Innovative ICT means in financial management

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***Abstract*—**This paper aims at proposing new innovative methods of artificial intelligence in financial management. The general objective of this article is to ensure an efficient way to make financial decision in internal management based on the "intelligence method-management problem" pair. Moreover, the research is extended also to the introduction of fuzzy system applications in the economic environment. Such an application is used to optimize the portfolio management of financial securities, providing the company an improved tool to extending its profits. Also, the economic environment itself benefits from such instruments by increasing competitiveness among companies.

***Keywords*—**artificial intelligence, artificial neural networks, financial securities, fuzzy systems, efficient financial management

I. The Financial System and the Artificial Intelligence

NOWADAYS The financial system has a global range. Financial markets and intermediaries are linked through a vast international telecommunications network, so that the transfer of payments and the trading of securities can go on virtually around the clock.

For example, if a large corporation based in Germany wants to finance a major new investment, there is a range of international possibilities that he might consider. Some options could be issuing stock and selling it on the New York/London stock exchanges or borrowing from a Japanese pension fund. If it chooses to borrow from the Japanese pension fund, the loan might be denominated in German marks, in Japanese yen, or even in U.S. dollars.

The interactions between the various players in the financial system are represented by a flow-of-funds. This is represented in the figure 4.1.1. Funds flow through the financial system from entities that have a surplus of funds (box on the left) to those that have a deficit (the box on the right).

This simple circuit (of the two boxes above mentioned) gets more complex as the level of the financial process raises. Financial intermediaries are defines as firms whose primary business is to provide financial services and products. They include banks, investment companies, and insurance companies. Their products include checking accounts, commercial loans, mortgages, mutual funds, and a wide range of insurance contracts.

To illustrate the flow of funds through intermediaries, suppose you deposit your savings in an account at a bank, and the bank uses the funds to make a loan to a business firm. In this case, you do not own a direct claim on the borrowing firm. Your bank deposit has different risk and liquidity characteristics from the loan to the business firm, which is now an asset of the bank. Your deposit is safe and liquid, whereas the loan held as an asset by the bank has some default risk and may be illiquid. Thus, when funds flow from surplus units to deficit units through a bank, the risk and liquidity of the financial instruments created along the way can be substantially altered. Of course, someone has to absorb the risk of the loans – either the bank's owners or the government entity that insures the bank's deposits.

The arrow pointing from the circle labeled intermediaries up to the circle labeled markets indicates that intermediaries often channel funds into financial markets.

The arrow pointing the circle labeled markets down to the circle labeled intermediaries indicates that in addition to channeling funds into the financial markets, some intermediaries obtain funds from the financial markets. A finance company that makes loans to households might, for instance, raise those funds by issuing stocks and bonds in the markets for those securities.

Financial intermediaries are firms whose primary business is to provide customers with financial products that cannot be obtained more efficiently by transacting directly in security markets. Among the main types of intermediaries are banks, investment companies and insurance companies. Their products include checking accounts, loans, mortgages, mutual funds and a wide range of insurance contracts.

The simplest example of a financial intermediary could be the mutual funds which pool financial resources of many small savers and invests their money in securities. This type of intermediary has substantial economies of scale in record keeping and in executing purchases and sales of securities, and therefore offers its customers a more efficient way of investing in securities than the direct purchase and sale of securities in the markets.

Banks

Most banks perform two functions: take deposits and make loans. Therefore, in USA these economic entities are called commercial banks. Nevertheless, in some countries, banks are virtually all-purpose financial intermediaries, offering customers not just transaction services and loans, but also mutual funds and insurance of every kind. In Germany, for example, universal banks fulfill virtually all of functions performed by the more specialized intermediaries.

Indeed, it is becoming increasingly difficult to differentiate among the various financial firms doing business around the world on the basis of what type of intermediary or financial service of provider they are. Thus, although Deutsche Bank is classified as a universal bank, it performs pretty much the same set of functions around the world as does Merill Lynch, which is usually classified as a broker/dealer.

Other depository savings institutions

Depository savings institutions, thrift institutions or simply thrifts is the term used to refer collectively to savings banks, savings and loan associations (S&Ls), and credit unions. In the US, they compete with commercial banks in both their deposit and lending activities. US thrifts specialize in making home mortage and consumer loans. In other countries there is a variety of special-purpose savings institutions that are similar to the thrifts and credit unions in the US.

