INFORMATYKA EKONOMICZNA BUSINESS INFORMATICS 3(33) • 2014
ISSN 1507-3858

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DESIGN AND EVALUATION OF TRADING STRATEGY IN A-TRADER SYSTEM[1]

Abstract: The article presents an approach to the performance analysis of trading strategies in the a-Trader system. A-Trader supports investment decisions on the FOREX market. The first part of the article contains a description of the a-Trader system from the user viewpoint. Next, the algorithms of the selected agents' strategies are presented. In the last part of the article, the performance evaluation of strategies is proposed and illustrated.

Keywords: Multi-agent systems, financial decisions, FOREX, investment strategies.

DOI: 10.15611/ie.2014.3.07

1. Introduction

Most trading decisions are supported by formal models based on mathematics, statistics, or artificial intelligence methods [Barbosa, Belo 2010; Chan, Wong 2011; Dempster, Jones 2001; Karjalainen 1999; Korczak, Lipinski 2008; LeBaron 2011; Martinez-Jaramillo, Tsang 2009; Palit et al. 2012]. The papers [Korczak et al. 2012, 2013] present a multi-agent system, called a-Trader, operating on the FOREX market (Foreign Exchange Market), where currencies are traded against one another in pairs, for instance EUR/USD, USD/PLN. This system uses tick data, on the basis of which minute aggregates (M1, M5, M15, M30), hourly aggregates (H1, H4), daily aggregates (D1), weekly aggregates (W1) and monthly aggregates (MN1) are computed.

Trading agents in the system form the investment strategies. The strategies are permanently evaluated, and those with the highest evaluation can be chosen to advise the trader. As a key measure the return on investment cannot be considered as the only evaluation criterion. The other aspects having influence on the effectiveness of the investment strategies, such as for instance investment risk [Jajuga, Jajuga 2000] or transaction costs, should also be taken into consideration.

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[1] Selected parts of this article were published under nonexclusive copyright in Proceedings of the Federated Conference on Computer Science and Information Systems FedCSIS 2014 (see [Korczak et al. 2014]).

The aim of this article is to propose a set of evaluation criteria and an approach to analyzing the performance of trading strategies implemented in the a-Trader system.

The first part of the article briefly characterizes the a-Trader system from the trader point of view. The algorithms of three selected agents that form the strategy are presented. In the final part, the article describes the results of the performance evaluation of trading strategy.

2. A-Trader system – functionalities and usage

A-Trader contains approximately 1200 agents, including about 800 agents processing quotations on the FOREX market (for instance they calculate trend indicators, oscillators) and 200 agents (running in all time periods) setting the buy-sell decision, and 200 agents providing the strategies. Agent Container (Figure 1) is an implementation of "Container" for agents. It acts as a server listening to messages sent by the protocol SOAP. Therefore the developer creating an agent does not have to worry about the communication layer. He implements only methods called by the incoming messages, processes them according to his own algorithm, and calls on the method to send the response. Agent Container is in charge of the whole process of communication in the whole system. It has been implemented in such a way that the most simplify the addition of new agents on any of the machines (supported by NET platform). The execution of the Agent Container gives an access to an available port

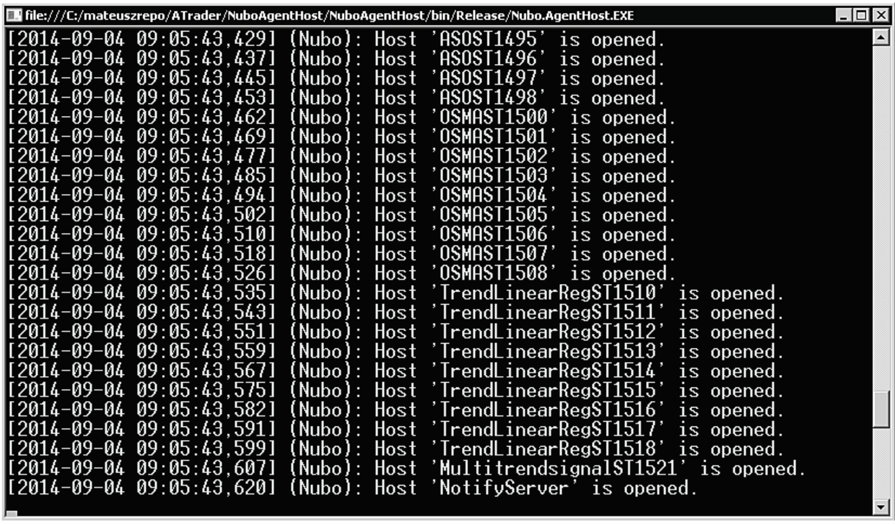


Figure 1. Container of agents

Source: own preparation.

