Intelligent Techniques in Stock Analysis

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Abstract. The paper presents computer system, named **S**tock **M**arket **E**lectronic **E**xpert (**SMEE**), for Stock Market Analysis. It is developed as friendly, useful and credible computer program giving advises concerning investment policy on Stock Market. Fundamental and technical analysis are made automatically, and – on the base of obtained partial results – system produces evaluation of companies' attractiveness as well as comments and suggestions for users in text format. The system uses some filter stated by the user in the program. **SMEE** was tested using real data from the Warsaw Stock Exchange. Obtained results reveal high accuracy.

Keywords: *Stock market analysis, fuzzy expert system, neural network*

Introduction

Computers are useful for such tasks as analyzing and prediction of Stock Exchange, computer programs can play the role of expert or advisor for investors. Different Stock Exchange can be analyzed using similar techniques, because all of them work under near the same law. The popular techniques for Stock analysis are *Fundamental Analysis* and *Technical Analysis*.

Very popular techniques from the field of Artificial Intelligence, used for financial analysis are *Artificial Neural Networks* (Mitchell 1997, Żurada, Barski, Jędruch 1996). But recently, others intelligent techniques, as expert systems and genetic algorithms, are developed to improve the judgement of traders, to derive automated trading strategies or to optimize portfolio management. Some examples of such attempts one can find in (Deboeck 1994).

In the presented project we tray to develop computer program useful for each trader, in fact for every one of us, who would like to invest on Stock. We focus on Warsaw Stock Exchange and developed system is verified using the data from this Stock. The general aim of our project can be defined as:

> To introduce a bit of intelligence into a computer program, enough to make it capable to analyze Stock Market data and sharing obtained results with users.

More detailed goal is:

> Evaluation of attractiveness of particular company (stock) in the **WSE** (**W**arsaw **S**tock Exchange).

Realization of above goal requires, that developed computer program ought to:

- use standard techniques of fundamental analysis,
- use standard techniques of technical analysis,
- use selected (appropriate) intelligent techniques for patterns matching,
- analyze obtained partial results in the intelligent way,
- present all required result in the friendly way,
- allow for adding new users and companies, and bringing up to date all market quotations from the text files,
- manage database keeping data from the two groups: companies and users.

The paper is structured as follow. The first part after introduction contains general description of the system. In the next section we describe techniques which we use in particular modules – fuzzy expert systems and artificial neural networks. The results given by the system using real data from the Warsaw Stock Exchange are presented and discussed in the fourth section. Short summary ends the paper.

Stock Market Electronic Expert – an overview

Developed computer program **SMEE** (**S**tock **M**arket **E**lectronic **E**xpert) improves and makes more efficient classic techniques of stock analysis. Intelligent techniques are used for prediction of changes in the market quotations. The general schema of the **SMEE** system is shown in **Fig.** 1. The *Central Unit* of the system (box 15) plays the role of control mechanism. It communicates with users by the *User Interface* (box 14). Communication between the system and users is possible only via *User Interface* and *Central Unit*. *Central Unit* controls all modules in the system.

Fundamental Analysis, in general, makes forecast on the base of macroeconomic data. It uses basic financial status of companies and macroeconomic data such as exports, imports, money supply, interest rates, foreign exchange rates, inflationary rates, etc. (Deboeck 1994).

In **SMEE**, modules collected in box named *Fundamental Analysis Tools* consist of the four Fuzzy Expert Systems – for four groups of indices.

1. Capital market indices

- Price/Earning ratio (P/E) – it suggests stocks that can be bought because their long run price increasing is high:

$$P/E = \frac{market\ \ price\ of\ \ one\ share}{gain\ on\ one\ share}, \tag{1}$$

where:

$$gain\ on\ one\ share = \frac{net\ \ profit}{number\ of\ \ issued\ \ stock}. \tag{2}$$

- Cover Ratio index (CovR) – it tells about inclination of company to pay dividend:

$$CovR = \frac{divident\ on\ one\ share}{gain\ on\ one\ share}. \quad (3)$$

- Price/Book Value index (P/BV) – it informs about the relative market to book value of the company:

$$P/BV = \frac{(market\ \ price\ of\ \ one\ share)\cdot(amount\ of\ \ issued\ \ stock)}{book\ value\ of\ \ company}. \quad (4)$$