Insurance companies

Insurance companies are intermediaries whose primary function is to allow households and business to shed specific risks by buying contracts called insurance policies that pay cash compensation if certain specified events occur. Policies that cover accidents, theft, or fire are called property and casualty insurance. Policies that cover sickness or the inability to work are called life insurance.

Insurance policies are assets of the households and business who buy them, and they are liabilities of the insurance companies who sell them. Payments made to insurance companies for the insurance they provide are called premiums. Because customers pay have the use of the funds for periods of time ranging from less than a year to several decades

Artificial Intelligence (AI) can be regarded as that part of informatics that aims to design those systems that are endowed with certain properties that we normally associate with human intelligence: language understanding, learning, reasoning, problem solving, theorems' demonstration.

Different definitions of artificial intelligence focus differently, either on cognitive processes or behavior. Thus, Artificial Intelligence can be regarded as the study of systems which:

- think like people do;
- think rationally;
- act like people do;
- act rationally.

In this paper is proposed the use of methods (paradigms) specific to artificial intelligence in financial management, aiming at finding some pairs {artificial intelligence method, financial management problem} in which the results have to be optimal and better than traditional methods.

Generally, application features remain valid in this case too, beneficial exploitation of ANN is taking place within the economic processes in which mathematical model is difficult to achieve, too complex or the existing mathematical model has not the necessary accuracy (*suitability* low).

It is underlined once again the criteria of using ANN, in order to associate it with those issues of financial management where their application is efficient:

- mathematical process model is unknown, has too much complexity associated with insufficient accuracy (precision) and in some cases can not be determined;
- available data are incomplete in some cases, there are noise signals too, disturbance signals (noise term can be extrapolated from technical field and in other types of economic, genetic processes, etc);
- there is a number of constraints (restrictions) applied to the process and must be simultaneously optimized.

The analysis and recommendations of the existing literature have outlined the following economic areas suitable for the use of ANN:

- verifying the authenticity of documents (including here for example verification of signature specimens);
- credit opportunities fund;
- predict of exchange rates and indices;
- assessment and diagnosis of certain elements of the firms' structure;
- predict university costs;
- credit card fraud detection system;
- market response for marketing problems, based on historical databases;
- predict firms' productivity;
- determining the optimum investment portfolio within financial institutions;
- class group operations (clustering), these types of operations fit within the unsupervised learning;
- customer segmentation;
- optimization issues (scheduling optimization, minimizing losses, etc).

It is expected that ANN can be used successfully in the following areas:

- Analysis and prediction of university costs;
- Stock and bonds investment risk assessment;
- Credit card fraud detection;
- Determining the market response based on a knowledge ground accumulated over time;
- Assessing productivity;
- Investment management.

It should be highlighted an increase in the impact ANN had in economic processes, impact that can be also underlined by the presence in most specialty journals like: Management Science, IEEE Transactions on Systems, Man of Cybernetics, Decisions Science, Computers & Operations Research.

II. Bankruptcy prediction using ANN. Comparison between traditional and specific methods to artificial intelligence

Within this subparagraph is proposed a comparison between methods called by the author as traditional (classical, conventional in the sense of their using and knowledge for several decades) and specific methods to artificial neural networks use. There are presented the theoretical grounds of the two methods, and gradually the results obtained after processing the same set of initial data, obviously it have been chosen the same initial data in order to make possible the comparison between the two methods, especially in terms of predicting accuracy.

Matlab program structure for implementation, training and use of a neural network used for bankruptcy prediction

Program source text is presented below; also there will be developed instruction significances and their correlation with economic context of the problem. Both the design of the program and the way of using it belong exclusively to the author.

```
It is presented
%Xtest=0:0.001:5;
%Ytest=0:0.001:5;
pr=minmax(P)

% it is implemented a ANN-MLP with:
% 4 inputs, 20 hidden neurons, 1 output neuron
%net1= newff(pr,[1 20 1],{ 'tansig' 'purelin' 'purelin'},'traincgf');
net1= newff(pr,[10 1],{'tansig' 'purelin'},'trainlm');
%net1= newff(pr,[15 1],{'tansig' 'purelin'},'traingdx');
%net1= newff(pr,[20 1],{'tansig' 'purelin'},'traincgp');

net1.trainParam.lr=2;
net1.trainParam.mc=0.5;
net1.trainParam.min_grad=1e-10;
net1.trainParam.show = 1;
net1.trainParam.epochs = 200;
net1.trainParam.goal = 0.001;

% network training
[net1,tr1]= train(net1,P,T);
% network using in case of data training and test
%y1test = sim(net1,Ptest);
y1antr = sim(net1,P);
```