to listen and runs the agent instances implemented in attached libraries. As a parameter it uses a configuration file with information indicating which agents of the library should be executed. In the command line console we can see all agent instances which are active in the container referred to (Figure 1).

The component which caused us to observe and analyze the agents' behavior is called the visualization agent. Tool functionalities are implemented to work in a multi-monitor environment. Agent List (Figure 2) allows us to set time interval and time period which should be shown on the main window. By double clicking, the user can choose agents which he will observe on the chart. The selected agents could be saved, by a user, as a user-defined set. It helps to switch between predefined groups of the agents.

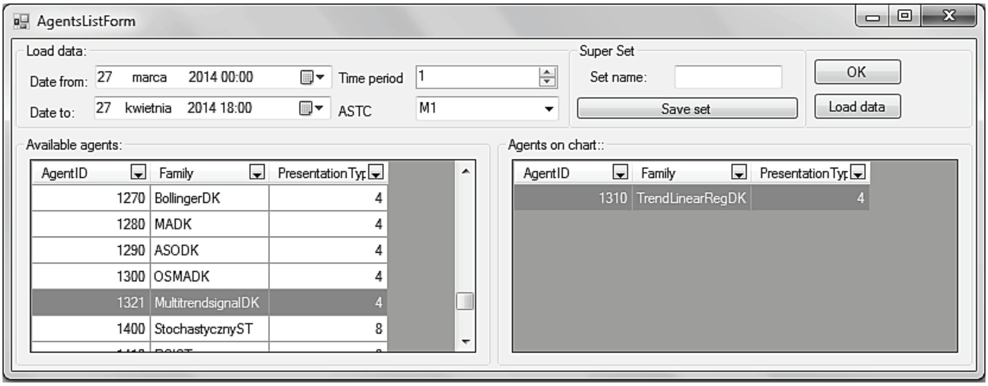


Figure 2. Agent selection window

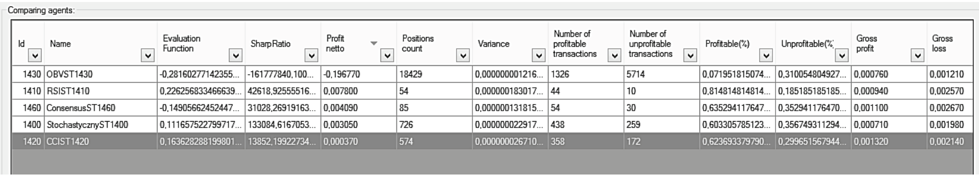
Source: own preparation.

The main window (Figure 3) contains a chart with the signals of selected strategy agents or technical analysis agents. The Multi-chart option allows the user to compare many strategies in the same or different time intervals. These functionalities are provided to make work easier with charts, zoom in, zoom out, and change time period. Mouse hovering over the area displays details about the situation of the observed financial instrument (actual price, actual time, etc.). When the user wants to calculate the differences between two points on a chart, he can just hold Ctrl key and move the mouse to the second point. The application automatically calculates the differences.

Selected strategies can be processed by the evaluation function module. The user can set weights of the evaluation function according to his preferences. He can take into account the risk, trading frequency, and many other performance factors. The Agent comparison panel (Figure 4) facilitates the analyzing process. All performance factors are presented in one table. This allows us to find all weaknesses and strengths of every analyzed strategy.

Figure 3. Main panel of a-Trader

Source: own preparation.

