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APPLICATION OF NEURAL NETWORKS FOR SOCIAL CAPITAL ANALYSIS

ZASTOSOWANIE SIECI NEURONOWYCH DO ANALIZY KAPITAŁU SPOŁECZNEGO

A b s t r a c t

The paper investigates the possibility of using soft computing for estimating the value of social capital. Our approach is applied to the case of Red Hat Inc. – the world's leading provider of open source solutions. The objective of the research was to develop an artificial neural network for forecasting the value of social capital. These studies also allow us to identify variables significantly affecting the value of social capital. Computer simulations and assessments were done using software package STATISTICA Automated Neural Networks. The paper concludes with discussion and proposals for further research.

Keywords: *artificial neural network, soft computing, multilayer perceptron, social capital, independent variables, fundamental equation, global sensitivity analysis*

S t r e s z c z e n i e

Głównym celem artykułu jest analiza możliwości zastosowania obliczeń inteligentnych do modelowania kapitału społecznego firmy Red Hat Inc. – światowego lidera rozwiązań *open source* dla biznesu. Zasadniczym celem badań jest zaproponowanie struktury sztucznej sieci neuronowej do analizy wartości kapitału społecznego. Zidentyfikowano zmienne istotnie wpływające na wartość tego kapitału. Wszystkie symulacje komputerowe oraz oszacowania przeprowadzono w pakiecie statystycznym STATISTICA Automatyczne Sieci Neuronowe. W artykule przedyskutowano wyniki testów otrzymanych z zastosowaniem zaprojektowanego modelu oraz zaproponowano tematykę dalszych badań.

Słowa kluczowe: *sztuczna sieć neuronowa, obliczenia inteligentne, perceptron wielowarstwowy, kapitał społeczny, zmienne niezależne, równanie fundamentalne, globalna analiza wrażliwości*

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1. Introduction

Since intangible assets, particularly social capital, are commonly understood to be the most precious assets of any IT company, the appraisal of their value should be essential for chief executive officers and managers. Estimating the value of social capital using tools developed so far, especially those based on financial balance sheets, turns out to be a laborious and time-consuming task. Therefore, we suggest the application of soft computing for the analysis and modeling of the value of the intangible assets of IT companies.

There exists a vast amount of studies in the area of social capital analysis, however, the widely accepted method for extrapolating and predicting the value of social capital has not been proposed so far. The attempts to develop an effective method to estimate the company's intangible assets have been undertaken by a number of scientists, as well as by the companies themselves. The most significant achievements in this area are by Swedes and Americans, whose methods have gained popularity in Poland: Intangible Assets Monitor IAM (Karl E. Sveiby); Balanced Scorecard BSC (Robert S. Kaplan and David P. Norton), Skandia Framework – SF (Edvinsson L., Malone). These are non-financial models, allowing for the identification and evaluation of the most important intangible factors defining the difference between the market value and the book value of a given company.

The literature review revealed that any soft computing tool for modeling the social capital of an IT company has not been developed thus far. This identified research gap was the most essential premise for considerations in this sphere. This paper demonstrates the proposition of an artificial neural network model as an innovative method for such assessments and forecasts.

For many years, artificial intelligence tools, including mainly neural networks, have been increasingly implemented not only in areas of engineering (pattern recognition, signal processing, control, optimization), but also in economics and management. Neural network models are often applied for anticipating economic phenomena, such as predicting trends in the stock market, sales forecasting etc. Artificial neural networks are efficient methods of data analysis and therefore, they are often used as an alternative to traditional analytical methods, providing satisfactory results [11].

The paper is organized as follows. First, a short profile of Red Hat Inc. is presented. Then basic terminology used throughout this paper and some theoretical considerations are introduced. The next section concerns background information about artificial neural networks and their training process. Section 4 contains the description of the training set, consisting of data for 8 years of the history of Red Hat. Then we discuss the structure and parameters of the obtained three-layer perceptron model. Finally, we provide first insights into the developed methodology for anticipating the value of the social capital of Red Hat Inc.