So, it is defined gradually those four-unidimensional vectors X1, X2, X3, X4, each made of 55 components, corresponding to 55 companies used in network training; the four vectors are corresponding to the four input used variables and namely: the four vectors were included in a matrix type structure (pattern) P = [X1 X2 X3 X4];
X1 – net profit/income report
X2 – Cash-Flow /debts report
X3 – debt /assets report
X4 – obligations /turnover *360' report

Further the vector is defined as T (target), used obviously, only in the training phase, the vector which stores the actual situation for the 55 companies analyzed, the case of non-bankruptcy was coded with 0, and with 1 bankruptcy case.

Newff instruction is used to create an ANN with forward propagation (feedforward), its syntax is:

Net1 = newff [pr, [2 25 1], {'tansig' 'purelin' 'purelin'}, 'traincgf'); in which:

Pr = min max (P), represents the codification for minimun matrix value and maximum of input variables;

[2 25 1] – sizes (numbers of neurons) for hidden layers (in this case two with 2 and respectively 25 neurons) and obviously a neuron for output layer, corresponding to bankruptcy prediction or not.

Tansig and Purelin are the functions used for transfer. Trainlm and training are functions used for training, within the training function can be set the parameters specific to the training session as follows:

Goal - the precision with which the proposed result is reached 0.01 representing, for example, an error of 1%;
Time - the maximum time of training in seconds;
Min_grad - Minimum performance gradient;
Show - the number of periods between two successive views of training session development;

By using **train** and **sim** functions is carried out the proper network training, in the sense of learning it with its features (basically is determined the weighting coefficients **wij**).

In the second phase is proceed to the proper operation of the program, thus is defined and initialized the four input vectors, Xt1, XT2, Xt3, Xt4 each of them containing data of the second set of companies considered for the use, and respectively for control system. Because within this stage are done both the check of ANN prediction correctitude, and the definition of Y vector fair values for the situation of each company.

Specified network data will be stored in prediction file known as network.txt opened in writing with the aid of open function. Finally the results of network use are presented tabulated using columns from the right end of the table having the following meaning:
Ynetwork – prediction given by the network presented encoded (1 - non-bankrupt, 0 - bankruptcy);
A - The function value presented in the paper where is indicated the way of assessment bankruptcy risk:
A <0 bankruptcy / failure;
0> A> 2.05 the uncertainty area;
A> 2.05 non-bankruptcy;
Real Y - coded representation of the actual situation of prejudice or not of bankruptcy. Fairness - by comparing columns Ynetwork and Yreal is displayed on the last column of the accuracy of prediction.

Finally it is presented the prediction accuracy percentage, which is actually the main parameter in assessing the results prediction.

It is estimated that the ANN use is very efficient in this case, efficiency increasing in the situation when there would be made a neuro-fuzzy hybrid system, which might tinge the expression of output form:

Company X has a degree of membership of 70% of companies in case of non-bankruptcy and 30% degree of membership in the area of uncertainty.

ANN structure and parameters optimization training in order to increase prediction accuracy of company bankruptcy. Quasi-empirical methods

The purpose of this subparagraph is that of improving prediction accuracy by optimizing ANN structures of the various parameters specific to ANN and to parameters of training.

It is estimated that it is one of the most difficult problems in the implementation and use of ANN, in many works being considered an art; increased difficulty of this problem is the large number of parameters that can be changed, some of them can not even be quantified, so the choice of the network structure (topology) and chosen training method is about the experience in the field of user, experience that have to be gained by applying the ANN to the most varied cases.

Further will be presented in the author's opinion the main parameters that could compete to optimize the prediction, being removed from the beginning ("in common sense”) those considered irrelevant. Obviously it requires a statistical study, using specific methods of removing the relevant parameters:

1. network topology (spread before perception, radial ...)
2. learning method;
3. non-linearity adopted function;
4. number of hidden layers;
5. number of neurons in each layer;
6. number of training epochs.

If each of the six factors considered aprioristic determinants would be considered only four different levels and would not make additional replicas for a given level of required parameters would be 46 = 4096 experiments, and therefore would be required the use of statistical methods for planning the experiment.

Within this paragraph will be presented a first organizing of the experiment, being elaborated a quasi-empirical planning, followed by a developing of the first set of preliminary conclusions. There are displayed in the tables, obtained experimental results, indicating that generally have been made three replicas (the successive experiments for each line were kept the same with input parameter values).