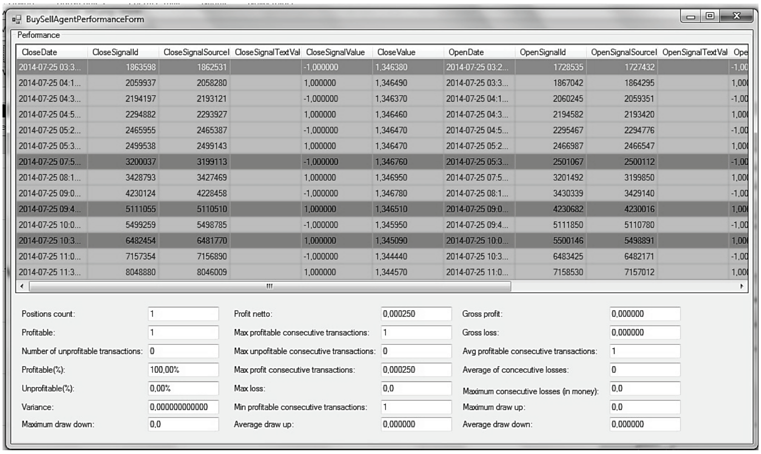


Comparing agents:

Id	Name	Evaluation Function	SharpRatio	Profit netto	Positions count	Variance	Number of profitable transactions	Number of unprofitable transactions	Profitable(%)	Unprofitable(%)	Gross profit	Gross loss
1430	OBVST1430	-0,28160277142355...	-161777840,100...	-0,196770	18429	0,000000001216...	1326	5714	0,071951815074...	0,310054804927...	0,000760	0,001210
1410	RSIST1410	0,226256833466639...	42618,92555516...	0,007800	54	0,000000183017...	44	10	0,814814814814...	0,185185185185...	0,000940	0,002570
1460	ConsensusST1460	-0,14905662452447...	31028,26919163...	0,004090	85	0,000000131815...	54	30	0,635294117647...	0,352941176470...	0,001100	0,002670
1400	StochastycznyST1400	0,111657522799717...	133084,6167053...	0,003050	726	0,000000022917...	438	259	0,603305785123...	0,356749311294...	0,000710	0,001980
1420	CCIST1420	0,163628288199801...	13852,19922734...	0,000370	574	0,000000026710...	358	172	0,623693379790...	0,299651567944...	0,001320	0,002140

Figure 4. Agent comparison panel

Source: own preparation.



BuySellAgentPerformanceForm

Performance

CloseDate	CloseSignalId	CloseSignalSourceI	CloseSignalTextVal	CloseSignalValue	CloseValue	OpenDate	OpenSignalId	OpenSignalSourceI	OpenSignalTextVal	Ope
2014-07-25 03:3...	1863598	1862531		-1,000000	1,346380	2014-07-25 03:2...	1728535	1727432		-1,00
2014-07-25 04:1...	2059937	2058280		1,000000	1,346490	2014-07-25 03:3...	1867042	1864295		1,00
2014-07-25 04:3...	2194197	2193121		-1,000000	1,346370	2014-07-25 04:1...	2060245	2059351		-1,00
2014-07-25 04:5...	2294882	2293927		1,000000	1,346460	2014-07-25 04:3...	2194582	2193420		1,00
2014-07-25 05:2...	2465955	2465387		-1,000000	1,346470	2014-07-25 04:5...	2295467	2294776		-1,00
2014-07-25 05:3...	2499538	2499143		1,000000	1,346470	2014-07-25 05:2...	2466987	2466547		1,00
2014-07-25 07:5...	3200037	3199113		-1,000000	1,346760	2014-07-25 05:3...	2501067	2500112		-1,00
2014-07-25 08:1...	3428793	3427469		1,000000	1,346950	2014-07-25 07:5...	3201492	3199850		1,00
2014-07-25 09:0...	4230124	4228458		-1,000000	1,346780	2014-07-25 08:1...	3430339	3429140		-1,00
2014-07-25 09:4...	5111055	5110510		1,000000	1,346510	2014-07-25 09:0...	4230682	4230016		1,00
2014-07-25 10:0...	5499259	5498785		-1,000000	1,345950	2014-07-25 09:4...	5111850	5110780		-1,00
2014-07-25 10:3...	6482454	6481770		1,000000	1,345090	2014-07-25 10:0...	5500146	5498891		1,00
2014-07-25 11:0...	7157354	7156890		-1,000000	1,344440	2014-07-25 10:3...	6483425	6482171		-1,00
2014-07-25 11:3...	8048880	8046009		1,000000	1,344570	2014-07-25 11:0...	7158530	7157012		1,00