2. Red Hat Inc. in a brief

Red Hat Inc. is a global software company, established in 1998, providing open-source software products. The company offers award-winning support, training, and consulting services as well as operating system, storage servers, virtualization, middleware and cloud technologies. It's corporate headquarter is in Raleigh (North Carolina, USA) with satellite

offices worldwide [7]. Red Hat is the world leader in providing open source solutions to businesses and the creator of the popular Linux distributions – Red Hat Linux, which is disseminated under the GNU General Public License free of charge.

The company benefits mostly from support and services achieving significant successes in the operating system market. Red Hat became the first one-billion dollar open source company in the fiscal year 2012, reaching $1.13 billion in annual revenue [1]. Its total revenue has been constantly growing for more than ten years. Red Hat became a part of the NASDAQ in 2005 – over-the counter, regulated stock market in the United States. The company listed its shares on the New York Stock Exchange (NYSE) under the ticker symbol RHT in 2006. Red Hat boasts a number of powerful customers including Amazon, DreamWorks, and Morgan Stanley [4].

For many years, the company has maintained a commanding lead in the area of Linux kernel development [2]. The Linux kernel is one of the most successful open source projects. The huge rate of change and the number of individual contributors prove that it has an active community, constantly causing the evolution of the kernel. The number of different developers who are doing the Linux kernel development have been increasing over different kernel versions in the last few years. There are about 1300 developers contributing to the newest kernel release [2]. The idea behind the development of open and free applications is common, parallel and creative work of a team of experts. The passion, commitment and enthusiasm of those developers determine the success of such applications. It is worth noting that the employees of Red Hat are responsible for about 11% of the total improvements to each Linux kernel release.

3. Basic definitions

3.1. Social capital

For the purpose of the paper, we define **social capital** as capital composed of formal and/or informal relationships among workers of IT company. These relationships are both positive (trust, cooperation, solidarity etc.) as well as negative (distrust, hypocrisy, inter--personal conflicts etc.) [13].

In the case of Red Hat, these are the relationships between software engineers, programmers, and testers, analysts etc. Red Hat employs those software developers for their talent, skills, experience, knowledge of programming languages and so on. All these features together form the social capital of the entire company and the whole community. These assets are, in the author's opinion, the most precious resources of Red Hat as well as of any IT company. Software is developed as a result of the joint, creative work of many developers. Unquestionably, company prosperity depends mostly on its employees, their codified and tacit knowledge, and their positive relationships mutual collaboration, trust, empathy etc.

Social capital is treated like any other capital and consequently, the question arises of how to estimate the social capital value. These new factors significantly affecting the market value resulted in the necessity to develop methods of analysis and tool for measuring this value. There are many approaches for the mentioned assessments, nevertheless, the widely acceptable method for such estimations have not been yet proposed.

Therefore, we suggest using soft computing for measuring the value of intangible assets.

3.2. Background information about neural networks

Analysis of the applicability of soft computing for modeling the value of social capital should start with some theoretical explications. The artificial neural model is considered as a system processing input signals into a single output [3].

Artificial neurons have *n* inputs and one output. Input information is always numeric and forms the vector of input values. Each input neuron is associated with a numerical factor called weight. Input values of weights are typically different and they are mostly determined automatically in the learning process. The operation of the neural consists of two phases, the first one can be defined as an aggregation of the input value, calculated by multiplying the weights and the corresponding input values. The second step lies in the fact that the aggregated sum of values becomes an argument in the activation function. At the beginning of the training process, the input variable gets initially randomly assigned weight – the strength of its effect on the output variable value. The proper values of the weighting factors are determined in the learning process [3].

