UDC 681.3:535

R. Kvietnyy, Dr. Sc. (Eng.), Prof.; O. Bunyak

OBJECTS RECOGNITION ON DYNAMIC BACKGROUND USING TWO-DIMENSIONAL PREDICTION MODEL WITH QUADRATIC NONLINEARITY

Method of objects recognition on dynamic background is researched in given work. Stochastic, linear and nonlinear prediction models are used for modelling of dynamic background as a signal that is changed in time and space. The best quality of object definition is received with help of simplified nonlinear model as a sum of linear and quadratic signal components. Influences of model order, supporting area size and threshold value on the signal object selection are researched.

***Keywords**: objects recognition, stochastic, linear and nonlinear prediction, autoregression models.*

Introduction

Problem of objects determination and recognition on noise background requires the development of different methods and algorithms according to each specific case. In given work, the term dynamic background means the surface that is changing in time and space and characterized by some reiteration, for example a marine and river surfaces with waves. The task of foreign objects recognition on such surfaces is very important nowadays. It concerns custodial and rescue services, ecology and fauna monitoring. Since the marine surface is very large, it can be controlled with the help of technical resources. For this purpose it is necessary to detect and register foreign objects using the information systems on the basis of observation cameras and data processing facilities. Such difficulties as appearance of fuzzy edges and additional noises, loss of image quality or sharpness arise during the process of object recognition. That is why the necessity of new methods creation and old methods improvement becomes obvious.

Analysis of last investigations

The problem of object recognition familiar to such problems as defect identification, images correction and image edges determination [1]. Great quantities of publications are devoted to these themes, were application of different methods according to the images type are considered. The statistical analysis of image fragments and its mutual correlation for the detection of discontinuous variation of color and illumination are used for image edges determination [1-4]. A lot of methods are based on using mathematical models which create definite interaction among separate pixels and images fragments [5-11]. At the same time, the analogy between images dynamic and physical processes is used. For solution of some tasks the stochastic models are used [6], including models which are based on the Markoff process [8], fractal methods. Also for solving the tasks of object recognition it is necessary to use the different filtration methods, for example inverse or Wiener filtering [12,13].

Purpose

The purpose of this article is to raise the accuracy of object recognition on noise background using models that represent background characteristics.

Problem definition

The analysis of image processing methods shows that objects recognition on noise background can be performed by creation of background image model. Using this model it is possible to delete background and to leave only those objects, which don’t satisfy the criterion of model quality. Reiteration is an important characteristic of dynamic background, so the two-dimensional autoregressive model can be used as background image model. This model combines the dynamical characteristics, that's why it can describe the characteristic oscillation spectrum of dynamic object, and stochastic properties, as it includes the innovation noise. In image processing the two-dimension linear autoregressive model is used as [9,10]

$$u_{i,j} = -\sum_{m,n=0(m,n\neq 0)}^{P,Q} a_{m,n} u_{i-m,j-n} + \varepsilon_{i,j}, \qquad (1)$$

where $u_{i,j}$ – image signal samples, $a_{m,n}$ – linear prediction coefficients, $\varepsilon_{i,j}$ – noise samples, P,Q – parameters which assign model order in OX, OY directions. Two-dimension second order of nonlinear autoregressive model is also used [6,10,11]

$$u_{i,j} = -\sum_{m,n=0(m,n\neq 0)}^{P,Q} a_{m,n} u_{i-m,j-n} - \sum_{k,l=0(k,l\neq 0)}^{L,M} \sum_{m,n=0(m,n\neq 0)}^{L,M} b_{k,l,m,n} u_{i-k,j-l} u_{i-m,j-n} + \varepsilon_{i,j}, \qquad (2)$$

where $b_{m,n}$, L, M – coefficients and order of nonlinear constituent.

The linear (1) and nonlinear (2) autoregression were researched for modeling of background as river water waves, that is presented on Fig. 1. The dispersion of the noise values $\varepsilon_{i,j}$ was used as the model quality criterion and as criterion of required objects samples selection. The quality of models (1) and (2) was compared with stochastic background model.

Fig. 1. Image fragment.

Background models research

Image is represented by three matrixes with size $N_x \times N_y$, each matrix represents one color component. Fragment of image background without any foreign objects with size $n_x \times n_y$ is used as the basis for generation of background model. The required objects were determined by comparing of model and image.