Positions count:	1	Profit netto:	0,000250	Gross profit:	0,000000
Profitable:	1	Max profitable consecutive transactions:	1	Gross loss:	0,000000
Number of unprofitable transactions:	0	Max unpofitable consecutive transactions:	0	Avg profitable consecutive transactions:	1
Profitable(%):	100,00%	Max profit consecutive transactions:	0,000250	Average of concecutive losses:	0
Unprofitable(%):	0,00%	Max loss:	0,0	Maximum consecutive losses (in money):	0,0
Variance:	0,000000000000	Min profitable consecutive transactions:	1	Maximum draw up:	0,0
Maximum draw down:	0,0	Average draw up:	0,000000	Average draw down:	0,000000

Figure 5. Performance panel – step 1

Source: own preparation.

The Strategy performance panel (Figure 5) is an agent behavior analyzing tool. All trade positions generated by agents' decisions in the selected time period are presented. The Performance panel is associated with the chart panel. Double clicking on the position row marks the position on the chart. The profitable positions get green color, unprofitable ones are marked red. The performance factors are counted automatically by selecting positions.

The presented functionalities of a-Trader allow for trading with using different strategies. The next part of the article describes selected strategies.

3. Description of trading strategies

In order to illustrate the performance analysis, two specific strategies were built: **MyStrategy** and **Consensus**. The agents provide these strategies on the basis of agents that set buy-sell decisions. These strategies are provided on the basis of more complex algorithms than the algorithms of typical technical analysis indicators [Bollinger 2001; Lento 2008].

Trading on FOREX relies on opening/closing long/short positions. A long position is a situation in which one purchases a currency pair at a certain price and hopes to sell it later at a higher price. This is also referred to as the notion of "buy low, sell high" in other trading markets. In Forex, when one currency in a pair is rising in value, the other currency is declining, and vice versa. If a trader thinks a currency pair will fall, he will sell it and hope to buy it back later at a lower price. This is considered a short position, which is the opposite of a long position.

The strategies providing in the a-Trader system determine when to open/close long or short positions. Strategies take into consideration signals generated by buy-sell decision agents, and on the basis of these signals, a position is open or closed.

The specific nature of the selected strategies will be presented in the subsequent part of the article.

The strategy called **MyStrategy** is composed of the signals coming from the following nine base agents:

- Average Directional Index (ADX),
- Relative Strength Index (RSI),
- Rate of Change (ROC),
- Commodity Channel Index (CCI),
- Moving Average of Oscillator (OsMA),
- Moving Average Convergence Divergence (MACD),
- Stop and Reverse (SAR),
- Williams %R,
- Moving Average (MA).

The strategy considers two time periods (M1, M5) in such a way that the open/close position signal in case of the period M5 is generated when the same signal is generated by most base agents also within the periods M1, M5.

The strategy algorithm can be defined as follows:

Data: Signals *AM1*= {*AM1*(1), *AM1*(2) .... *AM1*(9)}
AM5 = {*AM5*(1), *AM5*(2) .... *AM5*(9)}
consist of *9* agents' signals.
Result: The value *position* of open /close position (value 1 – open long and close short position, value -1 open short and close long position, value 0 – out of market – close short/long position).
BEGIN
1: Let *S*:=0;
S_1, S_0, S_{-1} // ancillary variable
2: *j*:=1.
3: *i*:=1.
4: If ($tM1_i(j)$ > 4) and ($tM5_i(j)$ > 4)
then S_i:= S_i È{e_j}. Go to: 6. // $tMxX_i(j)$ – the number of occurrences agents' signals (1, 0 or -1) in a given time period.
5: If *i*= 1 then *i*:=0. Ifi *i*=0 then *i*:=-1 . if *i*=-1 then go to: 6.
Go to: 4
6: If *j*<*N* then *j*:=*j*+1 go to: 3.
If *j*³*N* then go to: 7.
7: If (S_1>S_0) and (S_1>S_{-1}) then S:=1; (S_{-1}>S_0) and (S-$_1$>S_1) then S:=-1.
8: Let *position*:=0;
9: If *S*==0 then *position:=prevS*. If *S*==1 then *position:=1,prevS:=1*. If *S*==-1 then *position:=-1,prevS:=-1*.
Go to: END.
END.