The output neuron is given by the relation [3]:

$$y = f(\mathbf{w}^T \mathbf{x}) = f\left(\sum_{i=1}^{n} w_i x_i \right) \tag{1}$$

where **w** is the weight vector defined as [11]:

$$\mathbf{w} \stackrel{def}{=} \left[w_1, w_2 \ldots w_n \right]^T \tag{2}$$

x is the input vector:

$$\mathbf{x} \stackrel{def}{=} \left[x_1, x_2 \ldots x_n \right]^T \tag{3}$$

The activation function is denoted as $f(w^T x)$. Among the number of activation functions, the most commonly applied are: linear activation function; sigmoid activation function; Gaussian activation function; hyperbolic tangent activation function [10].

4. Data in the example

The main idea of our method is based on the assumption that there are seven input variables significantly affecting the output dependent variable – the value of social capital. Modeling the value of social capital is a problem of regression, that is why only one neuron, characterized by the dependent variable is presented in the output.

The analysis covered the following input, independent variables: market value; book value; stock price; number of shares; employment; total assets; liabilities.

The output (dependent) variable **Y** represents the value of social capital, calculated by the Fundamental Equation. The formula says that in a market economy, under the equilibrium conditions, when demand equals supply, the value of Red Hat equals the aggregate sum of four component values of its capital: financial; physical; human and social at any moment *t* of the firm's past, present and future [14].

The model was built and all the simulations were carried out in the software package STATISTICA Automated Neural Networks.

The market value of Red Hat Inc. (X_1), at a given moment t, is calculated by multiplying the number of issued stocks by their current stock price at the end of each quarter from the first quarter of 2006 to the third quarter of 2013. The book value of Red Hat Inc. (X_2) for a given moment *t*, is calculated as the difference between the sum of total assets and the total liabilities in the mentioned periods. All necessary independent and dependent variables are calculated on the basis of balance sheets published by Red Hat Inc. at the end of each quarter in the examined quarters [5]. The training set consisted of data concerning 31 quarters (from the first quarter of 2006 to the third quarter of 2013).

For instance, the values of input and output variables for the third quarter of 2013 are shown in Table 1. All variables are demonstrated in USD. For simplicity the values of social capital, assets, liabilities, the number of shares, the market value and the book value are converted to millions of USD. The volume of employment X_5 is presented in units. The stock price is presented in USD.

Table 1

Values of input and output variables in third quarter of 2013 (in millions $)

Market value	Book value	Stock price	Number of shares	Employment (in units)	Total asssets	Liabilities	**Social capital**
X_1	X_2	X_3	X_4	X_5	X_6	X_7	**Y**
8743	1686	46.14	189.5	5500	2662	0.976	4546

Out of the total samples, 80% samples were chosen for training set, 10% samples constituted the cross-validation and 10% samples were used for the testing set. The training set was used to train the neural network. Measures were determined based on the training set and allowed to assess the capacity for approximation. They point the precision in determining the output variable value for input vectors presented during learning. Much more important is the correctness for such input vectors that were not presented in the training process. The ability to proper operation of the network for data from outside the training set is called the ability to generalize. The measures determined on the basis of the test set enabled the evaluation of the network properties. The set of validation is used to calculate quality measures used to monitor the course of the learning process.

It was assumed that the relationships between variables are non-linear, therefore, the applicability of classical linear models to the analysis was groundless. The traditional linear regression, used for estimating the expected value of the dependent variable, can only be used to analyze linearly related data. It was hypothesized that artificial neural networks solve the problem of non-linearity of the data, significantly affecting the value of the social capital.

5. Neural network model

Undoubtedly, the operation of the artificial neural network depends primarily on the training process. Network learning is an iterative action, repeated many times, step by step, with the fundamental objective to optimize the network parameters – the weighting factors. Initially, each of the input variables gets randomly assigned weight, the strength of its effect on the value of the output variable. The values of the weighting factors are determined in the learning process – the higher the weight, the more important the variable [8].

The model should reflect the existing reality, the link between a set of input variables (independent), and a set of dependent variables (output). Most methods assume the existence of a single dependent variable.

