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Trends in the stock market and their price forecasting using artificial neural networks[1]

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Abstract: The article is devoted to the research of market trends in order to forecast stock prices on the basis of neuron networks. To demonstrate such a possibility the authors propose three networks for each considered trend. The article demonstrates that neuron networks can be an effective way to predict the market prices of shares.

Keywords: artificial neuron networks, stock exchange, market trends, GRW.

1. Introduction

The current situation in the stock market is becoming one of the main topics of interest for many people. The motivations are different – from a speculative desire to raise capital or savings, to the desire to predict on its basis the behavior of the entire economy. The stock exchange provides direct and indirect jobs, in a short time creates fortunes, and at the same time thwarts decades-long efforts of past generations. It is a place for beginning and advanced players. However, both have the same goal – to maximize profits. To achieve this, besides expertise, a variety of tools can be used. One of them is artificial neural networks (ANN).

The main aim of this work is to verify the validity of the thesis that neural networks can be an effective way of forecasting stock prices of companies included in the WIG index, regardless of the prevailing market trends.

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2. The history and application of artificial neural networks

The beginnings of research on artificial neural networks date back to 1943 when McCulloch and W. Pitts (1943) developed a model of an artificial neuron. Fourteen years later, F. Rosenblatt and C. Wightman (1957) built an artificial neural network which they called perceptron. Its task was to identify alphanumeric characters. In 1960, B. Widrow and M. Hoff (1960) constructed first the first neuro-computer, and two years later a learning algorithm. In the early 1970s through the publication of Minsky's and Papert's (1972) "Perceptrons", which demonstrated the limitations of the capacity to solve problems with the use of single-layer networks, the development of research on the ANN ceased for about ten years. In the 1980s there was renewed interest in artificial neural networks. There appeared networks learning without a teacher (Kohonen, 1982), as well as the first networks with feedback (Hopfield) for reconstructing pictures from their parts, and for solving optimization tasks. The race and interest in the issues of artificial neural networks continues to this day (Tadusiewicz, 1993: 8-11).

Artificial neural networks are used in many areas of life, for example, in the diagnosis of electronic circuits, psychiatric research, oil exploration, interpretation of biological research, analysis of medical research, planning the repairs of machines, napping in horse racing, analysis of manufacturing problems, optimization of commercial activity, spectral analysis, optimization of waste disposal, the selection of raw materials, selection of objectives in forensic investigations, selection of employees, control of industrial processes, stock market forecasts, forecasts of sales, price forecasts, prediction of the progress of science (Szabela, 2000: 97). ANN are also used to recognize handwritten characters, to classify invoices, to recognize speech and other signs.

Moreover, neural networks are used in economics and finance, for instance in: prediction (e.g. credit rating assessment, forecasting business development, forecasting market changes, stock prices and values of stock exchange indices), classification and identification of economic entities (e.g. identification of regions at risk of structural unemployment or plants of a given branch of industry worth investing), matching and analysis of data, data analysis, signal filtering or optimization (Tadusiewicz, 1993: 16).

3. Characteristics of artificial neural networks

An artificial neural network is a “computing architecture consisting of simple processing elements, neurons, that work in parallel and communicate with each other by sending signals (Krawiec and Stefanowski, 2003: 83).” The neural network is a very simplified model of the human brain. It consists of a large number of elements called neurons. Each neuron processes a finite number of input signals x_i ($i = 1, 2, ..., n$) for one output y using weights w_i. In general, the output signal y can be expressed using the formula:

$$y = f(s) \tag{1}$$

where:

s – the total excitation of a neuron, which is usually calculated as a linear combination of inputs complemented by a free unit,[2] which can be illustrated with the following formula:

$$s = \sum_{i=1}^{n} w_i x_i \tag{2}$$

f – activation function that specifies the mode of the excitation of s on the basis of weights w_i and the input signals x_i.