The algorithm complexity amounts to *O(18N*), where *N* means the number of currency pairs.

The **Consensus strategy** is detailed in [Hernes, Nguyen 2007; Nguyen 2006; Sobieska-Karpińska, Hernes 2012]. The Consensus agent (detailed in [Korczak et al. 2013]) provides a strategy on the basis of the set of decisions generated by different agents functioning in the system. The structure of the investment decision was defined in the study [Sobieska-Karpińska, Hernes 2012]. This decision is taken on the basis of financial instrument quotation such as, e.g., currency pairs EUR/USD, GBP/PLN and it is defined as follows:

Definition 1. Decision *D* about finite set of financial instruments $E = \{e_1, e_2, \ldots, e_N\}$ is defined as a set

$$D = \left\langle \{EW^+\}, \{EW^\pm\}, \{EW^-\}, Z, SP, DT \right\rangle, \quad (1)$$

where:

1) $EW^+ = \left\langle e_o, pe_o \right\rangle, \left\langle e_q, pe_q \right\rangle, \ldots, \left\langle e_p, pe_p \right\rangle$ – a positive set; in other words, it is a set of financial instruments about which the agent knows the decisions to buy, and the volume of this buying.

2) $EW^{\pm} = \langle e_r, pe_r \rangle, \langle e_s, pe_s \rangle, \ldots, \langle e_t, pe_t \rangle$ – a neutral set; in other words, it is a set of financial instruments, about which the agent does not know whether to buy or sell. If these instruments are held by an investor, that they should not be sold, or if they are not in the possession of the investor, should not be bought by them.

3) $EW^{-} = \langle e_u, pe_u \rangle, \langle e_v, pe_v \rangle, \ldots, \langle e_w, pe_w \rangle$ – a negative set; in other words it is a set of financial instruments of which the agent knows that these elements should sell. Couple $\langle e_x, pe_x \rangle$, where: $e_x \in E$ and $pe_x \in [0,1]$ denote the financial instrument and this instrument's participation in set EW^{+}, $EW^{\pm}$, EW^{-}.

Financial instrument $e_x \in EW^{+}$ is denoted as: e_x^{+}.

Financial instrument $e_x \in EW^{\pm}$ is denoted as: $e_x^{\pm}$.

Financial instrument $e_x \in EW^{-}$ is denoted as: .

4) $Z \in [0,1]$ – predicted rate of return.

5) $SP \in [0,1]$ – degree of certainty of rate *Z*. It can be calculated on the basis of the level of risk related with the decision.

6) DT – date of decision.

The strategy providing agent functioning algorithm is as follows:

Algorithm 4

Data: The profile *A*= {$A^{(1)}$, $A^{(2)}$ .... $A^{(M)}$ } consists of *M* agents' decisions. //$A^{(1)}$, $A^{(2)}$ .... $A^{(M)}$ – decisions of particular agents

Result: Consensus $CON = \langle CON_{+}, CON_{\pm}, CON_{-}, CON_{Z}, CON_{SP}, CON_{DT} \rangle$ according *A* and the value *position* of open /close position (value 1 – open long and close short position, value -1 open short and close long position, value 0 – out of market – close short/long position).

BEGIN

1: Let $CON_{+} = CON_{\pm} = CON_{-} = \varnothing, CON_{Z} = CON_{SP} = CON_{DT} = 0$. S:=0.

2: *j*:=1.

3: *i*:=+.

4: If $t_i(j) > M$ then $CON_i := CON_i$ È{e_j}. Go to:6.

// $t_i(j)$ – the number of occurrences of the financial instrument in the positive, neutral or negative set

5: If *i*=+ then *i*:=±

If *i*=± then *i*:=-

If *i*=-, then Go to:6

Go to:4.

6: If *j*<*N* then *j*:=*j*+1 Go to:3

If *j*³*N* then Go to:7.

7: *i*:=*Z*.

8: Determine *pr*(*i*). // ascending order

9: $k_i^1 = (M+1)/2$, $k_i^2 = (M+2)/2$.

