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EXPERIMENTAL APPROBATION OF IMPROVED AUTOMATED DECISION SUPPORT SYSTEM ON THE EXAMPLE OF THE FUNDAMENTAL ANALYSIS OF EXCHANGE MARKET TRADE

This paper examines the use of controlled information flow discipline when making decisions at the Foreign Exchange Market. The most effective use of the information value and aging performances makes it possible to apply such disciplines that would minimize the number of messages that become stale before delivery to the user in the conditions of minimum system resources. The author suggests the methods for improving the discipline. Computer simulation proved the feasibility and outlined the conditions of applicability of the proposed methods.

Key words: Forex, information flow discipline, adequacy of the mathematical model, value of information.

Problem statement. At present, the activity of the Foreign Exchange Market attracts the attention of a significant number of people. Advertising promotes the involvement of ordinary citizens in the ranks of exchange trade. Currency trading at the exchange market allows them to combine this type of earnings with the main place of work. It is not necessary to be present at the exchange market itself. The traders need simply to install specialized software on their computer, tablet or mobile phone. The so-called "platforms for transactions" are software products written by third-party organizations. The software complex, before its operation, is certified by the exchange market.

One of the important functions of the software package of a trader is the receipt and display of information messages in real time. The trader himself develops a strategy of behavior in the market and, depending on the information obtained, closes deals.

Analysis of recent research and publications. There are many methods for processing and analyzing information flows. Modern traders actively use technical and fundamental analyzes [1]. Technical analysis determines the product price, the

stock price or the currency rate based on demand and supply, while fundamental (factorial) analysis considers macro and microeconomic indicators. The complexity of processing a multitude of incoming messages narrows the circle of traders who use fundamental analysis.

The change in the ratio of quotations of currencies to each other often depends on external disturbances and is weakly formalized [2]. The trader monitors the fluctuations of the selected series of data in real time. Software capabilities, as a rule, allow partially automating the trade. Setting the terms of purchase and sale, the trader gives the program the right to independently carry out transactions. The software includes the ability to expand its functionality by adding modules developed in the internal programming language. With their help, it is possible to implement more complex conditions for the execution of transactions, allowing implementing a trading strategy in practice.

In addition to technical analysis, an experienced trader analyzes events and so-called "indicators" of fundamental analysis [2]. It should be noted that the set of indicators varies for continents and even countries. The trader analyzes the indicators of the countries of those currencies that are involved in its portfolio. For example, working with the euro, you have to analyze the performance of Germany, France, Britain, Italy, Switzerland and the Eurozone.

Not only the events themselves but also expectations thereof are the factors affecting the exchange rate [1]. Given the pre-known time of future important events in the life of states and the availability of statistical data, market participants have time to prepare. In anticipation of the event, the values of the indicators and the possible impact on the exchange rate are forecasted.

Traders follow the macroeconomic news, which are available to all market participants at the same time. For ordinary participants, it is much more important how the news will be perceived by the majority of participants. To do this, they monitor the so-called indicators, which allow them to determine the general trend in the price of currencies.

The most important indicators are: internal gross product, balance of payments deficit, employment and inflation indicators. The less important ones include: industrial output, capacity utilization, exchange rates on futures, stock indices, bank deposit rates, retail sales figures, housing market [3].

At the time of publication, the absolute value of a particular indicator is not as important, as its relative deviation from the forecast value. The reaction of market participants may not coincide with the forecasts. The importance of a particular indicator is also subject to change. The definition of the significance of a particular fundamental factor at the current time is included in the strategy of the trading member of the exchange market.

Forex market trader uses a "news calendar" for work, in which the occurred events are reflected in real time. For qualitative events, the experts of research units indicate the degree of importance, for quantitative ones - in addition their previous and forecast values. The degree of importance of the event is a subjective evaluation of the expert and is rather arbitrary. Currently, the experts classify the event importance by just three levels of gradation. For an individual trader, an event can act as a factor of fundamental analysis, and not be such. An event with its "importance" may not be relevant, i. e. may not have value for a particular trader of the Forex market. Thus, a separate trader needs to constantly update the values of regular events, rank the random ones, monitor the event impact duration. The constantly changing situation forces traders to organize the collection and processing of many events taking into account the value and aging of information.

