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Proposal to Use Artificial Intelligence in the Field of Opthalmology

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RELATÓRIOS TÉCNICOS

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Proposal to use artificial intelligence in the field of opthalmology[1]

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Abstract: This project consists of investigating a technology to make possible the automatic mensuration of the ocular refraction errors (astigmatism, hypermetropia and myopia). For this, it intends to use recognition techniques and images analysis that will operate on images acquired recently by technique used for the information acquisition from the ocular globe, called Hartmann-Shack. The system should process an image supplied by the acquisition technique and, later on, to analyze it, extracting the necessary information for an automatic diagnosis of the possible existence of refractive errors in the examined ocular globe.

The approach to be adopted uses techniques of artificial intelligence, more specifically, the use of neural networks. The huge progress in research and practical applications in that line in the last years certifies the precision and the efficiency of the same to analyze and to recognize external input data. It is believed that they can be used to identify an image from Hartmann-Shack sensor that corresponds to an eye with anomaly, which anomaly type, as well as to quantify the magnitude anomaly.

The purpose of using neural networks in the image analysis is to provide to the system with adaptability and robustness, that is, the system can respond (to measure) by understanding the data and not comparing the images as was accomplished previously. The use of intelligent software to evaluate the images also seeks to solve current problems of the difficulties that exist today for optimizing the system. Problems with small imperfections in the image acquisition or digitalization, in the preprocessing and segmentation of the images, can cause mistakes later on in the moment of the mensuration.

This approach offers various possibilities in terms of academic research and ocular globe recognition. The possibility to recognize and to analyze the pertinent characteristics of the ocular globe allows to diagnose the refraction errors, and to obtain other information about the health of the ocular globe.

Furthermore, a practical contribution of this approach is to suggest a new technology to measure the ocular refraction errors and the computational contribution based on analysis techniques and images recognition. Another contribution consists of the introduction of those techniques in a new field. It is possible that new application demands adaptations/new developments in the current processes, which can result in a contribution by this project for the computation area in addition to the immediate application of existent techniques. Finally, we believe the project provides a good opportunity for a closer approximation between the areas of Computer Science and Optometry.

Keywords: Neural network, Artificial intelligence, Images processing and analysis, Refractive error, Hartmann-Shack technique.

Homepage: http://www.opt.indiana.edu/oxyopia/fall01.htm#oct12

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School of Optometry
INDIANA UNIVERSITY

VISUAL SCIENCES GROUP

Proposal to use artificial intelligence in the field of ophthalmology

October 2001

Topics

- Objective and motivation
- Artificial intelligence techniques
  - Neural Nets
  - Fuzzy Logic
- System of measurement
  - Acquisition from Hartmann-Shack technique
  - Preprocessing of image (resize and clear)
  - Extraction of features (PCA)
  - Recognition and analysis of images
- Additional information (Linux and Difficulties)

Objective and motivation

To define a functional system capable of processing images of the human eye acquired by the Hartmann-Shack technique (HS) and, later, to analyze these images extracting the information necessary to formulate the diagnosis by means of Artificial Intelligence (Neural Nets/ Fuzzy Logic).

- To develop a new technology to measure the ocular refractive errors, by using other methods different from the patented systems.

Objective and motivation

- To provide the system with adaptability and robustness, that is, the system can respond, or measure, by understanding the data and not comparing the images as was accomplished previously.
- To introduce those techniques in a new field - Optometry/Ophthalmology.

To obtain other information about the health of the ocular globe by using the same image.

To formulate a multidisciplinary project.

To develop by LINUX (VDK – Free software).

What is artificial neural networks?

- ✓ They can be defined as parallel systems distributed that constitute a simple processing unit, highly interconnected, that can compute definitive mathematical functions.
- ✓ Such units are made using one or more linked layers and for a great number of connections, generally unidirectional.
- ✓ In the majority of the models these connections are associates the weights, which store the knowledge represented in the model and serve to ponder the input received for each neuron of the network.

