MVA '98 IAPR Workshop on Machine Vision Applications, Nov. 17-19, 1998, Makuhari, Chiba, Japan

13—28
Localization of Objects in Noisy Scenes for Robotics Applications Using Wigner Distribution

Vinay G. Vaidya *
Siemens Information Systems Ltd.
Scientific Applications Center

Rajeev Kaushal †
Siemens Information Systems Ltd.
Scientific Applications Center

Abstract

This paper presents a new method for localization of objects in a noisy scene using Wigner Distribution (WD). We have superimposed noise as high 100% random noise as well as upto -10 dB Signal to Noise Ratio (SNR). With such extreme amount of noise, it is difficult to locate the object with our eyes. However, with the proposed method we can locate the object. The Wigner distribution has been extensively used for speech processing. However, its use for image processing is relatively new. The proposed method can be used for robotics application, where a robot has to locate the objects in highly noisy scenario. The method can also be utilized for finding out the path for robot movement in a cluttered environment. The results indicate that the proposed method deals efficiently with high noise and segments out the objects from the scene.

Introduction

In robotics application, a key problem for robot is to identify and locate industrial parts in its work cell. To achieve this objective the robot needs to know distance of the object and its angular position in the world coordinates. The problem becomes acute when robot is working in a cluttered environment like smoke, fog, poor contrast between object and the background or objects with disturbed background. In such cases the information extracted from the images is likely to lack precision and therefore, localization of object becomes difficult.

In this paper a new approach using Wigner distribution has been proposed. The proposed method uses exponential kernel on the Wigner distribution (WD). This method is capable of localizing the objects under high noise environment, where even manual localization of the objects is impossible. Our results indicate that this technique removes noise significantly. After noise removal, next step is to segment out the object for its position identification. The results presented here clearly show that the proposed method can be applied successfully to highly noisy images and can successfully be used for machine vision applications.

*Address: Law College Road, Pune - 411004, INDIA. E-mail:vinay.vaidya@pun1.siemens.net

†Address: Law College Road, Pune - 411004, INDIA. E-mail:rajeev.kaushal@pun1.siemens.net

Assumptions and Problem Statement

Assumptions

The images are assumed to be 8 bit quantized i.e. gray scale value ranges from 0 to 255. The experimental results presented here use gray scale ranging from 1 to 255. During computation, if the image coordinates go beyond the frame size, it is assumed that the gray scale values are zero. In other words, the gray scale values do not repeat outside the frame boundary.

Problem Statement

To extract the objects from the highly noisy scenes so that the location of the object could be calculated and the necessary information could be provided to the robot. This paper deals with the extraction of the objects from the noisy background. To check the efficiency of the Wigner Distribution based method we have considered the high level of noise, which means that the object is hardly visible due to noise (i.e. the noise level is 50% or more and in case of SNR it is -2dB or more).

Literature Review

The Wigner distribution is a generalized time frequency representation. Wigner [4], in 1932, proposed this function for the study of quantum mechanics. Researchers, in speech processing area, extensively used this concept in the 1980's. Claasen and Mecklenbrauker [1], published a series of papers on the Wigner distribution in order to facilitate and promote the use of this technique to other areas of research. Three of such recent papers are by Zhao, Atlas, and Marks[5], by Vaidya and Haralick [2], and by Vaidya and Kaushal [3]. Vaidya and Haralick used Wigner distribution successfully to estimate motion parameters from noisy images. Vaidya and Kaushal discussed the Wigner distribution based method to deal with high amount of noise in medical images. They showed the capability of the proposed method to deal with different noise levels.

The Wigner distribution of two signals, $f(t)$ and $g(t)$, is defined as follows [4]:

$$\mathrm{WD}_{f,g}(t,\omega) = \int_{-\infty}^{\infty} e^{-j\omega k} f(t+\frac{k}{2}) g^{*}(t-\frac{k}{2}) dk$$

Where, ω is the frequency, t is time, and $g*$ is complex conjugate of the function $g(t)$. The auto Wigner distribution is given by:

$$\mathrm{WD}_{f}(t,\omega) = \int_{-\infty}^{\infty} e^{-j\omega k} f(t+\frac{k}{2}) f^{*}(t-\frac{k}{2}) dk$$

To use the Wigner distribution function for image processing, one needs to extend it to 2-D space. Such an extension results in a 4-D Wigner distribution function. The function has two space domain variables x and y, and two-frequency domain variables u and v. Additionally, the Wigner distribution is always a real function. Thus, The extension to 2-D space is then

$$\mathrm{WD}(x,y,u,v) = \frac{4}{MN} \sum_{l=-N/2}^{N/2} \sum_{k=-M/2}^{M/2} \cos(\theta) f(x+k, y+l) \star f(x-k, y-l) \quad (1)$$

Where, M = Number of columns, N = Number of rows, $\theta = 4\pi(\frac{uk}{M} + \frac{vl}{N})$, f = gray scale function.

