

P. Grabusts

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## “Analysing Bankruptcy Data with Neural Network Method”

Pēteris Grabusts  
Riga Technical University

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# Outline

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- **Overview of bankruptcy financial ratios**
- **Bankruptcy prediction methods**
  - **Multivariate discriminant analysis**
  - **Potential function method**
  - **Neural network approaches**
- **Experiment**

# Introduction

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- ❑ **Bankruptcy prediction has been an important decision-making process for financial analysts**
- ❑ **Many techniques have been proposed for helping financial analysts in this process**
- ❑ **The status of a firm analyzed is modeled by its financial ratios**

# Two basic approaches to bankruptcy prediction

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- First approach is based on financial data and comprises working with different ratios
- The second approach uses the data on bankrupt companies that were then compared to the data of the company under consideration

# First approach

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First approach is considered to be very effective but:

- ❑ companies that have financial problems normally publish their financial reports with a delay, hence, specific data might turn to be unavailable years
- ❑ even if the data are published, they might be “embellished” artificially, which also does not ensure objective information
- ❑ certain indicators of financial activity may give evidence for coming bankruptcy, whereas the others may serve as a reason for considering the company financially stable

# Second approach

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- The second approach is based on the comparison of financial ratios of yet bankrupt companies with those of “doubtful” ones
- The indicators of bankrupt companies' activity by years are also of great significance

# Bankruptcy financial ratios

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- Bankruptcy diagnostics is a directed financial analysis system whose area is crisis situation control at the enterprises
- In the analysis of the general financial situation of the company a separate group of financial ratios is made, using which it is possible to reason about the threat of bankruptcy

## Bankruptcy financial ratios (cont.)

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- In general case there is no theoretical background as to which financial ratios might be used in different bankruptcy studying models
- A lot of researchers performing an analysis of the bankrupt enterprise proceed in this way: they calculate several ratios and then select potentially most significant of them



# Example: Altman's Z-score

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- In Altman's model Z-score operates with five financial ratios
- Altman (1968) [1] supposes that these are the ratios that have the largest prediction possibility:

# Altman's Z-score

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1.  $X_1 = \text{Working capital} / \text{total assets}$   
(WC/TA)
2.  $X_2 = \text{Retained earnings} / \text{total assets}$   
(RE/TA)
3.  $X_3 = \text{Earnings before interest and taxes} / \text{total assets}$  (EBIT/TA)
4.  $X_4 = \text{Market value equity} / \text{book value of total liabilities}$  (MVE/TL)
5.  $X_5 = \text{Sales} / \text{total assets}$  (S/TA)

# Altman's Z-score (cont.)

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All the ratios ( $X_1$ ,  $X_2$ ,  $X_3$ ,  $X_4$  and  $X_5$ ) are consolidated in Z-number, after they have been multiplied by certain correlation coefficient whose value can give evidence for the importance of the specific ratio.

Z - number is expressed by formula:

$$Z = 1,2 * X_1 + 1,4 * X_2 + 3,3 * X_3 + 0,6 * X_4 + X_5$$

The calculation of the above ratios enables firm's executives to estimate their activities and financial ratios, and to respond to the problems appeared in proper time.

## Altman's Z-score (cont.)

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- If  $Z > 3$ , the possibility of bankruptcy is low and it is not necessary to perform further analysis of the financial situation
- If  $2.7 < Z \leq 3$ , bankruptcy may occur. The firm has faced certain problems concerning paying capacity that cannot be diminished
- If  $1.8 < Z \leq 2.7$ , the possibility of bankruptcy is high. The firm has serious financial problems. A thorough analysis of the financial situation is necessary
- If  $0 < Z \leq 1.8$ , the possibility of bankruptcy is very high. The firm's financial situation can only be improved by radical changes in the area of finance and investments