III. FINANCIAL MANAGEMENT THROUGH EXPERT SYSTEMS

Among methods and paradigms specific to Artificial Intelligence, expert systems are most “well-known”, being the first which were imposed in practice, overcome the theoretical research framework, in author’s appreciation, the avant-garde character, novelty, unconventional feature of expert systems is somehow obsolete, the membership to “artificial intelligence” field being in this moment questionable.

The reasons of this chapter in the present paper, taking into consideration the innovations and the author’s original contribution are significant, and are the followings:

- uniformity and minimum claim of completeness of the paper;
- design some hybrid systems, in which expert systems are a component;

In Fig.1 it is presented an expert system case used in deciding when to grant a customer credit.

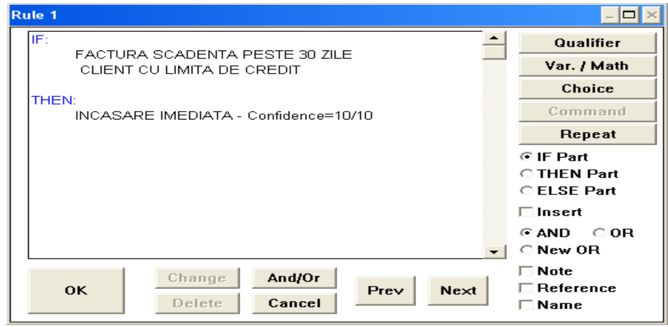

Fig.1 Input window rules.

In the category of premises one can have pieces of knowledge in the form of questions, variables, goals (if it wants to test the level reached by certainty factors). The same components are also found in conclusion category, stating that the goals are followed by a value award for certainty factor taking into consideration one of the variants specified in the control panel parameters. Control panel allows the printing as a file or directly to the printer of all parts of knowledge in a continuous or on different pages using one of three front sizes: 10, 12 or 14. Knowledge base of the prototype ANALYSIS was redirected to the file "CLIENT" from EXSYS working directory. This is presented below:

Subject:
OUTSTANDING INVOICE CUSTOMER TREATMENT

Author:
TITUS SLAVICI

Starting text:
EXSYS DEVELOPER EXPERT SYSTEMS OF MAKING DECISION OF CUSTOMER TAXES COLLETION

Ending text:
FOLLOWING EXSYS EXPERT SYSTEMS CONSULTATION IT HAS REACHED THE FOLLOWING CONCLUSIONS:

Uses all applicable rules in data derivations.
Probability System: 0 - 10

DISPLAY THRESHOLD: 2

QUALIFIERS:
1 OUTSTANDING INVOICE OVER 30 DAYS
CUSTOMER CREDIT LIMIT
BAD CUSTOMER

2 OUTSTANDING INVOICE OVER 60 DAYS
CUSTOMER CREDIT LIMIT
BAD CUSTOMER

GOALS:
1 IMMEDIATE CASH
2 SUPPLY SUSPENSION UNTIL THE COLLECTION OF OUSTANDING INVOICES

RULES:
RULE NUMBER: 1
IF:
OUTSTANDING INVOICE OVER 30 DAYS
CUSTOMER CREDIT LIMIT

THEN:
IMMEDIATE CASH - Confidence=10/10

RULE NUMBER: 2
IF:
OUTSTANDING INVOICE OVER 30 DAYS
BAD CUSTOMER

THEN:
SUPPLY SUSPENSION UNTIL THE COLLECTION OF OUSTANDING INVOICES - Confidence=9/10

RULE NUMBER: 3
IF:
OUTSTANDING INVOICE OVER 60 DAYS
CUSTOMER CREDIT LIMIT

THEN:
IMMEDIATE CASH - Confidence=8/10

RULE NUMBER: 4
IF:
OUTSTANDING INVOICE OVER 60 DAYS
BAD CUSTOMER

THEN:
SUPPLY SUSPENSION UNTIL THE COLLECTION OF OUSTANDING INVOICES - Confidence=7/10

IV. USING ARTIFICIAL NEURAL NETWORKS FOR EFFICIENT FINANCIAL DECISIONS

The question arises how efficient it is the use of neural networks in those types of applications that fully exploit the advantage of their specifics, obviously there are types of problems that almost perfectly folded using ANN, but other types that generate even incompatibles with them. Within this chapter were introduced basic concepts specific to use ANN, following to be repeated and developed within the present chapter together with examples and study cases related. Generally based on experience in the field can be said that ANN are used in those types of problems with the following features:

- mathematical model of the process is unknown, has too much complexity associated with insufficient accuracy (precision) and in some cases can not be determined;
- available data are incomplete in some cases, there are signals and noise disturbance (noise term can be extrapolated from technical field and in other types of economic, genetic processes, ...);
- there are a number of constraints (restrictions) applied to the process and have to be optimized simultaneously.

