ARISTOTLE UNIVERSITY of THESSALONIKI

SCHOOL of SCIENCES

DEPARTMENT of COMPUTER SCIENCE

Radial Basis Function Network Robust Learning Algorithms in Computer Vision Applications

PhD THESIS

BORŞ GHEORGHE ADRIAN

THESSALONIKI 1998

Contents

Radial Basis Function Network robust learning algorithms in computer vision applications

Abstract

This thesis introduces new learning algorithms for Radial Basis Function (RBF) networks. RBF networks is a feed-forward two-layer neural network used for functional approximation or pattern classification applications. The proposed training algorithms are based on robust statistics. Their theoretical performance has been assessed and compared with that of classical algorithms for training RBF networks. The applications of RBF networks described in this thesis consist of simultaneously modeling moving object segmentation and optical flow estimation in image sequences and 3-D image modeling and segmentation. A Bayesian classifier model is used for the representation of the image sequence and 3-D images. This employs an energy based description of the probability functions involved. The energy functions are represented by RBF networks whose inputs are various features drawn from the images and whose outputs are objects. The hidden units embed kernel functions. Each kernel is associated with an activation region from the input space and its output is fed to an output unit. In this thesis the hidden unit activation functions are considered Gaussians while the output unit activation functions are Perceptron-like.

The first chapter describes the state-of-the art in the RBF networks. A short history of the RBF networks as well as their relation to other pattern recognition techniques are presented in this chapter. Various functions used as hidden unit activation functions, weight interpretation and various properties of the RBF networks are described. Different training algorithms employed for training RBF networks are presented. Many and diverse applications of RBF Networks have been considered in the literature. The main application fields have been speech processing, telecommunication systems, image processing, time-series modeling and prediction, computer vision, computer graphics, etc.

In order to find the parameters of an RBF neural network in chapter 2 we take into consideration two different statistical approaches. The first approach uses classical statistical estimators in the learning stage and it is based on the second order statistics extension for the learning vector quantization algorithm. After the presentation of this approach, we introduce the Median Radial Basis Function (MRBF) algorithm based on the robust estimation of the hidden unit parameters. Marginal median and median of the absolute deviations from the median (MAD) estimators are employed for estimating the basis function parameters. Both algorithms are im-

plemented on-line. The theoretical performance is evaluated for an one-dimensional model consisting of the analysis of the expected bias for the parameters in the case of mixture of Gaussians distributions. A fast implementation for the proposed algorithm based on histogram modeling is presented in this chapter. The algorithms for training the networks are applied in two-dimensional distribution estimation problems and for optical flow segmentation from a real image sequence.

Various approaches have been proposed for simultaneous optical flow estimation and segmentation in image sequences. In chapter 3 the moving scene is decomposed into different regions with respect to their motion, by means of a pattern recognition scheme. The inputs of the proposed scheme are the feature vectors representing still image and motion information. Each class corresponds to a moving object. The classifier employed is the Median Radial Basis Function (MRBF) neural network which has been introduced in chapter2. An error criterion function derived from the probability estimation theory and expressed as a function of the moving scene model is used as cost function. Each basis function is activated by a certain image region. The image regions associated with the basis functions are merged by the output units in order to identify moving objects.

A prediction model for moving object velocity and location estimation derived from Bayesian theory is provided in chapter 4. The optical flow of a certain moving object depends on the history of its previous values. The joint optical flow estimation and moving object segmentation algorithm described in chapter 3 is used for the initialization of the tracking algorithm. The segmentation of the moving objects is determined by appropriately classifying the unlabeled regions. Segmentation and optical flow tracking is used in order to predict future frames.

In chapter 5 a pattern classification based approach for simultaneous 3-D object modeling and segmentation in image volumes is proposed. The 3-D objects are described as a set of overlapping ellipsoids. The segmentation relies on the geometrical model and graylevel statistics. The characteristic parameters of the ellipsoids and of the graylevel statistics are embedded in a Radial Basis Function (RBF) network and they are found by means of unsupervised training. A new robust training algorithm for RBF networks based on α-trimmed Mean statistics is employed in this chapter. The extension of the Hough Transform algorithm in the 3-D space by employing spherical coordinate system is used for ellipsoidal center estimation. The performance of the proposed algorithm when estimating the parameters of ideal ellipsoids and for segmenting a stack of microscopy images is anlysed.

Preface

This thesis includes most of the author research done between 1993 and 1998 while at the University of Thessaloniki, under the supervison of Professor Ioannis Pitas. The work presented in this thesis resulted in the submission of one book chapter, publication of 2 journal papers, while other 2 are still under review in international journals and 9 conference papers published and presented in various international conferences and workshops. The research work described in this thesis contributed in two European Research projects: *Nonlinear and Adaptive Techniques Basic Research Activity* and *Nonlinear Model-Based Analysis and Description of Images for Multimedia Applications*.