The activation function may take the form of both linear functions and non-linear functions, the most popular examples of which are:

– threshold

$$f(s) = \begin{cases} 1 & \text{if } s \geq 0 \\ 0 & \text{if } s < 0 \end{cases} \tag{3}$$

– logistic (sigmoid)

$$f(s) = \frac{1}{1 + e^{-\beta s}} \tag{4}$$

– hyperbolic tangent

$$f(s) = \tanh(\beta s) = \frac{e^{\beta s} - e^{-\beta s}}{e^{\beta s} + e^{-\beta s}} \tag{5}$$

[2] In literature referred to as BIAS

– signum

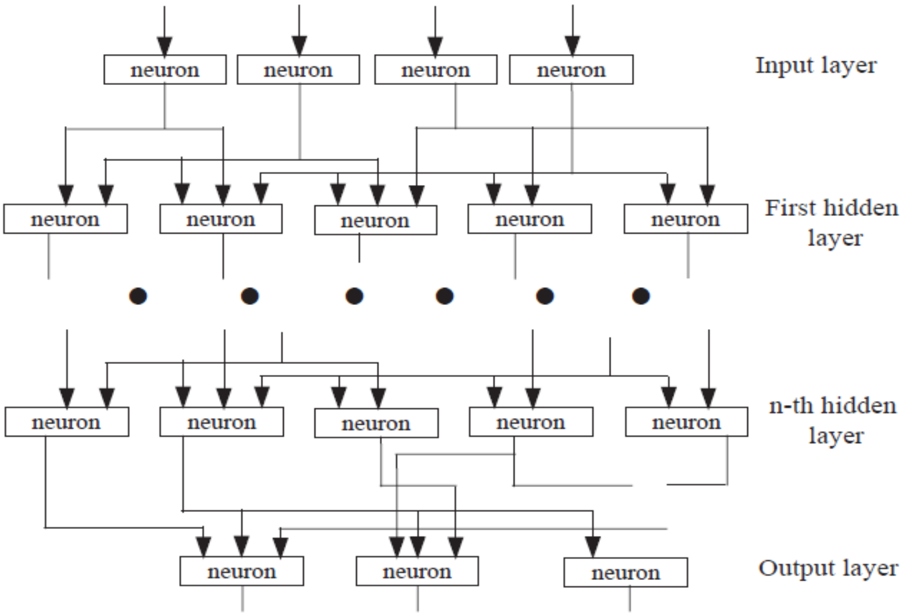
$$f(s)=\begin{cases}1 \text{ if } s>0\\ 0 \text{ if } s=0\\ -1 \text{ if } s<0\end{cases} \quad \text{or modificated} \quad f(s)=\begin{cases}1 \text{ if } s>0\\ -1 \text{ if } s\le 0\end{cases} \tag{6}$$

Input signals (results)

Neurons are connected and form a network through connections with parameters (weights) that are changed during the learning process. Most neural networks are constructed in a layered manner. Owing to availability during the learning process one can distinguish: an input layer, an output layer and hidden layers. An example structure of an artificial neural network is presented in Fig. 1.

Training of the network happens as follows: "The output values set for the neurons of one layer are placed on the inputs of neurons in the next layer. An exception is the first layer (called the input layer) consisting of neurons, at whose inputs are values brought from the outside of the network (concerning the values of input variables that appear in the solved problem as a prerequisite for inferences) and the last layer (output layer consisting of neurons designating values) later sent outside as whole network output values (treated in the solved problem as conclusions of reasoning) (Lula et al., 2007: 83)." In the case of artificial neural networks one can distinguish between two ways of training – with supervision (or with a teacher) and without supervision (without a teacher). The first method involves administration to the network of both input and correct values of output signals called the reference signals. In training without supervision the learning string consists only of input signals without a reference output signal.

Figure 1. One-way multi-layer network – example



Source: (Tadeusiewicz, 1993: 13).