- Dividend Yield index (D/Y) – ratio of dividend, it allows to compare efficiency of investment in the Stock Market with others (e.g., bank) investment:

$$D/Y = \frac{dividend\ on\ one\ share}{price\ of\ \ one\ share}. \quad (5)$$

2. Indices of effectiveness

- Financial Effectiveness index (FE) – it tells about amount of somebody else's capital (e.g., credit) used by the company:

$$FE = \frac{assets}{company\ capital}. \quad (6)$$

- Return on Assets index (ROA) – rates of assets efficiency:

$$ROA = \frac{net\ \ profit}{assets}. \quad (7)$$

- Return On Equity index (ROE) – rate of profit from the company capital, known as index of capital efficiency:

$$ROE = \frac{net\ \ profit}{company\ capital}. \quad (8)$$

- Net Profit Margin index (NPM) – known also as index of trade efficiency:

$$NPM = \frac{net\ \ profit}{net\ trade} \quad (9)$$

3. Indices of rotation

- Assets Turnover index (AT):

$$AT = \frac{net\ trade}{assets}. \quad (10)$$

- Inventory Turnover index (IT):

$$IT = \frac{trade}{reserves}. \quad (11)$$

- Payments (Obligations) Turnover index (PT):

$$PT = \frac{net\ trade}{obligations}. \qquad (12)$$

4. Indices of liquidity

- Current Ratio (CR) – it defines ability of company to meet obligations in time:

$$CR = \frac{circulating\ capital}{current\ obligations}. \qquad (13)$$

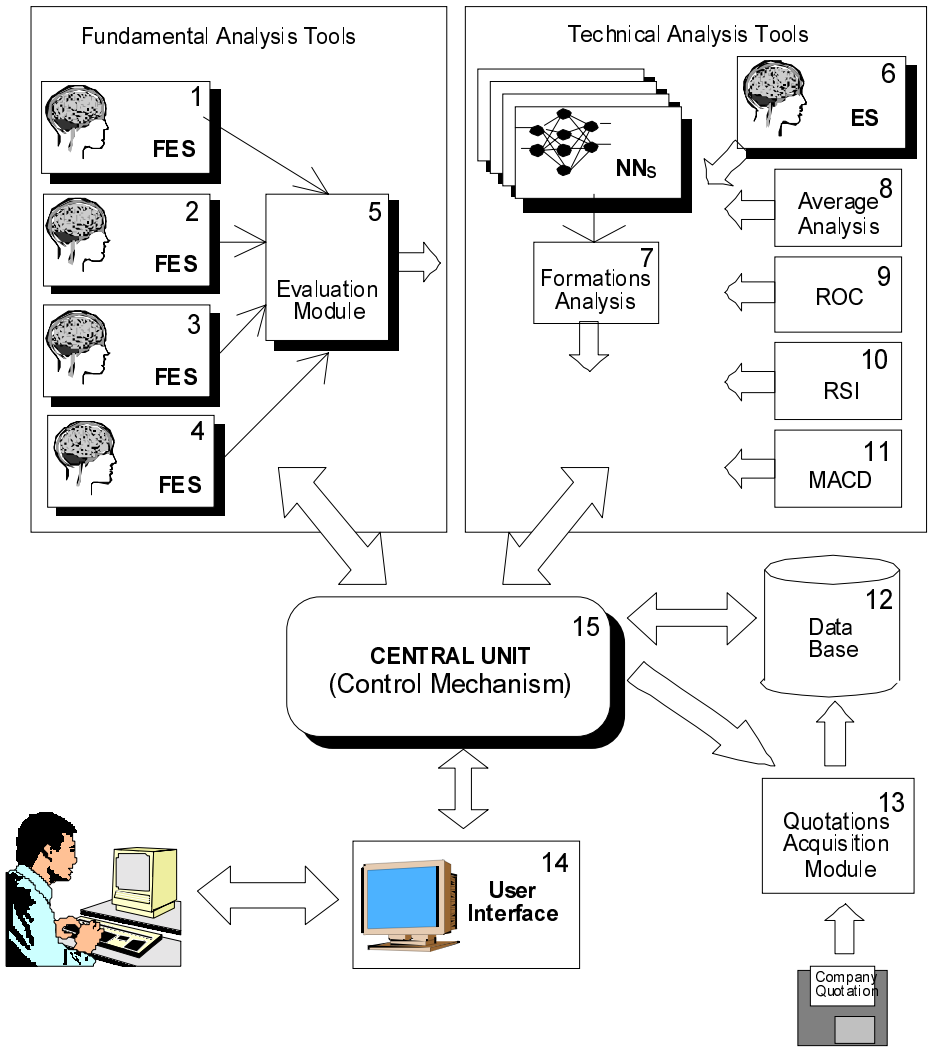

Fig. 1. The general scheme of the Stock Market Electronic Expert

- Quick Ratio (QR) – also called Acid Test, it is more restrictive than the former one:

$$QR = \frac{(circulating\ capital) - reserves}{current\ obligations}. \quad (\mathbf{14})$$

Evaluation module (box 5) produces joint attractiveness of the company as means weighted attractiveness given by the particular *fuzzy expert systems* (boxes 1, 2, 3, and 4) on the base of each from the four groups indices analysis.

Technical Analysis, in general, makes prediction by exploiting implications hidden in past trading activities, by analyzing patterns and trends shown in price and volume charts. It assumes that history will repeat itself and correlation between price and volume reveals market behavior (Deboeck 1994).

In **SMEE**, box named *Technical Analysis Tools* consists of the one *Expert System*, one module for matching and interpreting formations in graphs of stock prices – it uses four artificial neural networks, and four simple modules – each of them provides indices of technical analysis: moving averages prices analysis, ROC, RSI, and MACD indices.

Expert System – box 6 in **Fig.** 1, uses *point* & *figure* graphs for reasoning. Simple rules allow system to find trading signals (sell or buy) and to evaluate strength of trend on the base of point & figure graphs analysis.

Formation Analysis – box 7 in **Fig.** 1, uses four artificial neural networks (NNs) as tools for pattern recognition. NNs are used as searchers of significant formations on the graphs of price and graphs of volume. Formations can be treated as trading signals, but it should be considered together with others indices.

Moving average is used for analysis of trends (box 8). Resistance and support lines are characteristic trends used during technical analysis. If we can draw both lines (resistance and support) and they are parallel, we obtain trend canal. Breaking of trend lines indicates possible changes of stock price.

Boxes numbered 9, 10, 11, and 12 are modules for interpreting violence indices – ROC, RSI, and MACD:

- ROC – index of changes, it is based violence index. It represents a velocity of price changes:

$$\forall_{n \in N},\ ROC_t(n) = \frac{quotation(n)}{quotation(n-1)} \cdot 100, \quad (\mathbf{15})$$

where: t – number of sessions from which ROC is calculated,
n – number of Stock session,
N – set of sessions, the period in which we want to calculate ROC,
$quoation(n)$ – price of one share during n^{th} session.

- RSI – index of relative strength, a kind of measure of share strength:

$$\forall_{n \in N},\ RSI_t(n) = 100 - \frac{100}{1 + \frac{RCZ_t(n)}{ZCZ_t(n)}}, \quad (\mathbf{16})$$

where: t – number of sessions from which RSI is calculated,

n – number of Stock session,
N – set of sessions, the period in which we want to calculate RSI,
$RCZ_t(n)$ – average change of price "up" between $(n\text{-}t)^{th}$ and n^{th} sessions,
$ZCZ_t(n)$ – average change of price "down" between $(n\text{-}t)^{th}$ and n^{th} sessions.

If between $(n\text{-}t)^{th}$ and n^{th} sessions decreasing of price is absent, the $ZCZ_t(n)=0$, and RSI cannot be calculated. It is assumed that, in such cases, RSI=100 (Czekała 1998).