Artificial Neural Network

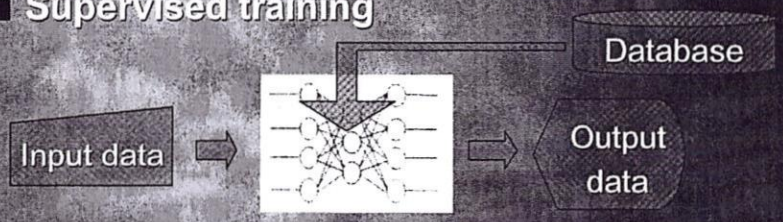
- The neural networks show a surprising number of typical properties of the human brain. For example, they learn from the experience, to generalize new examples from previous examples, and to obtain input features that have irrelevant data.
- The main feature of the neural networks is in considering the knowledge acquired during the training, and answering to the new input data in the way most appropriate, thus concluding, a generalization of it problem.

Artificial Neural Network

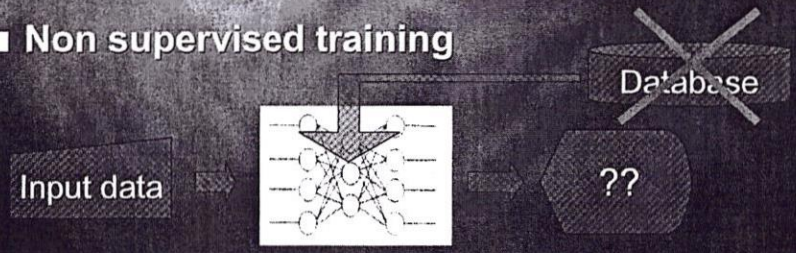
- The model of neural network is defined in accordance with the architecture of the network, function of transference and rule of learning, while its architecture is determined by the corresponding weights and projection of connections.
- The learning process involves the change in the values of the weights.
- Principal learning process: Supervised training and Non supervised training.

Artificial Neural Network

- Supervised training



- Non supervised training



The models of Neural Network

Multi-layer Perceptron (MLP)

- It is the most used model of neural network.
- There are many algorithms that can be used in the training process to reduce the errors rate.

Radial Basis Function (RBF)

- It generally is used in problems of implementing functions and pattern recognition.
- The neurons use radial base functions, being most common the Gauss function.

Artificial Neural Network

The main features for the solution of problems are:

- Capacity to learn by means of examples and to generalize this learning in way to recognize similar instances that never had been presented as example;

  Good performance in tasks badly defined, where it lacks explicit knowledge on how to find a solution;

Artificial Neural Network

- Raised immunity to the noise, that is, the performance of a neural network does not fail in presence of false or absent information, as it is the case of conventional programs, although to get worse in gradual way.
- It does not require knowledge of eventual mathematical models of the application domain;

What is Fuzzy Logic?

It was developed to provide algorithms with processing with information that can reason about, or to use, imprecise data.

The main advantages of the use are:

- It allows representation of the knowledge and inference of the specialists in the form of fuzzy rules, that are very close to the natural language;

Fuzzy Logic

- Simplification of the development, maintenance and experimentation, since it is much more easy to change rule rather than the programs;
- Representation of vague concepts, that is, incorporates and ponders the uncertainty of the system.

System of measurement

Acquisition System
- Hartmann-Shack

Phase 0

Preprocessing
- Segmentation
  - ✓ Thresholding
  - ✓ Boundary detection
- Mathematical Morphology
  - ✓ Aperture and locking
  - ✓ Dilation and erosion

Extraction of features
- Multivariate Analysis
  - ✓ Principal Component Analysis - Classical PCA

Phase 1

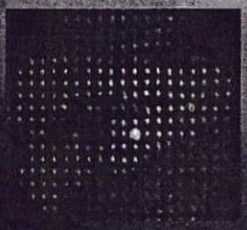
Recognition and analysis
- Neural Net
  - ✓ MLP
  - ✓ RBF
- Fuzzy Logic