# Financial ratios in previous bankruptcy prediction studies [2]

Ratios	Study	Ratios	Study
R1 Cash/Current Liabilities	E, D	R17 Net Income/Total Assets	B, D
R2 Cash Flow/Current Liabilities	E	R18 Net Quick Assets/Inventory	Bl
R3 Cash Flow/Total Assets	E-M	R19 Net Sales/Total Assets	R-F, A
R4 Cash Flow/Total Debt	Bl, B, D	R20 Operating Income/Total Assets	A, T, A-H-N
R5 Cash/Net Sales	D	R21 EBIT/Total Interest Payments	A-H-N
R6 Cash/Total Assets	D	R22 Quick Assets/Current Liabilities	D, E-M
R7 Current Assets/Current Liabilities	M, B, D, A-H-N	R23 Quick Assets/Net sales	D
R8 Current Assets/Net Sales	D	R24 Quick Assets/Total Assets	D, T, E-M
R9 Current Assets/Total Assets	D, E-M	R25 Rate of Return to Common Stock	Bl
R10 Current Liabilities/Equity	E	R26 Retained Earnings/Total Assets	A, A-H-N
R11 Equity/Fixed Assets	F	R27 Return on Stock	F, T
R12 Equity/Net Sales	R-F, E	R28 Total Debt/Total Assets	B, D
R13 Inventory/Net sales	E	R29 Working Capital/Net sales	E, D
R14 Long Term Debt/Equity	E-M	R30 Working Capital/Equity	T
R15 MV of Equity/Book Value of Debt	A, A-H-N	R31 Working Capital/Total Assets	W-S, M, B, A, D
R16 Total Debt/Equity	M		

Note: R2, R3, R7, R9, R31 was used in experimental part !

# Bancruptcy prediction methods

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- Early empirical approaches
  - Multivariate discriminant analysis (MDA)
  - Logistic regression analysis (LA)
- Neural Network approaches
- Other approaches
  - Genetic algorithms (GA)
  - Rule-based learning
  - ID3
  - Pattern recognition methods

# I Empirical approaches

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Beaver[3] was one of the first who has applied balance sheet data in bankruptcy research. His analysis was comparatively simple and was based on studying one financial ratio and comparing it with other ratios. He has concluded that ratio **R4: Cash flow / Total debt** is a very essential indicator which has to be accounted in bankruptcy analysis. Beaver's works became a beginning of multicriteria analysis application, which was later developed by Altman et al.

# I Empirical approaches (cont.)

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- Altman [1] employed classical multivariate discriminant analysis (MDA) in his research. Altman's Z-scores are widely used as input data in neural network algorithms
- Ohlson [4] uses regression approach analysis. It's a linear model with a sigmoid function

$$f(x) = \frac{1}{1 + e^{-x}}$$

- In literature, numerous other researchers are also mentioned who work on the basis of MDA: Lev(1974), Deakin(1972), Taffler(1982), Platt and Platt(1980), Gilbert, Menon and Schwartz(1990), Koh and Killough(1990) et al.



## II Neural Network approaches

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- **Odom and Sharda** [7] were one of those who first employed NN techniques in bankruptcy analysis. In the input of the network, Altman's Z-scores about 128 companies were used. It was shown that neural network approach yields better results than MDA
- **Tam and Kiang** [8] have compared different techniques applied in bankruptcy diagnostics (MDA, LA, ID3, single layer network and multilayer network) and have shown that in the „one-year-ahead“ data the multilayer network was most effective whereas in the “two-year-ahead” data the LA method turned to be most effective

## II Neural Network approaches(cont.)

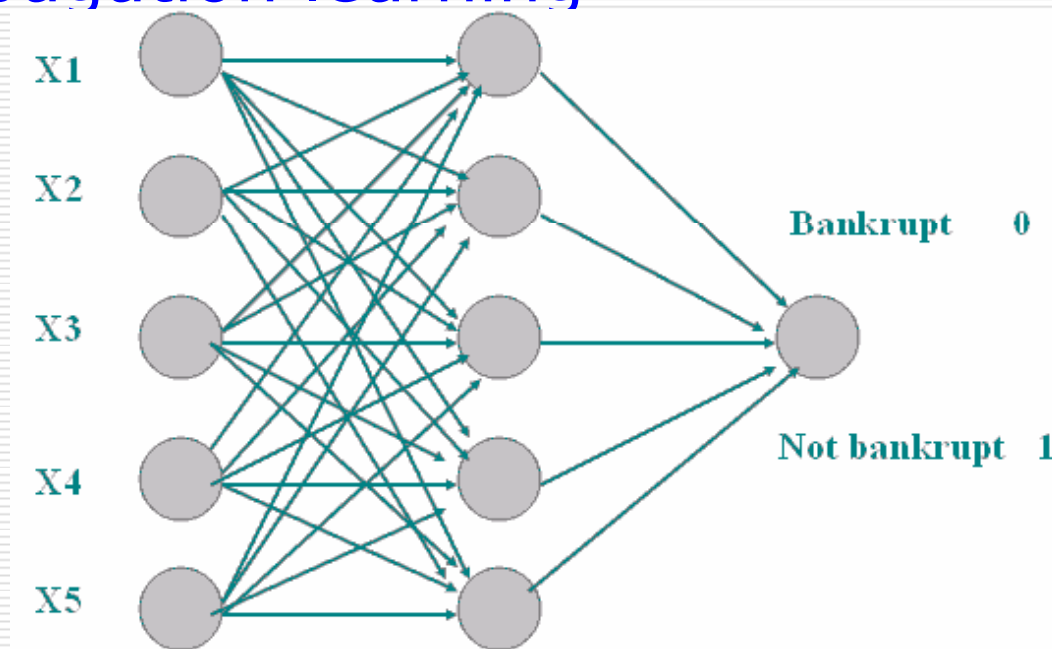
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Analysing the NN network application in bankruptcy analysis, these conclusions were made:

- NN ensure approximately 90% accuracy compared to the 80-85% accuracy of other methods (MDA, LA, and ID3)
- bankruptcy can be predicted several years before it happens, the accuracy of prediction being practically the same for the "one-year-ahead" data and for the "two-year-ahead"

## II Architecture of the Bankruptcy Prediction Neural Network

- Multilayer network MLP with error back propagation learning



- Kohonen map

## III Other approaches

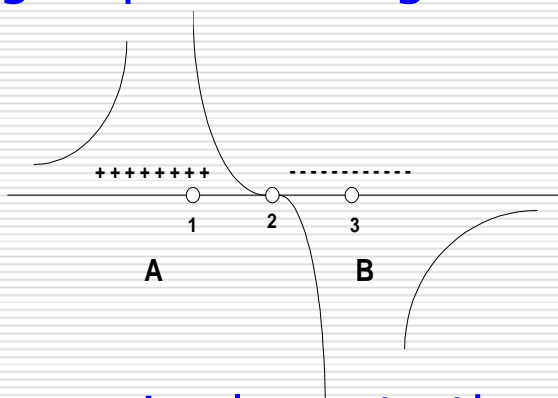
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- Genetic algorithms (GA)
- Rule-based learning
- ID3
- Pattern recognition methods
  - Potential function method [11]

# Potential function method

The algorithm of the potential function method is based on the hypothesis about the function character that separates sets according to different classes of patterns.

Assume that there are two compact groups of charges in the space. In the one group the charges are negative but in the other positive.



Each point of the space is closer to the set whose potential at that point is larger and exist separation function which divide points into class.

# Experimental part

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- Main motivation – compare ability of methods
- Dataset – taken from [12],[13]
- Environment – SPSS (for MDA) and Matlab