ANN Application for predicting stock market shares Nikko System

In the present paragraph is presented one of the most successful uses of ANN, the author's contribution is resumed to the data processing performed by ANN implementations in Matlab tool. The reason of application processing from bibliographic sources cited in the context of this paper is to illustrate a first example of data organizing with the aim of ANN use.

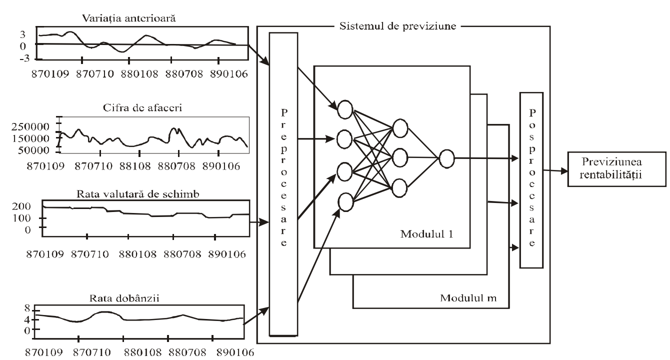

Fig.2. ANN structure.

V. THE POSSIBILITY OF APPLICATION OF FUZZY SYSTEMS FOR ECONOMIC GROWTH. GENERAL CONSIDERATIONS

Following the development of economics in recent decades can be noticed the introduction of a solid axiomatic support, the increased of accuracy and involving of mathematical apparatus, but it is still maintain a distance between theory and mathematical modeling which were imposed and economic practice, which often can be of *inertia*. Tradition and conservatory reject them, remains to be seen whether evolution in the two sides will be converging, parallel or divergent in the worst case.

There are several reasons that may explain why economic theories haven't had a fully successful implementation in economic reality:

- A first reason would be the fact that theories are formulated in mathematics classic terms, with two logical variables (Boole) and related classical theory, this thing is not realistic in the economy because human thinking and decision is made and is based on relative uncertainty, which is very specific human language, classical mathematics is not able to express this uncertainty, there is also a human preference for complex choices that can not be quantified by classical rules;

The second reason refers to the complexity of existing models wanting to capture the entire economic reality in an extraordinary expansion, requiring more sophisticated models, naturally occurs the requirement for simplification, but with the risk to low the accuracy of goals; so there is a compromise that have to be made between accuracy, uncertainty and relevance; however, often the decisions and economic predictions are operated with linguistic terms such as "oil prices is expected not to be a substantial increase in the next period" such predictions are also determined by a common sense, using economic knowledge and information relevance, which is often expressed in terms of linguistic nuance.

VI. USING FUZZY SYSTEMS FOR TH E EFFICIENCY INCREASE OF PORTFOLIO MANAGEMENT OF FINANCIAL SECURITIES

In the system example that is developed in this paragraph are considered two input variables:
X – tendency of financial securities;
Y – the volatility of financial securities;
and a output variable
Z – position adopted in business

For the two input variables can be considered two sub-field (classes) for example as a coded representation:

$X^1 = \{0.3, 0.7, 0.5\}$
$Y^2 = \{0.4, 0.0, 1.0\}$

In which the extreme values represent the ends of ranges (minimum and maximum values) but that in the middle the level of membership; the main mathematical used operators are presented in Fig. 1.

In fact the set of fuzzy rules is a knowledge base (according to those presented in the chapters related to database expert systems), and is of utmost importance for its ability to respond to all possible combinations of values. Creation of this knowledge base and its translating into sets of fuzzy rules is based on experience in the field, but unlike those systems based on artificial neural networks is not as complex, in case of ANN having an exclusive nature.

