FACTA UNIVERSITATIS
Series: **Mechanical Engineering** Vol. 8, N° 1, 2010, pp. 39 - 46

NON-LINEAR IMAGE CONTRAST ENHANCEMENT FOR DETERMINING DIMENSIONS OF OBJECTS IN THE PRESENCE OF INDUSTRIAL EVAPORATION

UDC 004.932

Aca D. Micić, Biljana R. Đorđević,
Vlastimir D. Nikolić, Miodrag M. Stojiljković

Faculty of Mechancal Engineering, University of Nis, Aleksandara Medvedeva 14
18000 Nis, Serbia
E-mail: acamicic@masfak.ni.ac.rs; bilja@masfak.ni.ac.rs;
vnikolic@masfak.ni.ac.rs; misa@masfak.ni.ac.rs

Abstract. *Automatic measuring of the object's physical dimensions is crucial for some mechatronical systems which work in the presence of the industrial vapours. This paper analyzes the industrial vapor impact. The basic models of the vapours are analyzed and an adequate real system, for dimension measurements of an object, is proposed. The system behavior is analyzed using a high symmetry object.*

Key Words: *Measurement, Non-linear Image Contrast enhancement, Homomorphic Filtering*

1. INTRODUCTION

As the technology developed, some problems, as well as the solving methods, have become increasingly complex. In some technological processes, which require good visibility, industrial vapours have become an influential factor, and also a great obstacle. Smoke is the main product of combustion and so is a significant part of industrial gases and vapour, whose composition is very similar to the cloud. By applying the techniques of digital image processing, it is possible to obtain better information about dimensions of objects under some unfavourable circumstances. These relatively simple methods, which are significantly improved, can be used for solving the problem of moving object detection and distance estimation. Therefore, the possibilities for determining the exact dimensions of the object increase. The process of the light transmission through the smoke must be known for the process to be realized and for the obstacles to be removed. Knowing this provides an opportunity for the development of techniques for the elimination of interference in order to achieve reliable results.

Received February 20, 2010

Smoke attenuates the light in the sense of absorption and diffusion. Because of that the disappearance coefficient is equal to the sum of diffusion coefficient and absorption coefficient. In this relation the phenomenon of diffusion, which diverts the light from the initial path, is dominant. Based on this research, Duntley [1] has brought the law of atmospheric attenuation contrast:

$$C = C_0 \, e^{-kd} \tag{1}$$

Here C indicates the pseudo-contrast to distance d, and C_0 essentially a contrast object in relation to the background. This law is applicable only to uniform illumination atmosphere. 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.

Removing influences of the smoke can be realized by using modified Koschmieder theory [1]. He has noticed that objects, when distant, merge with sky: he has found a simple relation between distance d object, intrinsic luminance L_0 and apparent luminance L:

$$L = L_0 \, e^{-kd} + L_f (1 - e^{-kd}), \tag{2}$$

where L_f denotes the luminance of the sky, and k the extinction coefficient of the atmosphere.

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

Narasimhan and Nayar [6] suggest an image restoration method which assumes the applied Koschmieder's law for modeling degradation of the contrast depending on the distance.

Bush and Debes [7] propose the calculation of the contour in the image based on wavelet transformation; this serves as the base for measuring the distance of further pixels that are still running in the contrast greater than 5% in accordance with the recommendations of CIE. Pomerlau [8] estimates visibility by measuring level of contrast attenuation.

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

The main object of the research 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 show that the regions covered by smoke have increased local lighting, as a result of reflection of light from smoke layer while reducing the contrast due to local reduction of light intensity signals originating from light sources. Improving the quality of images implies inverse process i.e. increases in the local contrast and reduction of local brightness.

2. NONLINEAR ENHANCEMENT USING HOMOMORPHIC FILTER

Based on consideration of the existing systems, a system in Fig.1 is proposed for the image quality enhancement. This system is a special case of two-channel processing. The image has two components: 'local luminance mean' and 'local contrast', which are modified separately. By combining the results, the processed image is being formed.