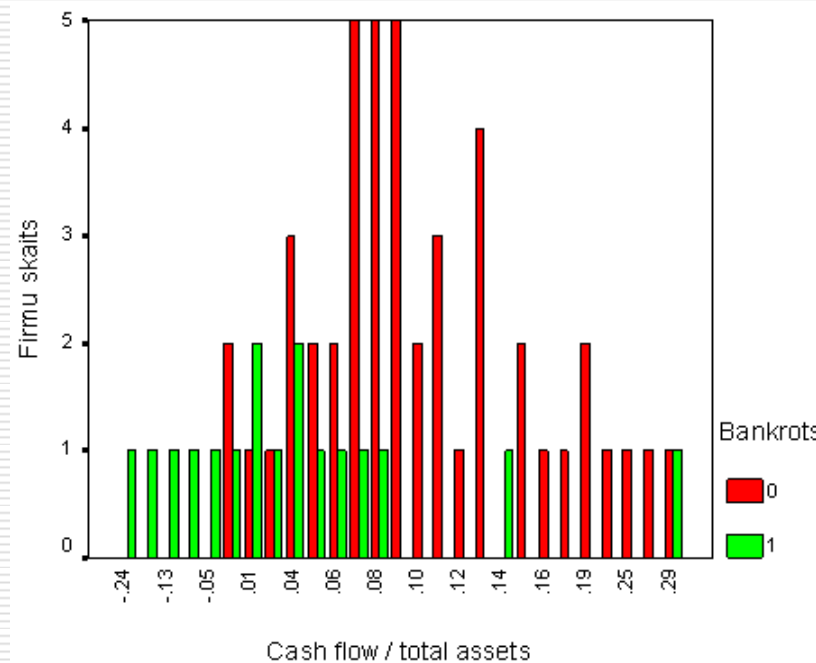
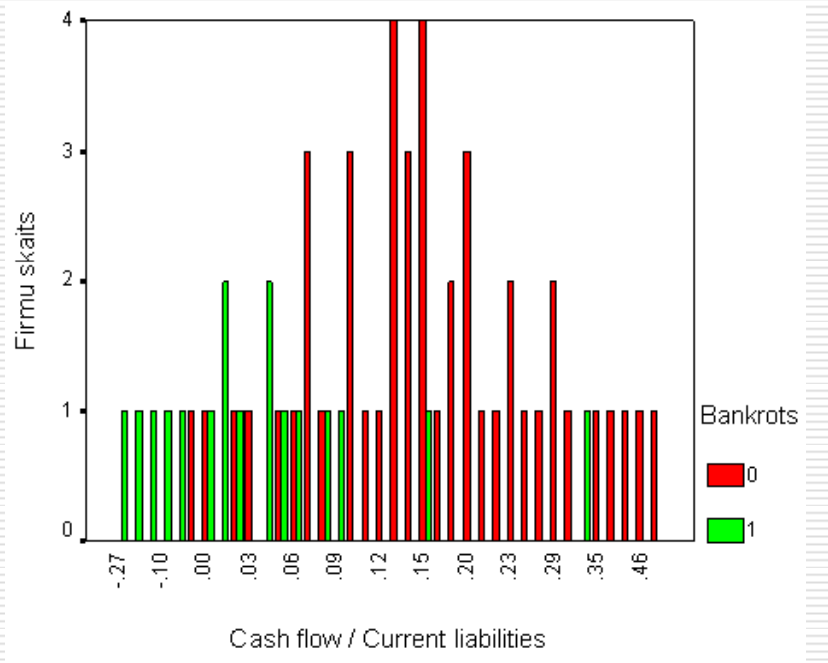
# Data

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Balance sheet data of 63 companies were used (46 - bankruptcy and 17 - not bankruptcy). It was decided to calculate the following financial ratios on the basis of the data available and further use them in all the experiments:

- R2: Cash Flow / Current Liabilities;
- R3: Cash Flow / Total Assets;
- R7: Current Assets / Current Liabilities;
- R9: Current Assets / Total Assets;
- R31: Working capital / Total assets.