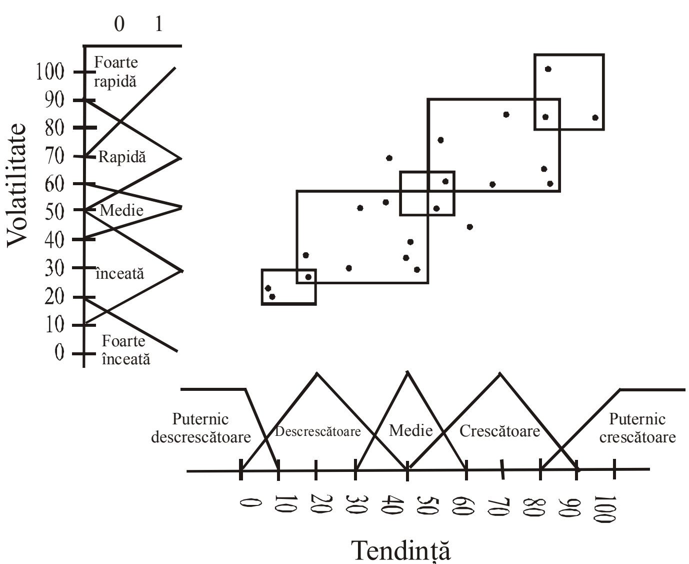

Fig.3. Graphical representation of input corresponding classes.

Currently there is specialized software which make the set of fuzzy rules using the existing database (historical data); for example: a set of fuzzy rules is presented in Table 1.

Defuzzication of results

From previous analysis it is clear that using fuzzy inputs and a set of fuzzy rules will be obtained fuzzy outputs too, for considered example there were presented in Fig. 3 recommendations for the output position (short, long, medium) according to possible combinations of input positions, these fuzzy outputs have to be moved back into discrete values, numerical (crisp) in order to be used, in this case there are several methods which have been partially analyzed in the general section of this chapter.

Gravity centre method, consider the position of gravity centre of the area corresponding to fuzzy output and determine a numeric result used for it.

	Strong Desceding tendency	**Descending Tendency**	**Stability**	**Increasing tendency**	**Strong Increasing tendency**
Very quick volatility	1	0.14	0.31	1	0
Quick volatility	0.47	0.14	0.31	0.47	0
Average Volatility	0.98	0.83	0.92	0.76	0
Slow Volatility	0.28	0.89	0.9	0.98	0.85
Very slow Volatility	0.28	0.93	0.86	0.99	1

Table. 1. A set of fuzzy rules

VII. INNOVATIVE TOOL FOR THE IMPLEMENTATION OF FUZZY SYSTEMS USED IN THE OPTIMIZATION OF FINANCIAL DECISION. MATLAB PROGRAM

In this paragraph is proposed the implemetation of the application defined in previous paragraph; in the first phase is presented the application text implemented in Matlab.

```
Name='Titus'
Type='mamdani'
Version=2.0
```

NumInputs=2
NumOutputs=1
NumRules=25
AndMethod='min'
OrMethod='max'
ImpMethod='min'
AggMethod='max'
DefuzzMethod='centroid'

[Input1]
Name='Tendency'
Range=[0 1]
NumMFs=5
MF1='strong-descending':'trimf',[-0.1 0 0.15]
MF2='Desceding':'trimf',[0.1 0.2 0.35]
MF3=strong-incresing':'trimf',[0.834730158730159 1.00573015873016 1.13073015873016]
MF4='Stability':'trimf',[0.3 0.5 0.7]
MF5='Incresing':'trimf',[0.61 0.803 0.921957671957672]

[Input2]
Name='Volatility'
Range=[0 1]
NumMFs=5
MF1='Very-quick':'trimf',[-0.1 0 0.15]
MF2='Average':'trimf',[0.3 0.5 0.7]
MF3='Very-slow':'trimf',[0.85 1 1.15]
MF4='Quick':'trimf',[0.1 0.2 0.35]
MF5='Slow':'trimf',[0.65 0.8 0.9]

[Output1]

Following the paragraph where are explained the graphs generated by Matlab (Fig. 4 to Fig.10).