Exponential Kernel

In the proposed method, the main Winger Distribution kernel is multiplied by another kernel, which is exponential. The exponential kernel is defined by

$$\mathrm{Kernel} = e^{-\lambda \|(k,l)\|}$$

The main idea behind this kernel is the pixel (x, y) where the WD is being calculated should have the maximum influence on the calculations. As one goes away from the pixel (x, y), the influence should rapidly go down.

The equation (1) when modified with the exponential becomes:

$$\mathrm{WD}(x,y,u,v) = \frac{4}{MN} \sum_{l=-N/2}^{N/2} \sum_{k=-M/2}^{M/2} e^{-\lambda \|(k,l)\|} \star \cos(\theta) f(x+k, y+l) \star f(x-k, y-l) \quad (2)$$

Experimental Protocol

To test the Wigner Distribution based method for object location in a noisy scene; we carried out experiments on 8 bit quantized synthetic images. Different amount of noise is generated and added to the images. The noise was generated using the random and SNR noise models. Eight test cases have been considered. Each case deals with different amount of noise level and also different types of objects to check the robust behavior of the proposed method. Once the level of noise is reduced by the Wigner Distribution based method (with frequency components $u = 0$ and $v = 0$), the output is segmented to segregate out the objects from the background to localize the objects. The output of all the test cases are shown in Appendix.

Results

To judge the robustness of the algorithm we considered more than fifty cases (total fifty-four) consisting of different noise compositions, object types, contrast variations, and multiple objects. The success rate of localization of the object is approximately 95% (i.e. fifty-one successful test cases). The proposed algorithm failed in cases where objects were placed very closely under high noise (65 % or more random noise). The algorithm recognized all the objects as a single blob.

Conclusion

The results indicate that the proposed method can be used successfully for machine vision operations. Various cases have been considered with varying noise levels, contrast, and number of objects. It has been observed that in most of the cases objects can be located, irrespective of noise levels. The system does not produce acceptable results when the multiple objects are located nearby and the noise level is high. In such cases, It represents all the objects by a single segment.

[1] Classen, T.A.C.M. and W.F.G. Mecklenbrauker, "The Wigner Distribution - a Tool for Time - Frequency Signal Analysis, Part II: Discrete Time Signals", Phillips J. Res., 35, 1980, pp.276 - 300.

[2] Vaidya and Haralick, "Wigner Distribution for 2D Motion Estimation from Noisy Images", Journal of Visual Communication and Image Representation, Vol. 4, No. 4, December 1993, pp. 281 - 297.

[3] Vaidya and Kaushal, "The Use of Wigner Distribution for Noise Reduction in Medical Images and It's Comparison with Fuzzy and Crisp Methods", Proceedings of Applied Machine Vision'98 Conference, May 19 - 21, 1998, Tennessee (USA).

[4] Wigner E., "On the Quantum Correction of Thermodynamic Equilibrium", Phys. Rev. 40, 1932, pp. 749 - 759.

[5] Zhao, Atlas, and Marks II, " The Use of Cone Shaped Kernels for Generalized Time Frequency Representations of Nonstationary Signals", IEEE Trans. Acoustics, Speech, and Signal Processing, Vol. 38, No. 7, 1990, pp. 1084 - 1092.

APPENDIX

Case I : 100% Random Noise

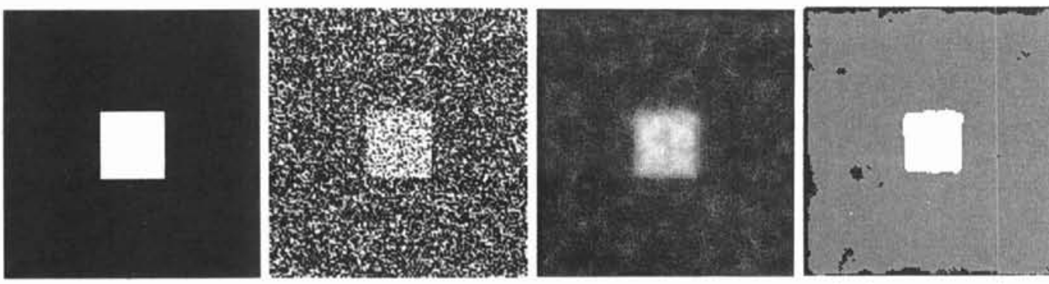

Fig 1: (a) Noise Free (b) Noisy (c) WD on (b), λ=0.5 (d) Segmentation of (c)