Phase 2

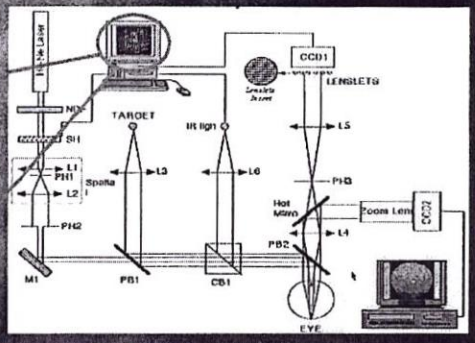
School of Optometry

Acquisition from HS technique

Normal eye

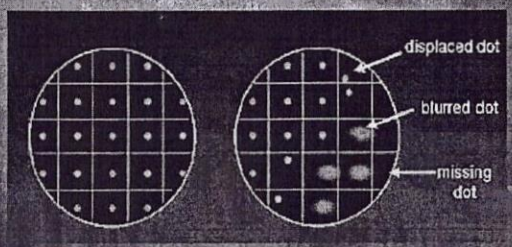


Aberrated eye



IU Aberrometer

Acquisition from HS technique

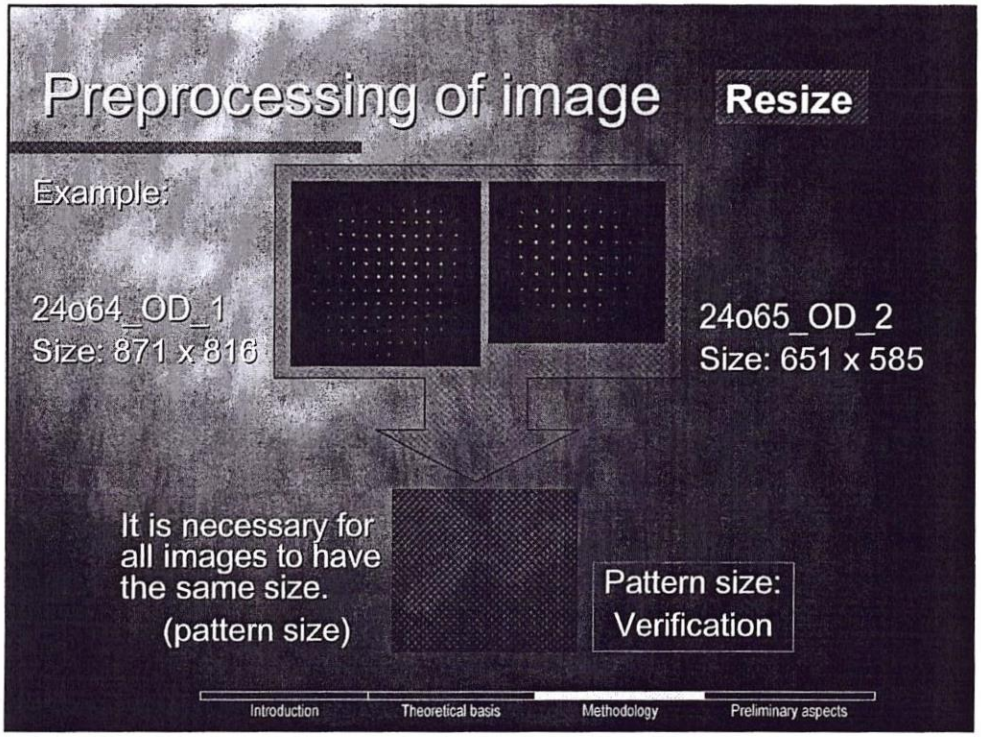


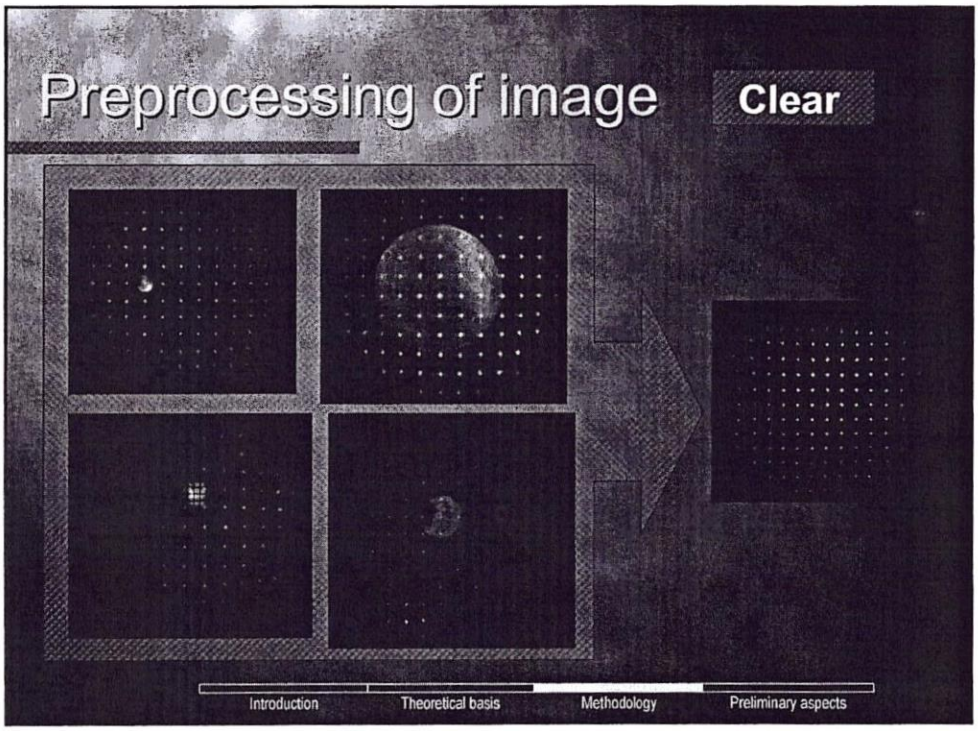
No aberration, no scatter

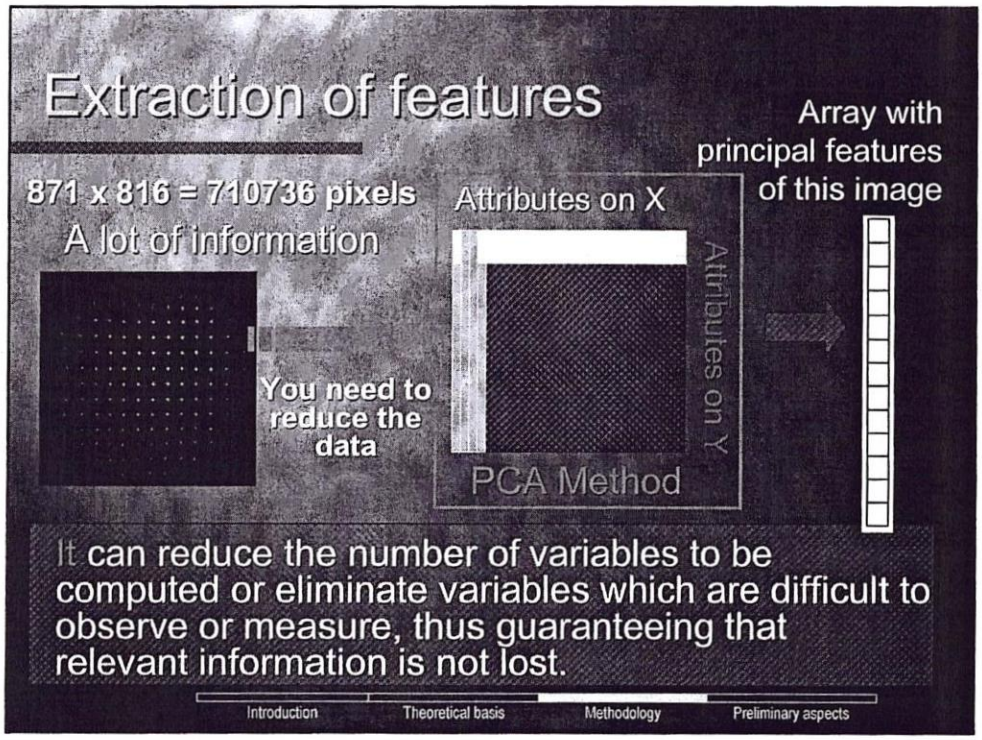
aberration and scatter

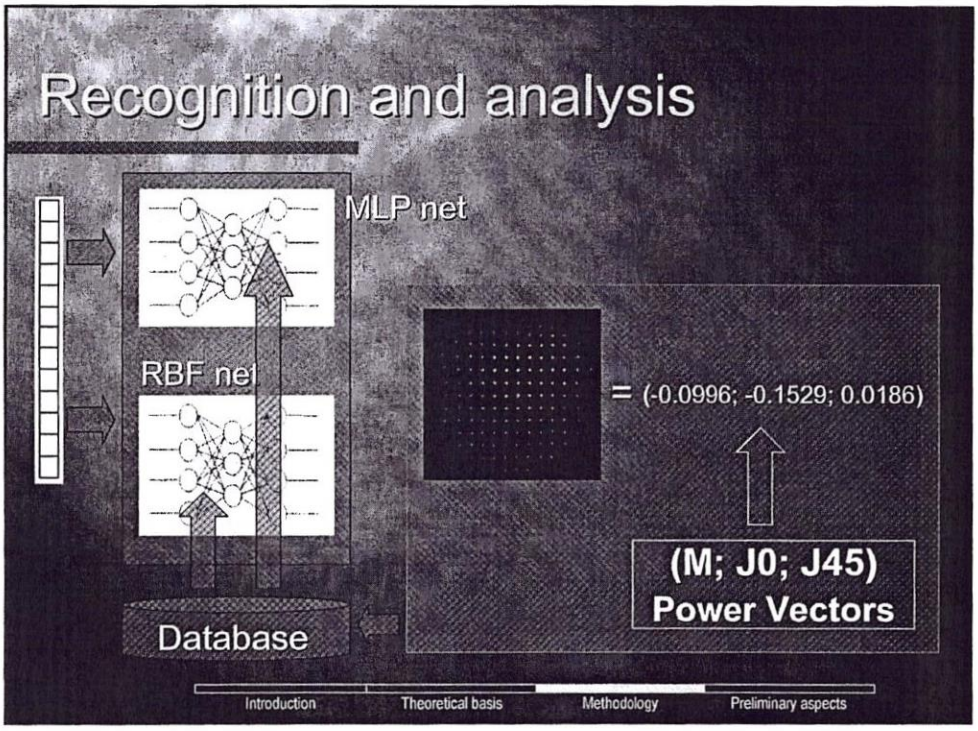
Is it new information?

Affirmation: Today, we use only information from *centroid* and the rest of image we don't use.


Preprocessing of image
Resize
Example:
24o64_OD_1
Size: 871 x 816
24o65_OD_2
Size: 651 x 585
It is necessary for all images to have the same size.
(pattern size)
Pattern size:
Verification
Introduction
Theoretical basis
Methodology
Preliminary aspects


Preprocessing of image
Clear
Introduction
Theoretical basis
Methodology
Preliminary aspects


Extraction of features
871 x 816 = 710736 pixels
A lot of information
You need to reduce the data
Attributes on X
Attributes on Y
PCA Method
Array with principal features of this image
It can reduce the number of variables to be computed or eliminate variables which are difficult to observe or measure, thus guaranteeing that relevant information is not lost.
Introduction
Theoretical basis
Methodology
Preliminary aspects


Recognition and analysis
MLP net
RBF net
Database
= (-0.0996; -0.1529; 0.0186)
(M; J0; J45)
Power Vectors
Introduction
Theoretical basis
Methodology
Preliminary aspects

Power Vectors (M; J0; J45)

Description of sphero-cylinder lenses by viewpoint of Fourier analysis (Fourier series in rectangular form).

Advantages of this representation of a sphero-cylinder lens for numerical and graphical analysis of optometric data area are described for problems involving lens combinations, comparison of different lenses, and the statistical distribution of refractive errors.