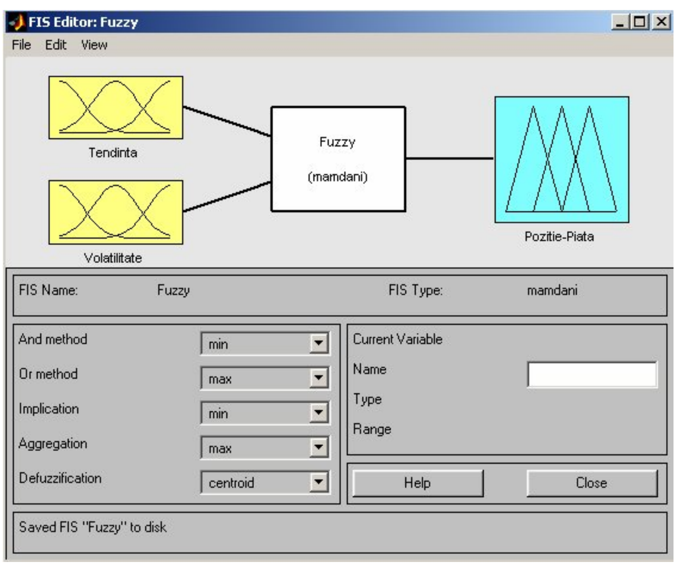

Fig. 4. Inputs and outputs' definition

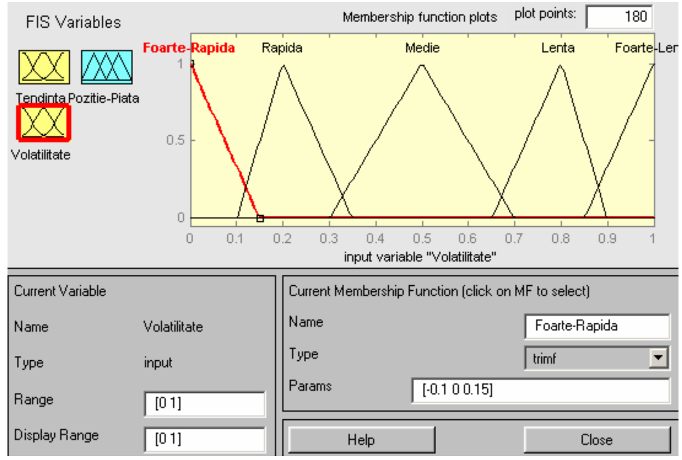

Fig. 5. Fuzzy volatility variable.