Case II : -10 dB Noise

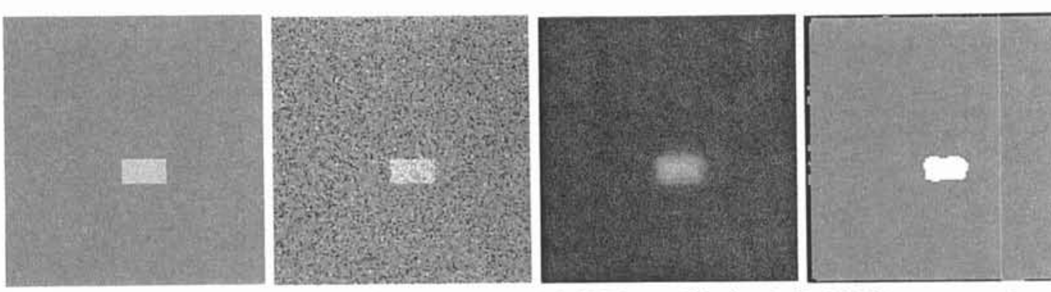

Fig 2: (a) Noise Free (b) Noisy (c) WD on (b), λ=0.5 (d) Segmentation of (c)

Case III : 50% Random Noise

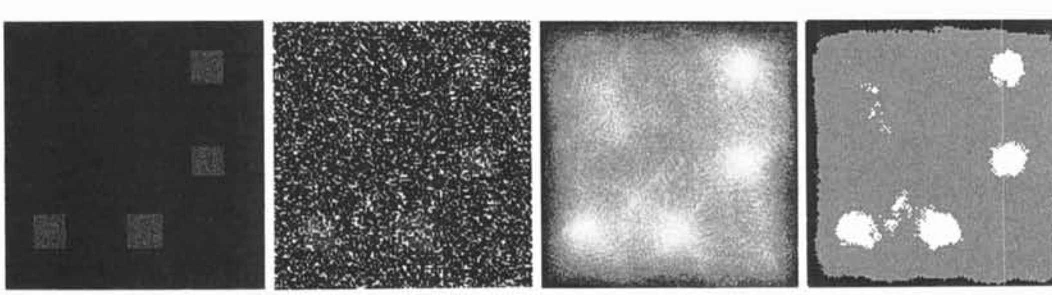

Fig 3: (a) Noise Free (b) Noisy (c) WD on (b), λ=0.18 (d) Segmentation of (c)

Case IV : 50% Random Noise

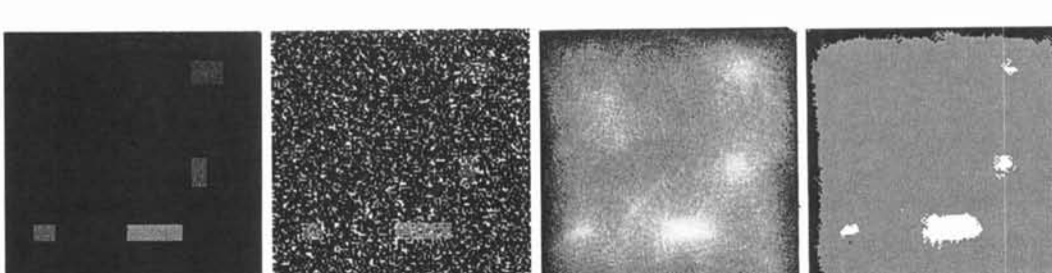

Fig 4: (a) Noise Free (b) Noisy (c) WD on (b), λ=0.5 (d) Segmentation of (c)