10: $k_i^1 \le CON_i \le k_i^2$.

11: If *i*=*Z* then *i*:=*SP*.

If *i*:=*SP* then *i*:=*DT*.

If *i*:=*DT* then go to 12.

Go to: 8.
12: If ($CON_+ > CON_\pm$) and (($CON_+ > CON_-$) then S:=1; if ($CON_- > CON_\pm$) and (($CON_- > CON_+$) then S:=-1.
13: Let *position*:=0;
14: If *S*==0 then *position:=prevS*. If *S*==1 then *position:=1,prevS:=1*.If *S*==-1 then *position:=-1,prevS:=-1*.
Go to: END.
END.

On the basis of *S* signal, the Algorithm 1 is running in the permanent manner.

The complexity of the algorithm amounts to $O(3NM)$, where N means the number of currency pairs and M means the number of agents belonging to the profile (in the research experiment conducted in the next part of the article, $M = 25$, $N = 1$).

Computational complexities of the algorithms of strategies have an impact on the performance of the whole a-Trader system. Taking into consideration the fact that the system is processing tick signals as well as a large number of agents, short time of computation made by particular agents is very significant.

In general, agents in the system can also use fundamental analysis methods, neural networks, evolution algorithms or behavioral models for providing strategies.

The key part of the system is the Supervisor agent. Its task is, among others, to coordinate the functioning of strategy providing agents (agents opening/closing the positions) and presenting the final strategy (open/close positions suggestions) to the trader. This agent analyses various strategies and evaluates their performance.

A case study relating to the method of evaluating the performance of selected trading strategies is presented further in the article.

4. Evaluation of strategy performance – case study

The performance analysis was performed for data within the M5 range of quotations from the FOREX market. For the purpose of this analysis, a test was carried out in which the following assumptions were made:

1. GBP/PLN quotes were selected from randomly chosen periods, notably:
- 10-09-2014, 9:20 am to 12-09-2014, 18:00 pm,
- 16-09-2014, 0:00 am to 19-09-2014, 1:00 pm,
- 24-09-2014, 0:00 am to 26-09-2014, 1:00 pm,

2. At the verification, the strategies (signals open long/close short position-value 1, close long/open short position-value –1) generated by the strategies MyStrategy and Consensus are used (the example is presented in Figure 6, where the green line means the “long position”, the red one – the “short position”).

3. It was assumed that the unit of performance analysis ratios (absolute ratios) is pips (a change in price of one “point” in Forex trading is referred to as a pip, and it is equivalent to the final number in a currency pair’s price).

4. The transaction costs are directly proportional to the number of transactions.

Figure 6. The example of strategy visualization

Source: own preparation.

5. The capital management – it was assumed that in each transaction the investor engages 100% of the capital held at the leverage 1:1. It should be pointed out that the investor may define another capital management strategy.

6. The strategies' performance analysis was performed with the use of the following measures (ratios):

- Rate of Return (ratio x_1),
- number of transactions,
- gross profit (ratio x_2),
- gross loss (ratio x_3),
- total profit (ratio x_4),
- number of profitable transactions (ratio x_5),
- number of profitable consecutive transactions (ratio x_6),
- number of profitable consecutive transactions (ratio x_7),
- Sharpe ratio (ratio x_8)

$$S = \frac{E(r) - E(f)}{|O(r)|} \cdot 100\% , \qquad (2)$$

where:
$E(r)$ – arithmetic average of the rate of return,
$E(f)$ – arithmetic average of the risk-free rate of return,
$O(r)$ – standard deviation of rates of return.

- the average coefficient of volatility (ratio x_9) is the ratio of the average deviation of the arithmetic average of the rate of return multiplied by 100% and is expressed:

$$V = \frac{s}{\left|E(r)\right|} \cdot 100\% \,, \tag{3}$$

where:
V – average coefficient of volatility,
s – average deviation of the rates of return,
E(r) – arithmetic average of the rates of return.

- the average rate of return per transaction (ratio x_{10}), counted as the quotient of the rate of return and the number of transactions.