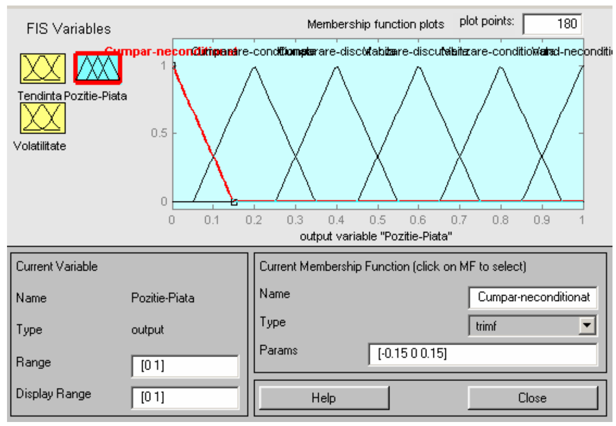

Fig. 6. Fuzzy Output

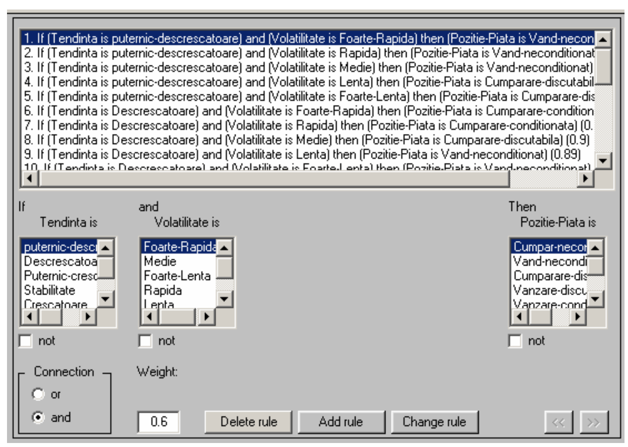

Fig. 7. Definition Rules

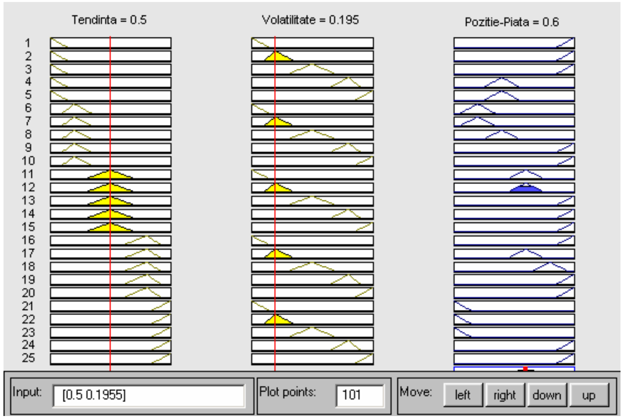

Fig. 8. Defuzzication of results

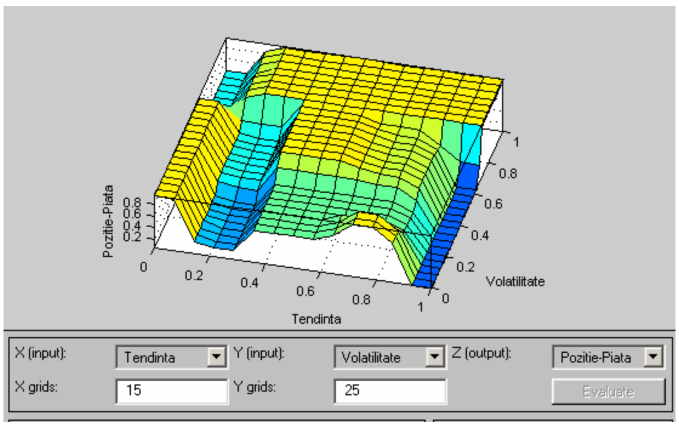

Fig. 9 Spatial graphic representation of input-output dependence

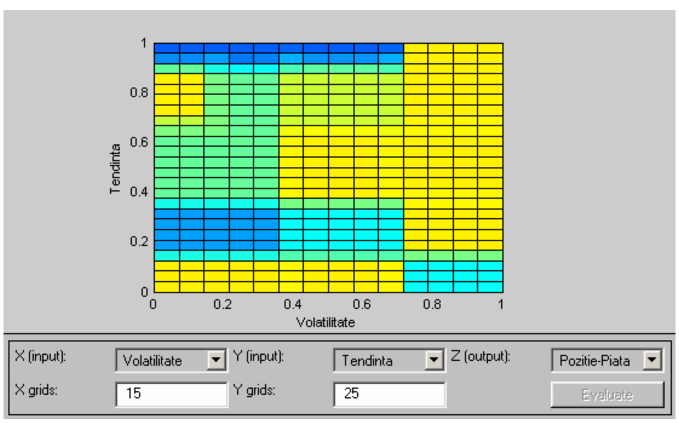

Fig. 10. Planar graphic representation of input-output dependence

VIII. APPLICATION OF GENETIC ALGORITHMS IN CLASSIFICATION OPERATIONS FOR SECURITIES MANAGING PORTFOLIO

The problem of systems classification with GA aid is one of the most exciting applications GA, the power of this technique is extraordinary.

It is considered the example of a managing equity portfolio system; decisions taken are related to stakes that are appropriate to be sold and to be bought, obviously those decisions will be taken according to several criteria specified in the first line of the next table. In assessing inputs are used three codes, namely 1 for the situation acceptable from the point of view of that criterion, 0 unacceptable situation and # signifies irrelevance according to considered criterion.

Criterion	Ex1	Ex2	Ex3
Tendency of share value	1	1	#
Issuer representativeness	#	#	1
Stock institution representativeness	#	#	#
Dividend growth tendency	#	#	#
Leverage factor	1	1	#
………			
Purchasing decision	1	1	0
Sale decision	0	0	1

Table. 2. Possible criterions

In case of outputs there are only two codes corresponding to validation option for purchasing, respectively for sale, for the first example is considered, reaching the conclusion that the purchase is appropriate.

IX. CONCLUSIONS

In certain situations, for example the use of artificial neural networks, has been found an exceptional applicability of those in economic field, fitting in the specifics of the economic data and processes: mathematical models of many economic processes have a high complexity associated with an insufficient accuracy and that available data are incomplete in many cases, there are disturbing signals, so for example: Percentage accuracy predictions of companies' bankruptcy were 93-97% higher than those obtained by traditional methods.

In other situations, for example in genetic algorithms case has been found a less efficient application of those in financial field; however their specific techniques could be used in case of some hybrid intelligent systems, helping to optimize other specific artificial intelligence methods.

In case fuzzy expert systems and expert one the results were relatively good, those being improved by their inclusion within hybrid systems.

Analyzing the example considered, but also from other analyzed situations can be broken off the following information:

- When the entries are continuous;
- There are no mathematical situations (modeling) between outputs and inputs, or in case of existence are complex and have a high degree of approximation;
- There is great disturbance of inputs;

Based on these features were produced valuable works in the fields of:

- Selection of investments in shares, being distinguished Wong contributions, he developed for this purpose a hybrid neural – fuzzy system;
- Investment portfolio optimization.

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