_l,n_2)$ denotes the unprocessed image. The sequence $f_L(n_l,n_2)$ which denotes the local luminance mean of $f(n_l,n_2)$ is obtained by lowpass filtering $f\ (n_l,n_2)$**.** The sequence $f_H(n_l,n_2)$, which denotes the local contrast, is obtained by subtracting $f_L(n_l,n_2)$ from $f(n_l,n_2,)$. The local contrast is modified by multiplying $f_H(n_l,n_2)$ with $k\ (f_L)$, a scalar that is a function of $f_L(n_l,n_2)$. The modified contrast is denoted by $f_H(n_l,n_2)$. The modified local contrast and local luminance means are then combined to obtain the processed image, $p(n_l,n_2)$**.** To increase the local contrast and decrease the local luminance mean when the local luminance mean is high, we choose a larger $k(f_L)$ for a larger f, and we choose the nonlinearity, taking into account the local luminance mean change and the contrast increase. The function $k(f_L)$ and the nonlinearity used are shown in Fig.2 (a) and (b). The lowpass filtering operation was performed by using an FIR filter with an 8 **x** 8-point rectangular window.

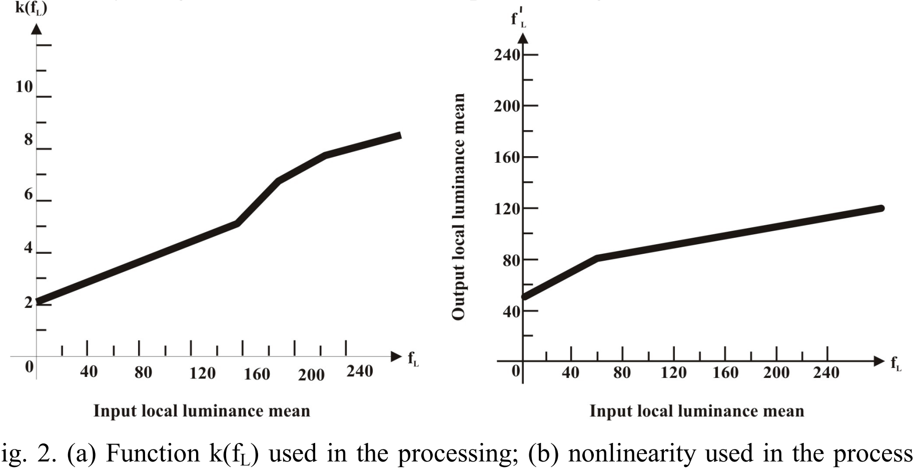


Fig. 2. (a) Function $k(f_L)$ used in the processing; (b) nonlinearity used in the processing after [Peli and Lim].

The image obtained by the above mentioned method can be processed to reduce the dynamic range and increase the local contrast. Because of that a homomorphic system for multiplication to an image formation model is applied. An image is typically formed by recording the light reflected from an object that has been illuminated by a light source. Based on this observation, one simple model of an image is $f(n_1,n_2) = i(n_1,n_2)\ r(n_1,n_2)$ where $i(n_1,n_2)$ represents the illumination and $r(n_1,n_2)$ represents the reflectance. In developing a homomorphic system for image enhancement, the illumination component $i(n_1,n_2)$ is assumed to be the primary contributor to the dynamic range of an image and is assumed to vary slowly, while the reflectance component $r(n_1,n_2)$ that represents the details of an object is assumed to be the primary contributor to local contrast and is assumed to vary rapidly. To reduce the dynamic range and increase the local contrast, then, we need to reduce $i\ (n_1,n_2)$ and increase $r\ (n_1,n_2)$.

The simplified system is shown in Fig.3. The system can be considered as highpass filtering in the log intensity domain.

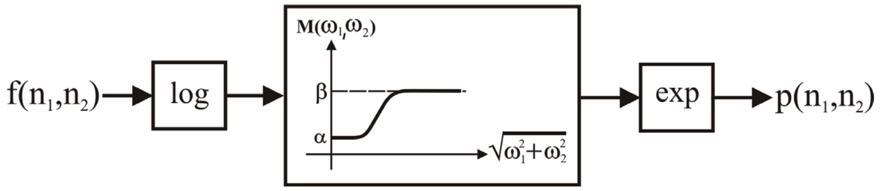


Fig. 3. Block diagram of the system for reducing dynamic range and increase local contrast

2. MEASURING OBJECT DIMENSIONS AND ESTIMATION DISTANCE

In order to determine dimensions of objects, it is necessary to have at least two images. The paper discusses the cases of a fixed camera where intrinsic and extrinsic parameters are known. The object is symmetric, so the process of analyzing would be easier, it is mobile, and its movement is linear and planar. Speed is considered to be uniformity because the changes in intensity, direction and the direction are negligibly small. The spatial position of the camera and the mobile object are shown in Fig.4. For the analysis of the two arbitrary positions of a mobile object P_1 and P_2 are chosen.