7. For the purpose of the comparison of the strategies performance, the following evaluation function was elaborated:

$$y = (a_1 x_1 + a_2 x_2 + a_3(1 - x_3) + a_4 x_4 + a_5 x_5 + a_6 x_6 + \dots \\ + a_7(1 - x_7) + a_8 x_8 + a_9(1 - x_9) + a_{10} x_{10}) \tag{4}$$

where x_i denotes the normalized values of ratios defined in item 6 from x_1 to x_{11}. It was adopted in the test that coefficients a_1 to a_{10}=1/10.

It should be mentioned that these coefficients may be modified with the use of, for instance, an evolution method or determined by the user (investor) in accordance with his/her preference (for instance the user may determine whether he/she is interested in the higher rate of return with simultaneous higher risk level or lower risk level but simultaneously agrees to a lower rate of return).

The domain of the function is in the range [0..1], and the strategies' efficiency is directly proportional to the function value.

8. The results obtained by the tested strategies were compared with the results of the Buy-and-Hold strategy (a trader buys a currency on the beginning and sell a currency on the end of investment period) and the strategies using EMA (Exponential Moving Average –- a type of moving average that is similar to a simple moving average, except that more weight is given to the latest data).

Table 1 presents the results obtained in the particular periods.

It may be noticed that the values of efficiency ratios of particular strategies differ in each period. The values of such ratios as *Gross profit* and *the number of profitable consecutive transactions* are approximative, however, the values of ratios *rate of return*, *gross loss*, *Sharpe ratio* and *the average rate of return per transaction* are characterized by significant distribution in the case of particular strategies. It may also be noticed that in case of the strategies MyStrategy, Consensus and EMA, the values of ratios have shown variability in particular periods. The GBP/PLN quotation is characterized by a greater fluctuation than, for example, EUR/USD or EUR/PLN quotations. A large scope of changes of ratios significantly hinders the analysis by the user and, as a consequence, the time for choosing the appropriate strategy is lengthened. And the application of the evaluation function allows for immediate choice of a best efficiency strategy. It may be noticed that the evaluation function

Table 1. Result of the strategies evaluation

Ratio	MyStrategy			Consensus			B&H			EMA		
	Period 1	Period 2	Period 3	Period 1	Period 2	Period 3	Period 1	Period 2	Period 3	Period 1	Period 2	Period 3
Rate of return [Pips]	–650	19200	2320	220	–9240	3100	–220	7300	2950	–37120	14390	–62560
Number of transactions	10	18	20	5	5	7	1	1	1	762	240	579
Gross profit [Pips]	2090	8840	2390	1580	1450	3580	0	7300	2950	900	5490	1070
Gross loss [Pips]	1800	–2030	–1090	1400	–1750	–1200	–220	0	0	1240	–3210	1000
Total profit [Pips]	1860	24850	4870	3200	1000	4850	0	0	0	2590	59010	4040
Number of profitable transactions	5	15	14	3	2	6	0	1	1	81	119	162
Number of profitable consecutive transaction	2	6	6	2	1	5	0	1	1	5	8	6
Number of unprofitable consecutive transaction	2	1	3	2	1	1	1	0	0	29	5	22
Sharpe ratio	–2,32	2,75	13,25	15,69	–1,02	3,14	0,00	0,00	0,00	–3906,32	1,18	–6809,58
Average coefficient of volatility [%]	2,80	69,73	1,75	0,14	90,70	9,87	0,00	0,00	0,00	1,10	120,15	9,90
Average rate of return per transaction	–65,00	1066,67	116,00	44,00	–1848,00	442,86	–220,00	7300,00	2950,00	–48,71	59,96	–39,62
Value of evaluation function (y)	0,32	0,69	0,33	0,12	0,31	0,41	0,11	0,34	0,38	0,01	0,08	0,30

Source: own elaboration.

values oscillate in the range from 0.01 to 0.69. Thus, despite large deviations in the values of particular ratios, the strategies are evaluated in the range of smaller value deviation. The results of the experiment allow us to state that the ranking of strategies' evaluation differs in particular periods. In the first period, the MyStrategy was the best strategy and the Consensus strategy was ranked higher than the B&H and EMA benchmark strategies. In the second period, the MyStrategy was ranked higher and the Consensus strategy was ranked lower than the B&H. The EMA benchmark strategies were ranked the lowest in this period. Considering the third period, it may be noticed that the evaluation ranking is similar to the one in the second period, where the Consensus was ranked higher and the MyStrategy was ranked lower than B&H. The EMA benchmark strategies were also ranked the lowest in this period.