The author would like to express his gratitude to Professor Ioannis Pitas, thesis advisor, for providing him with the opportunity of doing his PhD research in Artificial Intelligence and Computer Vision laboratory and for his expertise in guiding the author's research for the past five years. The author is particularly greatfull to A. Nikolaidis, V. Solachidis, P. Nikopolitidis and J. Fisher-*Rodríguez* for their help and friendly colaboration. Certainly, many thanks to Y. Batsiolas for his professional and efficient technical assistance. The author would like to thank also to Dr. Kotropoulos, Dr. Nikolaidis, V. Chatzis, S. Tsekeridou, G. Theocharous and A. Tefas for creating a fruitfull and academic challenging environment and for usefull discussions. Many thanks are due to the family and to all the professors who helped the author in the past to achieve the necessary knowledge for successfully pursuing research and obtaining the results reported in this thesis.

Thessaloniki, November 1998

List of Publications

Book Chapter

[1]. A. G. Borş, I. Pitas, "Radial Basis Function Neural Networks and their applications," submitted for *The Handbook of Applied Computational Intelligence* CRC Press. M. L. Padgett, N. B. Karayiannis, L. A. Zadeh, eds.

Journal Publications

[1]. A. G. Borş and I. Pitas, "Median Radial Basis Functions Neural Network," *IEEE Trans. on Neural Networks,* vol. 7, no. 6, pp. 1351-1364, Nov. 1996.

[2] A. G. Borş and I. Pitas, "Optical Flow Estimation and Moving Object Segmentation Based on Median Radial Basis Function Network," *IEEE Trans. on Image Processing,* vol. 7, no. 5, pp. 693-702, May 1998.

[3] A. G. Borş and I. Pitas, "Object Classification in 3-D Images Using Alpha-Trimmed Mean Radial Basis Function Network," accepted to *IEEE Trans. on Image Processing,* 1998.

[4] A. G. Borş and I. Pitas, "Prediction and Tracking of Moving Objects in Image Sequences," submitted to *IEEE Trans. on Image Processing,* 1998.

Conference Publications

[1] A. G. Borş, I. Pitas, "Robust estimation for radial basis functions," *Proc. of IEEE Workshop Neural Networks for Signal Processings,* Ermioni, Greece, pp. 105-114, Sep. 1994.

[2] A. G. Borş, I. Pitas, "Median Radial Basis Functions Network for Motion Field Processing," *Proc. of IEEE Workshop on Nonlinear Signal and Image Processing,* I. Pitas (Ed.), Neos Marmaras, Greece, pp. 702-705, June 1995.

[3] A. G. Borş, I. Pitas, "Segmentation and Estimation of the Optical Flow," *Lecture Notes in Computer Science 970, International Conference of Computer Analysis of Images and Patterns,* Prague, Czech Rep., pp. 680-685, Sep. 1995.

[4] A. G. Borş, I. Pitas, "Moving Object Recognition Based on Radial Basis Functions Networks," *9th Image and Multidimensional Signal Processing Workshop,* Belize City, Belize, pp. 34-35, Mar. 1996.

[5] A. G. Borş, I. Pitas, "Moving Scene Segmentation using Median Radial Basis Function Network," *IEEE Symposium on Circuits and Signals (ISCAS'97),* Hong Kong, vol. I, pp. 529-532, 9-12 June 1997.

[6] A. G. Borş, I. Pitas, "Alpha-trimmed Mean Radial Basis Functions and their Application in Object Modeling," *CD-ROM Proc of the IEEE Workshop on Nonlinear Signal and Image Processing (NSIP'97),* vol. 1, paper # 211, Mackinac Island, Michigan, USA, 7-11 September 1997.

[7] A. G. Borş, I. Pitas, "Object segmentation and modeling in volumetric images," *Noblesse Workshop on Non-Linear Model Based Image Analysis,* Glasgow, U.K., pp. 295-300, 1-3 July 1998.

[8] A. G. Borş, I. Pitas, "Object segmentation in 3-D images based on alpha-trimmed mean radial basis function network," *European Conference on Signal Processing (EUSIPCO'98),* Rhodes, pp. 1093-1096, vol. II, Greece, 8-11 Sep. 1998.

[9] A. G. Bors, I. Pitas, "Motion and Segmentation Prediction in Image Sequences Based on Moving Object Tracking," *IEEE Int. Conference on Image Processing (ICIP'98),* Chicago, Illinois, USA, pp. 663-667, vol III, 4-7 October 1998.