The purpose of the fundamental analysis of Forex is to study the price movement of currency pairs at the macroeconomic level and, proceeding from the currency pair, to assess the state of the economy of the selected country. The trader, on the basis of fundamental analysis, creates trading strategy models. These models use series of data to predict market behavior and future prices. For a single country and, as a consequence, its national currency, there are about fifty fundamental indicators and each indicator has its own causal relationship. Being unable to control everything, a trader chooses several indicators, in his opinion, the most important. At the same time, there is a risk of missing the objectively significant ones.

It is worth noting that although the news is scheduled to be published at a specific time, there are small deviations - time delays or advance. When creating decision support systems, this fact should be taken into account.

The right strategy, using a combination of fundamental and technical analysis, can build a rational decision-making system. This combination will reduce the risk of decision-making. One form of combination may be the initial definition of a strategic direction through fundamental analysis and the subsequent decision-making based on technical analysis.

Formulation of aims of article. The data processing computing systems operate with information flows of different intensity and it is necessary to solve the question of the order of processing of messages contained in them. In this case, the data flow discipline is applied. The most effective use of the information value and aging characteristics makes it possible to apply such disciplines that would, under the conditions of minimal system resources, prevent from loss of messages during processing and minimize the number of messages that become stale before delivery to the user.

For the processing of information messages that enter the system, it is suggested to use the service discipline [4]. The merits of this discipline include its

ability to establish a link among the information value and aging characteristics. However, the information processing methods under consideration are convenient for the organization of rational information processing in the systems whose input data flows are determined. During practical implementation of the managed data flow discipline, in some cases there are deviations in the values of the wait time function $W_i(t)$, calculated using the model, from the values obtained in practice. To improve the adequacy of the mathematical model of the information flow discipline under consideration, there are proposed methods for preliminary reforming of input information flows. As a result of using the methods of information flow sifting and superposition, the variance of input flows will be reduced. The information flows generated in this way have parameters different from those of the initial information flows, as a result of which the characteristics of message processing change. Reformed information flows add to the load of the system, placing it in more stringent working conditions. Increasing of the load on the message processing system is achieved by reducing downtime.

The study of the application effectiveness of the proposed methods includes information processing modeling in accordance with the controlled discipline and is carried out by the simulation method using the simplest flow. The input information flow is formed by generating intervals between the message reception times according to the exponential distribution. Modeling of the information processing system occurs at different values of the input information flow intensity.

Presenting of the main material. The modeling of the computer system behavior using the proposed methods for the formation of input information flows resulted in determining the usability conditions for these methods.

In particular, the method of superposition of information flows under the condition of low message intensity always results in a smaller total variance of the reformed information flows compared to the total variance of the initial flows. As the intensity of messages grows, the total variance of the reformed information flows increases and exceeds the total variance of the initial flows.

The method of information flow sifting has shown its effectiveness for any input conditions of the functioning of the computer system. Its application does not depend on the number of message flows in the system at the current time and the intensity of the flows themselves. The information flows reformed with its help almost always have a lower total variance compared to the total variance of the initial information flows.

The second part of the experiment presents the analysis of the computer system functioning:

- with uniform minimum quantization of message queue processing time;

● with uniform extensive increase in the quantization of message queue processing time;

● with controlled change in the quantization of message queue processing time.

Analysis of the computer system functioning with uniform extensive increase in the quantization of message queue processing time allows us to show inefficiency due to insufficient quantization of loaded queues. To test the assumption, we simulated the operation of the computer system in the intensity range of the input information flows from 0 to 500 messages per time unit with step of 5.

Each queue is assigned with one quantum, modeling is carried out in the indicated intensity range, the performance figures are calculated. Simulation is repeated for two quanta, then for three quanta with the calculation of the computer system performances. In the course of the experiment, the performances of the computer system for the initial, sifted and superimposed flows are compared.

As an additional means of improving the functioning of the computer system in general and increasing the adequacy of the mathematical model of the service discipline, an adaptive control of the quantization vector $\overline{T}_k$ is proposed. The meaning of the method is the redistribution of quanta between individual message queues, i.e. in the controlled change in quantization of the message queue processing time. More loaded queues are assigned with more processing quanta. The values of the vector $\overline{T}_k$ are given by the method of factorization to the minimum multiplier. Then the queues with small values of the processing time vector $\overline{B}_i$ receive more quanta. Within the study of the computing system behavior, the method provides once redistributed processing time quanta for the entire time interval. If necessary, the vector $\overline{T}_k$ can be recalculated in real time, because it does not require large computational resources.