Taking into consideration all the periods, it may be stated that the MyStrategy was ranked highest most often (2 out of 3 periods) although the Rate of Return of this strategy was not always the highest. The low level of risk is connected with investing on the basis of the Consensus and MyStrategy strategies. And, on the other hand, the EMA strategy was ranked low most often (3 out of 3 periods) because at a relatively high risk level it generated little Rate of Return. Moreover, it generated a high number of transactions, so transactions costs are very high. In addition, EMA characterized a high risk level and a large number of loss transactions in a row. In most cases, in the other systems (e.g. in the MetaTrader system), the evaluation analysis is done "manually" by the trader. Due to its time consumption, its utility in the systems operating in real time is very limited. Besides, these systems offer only the functions to compute the basic ratios (Rate of Return, number of transactions, highest profit, highest loss, total profit, number of profitable transactions, number of profitable transactions in a row, number of loss transactions in a row). In the a-Trader system also, additional ratios are calculated, such as the risk measures (Sharp ratio, average value coefficient), or the average rate of return on transaction.

The evaluation function, elaborated in this article, enables the measurement and the performance evaluation of designed strategies. These operations are made automatically, in time close to real time, by the Supervisor agent, which may then suggest to the trader a final strategy on the basis of the strategies with the highest level of performance. In addition, enabling the user to change a_i and x_i parameters of the evaluation function allows for considering his/her preferences concerning the importance of particular evaluation ratios. The evaluation value also considers the transaction costs, with the assumption that the dependency between the number of transactions and the average rate of return from the transactions is reflected. However, this simple principle cannot be adopted, because a large number of transactions have impact on the reduction of the strategy's efficiency level, especially for the transactions with a high rate of return.

The elaborated evaluation function may be extended by other ratios which do not have directly or (reversely) proportional impact on the function value. For example, this may be the correlation between the Rate of Return and the ratios defining the risk.

5. Conclusions

The strategies in the a-Trader system open/close independent long/short position use various methods for this purpose. The functioning of these strategies involves, however, the need to perform constant analysis of their performance, which should be performed by the Supervisor agent. As a consequence, this enables the investor to present a strategy provided by the best strategies. The analysis results presented in this article allow us to draw conclusions that, depending on the current situation on the FOREX market, the level of performance of particular strategies changes. There is no strategy which definitely dominates over the other ones. And the use of this performance evaluation function allows for automatic setting of the best strategy in time close to real time, which has, in turn, a positive influence on investment effectiveness.

Strategies based on artificial intelligence methods also function in the a-Trader system. Neural networks recognize the models or sequences of changes of agent signals, and on this basis they provide the strategies. Evolution algorithms are developed, which are able to calculate most effective combinations of agents over a few hundred seconds. Owing to this, they adjust to the variable situations dynamically. Intelligent methods will be described in the successive articles.

Currently, experiments are being performed on the implementation of the "directional change algorithm" [Glattfelder et al. 2011], the evolution method of determining a_i coefficients in the a-Trader system. The implementation of cognitive agents, performing the fundamental analysis strategies and strategies based on analyzing experts' opinions will be the main issues of our future research.

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PROJEKTOWANIE I OCENA STRATEGII INWESTYCYJNYCH W SYSTEMIE A-TRADER

Streszczenie: W artykule przedstawiono problematykę projektowania i oceny strategii inwestycyjnych w systemie wieloagentowym a-Trader. System ten umożliwia wspomaganie decyzji inwestycyjnych na rynku FOREX. W pierwszej części artykułu dokonano charakterystyki systemu a-Trader z punktu widzenia jego użytkownika. Następnie przedstawiono algorytmy wybranych strategii. W końcowej części opracowano funkcję oceny efektywności strategii, jak również zaprezentowano sposób przeprowadzenia oraz wyniki analizy tej efektywności.

Słowa kluczowe: systemy wieloagentowe, decyzje finansowe, FOREX, strategie inwestycyjne.