# Distribution of the parameters- 1

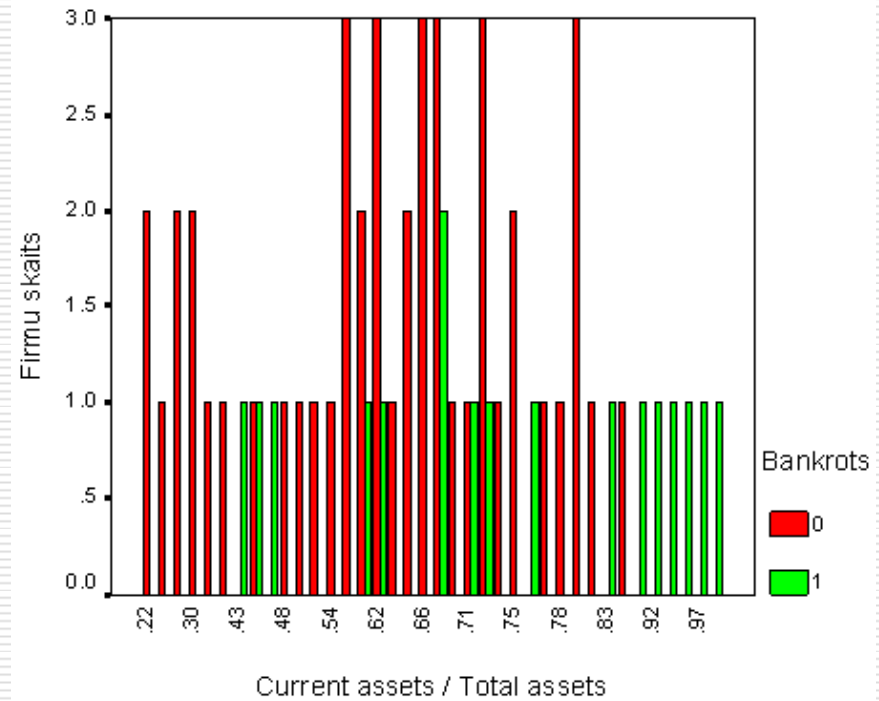
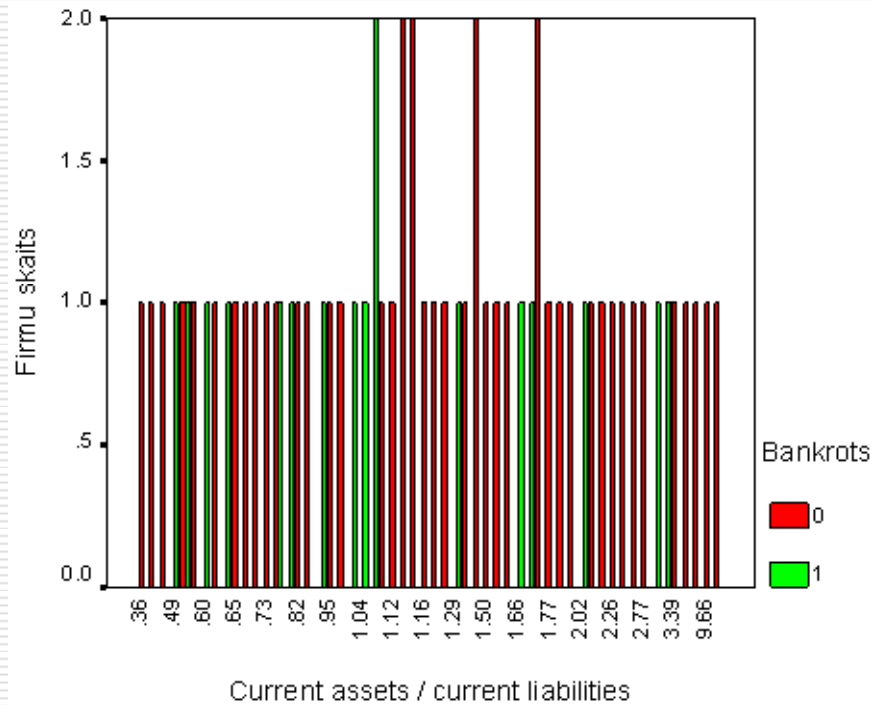