- MACD – Moving Averages Convergence Divergence – index of convergence and divergence of moving averages. Two exponential moving averages are used for MACD calculation: MACD is a result of subtraction of shorter moving average from the longer one.

Stock Market Electronic Expert – implemented algorithms

The three kind of intelligent techniques are embodied into the **SMEE**. Four used Fuzzy Expert Systems are similar, they differ mainly in knowledge embodied. They are parts of fundamental analysis. One Expert System analyses point & figure graphs. It contains a set of simple rules. As tools for pattern recognition we apply Artificial Neural Networks. Their task is to recognize defined patterns on the price graphs and volume graphs. The length (a number of sessions) of patterns is not stated, NNs have to search different length patterns.

Fundamental Analysis Modules

In this section we shortly describe all modules used in fundamental analysis. All of them are fuzzy expert systems, they produce partial results – attractiveness of company. *Evaluation Module* (box 5, **Fig.** 1) produces final result of fundamental analysis.

Fuzzy Expert System (FES)

Expert System (**ES**) is a computer program capable to replace human expert in usually narrows domain. To fulfil the above task, **ES** has to have embodied appropriate knowledge and inference skills (Mitchell 1997, Mulawka 1996). The core of **ES** is *Inference Engine*. It uses *Knowledge Base* to infer new *facts* on the base of known *true* facts. Usually domain knowledge is represented in the form of inference rules: if $p_1 \wedge p_2 \wedge ... \wedge p_n$ then q_r. **ES** must be able to *explain* produced conclusions. A module for knowledge acquisition is also a part of typical **ES**. Communication **ES** $\leftrightarrow$ user occurs by friendly *Interface*.

A number of methods were developed to cover uncertain and/or incomplete knowledge. One of such techniques is *Fuzzy Logic* (Mitchell 1997). In fuzzy logic, the same fact can belong to a number of sets with given *membership* values. Membership function can have any shape, but triangular and trapezoid ones are very popular, they are simple and give satisfactory results (**Fig.** 2). The fuzzy inference is shown in **Fig.** 3.

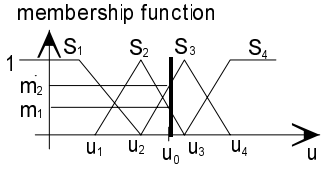

Fig. 2. Fuzzy sets (an example)

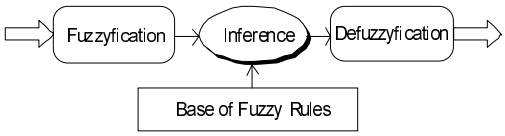

Fig. 3. Idea of fuzzy inference

Fuzzyfication process is made on the base of fuzzy sets defined for the input variable: in **Fig.** 2 we can see that crisp value u_0 belongs to the set S_2 with membership function equal to m_1, and to the set S_3 with membership m_2. Defuzzyfication process is the calculation of crisp value of output variable. We do it using *Center of Gravity* method (Ciosmak 2000).

FES for capital market indices interpretation

Fuzzy Expert System (box 1, **Fig.** 1) estimates attractiveness of given stock (company) on the base of Price/Earning ratio (P/E) and Price/Book Value index (P/BV). For P/E we assume two fuzzy sets: low, high (L,H); for P/BV – three sets: *law*, *medium*, *high* (L, M, H). Output variable, Attractiveness (A) has three triangular sets: *law*, *medium*, *high* (LA, MA, HA). Knowledge base contains rules shown in Table 1. The system concludes attractiveness of company in a form of number from the range [0,10]. The second step is calculation of indices CR and D/Y. On the base of their values, system produce suggestions for the user in a text format, e.g.:

Table 1. Set of fuzzy rules on the base of P/E and P/BV

P/E\P/BV	L	M	H
L	MA	HA	MA
H	LA	MA	LA

1. if *attractiveness* < *treshold_attractiveness* then *do not invest*
2. if *attractiveness* ≥ *treshold_attractiveness* and *CR* ≥ *sCR* and *D/Y* ≥ *sD/Y* then *invest for dividend*
3. if *attractiveness* ≥ *treshold_attractiveness* and *CR* ≥ *sCR* and *D/Y* < *sD/Y* then *do not invest because effectiveness of dividend is very low* (*you should find others investment*)
4. if *attractiveness* ≥ *treshold_attractiveness* and (*CR* ≥ *sCR* or *CR does not exist*) then *invest because the increase of stock price is possible* (*investment policy of company*)