Positive-cylinder

$M = S + C/2$

$J0 = - C/2 \cos 2 (A + 90^{o})$

$J45 = - C/2 \text{ sen } 2 (A + 90^{o})$

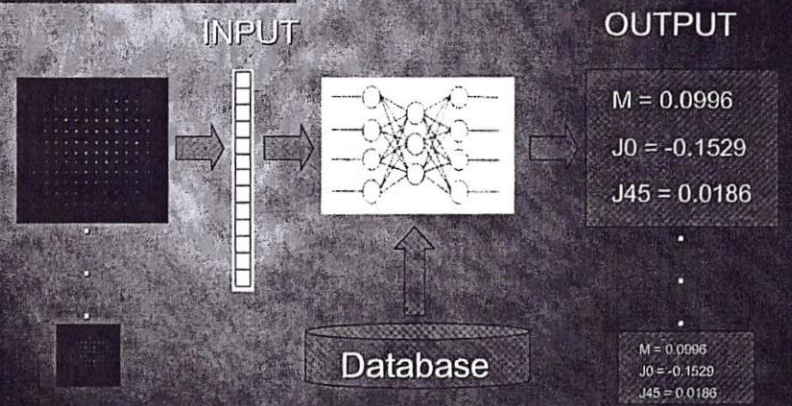
Negative-cylinder

$M = S' + C'/2$

$J0 = - C'/2 \cos 2 A$

$J45 = - C'/2 \text{ sen } 2 A$

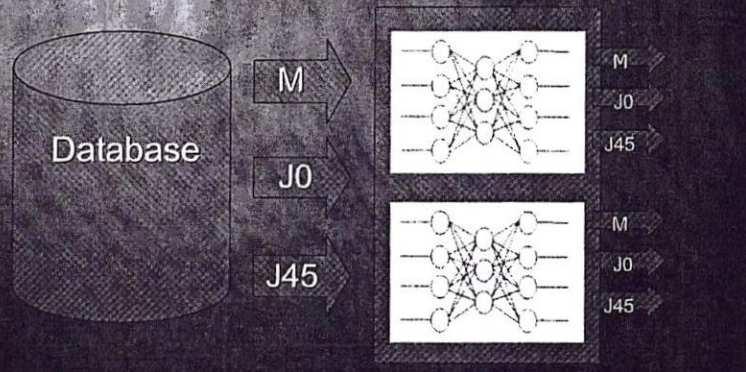
Recognition and analysis



Period of training - The weight of the net will be balanced.

Recognition and analysis

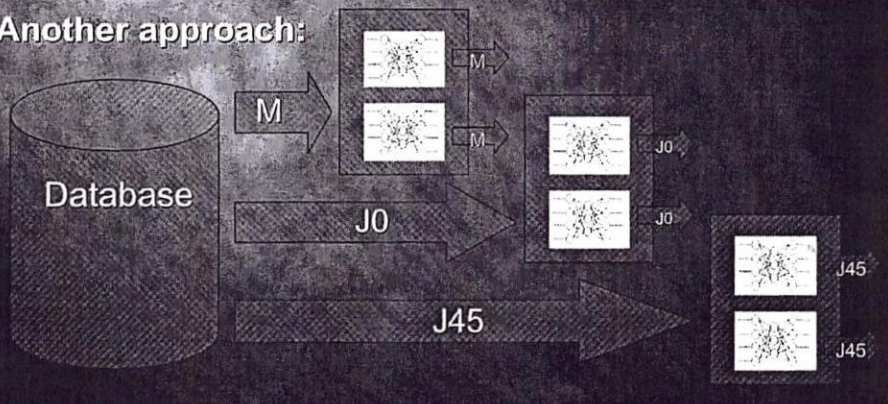
It will be presented as output of the net in the period of training, the 3 elements at the same time. The net must recognize that the array of features coming of the image, represents the 3 elements.



Recognition and analysis

Separate Neural net for each element?