The stochastic background model is represented by Gaussian noise with mean value m and dispersion σ in base area. It is easy to evaluate the given parameters using the known methods [14]. Maximum signal deviation is 2σ, therefore as minimum threshold value for the object selection 3σ can be chosen. The algorithm of objects image creation is the following:

$$if \;\; abs(u_{i,j} - m) > 3\sigma \;\; then \;\; v_{i,j} = u_{i,j} \;\; else \;\; v_{i,j} = 0,$$

where $u_{i,j}$ - image matrix elements, $v_{i,j}$ - objects matrix elements. Image processing result is represented on Fig. 2. Image matrixes size is 600×600, base area size is 80×80. As it can be seen from Fig. 2, the given model has rather high level of error. This error can be reduced by increasing the threshold value, but as numerous experiments have shown the image of objects gets worse. Therefore, the stochastic model badly approximates background signal and can't separate completely the required objects from background. The stochastic model can be improved by increasing basic area, but in this case the size and quality of required objects will be reduced.

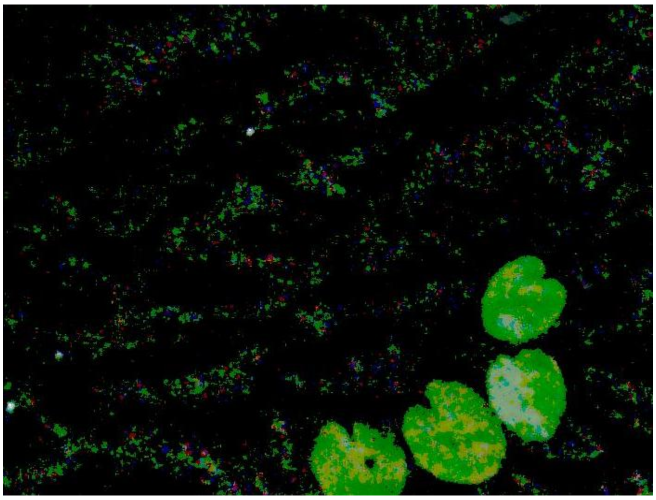

Fig. 2. Object recognition with the help of stochastic model

Object recognition with the help of models (1) and (2) is performed in such a way. Background model, just as in the case of stochastic model, was created in the basic area with size $n_x \times n_y$. The model order was determined with the help of method [15] by analysis of correlation characteristics of image signal in basic area separately in OX, OY directions. The model order is equal to $P, Q = 8$. Parameters of nonlinear model order are $L,\ M = 2$. Parameters of linear (1) and nonlinear (2) autoregressive models were defined by least-squares method with using of pseudoinversion by singular decomposition [14]. Maximum error ε_{max} and root mean square value of error σ were determined for each model on samples set of basic area.

Parameters estimations of image signal were defined according to equations (1) and (2) separately for each color component. Image matrixes of required objects were created correspondingly to the following condition:

$$if\ \ abs(\tilde{u}_{i,j} - u_{i,j}) > \varepsilon_{thr}\ \ then\ \ v_{i,j} = u_{i,j}\ \ else\ \ v_{i,j} = 0,$$

where $\tilde{u}_{i,j}$ – estimation of image elements, ε_{thr} – threshold value. As threshold value ε_{max}, $\sqrt{2\sigma^2}$ and 2σ were used.

As a result of computational actions it was determined that linear model approximates background signal with high accuracy (signal-to-noise ratio $SNR > 100\ \ dB$), but it can't define the difference between object and background. It can be explained that linear model is insensitive to signal displacement on constant value. But such signal displacement indicates the difference between object and background. Linear model allows only to determine the objects edges.

Nonlinear model (2) approximates background signal with $SNR` \approx 70\ \ dB$ and allows to recognize objects with low quality, as the stochastic model. Since the quality depends on the nonlinear constituent we can intensify it by using only the quadratic constituents with higher order. Such quadratic model can be represented as:

$$u_{i,j} = -\sum_{m,n=0(m,n\neq 0)}^{P,Q} \left(a_{m,n} u_{i-m,j-n} + b_{m,n} u_{i-m,j-n}^2 \right) + \varepsilon_{i,j} \tag{3}$$