Ratio R2 **cash flow/current liabilities**

Ratio R3 **cash flow/total assets**



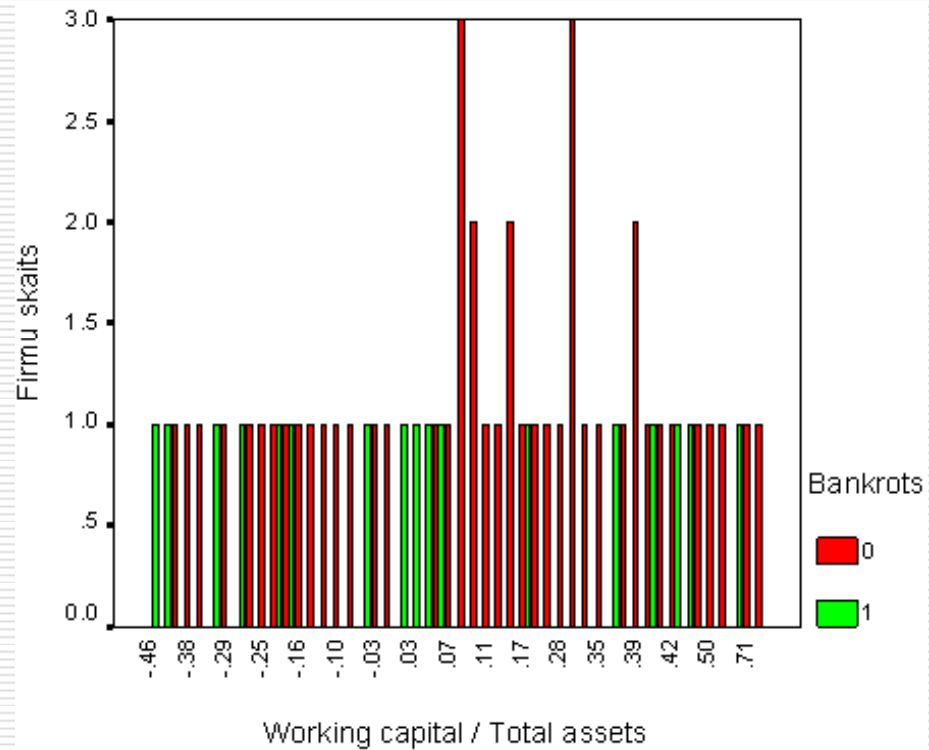
# Distribution of the parameters- 2



Ratio R7 **current assets/current liabilities**

Ratio R9 **current assets/total assets**

# Distribution of the parameters- 3



Ratio 31 **working capital/total assets**

# Experiment I - MDA

To accomplish the MDA, the SPSS statistical package was used. Discriminant analysis classification results:

		Bankrupt	Predicted Group Membership		Total
			0	1	
Original	Count	0	39	7	46
		1	4	13	17
	%	0	84.8	15.2	100.0
		1	23.5	76.5	100.0

• **82.5 % of original grouped cases correctly classified**

• **Misclassified cases are: 14, 26, 28, 35, 36, 37, 41, 58, 59, 60, 62.**

## Experiment II – potential functions

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As a potential function was used:

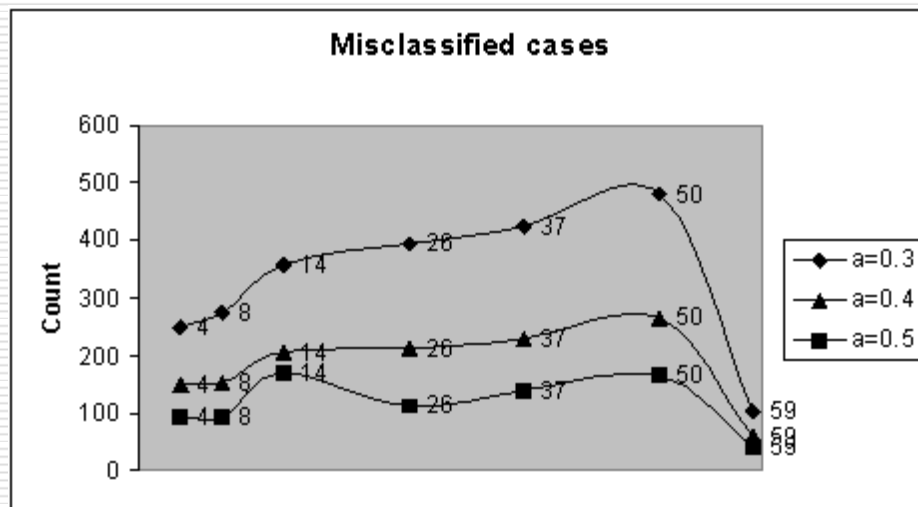
$$\varphi(R) = \frac{\lambda}{1 + \alpha R^2}$$

- $\alpha$  - learning parameter
- $R$  – the distance between the point where the potential is calculated and the point of learning set
- $\lambda$  - the value of potential that is assigned to the point in the process of learning (weight)

# Experiment II – results

Experimental results (misclassified cases and its  $\lambda$  parameter):

$\alpha=0.3$	Cases	$\lambda$		$\alpha=0.4$	Cases	$\lambda$		$\alpha=0.5$	Cases	$\lambda$
	4	249			4	148			4	92
	8	274			8	153			8	94
	14	357			14	206			14	168
	26	393			26	212			26	112
	37	424			37	228			37	140
	50	482			50	265			50	165
	59	104			59	60			59	39