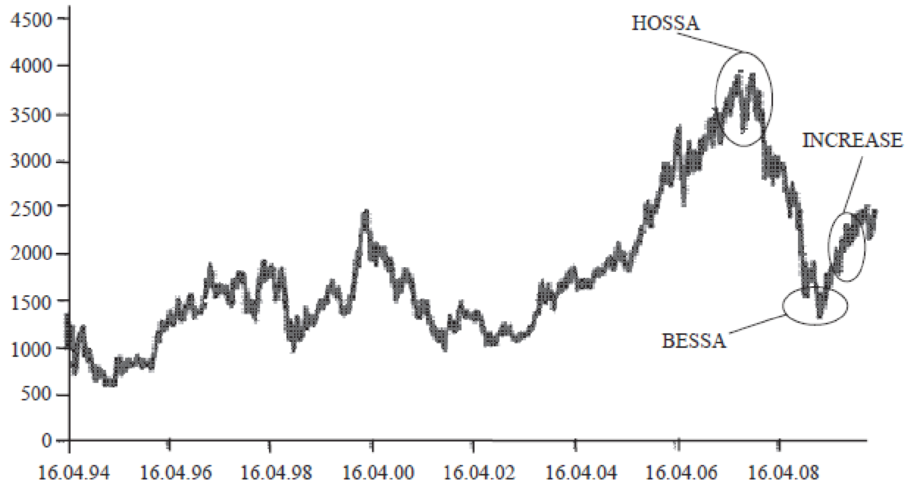
The most important features of ANN include: the ability to "learn" which allows the network to learn appropriate responses to a particular set of stimuli; reduced sensitivity to elements damage, because the network can operate correctly even in case of damage to some of the elements, breaking of connections or loss of information; ability to abstract which makes possible the generalization of the knowledge gained during the training process. Other properties of artificial neural networks include: ability to process information that is fuzzy, chaotic, incomplete or even contradictory; fast and efficient processing of large amounts of data; parallel, distributed processing; associative access to the information contained in the network – the so-called associative memory (Witkowska, 2000: 2).

4. Construction and analysis of neural networks

This paper attempts to assess the impact of market trends on the possibility of forecasting using ANN. To do it, joint stock companies listed in the WIG index were examined. Separate neural networks were built for each of the three sub-periods:

– bull market, i.e. the period from 30.04.2007 to 29.05.2007,
– fall, i.e. the period from 17.09.2008 to 14.10.2008,
– moderate growth, i.e. the period from 13.07.2009 to 7.08.2009.
Justification for this division is illustrated in Fig. 2.

Figure 2. WIG index on the Warsaw Stock Exchange 1994-2008



Source: author's own elaboration based on the website: http://www.gpw.pl/zrodla/gpw/spws/portfele/ wig20h_pl.html

Given the availability of data, the analyzed companies are companies listed in the Stock Exchange on the day of collecting data, i.e. 8.03.2010. The analysis did not take into account: the rights to shares, subscription rights, the companies withdrawn from the stock exchange prior to the date of data collection, as well as companies whose trading was suspended on at least one day of the studied sub-periods, regardless of the reason for this suspension. It must be stressed that a company did not have to be listed in all three sub-periods.

In the conducted analysis every listed company was characterized with variables such as: the opening rate, the maximum rate, the minimum rate, the closing/rate and volume of shares for each of subsequent 19 trading days. The data concerning the companies come from the database of MetaStock.

To build the neural networks, the Neuronix systemu from the SPHINKS package was used. The companies used in the learning (learning file) and testing (test file) processes were selected at random. The "test" companies constitute 10% of all analyzed companies. The learning and the testing files have disjoint con-tents. Exact figures for each of the sub-periods are presented in Table 1.

Table 1. Number of companies analysed in the subperiods

Analysed period	Time horizon	Number of companies	Number of "learning" companies	Number of "test" companies
Bull market	30.04.2007 – 29.05.2007	240	216	24
Fall	17.09.2008 – 14.10.2008	262	236	26
Moderate growth	13.07.2009 – 07.08.2009	316	284	32

Source: author's own elaboration

Table 2. Results of the analysis

Analysed period	Teaching the network		Testing the network		
	Companies beyond tolerance	Companies beyond tolerance [%]	Companies beyond tolerance	Companies beyond tolerance [%]	RMS error
Bull market	8	3.7	1	4.17	0.0081
Fall	13	5.51	2	7.63	0.0072
Moderate growth	15	5.27	1	3.16	0.0033

Source: author's own elaboration.