Another approach:



Recognition and analysis

50% of images

Training of the neural nets

Database

687 images

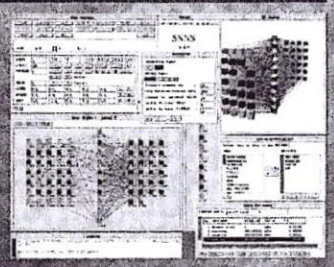
25% of images

Validation of the system

25% of images

Recognition tests (verification of the performance)

Recognition and analysis



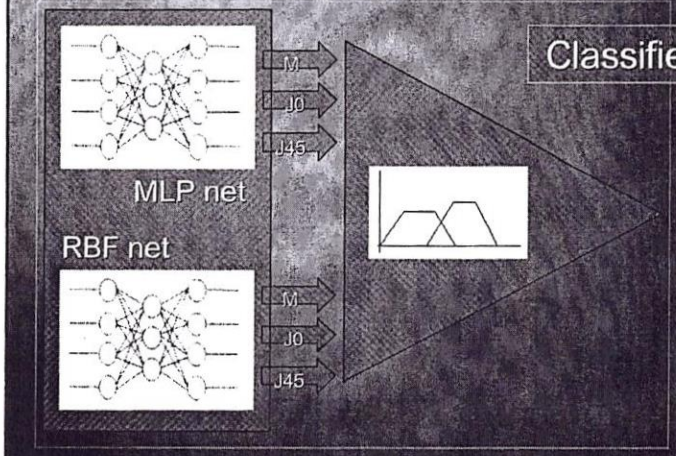
How does verify the best layout of net performance?

It will be use the SNNS (Stuttgart Neural Network Simulator).

It is a software simulator for neural networks on Unix workstations developed at the Institute for Parallel and Distributed High Performance Systems (IPVR) at the University of Stuttgart.

The goal of the SNNS project is to create an efficient and flexible simulation environment for research on and application of neural nets.

Recognition and analysis

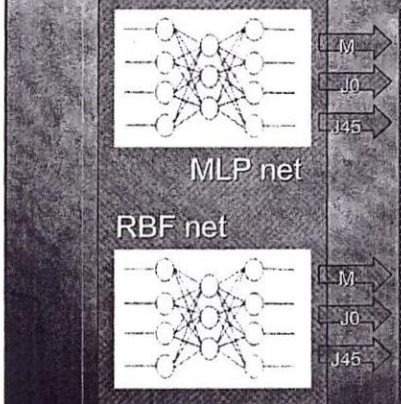


Classifier combination

The best performance up to 97% of certain

Neural-fuzzy system

Recognition and analysis



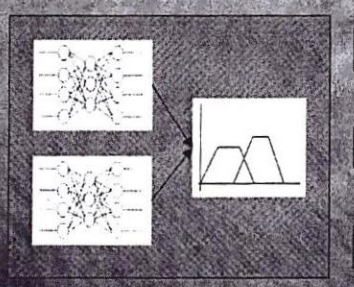
Another technique can be created for combining the data.

It will depend of output performance.

It is possible that the Neural Nets is enough for this system.

Classifier combination

Recognition and analysis



Neural-fuzzy system

Positive-cylinder

$$S = M - \sqrt{J0^2 + J45^2}$$

$$C = 2\sqrt{J0^2 + J45^2}$$

$$A = 1/2 \tan^{-1}(J45/J0) + 90^{o}$$

Negative-cylinder

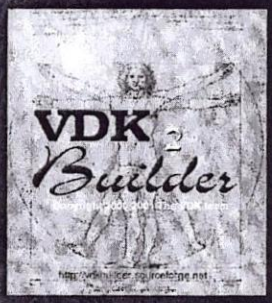
$$S' = M + \sqrt{J0^2 + J45^2}$$

$$C' = -2\sqrt{J0^2 + J45^2}$$

$$A' = 1/2 \tan^{-1}(J45/J0)$$

You need to transform to Sphere, Cylinder and Axle

Additional information



- It is a Rapid Application Development tool based on VDK - "The Visual Development Kit" (C++ library).
- It is a tool that helps programmers in constructing GUI interfaces, editing, compiling, linking, and debugging within an integrated environment.

It reduces developing time since all code related to GUI construction and signal processing is automatically generated, maintained and updated.

Additional information

Difficulties at the moment

- To verify whether the system will work with different pupil size (Max pupil).
- Pattern size of images.
- One Neural net for each element – M, J0, J45 (Power Vectors).
- Classifier Combination (Fuzzy Logic or another technique).

The End

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