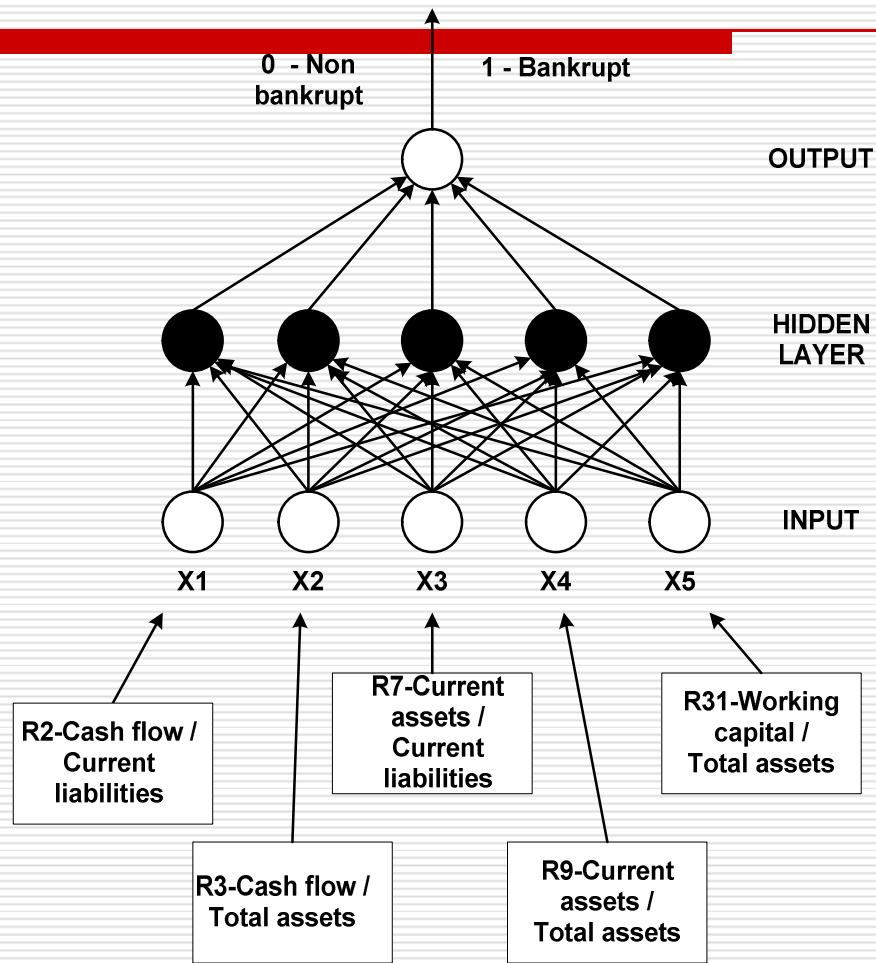


## Experiment III – Multilayer feedforward NN

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- ❑ Input nodes - 5 neurons
- ❑ Hidden layer - 5 neurons
- ❑ Output nodes - 1 neuron (1- bankrupt, 0 - not bankrupt)
- ❑ Learning rate - 0.25
- ❑ Stopping condition - the training is stopped if MSE=0.5
- ❑ Momentum rate -  $\alpha$
- ❑ Slope of the tanh activation function -  $\beta$