Each network is a one-way network supplemented by the free unit BIAS, containing 1 hidden layer consisting of 10 neurons. The value of learning rate was set at 0.7, and of the moment rate at 0.5. The condition for completion of the learning process was RMS error smaller than 0.005. Tolerance for both the learning and testing processes was 0.01. Table 2 presents the results of the analysis of each of the three constructed neural networks.

When analyzing a constructed network one should remember that the knowledge in neural networks is expressed in an implicit form. Is represented in this rather specific structure through connections between neurons and the value the neurons weights. In this type of representation it is difficult to set completeness, adequacy or efficiency of knowledge. Cohesion, in turn (as in the case of generated knowledge), is obtained automatically if a correct generating program is used. When testing neural networks, only their reliability can be assessed without problems. Verification and evaluation by other criteria requires additional information concerning, for example, the training set and teaching methods (Owoc, 2004: 91).

On the based on the analysis, it can be stated that:

1. A relatively small percentage of rejected companies at the network learning stage – 3.7%, 5.51% and 5.27%, respectively – combined with a low tolerance parameter indicates that the network accurately selected weights to the data used.
2. Individual cases of rejection in the testing process (1 company for the bull market period and for the moderate growth period plus 2 companies for the bear market period) show that in the adopted sub-periods, network was characterized by a high predictive ability.
3. The presented individual exclusions of companies at the stage of learning and testing can result from the specific information concerning a given company that has been released during the study period.
4. The results observed for each of the networks were only slightly different from one another. It can therefore be inferred that the thesis proposed at the beginning of the work, saying that ANN can be an effective way to predict companies' stock prices irrespective of the dominant trends on the market is true.
5. To further verify the proposed thesis, one should build a model based on other time series.
6. One can assume that a wider range of input data would lead to more accurate calculations.

5. Conclusions

The Stock Exchange is a particle of chaos which discounts everything. However, practice shows that even in this chaos there are those who manage better than others. Observing entities which in the long term achieve better results on the trading floor than the market, one can easily notice some regularity. In most cases these are entities with considerable theoretical and (or perhaps, above all) practical knowledge. The knowledge acquired by thematic study of the literature and by practice on the market is necessary to effective decision making – necessary, but not sufficient. In addition to knowledge, an increasingly important role is played by analytical tools that allow faster decision-making process and the observation of relationships that would be hard to detect by the human mind. They also allow for an objective evaluation of often subjectively perceived data. The range of the capabilities of the tools is very wide: starting with simple calculations in Excel, through packets used to forecast trends, to more complicated tools from the field of artificial intelligence. And it is the last group that is becoming increasingly popular as systems of comprehensive analysis capable of capturing even slightly visible and complex relationships between individual elements of the analysis. This is confirmed by the proof presented in this paper, which simultaneously allows the positive verification of the thesis proposed at the beginning.

Nevertheless, one should not treat ANN's calculations as decision-making, but only as supporting decision-making. Indeed, the complexity of the world often goes beyond the capabilities of the model.

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TRENDY NA RYNKACH PAPIERÓW WARTOŚCIOWYCH ORAZ PROGNOZY CEN PRZY WYKORZYSTANIU SZTUCZNYCH SIECI NEURONOWYCH

Streszczenie:

Niniejszy artykuł został poświęcony badaniom trendów rynkowych w celu prognozowania cen giełdowych w oparciu o sieci neuronowe. Aby zademonstrować takie możliwości, autorzy zaproponowali trzy sieci dla każdego z rozpatrywanych trendów. Artykuł ukazuje, iż sieci neuronowe mogą stanowić efektywne narzędzie przewidywania rynkowych cen akcji i udziałów.

Słowa kluczowe: sztuczne sieci neuronowe, giełda, trendy rynkowe, GRW.