FES for indices of effectiveness interpretation

Fuzzy Expert System (box 2, **Fig.** 1) estimates attractiveness of given stock (company) in five steps. The first step is made on the base of Financial Effectiveness index (FE) in the context of market average (mFE) and branch average (bFE). For both indices (mFE and bFE), three fuzzy sets are defined (L, M, H). System inferences about company attractiveness: *very law*, *low*, *good*, *high*, *very high* (vLA, LA, GA, HA, vHA). Set of rules is given in Table 2. Attractiveness is calculated and scaled to the range [0,10]. In the second step system estimates attractiveness of company using Return on Assets index (ROA) in the context of market average (mROA) and branch average (bROA). For both input variables we use two fuzzy sets (L, H), for output variable – attractiveness, we define three sets (LA, MA, HA). Simple rules are shown in Table 3. Third and fourth steps are similar to the second one, but system uses Return On Equity (ROE) and Net Profit Margin

Table 2. Set of fuzzy rules on the base of bFE and mFE

bFE\mFE	L	M	H
L	vLA	LA	LA
M	GA	GA	GA
H	HA	HA	vHA

Table 3. Set of fuzzy rules on the base of bROA and mROA

bROA\mROA	L	H
L	LA	MA
H	MA	HA

(NPM) indices respectively. The fifth step is simple calculation of average attractiveness obtained in the former four steps.

FES for indices of rotation interpretation and **FES for indices of liquidity interpretation**

These fuzzy expert systems (boxes 3 and 4, **Fig.** 1) work in similar way as previous one. The last system estimates attractiveness on the base of Current Ratio (CR) and Quick Ratio (QR) indices, but the former one uses Assets Turnover (AT) and Inventory Turnover (IT) indices. Both systems calculate output attractiveness as average value. They all generate text commentary for the user.

Box 5 in **Fig.** 1 – Evaluation Module, calculates final attractiveness on the base of Fundamental Analysis using outputs of four fuzzy expert systems:

$$A = \sum_{i=1}^{4} a_i \cdot w_i \,, \tag{17}$$

where: A – final attractiveness,

a_i – output of ith analyzer (boxes 1, 2, 3, 4, **Fig.** 1)

w_i – weight for ith analyzer: w_i = 0.4, 0.2, 0.2, 0.2 for i=1, 2, 3, 4 respectively.

Analysis of indices is significant part of fundamental analysis. The above described system is able to evaluate financial condition of company and to generate short text description for the user. Final assessment given by the system allows user for easy and complete comparison of companies. Such system can be useful, but together with technical analysis should give more credible results.

Technical Analysis Modules

The part of **SMEE** responsible for technical analysis consists of one simple expert system – his task is to interpret *point* & *figures* graphs. Analysis of price graphs is made using four different neural networks. The other modules calculate and interpret some indices useful in Stock Market analysis.

Expert system for point & figure analysis

System (box 6, **Fig.** 1) receives preprocessed *point* & *figure* chart, and we expect that it find characteristic formations on this figure. We distinguish 12 formations. All formations are defined as set of simple rule, considering internal representation of figures. Figures are represented in the form useful for computer processing. The system automatically evaluates figures from the point of view of trade signals and

strengths of found trends. The wider description of this task and used set of rules one can find in (Ciosmak 2000).

Artificial Neural Network (NN) as pattern recognition tool

Price formations are significant part of technical analysis. We use four feedforward neural networks: two of them work with graphs of price changes, two – with graphs of volume changes. One network is trained to recognize patterns directly on the real prices and one is trained on the base of increments in successively quotations. The same situation is with volume changes graph: one NN works on the volume changes, the second on the increments. Networks searching formations on the price graphs were trained for 7 formations, networks searched formations on the volume graphs were trained for 5 formations. Parameters of used networks are defined in table 4. The NNs were developed after a number of experiments with the task of pattern recognition. Emergent problems were analyzed and taken into account during developing process. A number of tests with real data from the Warsaw Stock Exchange (**WSE**) confirm correctness of NNs modules.