# Experiment III – Architecture



## Experiment III – Results

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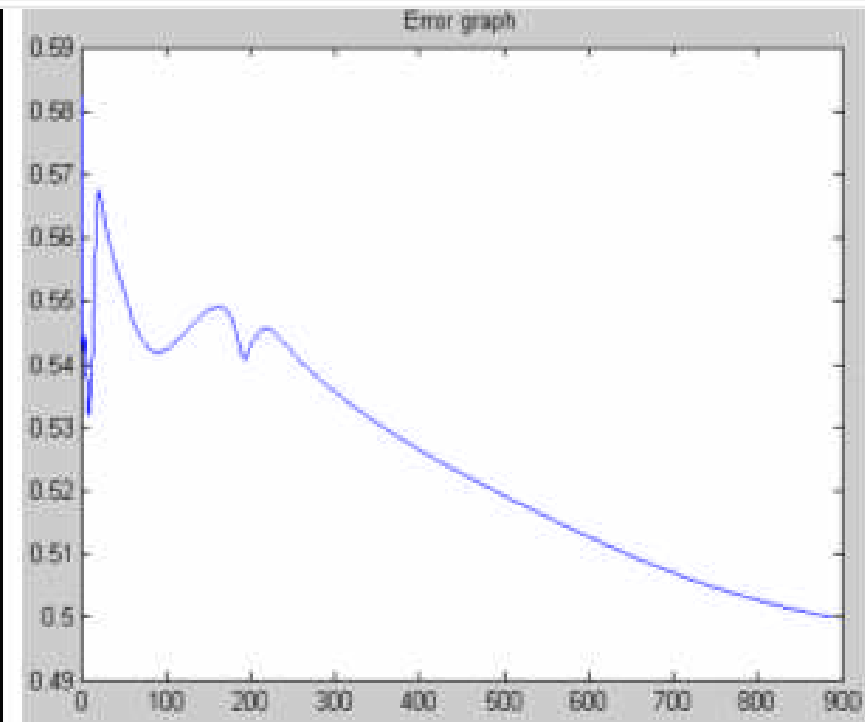
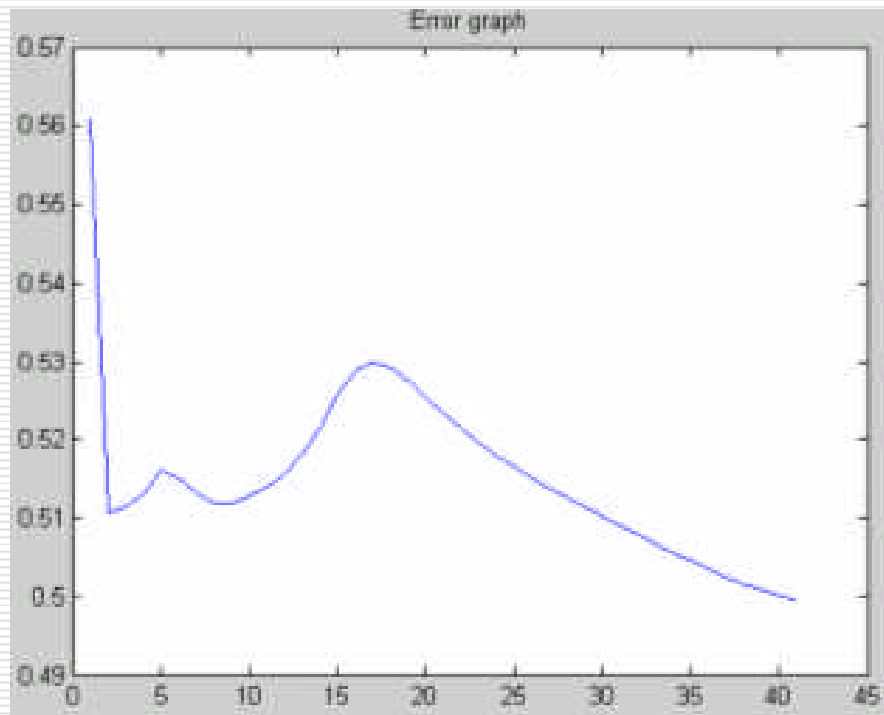
Experimental results (parameters  $\alpha$ ,  $\beta$  and its misclassified cases)

Parameter $\alpha$	Parameter $\beta$	Epochs	No. of misclassified cases	Cases
$\alpha = 0.8$	$\beta = 0.8$	41	9	14,26,36,37,41,58,59,60,62
	$\beta = 0.9$	889	6	37,50,58,59,60,62
$\alpha = 0.9$	$\beta = 0.8$	46	9	14,26,35,36,37,41,58,59,62
	$\beta = 0.9$	1489	7	37,50,58,59,60,62,63



## Experiment III – Error graphs

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Error graph (left:  $\beta = 0.8$

and

right:  $\beta = 0.9$ )

## Summary table about used methods and misclassified cases

Method		Misclassified cases														
MDA				14	26	28	35	36	37	41		58	59	60	62	
Potential		4	8	14	26				37		50		59			
NN-1	$\alpha = 0.8, \beta = 0.8$			14	26			36	37	41		58	59	60	62	
NN-2	$\alpha = 0.8, \beta = 0.9$								37		50	58	59	60	62	
NN-3	$\alpha = 0.9, \beta = 0.8$			14	26		35	36	37	41		58	59		62	
NN-4	$\alpha = 0.9, \beta = 0.9$								37		50	58	59	60	62	63

- For the specific bankruptcy data sample, all the methods are unable to classify data vectors 37 and 59.
- Calculating in absolute numbers, we obtain that NN-2 correctly classified 90.5% cases
- The potential function method and NN-4 - 89% cases
- NN-1 and NN-3 - 85.7%
- MDA - 82.5%.

It can be concluded that for the given data sample the NN method performs bankruptcy data classification more effectively, which actually corresponds to the conclusions about the results achieved by Tam and Kiang [8].

# Conclusions

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- We have presented potential functions and neural network implementation possibility in bankruptcy prediction
- The experiments have shown that these methods can be viewed as alternatives to traditional bankruptcy prediction methods
- The most impact factor on bankruptcy prediction is selection of financial indicator

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Thanks !