Multilayer perceptrons (MLP) are layered feedforward networks, typically trained with the backpropagation algorithm, as well as one of the most widely implemented neural network topologies. The backpropagation algorithm allows for the learning of input and output mappings from training samples. The network learns the relationship between the set of example patterns, and could be able to apply the same relationship to new input patterns [10].

In the present case, a supervised, learning-with-a-trainer approach was adopted (Fig. 1). It should be noted, therefore, in addition to the input signals, the desired (expected) answers – the output signal should be determined. To make a diagram easier to read not all weights are presented [12]. The network was trained on the basis of the knowledge of the values of social capital, calculated by the Fundamental Equation.
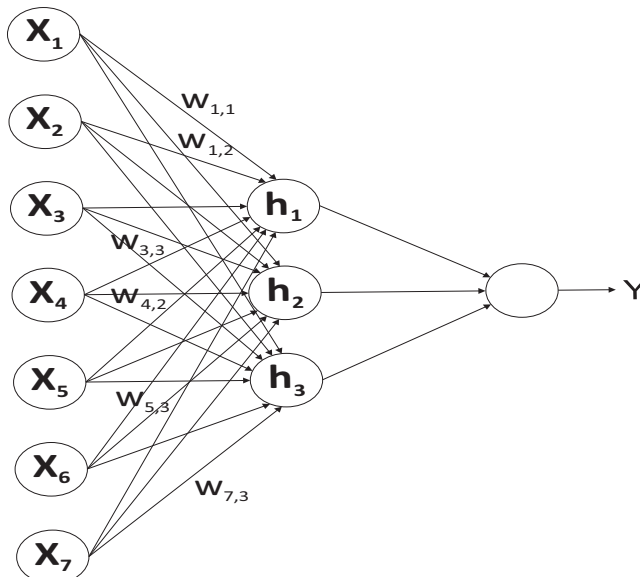

Fig. 1. Supervised learning of three-layered perceptron

The model was trained with the backpropagation algorithm, proposed by Rumerhart in 1986. Backpropagation is one of the most frequently implemented and the most effective learning algorithms of multilayer neural networks. This algorithm is based on the collected

data and modifies the weights and the threshold value so that the network minimizes the error (for example, the prediction error) for all data included in the training set. Errors that occur at the output of the network are propagated in the opposite direction than the signals passing through the network, from the output layer to the input [8].

Before the final construction of the network was chosen, many structures and parameters were checked. The neural networks differed in terms of parameters such as the number of hidden neurons, the activation function, the learning algorithm etc. The software package Automated Neural Networks allows us to implement only one hidden layer. However, the considering problem was not so complicated to use two hidden layers. Three neurons were used in the hidden layer (h_1, h_2, h_3). The choice of the number of neurons in the hidden layer is an essential issue – the excess can cause that the network learns relations on memory; their scarcity may remove the network's capacity for learning. Finally, the following ones were adopted as the activation functions, the hyperbolic tangent in the hidden layer and the linear function in the output layer. This choice did not allow for the loss of the prediction ability and it also improved the ability to extrapolate the results.

6. Results

Table 2 presents a summary of the parameters of the obtained three-layer perceptron:

Table 2

Parameters of obtained neural network model

Neural network	Activation function (hidden neurons)	Activation function (output neurons)	Error	Learning algorithm
MLP 7-3-1	Tanh $y = \mathrm{tg}h\left(\dfrac{\alpha\varphi}{2}\right) = \dfrac{1 - \exp(-\alpha\varphi)}{1 + \exp(-\alpha\varphi)}$	Linear $y(x) = ax + b$	Sum of squares (SOS)	BFGS (Broyden – Fletcher – Goldfarb – Shanno)

All elements belonging to the training set were presented for 131 times (131 epochs) to reach the minimum of network error. The learning error decreased rapidly at first and then tended gently to zero.

Some available regression statistics enabled us to assess the accuracy of estimates. Table 3 presents the values of Data Mean and Data Standard Deviation for data in the training, test and validation sets.