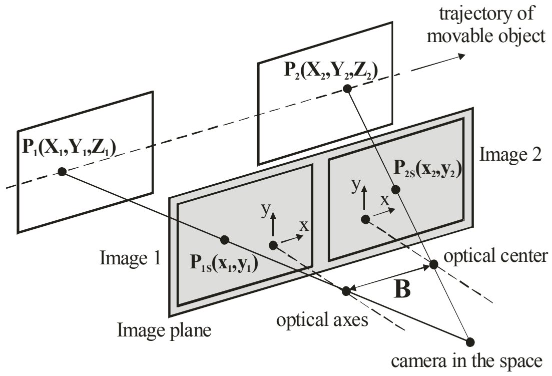


Fig. 4. Spatial position of the camera and object

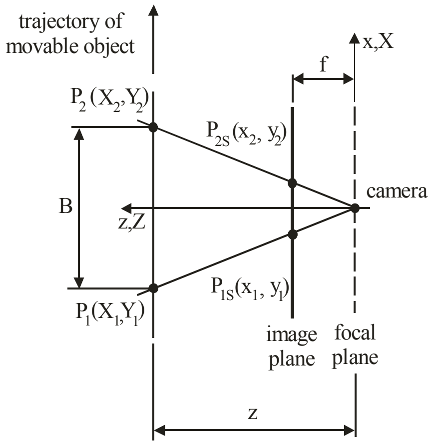


Fig. 5. Position of the camera and object

Coordinate system and camera images are considered to be coincident. Optical axis z is orthogonal to the image plane and passing through the optical centre. Point P(X,Y,Z) is an arbitrary point in space, and $p_S(x,y)$ is its projection in the image plane. The dependence between their coordinates is given by following relations:

$$\begin{aligned} \frac{x}{f} &= -\frac{X}{Z-f} = \frac{X}{f-Z} \\ \frac{y}{f} &= -\frac{Y}{Z-f} = \frac{Y}{f-Z} \end{aligned} \tag{4}$$

Equation (5) gives the relation between coordinates of points in space and the known coordinates of points in the image plane, which is the projection, and can be solved by the inverse perspective transformation:

$$W_h = P^{-1} \cdot c_h \, . \tag{5}$$

Here is:

W_h - Matrix that describes the position of point P in the space

P^{-1} - Matrix of the inverse perspective transformation

c_h - Matrix of coordinates of points in the projected image plane

$$W_h = \begin{bmatrix} kX \\ kY \\ kZ \\ k \end{bmatrix} \qquad c_h = \begin{bmatrix} kX \\ kY \\ kZ \\ \dfrac{-kZ}{f} + k \end{bmatrix} \qquad P = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & \dfrac{-1}{f} & 1 \end{bmatrix}, \tag{6}$$

where *k* is a nonzero constant.

These mathematical relations are valid for a coincident coordinate system, most often this is not the case. A camera coordinate system, i.e. image plane, takes arbitrary position in relation to the world coordinate system. Transition relation, from the arbitrary position in the coincident position, may exceed the number of transformations that involve a number of rotations and translations in space. Because of that the matrix of the perspective transformations changed and its final form depends on the particular case. It is possible to realize all three coordinate translation along all three axes and rotation around the coordinate axis. Matrix transformation which is needed to connect a single matrix, or specify the matrix equations individually is given by:

$$c_h = P \cdot T \cdot R \cdot W_h\,, \tag{7}$$

where:

T – matrix of translation and

R – matrix of rotation

Inverse perspective transformation in matrix form, in this case, is defined by the relation:

$$W_h = P^{-1} \cdot T^{-1} \cdot R^{-1} \cdot c_h \tag{8}$$

Based on the previously mentioned positions and considering that the relation $y_1=y_2$ is true:

$$\begin{gathered} \frac{B}{d} = \frac{z}{f} \\ z = B\frac{f}{d} \end{gathered} \tag{9}$$

where:

$z = Z$ - distance of point P from the camera

f – focal length camera

B – the distance of two mobile object positions

d – distance between two position images of moving object

Relations above indicate the possibility of evaluation of the distance of the object recorded by the camera with the knowledge of some initial parameters and the possession of at least two images of the object. Solving the above equations can not get a unique solution for the distance of points in space, since one point in the picture (x_0, y_0) corresponding to a number of points in 3D space that lie on the straight and defined point the optical centre. For 3D reconstruction of points based on its inverse image perspective transformation knowledge of at least one additional condition is needed. In the discussed example where all dimensions are known, assessment of the distance of the object focal length camera and applied distance between the positions of mobile object is assumed.

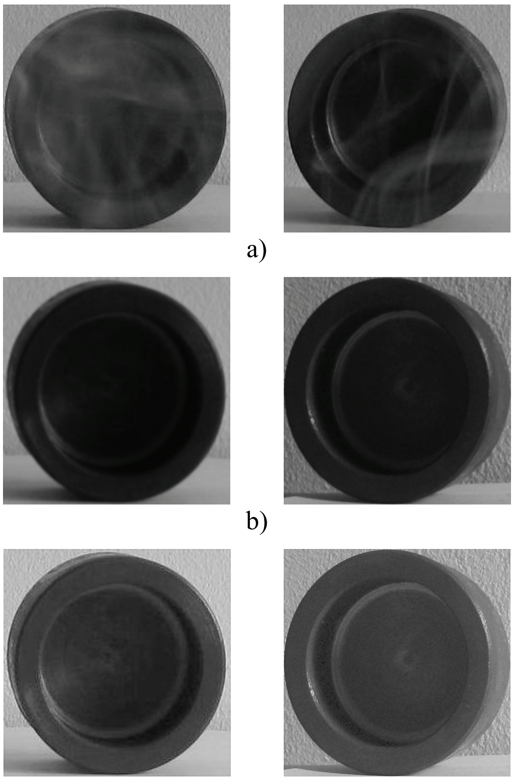
3. EXPERIMENTAL RESULTS

To solve the problem, the following algorithm can be applied:

1. Acquisition of at least two images
2. Smoke presence detecting

3. If smoke is present apply method 1, otherwise go to the step 4
4. Apply methods for quality enhancement
5. Dimension measurements

In the experiment carried out, the applied object is symmetrical, and all deviations from symmetry are considered negligibly small. Distance to the camera and recording frontline page object is z = 60cm. Moving object is planar and linear. Small changes in velocity are ignored and the movement is considered uniform. Vertical distance from the camera base is 50cm. Mobile object distance between the two positions of the recording is B=66cm. The camera is applied with a focal length 6 mm, breaking current speed of 1/60 s, exposure time 1/60s, dimensions X in pixels 3264 and dimensions Y in pixels 2448. In Fig.6 a) the recording cylindrical object without the presence of smoke, b) in a cloud of smoke, c) and d) the result achieved by filtering and removing interference.



a)

b)

c)

Fig. 6. Object image a) with smoke b) obtained by applying the method [2]
c) obtained by applying the proposed system for filtering

The results of the measurement dimensions of the object in the presence of smoke are given in Table I.

Table I Measurement dimensions of object

	D_1 (mm)	D_2 (mm)
Measured dimensions of the object (with smoke)	Ø 60.54	Ø 46.63
Measured dimensions of the object (without smoke)	Ø 60.53	Ø 46.62
Real object dimensions	Ø 60.50	Ø 46.60
Absolute difference of measured values	0.04	0.03

4. CONCLUSION

Methods presented in this paper allow the establishment of the applicable real system whose primary purpose is contactless measurement of dimensions of an object and assessment of the distance through the building. Combining various techniques of image processing provides the ability to process the application in unfavorable conditions as well as in cases where the object is inaccessible.

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MERENJE DIMENZIJA OBJEKATA U PRISUSTVU INDUSTRIJSKIH ISPARENJA PRIMENOM TEHNIKA DIGITALNE OBRADE SLIKA

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Ovaj rad analizira uticaj idustrijskih isparenja na merenja fizičkih dimenzija objekta. Na bazi osnovnih modela isparenja predložen je adekvatan realni sistem za merenje dimenzija objekta u prisustvu smetnji. Ponasanje sistema analizirano je na primeru objekta sa visokim stepenom simetričnosti.

Ključne reči: *industrijska isparenja, merenja.*