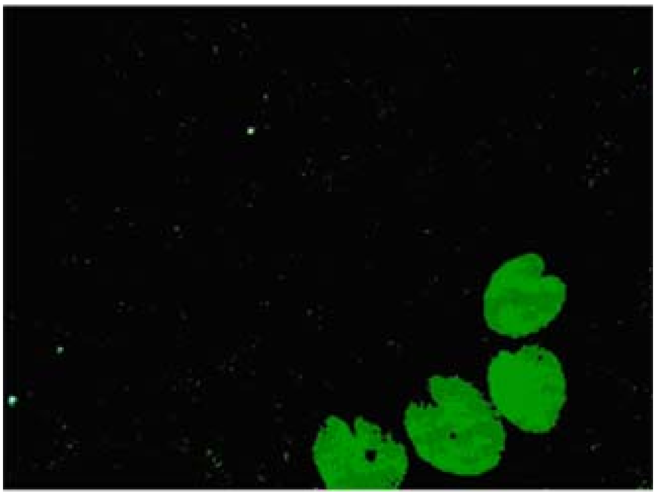

Fig. 3. Object recognition with the help of quadratic model

As the experiments showed, the quadratic model approximates background signal with accuracy of nonlinear model (2), but it gives better result on objects recognition. The result of application of quadratic model is represented on the Figure 3. As it can be seen from the Figure 3, big objects (leaves) and very small objects (distorted camera pixels) are accurately extracted.

Conclusions

Influence of model order, basic area size and threshold value on quality of object recognition were researched. According to realized experiments we can make the following conclusions:

With reducing of quadratic model order or base area the sensitivity is increased, but at the same time the quality of objects image gets worse. In some cases the quality can be improved by filtration;

With increasing of quadratic model order or basic area the sensitivity is reduced and it makes the edges of required object fuzzier;

Best results were observed with threshold value $\sqrt{2\sigma^2}$.

Application of stochastic, linear, nonlinear and quadratic models was researched in the given article. The research demonstrates that quadratic model (3) reflects the changes in signal dynamic in the best way. Method allows to obtain image with accurate verges and without edges fuzziness. Given model can be used for recognition of any size objects.

REFERENCES

1. Хорн Б.К.П. Зрение роботов: Пер. с англ. – М.: Мир, 1989. – 487 с.

2. Criffith A.K. Edge Detection in Simple Scenes Using A Priori Information // IEEE Trans. On Computers. – 1971. – V. –22. – № 5. – P. 551 – 561.

3. Wei G.W., Jia Y. Q. Synchronization-based image edge detection // Europhysics Letters. – 2002. – V. 59. – № 6. – P.814 – 819.

4. Johnson R. P. Contrast based edge detection // Pattern Recognition. – 1990. – V. 23. – № 3 – 4. – P. 311 – 318.

5.Deng G., Pinoli J.-C. Differentiation-based edge detection using the logarithmic image processing model // Journal of Mathematical Imaging and Vision. – 1998. – V. 8. – № 2. – P. 161 – 180.

6. Demoment G. Image reconstruction and restoration: overview of common estimation structures and problems // IEEE Trans. – 1989. – V.ASSP-37. – № 12. – P. 2024 – 2036.

7. Yuhui Sun, PeiruWu, Wei G.W. Evolution-Operator-Based Single-Step Method for Image Processing // International Journal of Biomedical Imaging Volume. – 2006. – Article ID 83847. – P. 1 – 27.

8. Charbonnier P., Blanc-Feraud L., Barlaud M. Noisy image restoration using multi resolution Markov random fields // Journal of Visual Communication and Image Representation. – 1992. – V. 3. – № 4. – P. 338 – 346.

9. Marzetta T.M. TwoDimensional Linear Prediction: Autocorrelation Arrays, Minimum Phase Error Filters, and

Reflection Coefficient Arrays // IEEE Trans. – 1980. – V.ASSP-28. – № 4. – P. 725 – 733.

10. Goh W.B., Chong M.N., Kalra S. A Bi-Directional 3D AR Model Approach to Motion Picture Restoration // IEEE Int. Conf. on Acoustics, Speech & Signal Processing. – May 1996. – P. 2277 – 2280.

11. Kokaram A.C., Morris R.D., Fitzgerald P.J. Interpolation of Missing Data in Image Sequences // IEEE Trans. Image Proc. – 1995. – V. 4. – № 11. – P. 1509 – 1519.

12. Price P J Voice Source Characteristics: Inverse Filtering Results // Journal of Speech Communications. – 1989. – 8:3:261 – 277.

13. Image Processing Toolbox For Use with Matlab, User's Guide. Version 3. – The Math Works Inc., 2004. – 775p.

14. Марпл-мл. С.Л. Цифровой спектральный анализ и его приложения: Пер. с англ. – М.: Мир, 1990. – 584 с.

15. Квєтний Р.Н., Буняк Ю.А. Кореляційний метод визначення оптимального порядку моделі авторегресії // Вісник Вінницького політехнічного інституту. – 2005. – № 2. – С. 20 – 22.

Roman Kvietnyy – Head of the Department;

Olga Bunyak – Master student of the Department.

The Department for Automatics and Information Measuring Devices, Vinnytsia National Technical University