Measures determined based on the training set allowed us to assess the capacity for approximation. They point the precision in determining the output variable value for input vectors presented during learning. Much more important is the accuracy of such input vectors that were not presented in the training process. The ability of the network to properly operate for data outside the training set is called the ability to generalize. The measures determined on the basis of the test set enabled the evaluation of the network properties. The set of validation is used to calculate quality measures used to monitor the course of the learning process.

Data statistics in the training, test and validation sets

	Data Mean			Data Standard Deviation		
	Training set	Test set	Validation set	Training set	Test set	Validation set
Market value X_1	6475001	7137511	6473114	2695142	2388960	2438974
Book value X_2	1331295	1302916	1426957	244994	352167	566777
Share price X_3	34.06	37.27	31.80	13.69	12.43	10.05
Share number X_4	190898.2	191413.3	191043.3	2904.7	1024.6	5059.2
Employment X_5	3428	3666.66	3666.66	1154.88	1850.22	2286.19
Assets X_6	1943948	1880415	2161915	398011	713250	1191906
Liabilities X_7	612653.2	577499.3	734958	259678.7	361097.9	625209.3
Social capital **Y**	3332266	3807065	3278134	1715346	1363508	1271606

Table 4 presents the results of the predicted value of social capital **(Y*)** of Red Hat for the fourth quarter of 2013. The data concerning the fourth quarter of 2013 were not in the training set, therefore, were not trained in the network learning process. The value of the predicted social capital was provided by trained model MLP 7-3-1. This estimation was possible owing to the ability to generalize the data.

The value of social capital in the fourth quarter of 2013 (in millions USD)

Market value	Book value	Stock price (in USD)	Number of shares	Employment (in units)	Total asssets	Liabilities	**Social capital (Fundam. Equation)**	**Social capital (MLP 7-3-1-)**
X_1	X_2	X_3	X_4	X_5	X_6	X_7	Y	Y*
10 622	1326	56.04	189.5	6100	2851	1025	5904	5729

The predicted value of social capital **(Y*)** in the fourth quarter of 2013 was anticipated using obtained three-layer perceptron MLP 7-3-1. The value of social capital **(Y)** was calculated using the Fundamental Equation. The difference between those values is only 3%, which authenticates the proposed method as a reliable tool for credible estimations of the value of intangible assets.

7. Conclusions

This contribution examined the possibility of using an artificial neural network for modeling the value of the social capital of IT companies. The results of the conducted survey confirmed the research hypothesis that artificial neural networks solve the problem of non-linearity of the data that significantly affect the value of social capital. On the basis of those investigations and obtained results, it can be concluded that neural networks are sophisticated modeling techniques, capable of mapping extremely complex functions. In particular, neural networks are non-linear models, which significantly extends the capabilities of their applications.

The investigated neural network model is based on data, not on an analyst's knowledge, therefore one does not need to examine the relationships between data in the training set before setting up the neural network model. Artificial neural networks can be implemented in virtually any situation where the objective is to determine an unknown relationship or a set of relationships between dependent and independent variables.

The possibility of using proposed method for predicting the value of social capital constitutes likewise a promising area of upcoming research. Such assessments are likely to be accurate using the function predictions for new data, as well as using the developed model as a regression time series. Further work in the research area of this contribution will involve employing a developed model to identify the relationships among dataset characterizing the world's biggest companies in the information technology industry: Microsoft; IBM; Oracle; Novell; SAP. Next, the goal for future research should be to estimate the social capital value of companies operating on the Polish software market. The subjects of the author's interests are Asseco Poland SA, Comarch, ABC Data etc.

Furthermore, the developed model of the artificial neural network, can also be adopted to predict the value of social capital for completely new data, which did not belong to the training set during the learning process. This could be possible owing to the ability to generalize data and on the basis of the previously learned dependency. Moreover, it can be assumed that the constructed model will be useful for analysis and modeling of the value of social capital of companies operating in other economic sectors.

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