Table 4. Parameters of used neural networks in technical analysis

Parameter	NN 1	NN 2	NN 3	NN 4
Number of input neurons	20	20	20	20
Number of hidden neurons	13	12	11	9
Number of output neurons	7	7	5	5
Learning rate (η)	0.4	0.4	0.2	0.4
Momentum (α)	0.9	0.9	0.9	0.9
Error (Ep)	0.005	0.0005	0.05	0.005
Times of learning [epoch]	≈2500	≈1500	≈15000	≈1000

Central Unit (**CU**) manages tasks of all analyzers and it communicates with users. **CU** is focused on:

- calling analyzers for user demand,
- supplying analyzers with needed data from the system database,
- receiving and interpretation of results produced by analyzers,
- generation of companies evaluation,
- generation of suggestions – each user establish filters (program options), the strength of suggestion is generated on the base of all company evaluations existing in the system, it ranges from 1 (the least attractive) to 10 (the most attractive).

SMEE is easy for users, therefore adding data concerning new quotations is simple, it can be done by reading text file, gathering for example from the home page of **WSE**.

Stock Market Electronic Expert – experiments with real data

Computer program has to be installed under Microsoft Windows 95/98/2000/NT. All windows and parameter description are in Polish. Portfolio and history of transactions of each user are stored in database. Exemplary windows are shown in **Fig.** 4, 5, 6, 7.

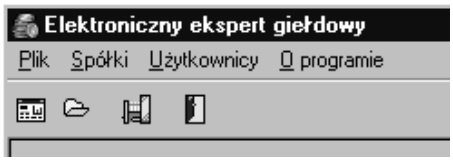

Fig. 6. SMEE - main menu

Developed system should support user financial decision. A number of experiments have been made for **SMEE** verification. Full description of experiments is in (Ciosmak 2000), here we present only excerpts from them.