For the variant of superimposed information flows, the adaptive control method for vector $\overline{T}_k$ is not considered because of a small sample of admissible variants according to the condition of the total variance of the newly generated information flows.

In the course of the experiment, the following characteristics and statistical measures are calculated:

1. Total deviations of the wait time function $W_i(t)$;

2. Total downtime of the computing system;

3. Variation coefficient in range of the wait time function $W_i(t)$;

4. Percentage ratio of $W_i(t)$ in the confidence interval;

5. Maximum queue length C_i;

6. Approximation of the message processing time of the i-*th* queue to the value of the threshold processing time T_{thresh_i}.

The performance "Total deviations of the wait time function $W_i(t)$" is calculated as the sum of the ratio of the difference in the wait time function $W_i(t)$, calculated according to the mathematical model D1, and the values $W_i(t)^*$ of the analytical model to the value $W_i(t)^*$ of the analytical model:

$$\sum_{i=1}^{n} \frac{W_i(t) - W_i(t)^*}{W_i(t)^*} \quad (1)$$

It allows to estimate the accuracy of the determination of the wait time function according to the mathematical model D1 and to determine the efficiency of the considered methods for the formation of input information flows.

The performance "Total downtime of the computing system" is calculated as the sum of the idle times for a fixed time interval for all message queues.

The performance "Variation coefficient in range of the wait time function $W_i(t)$" is defined as the difference between the maximum and minimum values of the wait time function $W_i(t)$ of the model D1, referred to the average value of the wait time function of the i-*th* queue. Then the maximum value among the values for all queues is calculated:

$$\max \frac{\max W_i(t) - \min W_i(t)}{\overline{W_i(t)}} \quad (2)$$

The performance "Percentage ratio of $W_i(t)$ in the confidence interval". The confidence interval is calculated and the number of $W_i(t)$ values that fall within its boundaries is counted. Then the percentage of the calculated value is taken to the total number of messages in the computing system for a fixed period of time.

The performance "Maximum queue length C_i". Analysis of the performance gives an idea of the presence in the computing system of the queue or queues, in which the accumulation of messages occurs. It indicates the insufficiently rational distribution of quanta over a given time interval.

The performance "Approximation of the message processing time of the i-*th* queue to the value of the threshold processing time T_{thresh_i}". With the help of this performance, it is possible to calculate the degree of approximation of the model to the "ideal state", when the processing time of an individual message approaches the value of the threshold processing time. It is calculated as the sum of the difference between the values $W_i(t)$ and T_{thresh_i} of each message for all queues at a fixed time interval of the system operation. It should be noted that the performance has a negative value and reaches zero in the "ideal" state. Thus, analyzing the value of the

performance, one can judge the underload of the computing system (performance value modulus growth) or the rational loading of the system (values close to zero).

In the second part of the experiment, the following sequence is assumed:

● generation of intervals for reception of messages of the total flow with a given intensity, calculation of the variance of the total message flow;

● distribution of messages in the queue by the threshold processing time criterion, calculation of the variance of each information flow;

● simulation of the behavior of the computer system in accordance with the controlled discipline D1 and analytical calculation of the system behavior on real, non-averaged data;

● calculation of the six performances indicated above;

The sequence of actions is repeated in a cycle for greater intensity of the input information flows in the above-mentioned range.

Conclusions and recommendations for further research. The experiment resulted in the collection of significant amount of statistical information. Below there are the results of its processing, in particular, the averaged values of the performances studied. Average features of the functioning of computer system with initial information flows (table 1), sifted information flows (table 2) and superimposed information flows (table 3) were obtained as a result of 100 simulations of the computer system functioning in the intensity interval from 0 to 500 with a step of 5 of the total information flow.

Table 1

Average features of the functioning of computer system with initial information flows

Perfor-mance	Performance parameters	1 quantum	2 quanta	3 quanta	Controlled quantization vector
1	Total deviation	157.85	175.07	175.72	162.93
	Negative deviation	129.93	128.24	131.92	118.96
	Positive deviation	27.92	46.83	43.80	43.97
2	Analytical calculation	1.39	5.07	5.08	4.06
	D1	0.30	9.45	8.58	9.60
3	MAX variation coeff. in range Wi	2.33	2.08	2.24	2.38
4	Number of Wi in confid. Interval,%	30.38	31.83	28.64	24.71
5	Max queue length Ci-Anal.	3.03	3.03	3.01	3.02
	Max queue length Ci-D1	1.09	1.12	1.12	1.12
6	Approximation to $T_{threshold}$	-148511.96	-102346.36	-103933.33	-104569.14