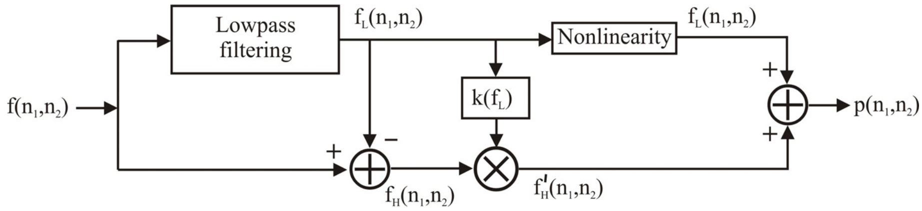


Fig.1 Block diagram of the system for industrial vapor suppression

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, $f(n_1,n_2)$ denotes the unprocessed image. Sequence $f_L(n_1,n_2)$ which denotes the local luminance mean of $f(n_1,n_2)$ is obtained by lowpass filtering $f(n_1,n_2)$. Sequence $f_H(n_1,n_2)$, which denotes the local contrast, is obtained by subtracting $f_L(n_1,n_2)$ from $f(n_1,n_2,)$. The local contrast is being modified by multiplying $f_H(n_1,n_2)$ with k (f_L), a scalar that is a function of $f_L(n_1,n_2)$. The modified contrast is denoted by $f_H^{'}(n_1,n_2)$. The modified local contrast and local Luminance means are then combined to obtain processed image $p(n_1,n_2)$. 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 consideration that the local luminance mean changes and the contrast increases. The function $k(f_L)$ and the nonlinearity used are shown in Figs. 2 (a) and (b). The lowpass filtering operation was performed by using an FIR filter with an 8 × 8-point rectangular window.

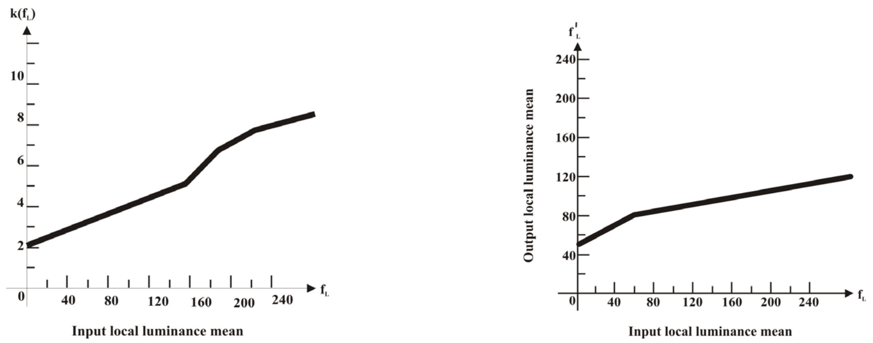


Fig. 2 (a) Function $k(f_L)$ used in the processing; (b) nonlinearity used in the processing after [Peli and Lim], [2]

The image obtained in the above-given method can be processed by applying a homomorphic system for multiplication. The simplest model of an image is mathematically presented with

$$f(n_1,n_2) = i(n_1,n_2)\ r(n_1,n_2) \tag{3}$$

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, illumination component $i(n_1,n_2)$ is assumed to be the primary contributor to the dynamic range of an image and varies very slowly. Reflectance component $r(n_1,n_2)$ represents the details of an object; it is assumed to be the primary contributor to the local contrast and varies very rapidly. To reduce the dynamic range and increase the local contrast, 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.

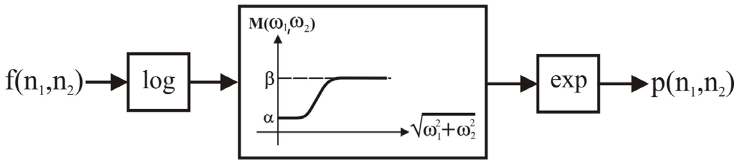


Fig. 3 Block diagram of the system for reducing dynamic range and increase local contrast

3. Estimation distance and measuring of object dimensions

For the determination of dimensions of objects, it is necessary to have at least two images. The paper discusses the cases of a fixed camera with the known intrinsic and extrinsic parameters. 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 uniform because the changes in intensity, direction and the direction are negligibly small. Spatial position of the camera and the mobile object are shown in the Fig.4. For analysis of the two arbitrary positions of mobile object P_1 and P_2. are chosen.

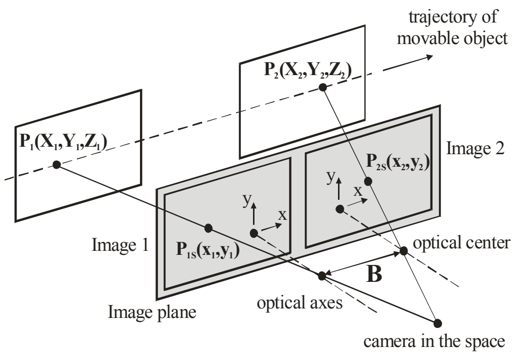


Fig. 4 Spatial position of the camera and object

The coordinate system and the 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. Dependence between their coordinates is given by following relations:

$$x = \frac{fX}{f - Z} \quad y = \frac{fY}{f - Z} \tag{4}$$

Equation (5) gives relation between coordinates of points in space and 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