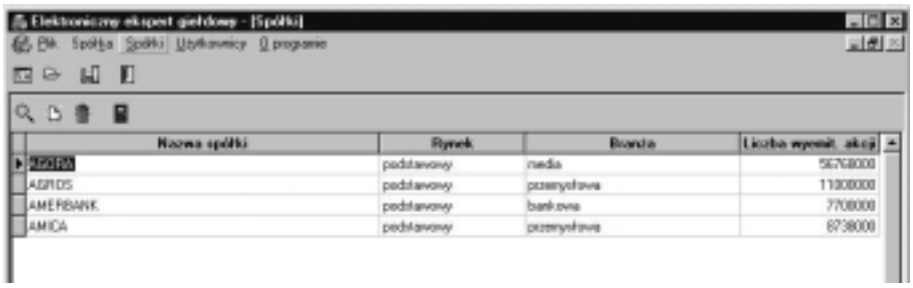

Fig. 4. SMEE – companies window

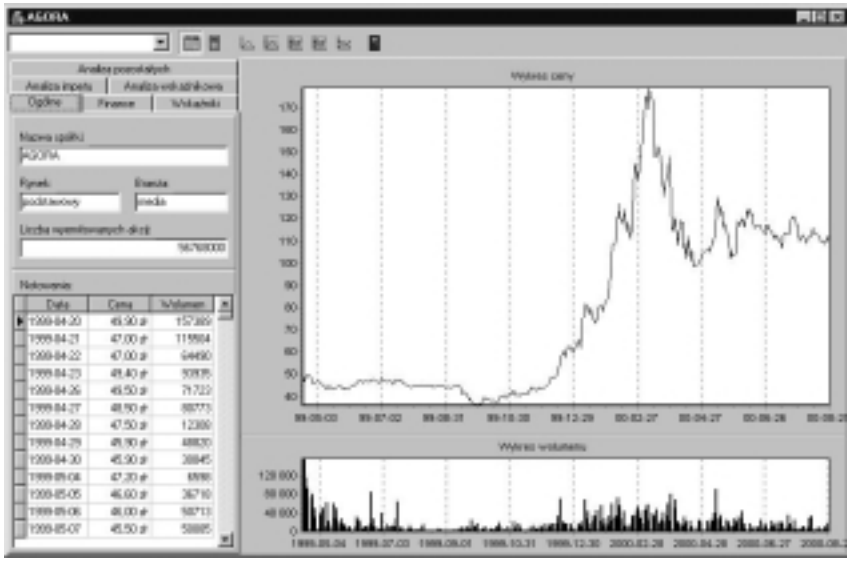

Fig. 5. SMEE – examples of company window

Experiment 1. Test of credibility of market price forecast using standard parameters.

For this experiment we have randomly selected 30 companies. Considered quotations begin on 20 October 1999. For each company, following financial data are

used by the system: a number of issued shares; assets; company capital; net trade (year); net profit (year); dividend on share; book value.

Standard system parameters are no restrictive, therefore we should assume soft criteria of forecast accuracy, namely:

- forecast of *increase* is accurate if during the period not less then two months, the market price reaches 120% of initial value (dated on 29.10.1999),
- forecast of *decrease* is accurate if during the period no less then two months, the market price decreases up to 90% of initial value (dated on 29.10.1999), and – during the same period, it increases no higher then 110% initial price (dated on 29.10.1999).

We accept result as *forecast of increase* only if signal *to bay* is produced with strength attribute greater or equal to 7, and as *forecast of decrease* only if signal *to sell* is produced with strength attribute greater or equal to 7. The results are collected in Table 5. The sign '+' means that forecast is adequate, but '–' that obtained forecast does not fulfill stated criteria.

Accuracy rate is equal to 78% what seems to be satisfactory. It is worth to mention that the system does not produce suggestion which gives user great financial loss. Majority of suggestions concerning baying seems to bring profit.

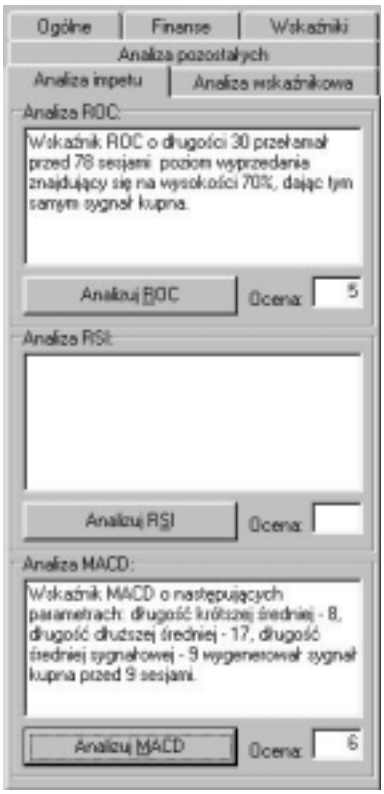

Fig. 7. SMEE – violence analysis

Experiment 2. Test of credibility of market price forecast using standard parameters, but the beginning of the analysis period comes when we observe the end of boom.

We take into account the period in which we observe the end of boom (31 March 2000). Here, the accuracy rate is equal to 60% (Table 6). But only two forecasts are 'quite' wrong (for BIG and Amica, two lasts rows in Table 6), what means that they suggest price increasing, but real price decreased. For the other companies for which forecast is marked as wrong, forecasted changes of market price are in proper direction but they are too slow to fulfill assumed criteria. In this experiment, predictions of prices decreasing dominate, Warsaw Stock Exchange entered the phase of slump. Somebody investing according to forecasts given by the system could not expect high profits, but potential losses are also not very high.