Table 2

Averaged features of the functioning of computer system with sifted information flows

Perfor-mance	Performance parameters	1 quantum	2 quanta	3 quanta	Controlled quantization vector
1	Total deviation	221.33	358.96	375.13	98.67
	Negative deviation	187.14	1.53	0.00	1.77
	Positive deviation	34.19	357.43	375.13	96.90
2	Analytical calculation	7.36	0.00	0.00	0.00
	D1	32.88	29.81	30.40	24.74
3	MAX variation coeff. in range Wi	3.10	2.51	3.30	2.51
4	Number of Wi in confid. interval,%	26.99	24.70	27.16	15.79
5	Max queue length Ci-Anal.	4.09	29.50	37.93	54.96
	Max queue length Ci-D1	5.61	6.24	6.51	81.77
6	Approximation to $T_{threshold}$	-434502.95	-419710.30	-468232.93	-150297.29

Table 3

Average features of the functioning of computer system with superimposed information flows

Perfor-mance	Performance parameters	1 quantum	2 quanta	3 quanta	Controlled quantization vector
1	Total deviation	181.02	176.17	180.40	-
	Negative deviation	137.76	132.59	136.72	-
	Positive deviation	43.26	43.58	43.68	-
2	Analytical calculation	26.02	27.45	27.27	-
	D1	41.72	43.84	44.03	-
3	MAX variation coeff. in range Wi	3.98	4.00	4.95	-
4	Number of Wi in confid. Interval,%	25.42	28.22	27.18	-
5	Max queue length Ci-Anal.	39.92	39.48	39.82	-
	Max queue length Ci-D1	39.30	38.85	39.18	-
6	Approximation to $T_{threshold}$	-455521.04	-448520.00	-448695.68	-

In practice, the disturbance factors lead to a mismatch in the performance parameters, and as a result, to downtime in the computer system operation. Improved discipline of information flow helps to reduce such downtime. The results of

modeling prove that methods of preliminary formation of input information flows in most cases provide for increased efficiency of the computing system functioning. The application of the method of information flow sifting together with the controlled processing time quantization vector ensure an increase in the adequacy of the controlled discipline D1.

The economic effect of applying the improved discipline will be higher due to the smaller values of the loss cost function.

The practical value of the results obtained is expressed in:

- Increased adequacy of the mathematical model of the information flow discipline;
- Wider range of tasks for application;
- Improved loading performance of the computing system inherent in its design;
- Reduced capital and operating costs for a set of technical means.

Thus, to the previously considered areas of application of the controlled discipline [5-7], there was carried out approbation of the methods developed by the author for improving the information flow discipline, taking into account the value and information aging performances with reference to the fundamental analysis of exchange market trade.

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Експериментальна апробація вдосконаленої автоматизованої системи підтримки прийняття рішень на прикладі фундаментального аналізу торгівлі на валютній біржі

В роботі розглянуто застосування керованої дисципліни обслуговування інформаційних потоків при прийнятті рішень на валютній біржі Forex. При найбільш ефективному використанні характеристик цінності і старіння інформації стає можливим застосування таких дисциплін обслуговування, які б в умовах мінімально витрачених ресурсів системи зводили до мінімуму кількість повідомлень, застарілих до видачі користувачу. Запропоновано методи вдосконалення дисципліни обслуговування. За допомогою комп'ютерного моделювання доведена доцільність та визначено умови застосування запропонованих методів.

Ключові слова: Forex, дисципліна обслуговування інформаційних потоків, адекватність математичної моделі, цінність інформації.

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Экспериментальная апробация усовершенствованной автоматизированной системы поддержки принятия решений на примере фундаментального анализа торговли на валютной бирже

В работе рассмотрено применение управляемой дисциплины обслуживания информационных потоков при принятии решений на валютной бирже Forex. При наиболее эффективном использовании характеристик ценности и старения информации становится возможным применение таких дисциплин обслуживания, которые бы в условиях минимально затрачиваемых ресурсов системы сводили к минимуму количество сообщений, устаревающих до выдачи пользователю. Предложены методы совершенствования дисциплины обслуживания. С помощью компьютерного моделирования доказана целесообразность и определены условия применимости предложенных методов.

Ключевые слова: Forex, дисциплина обслуживания информационных потоков, адекватность математической модели, ценность информации.