These mathematical relations are valid for the coincident coordinate system, but most often this is not the case. The camera coordinate system, i.e. image plane, takes an arbitrary position in relation to the world coordinate system. The 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 is changed and its final form depends on the particular case. It is possible to realize all three coordinate translations along all three axes and rotations around the coordinate axis. The matrix transformation which is needed to connect a single matrix, or to specify the matrix equations individually is given by:

$$c_h = P \cdot T \cdot R \cdot W_h \, , \tag{6}$$

where is:
T – matrix of translation and
R – matrix of rotation
Inverse perspective transformation in matrix form, in this case, is defined by the relation:

$$W_h = P^{-1} \cdot T^{-1} \cdot R^{-1} \cdot c_h \tag{7}$$

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

$$z = B \frac{f}{d} \tag{8}$$

where:
$z = Z$ – distance of point P from the camera
f – focal length camera
B – distance of two mobile object position
d – distance between two position images of moving object

The above given relations 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 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) corresponds to a number of points in 3D space that lie on the straight and defined point of the optical centre. For 3D reconstruction of points based on its inverse image perspective the 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.

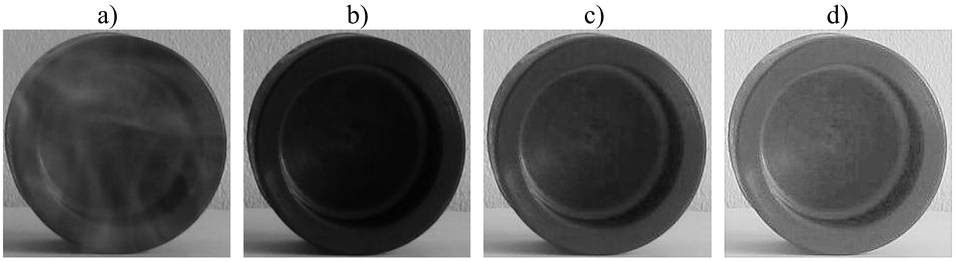
4. EXPERIMENTAL RESULTS

For problem solution the following algorithm can be applied:

1. Acquisition of at least two images
2. Smoke presence detection
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. The 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.5a) the recording cylindrical object in a cloud of smoke, b) without the presence of smoke and c) and d) the result achieved by filtering and removing interference.

a) b) c) d)



a) b) c) d)

Fig. 5 Object image a) with smoke b) without the presence of smoke c) obtained by applying the method [2] and d) obtained by applying the proposed system for filtering

Results of the measurement dimensions of object in the presence of smoke are given in Table 1.

Table 1 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

5. Conclusion

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

References

1. Middleton, W.: "Vision Through the Atmosphere", University of Toronto Press, Toronto (1952)
2. T. Peli and J. S. Lim, Adaptive filtering for image enhancement, J. *Opt. Eng.*, Vol. 21,JanuaryIFebruary 1982, pp. 108-112.
3. Nicolas HAUTIERE, Raphael LABAYRADE, Didier AUBERT, "Estimation of the Visibility Distance by Stereovision:A Generic Approach", IEICE TRANS. INF. & SYST., VOL.E89–D, NO.7 JULY 2006
4. Nicolas Hautiere, Jean-Philippe Tarel, Jean Lavenant, Didier Aubert, " Automatic fog detection and estimation of visibility distance through use of an onboard camera", Machine Vision and Applications (2006) 17(1): 8–20 DOI 10.1007/s00138-006-0011-9
5. International lighting vocabulary. 17.4. Commission Internationale de l'Eclairage (1987)
6. Narasimhan, S.G., Nayar, S.K.: "Contrast restoration of weather degraded images". IEEE Trans. Pattern Anal. Mach. Intell. 25(6), 713–724 (2003)
7. Bush, C., Debes, E.: "Wavelet transform for analyzing fog visibility". IEEE Intell. Syst. 13(6), 66–71 (1998)
8. Pomerleau, D.: "Visibility estimation from a moving vehicle using the ralph vision system". IEEE Conf. Intell. Transp. Syst. 906–911 (1997)
9. J. E. Hall and J. D. Awtrey, "Real-time image enhancement using 3 x 3 pixel neighborhood operator functions", *Opt. Eng.,* Vol. 19, MayIJune 1980, pp. 421-424.

NELINEARNO POBOLJŠANJE KONTRASTA SLIKE ZA ODREĐIVANJE DIMENZIJA OBJEKATA U PRISUSTVU INDUSTRIJSKIH ISPARENJA

Aca D. Micić, Biljana R. Đorđević,
Vlastimir D. Nikolić, Miodrag M. Stojiljković

Automatsko merenje fizičkih dimenzija objekta je značajno za mehatroničke sisteme koji rade u prisustvu industrijskih isparenja. Predložen je adekvatan realni sistem za merenje dimenzija u prisustvu smetnji. Analizirani su osnovni modeli isparenja i predložen je realni sistem za merenje dimezija objekta. Ponašanje sistema je analizirano na primeru objekta sa visokim stepenom simetričnosti.

Ključne reči: *Merenja, nelinearno poboljšanje kontrasta, homomorfno filtriranje*