Case V : 70% Random Noise

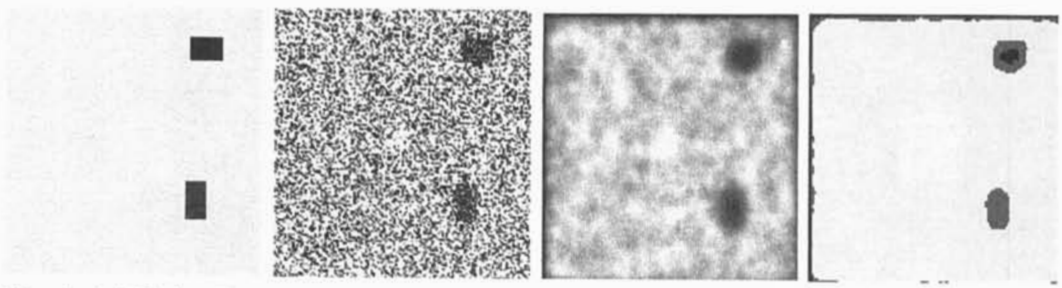

Fig 4: (a) Noise Free (b) Noisy (c) WD on (b), λ=0.5 (d) Segmentation of (c)

Case VI : 65% Random Noise

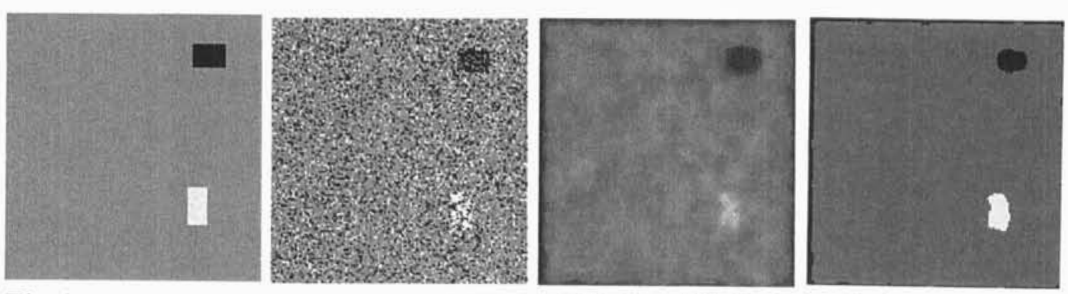

Fig 4: (a) Noise Free (b) Noisy (c) WD on (b), λ=0.5 (d) Segmentation of (c)

Case VII : 50% Random Noise

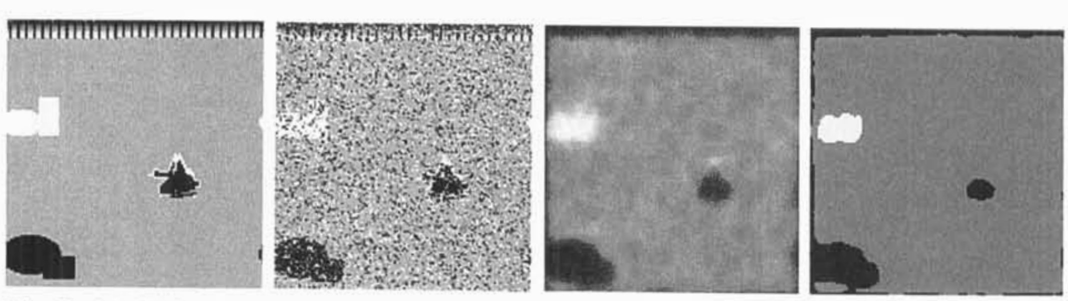

Fig 7: (a) Noise Free (b) Noisy (c) WD on (b), λ=0.5 (d) Segmentation of (c)

Case VIII (Fail Case) : 55% Random Noise

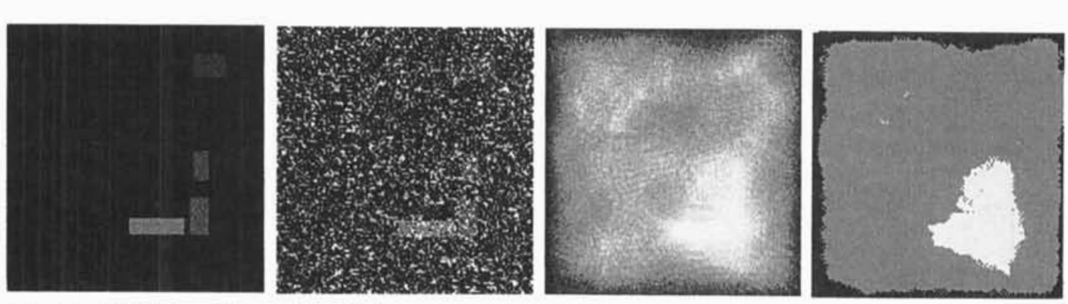

Fig 8: (a) Noise Free (b) Noisy (c) WD on (b), λ=0.5 (d) Segmentation of (c)