Table 5. Summary results obtained in experiment 1

Company	Sugestion (forecast)	Real changes of market prices	Forecast accuracy
Dębica	to bay (increase)	First 20 days: decrease up to 92%, next increase up to 125% (to 03.01.2000)	+
Mennica	to bay (increase)	Market price increase up to 144% (to 22.12.99), next – up to 197% (17.03.2000)	+
KGHM	to bay (increase)	Increase of price up to 113% (27.12.99), next to 149% (25.02.2000), forecast does not fulfill initial conditions.	–
Amica	to bay (increase)	27.12.99 price=136%, without significant decrease, in next months it increases up to 205% (29.03.2000).	+
Kable	to bay (increase)	18.11.99 market price decreases below 90%	–
Best	to bay (increase)	To the end of 99, price increases up 126%.	+
Indykpol	to bay (increase)	Increase up to 135% to the end of 99.	+
Delia	to bay (increase)	No significant increases or decreases	–
Softbank	to bay (increase)	During two months increase to 124%, next months – huge increase – to 291% (the end of March 2000).	+
Irena	to bay (increase)	Increase up to 137% (27.12.99)	+
Prokom	to bay (increase)	Increase up to 143% (the end of 1999), next higher increase (353%)	+
Cersanit	to bay (increase)	Increase up to 126% (27.12.99.), next to 243% (07.04.2000)	+
Bre	to bay (increase)	Increase up to 120% before the end of 99.	+
BIG	to bay (increase)	Increase up to 160%, next – to 238%	+
Bytom	to sell (decrease)	Not significant (but more then 110%) increase. Forecast does not fulfill criteria.	–
Elektrim	to sell (decrease)	During few days (to 08.11.99), decrease up to 70%	+
Bakoma	to sell (decrease)	Decrease up to 89% (18.11.99)	+
Agros	to sell (decrease)	Market price quickly decreases up to 88%	+

In other experiments some analyzers are excluded. Using two analyzers, **SMEE** was able to give forecasts with accuracy rate equal to 72%, but in 3 cases forecasts are quite wrong (5 companies do not fulfill forecast criteria). The analysis of moving averages plays the big role in this experiment (it is used together with *point* & *figures* analyzer).

Table 6. Summary results obtained in experiment 2

Company	Sugestion (forecast)	Real changes of market prices	Forecast accuracy
Indykpol	to sell (decrease)	Market price decrease, but during 2 months, price is still greater then 90% of initial value.	–
Kable	to sell (decrease)	Market price decrease up to 75% (to 25.04.2000).	+
Softbank	to sell (decrease)	Market price decrease up to 63% (to 09.05.2000).	+
Jelfa	to sell (decrease)	Market price decrease up to 88% (to 26.05.2000).	+
Agora	to sell (decrease)	Market price decrease up to 86% (to 29.04.2000).	+
Elelektrim	to sell (decrease)	Market price decrease up to 78% (to 24.05.2000).	+
Pekao	to sell (decrease)	Market price decrease up to 88% (to 17.04.2000).	+
Prokom	to sell (decrease)	Market price decrease up to 75% (to 09.05.2000).	+
Rafako	to sell (decrease)	Market price decrease up to 79% (to 29.05.2000).	+
Warta	to sell (decrease)	Market price decrease up to 73% (to 26.05.2000).	+
Handlowy	to bay (increase)	Increase up to the middle of July, but too slow, so forecast is not accurate.	–
Cersanit	to bay (increase)	Increase, but only to 107% (07.04.2000.), next – decrease.	–
Bytom	to bay (increase)	Increase up to 107% (24.04.2000), too slow.	–
BIG	to bay (increase)	Wrong forecast, market price decrease up to 69% during 20 days.	–
Amica	to bay (increase)	Wrong forecast, market price decrease up to 69% (during days).	–

Summary

The developed system seems to work acceptable. Experiments show that obtained forecasts have about 70% accuracy – this result can be seen as satisfying for such difficult task. Majorities of the "wrong" forecasts are obtained only because changes on the Stock Exchange are too slow, taking into account defined criteria, but the directions of changes are adequate. It is very significant feature of the system, because 'quite wrong' forecast can cause big financial loss for potential users. In all experiments, only 14% forecasts are quite wrong, that means, they bring potential investors losses.

The system has big possibilities to analyze and to present obtained results, however the user interface can be extended.

The program is ready for use by potential investors, but the authors have not invested in the Stock Exchange and do not take responsibility for profits and losses of potential users.

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