

ISSN 2518-1483 (Online),  
ISSN 2224-5227 (Print)

2017 • 5

ҚАЗАҚСТАН РЕСПУБЛИКАСЫ  
ҰЛТТЫҚ ҒЫЛЫМ АКАДЕМИЯСЫНЫҢ

## БАЯНДАМАЛАРЫ

## ДОКЛАДЫ

НАЦИОНАЛЬНОЙ АКАДЕМИИ НАУК  
РЕСПУБЛИКИ КАЗАХСТАН

## REPORTS

OF THE NATIONAL ACADEMY OF SCIENCES  
OF THE REPUBLIC OF KAZAKHSTAN

ЖУРНАЛ 1944 ЖЫЛДАН ШЫҒА БАСТАҒАН  
ЖУРНАЛ ИЗДАЕТСЯ С 1944 г.  
PUBLISHED SINCE 1944



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«Қазақстан Республикасы Ұлттық ғылым академиясының баяндамалары»

ISSN 2518-1483 (Online),

ISSN 2224-5227 (Print)

Меншіктенуші: «Қазақстан Республикасының Ұлттық ғылым академиясы» Республикалық қоғамдық бірлестігі (Алматы қ.)  
Қазақстан республикасының Мәдениет пен ақпарат министрлігінің Ақпарат және мұрағат комитетінде 01.06.2006 ж.  
берілген №5540-Ж мерзімдік басылым тіркеуіне қойылу туралы куәлік

Мерзімділігі: жылына 6 рет.

Тиражы: 2000 дана.

Редакцияның мекенжайы: 050010, Алматы қ., Шевченко көш., 28, 219 бөл., 220, тел.: 272-13-19, 272-13-18,  
<http://nauka-nanrk.kz>, [reports-science.kz](http://reports-science.kz)

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Типографияның мекенжайы: «Аруна» ЖК, Алматы қ., Муратбаева көш., 75.

Главный редактор  
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Доклады Национальной академии наук Республики Казахстан»

ISSN 2518-1483 (Online),

ISSN 2224-5227 (Print)

Собственник: Республиканское общественное объединение «Национальная академия наук Республики Казахстан» (г. Алматы)

Свидетельство о постановке на учет периодического печатного издания в Комитете информации и архивов Министерства культуры и информации Республики Казахстан №5540-Ж, выданное 01.06.2006 г.

Периодичность: 6 раз в год.

Тираж: 2000 экземпляров

Адрес редакции: 050010, г.Алматы, ул.Шевченко, 28, ком.218-220, тел. 272-13-19, 272-13-18

<http://nauka-nanrk.kz> [reports-science.kz](http://reports-science.kz)

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Owner: RPA "National Academy of Sciences of the Republic of Kazakhstan" (Almaty)

The certificate of registration of a periodic printed publication in the Committee of Information and Archives of the Ministry of Culture and Information of the Republic of Kazakhstan N 5540-Ж, issued 01.06.2006

Periodicity: 6 times a year

Circulation: 2000 copies

Editorial address: 28, Shevchenko str., of.219-220, Almaty, 050010, tel. 272-13-19, 272-13-18,

<http://nauka-nanrk.kz> / [reports-science.kz](http://reports-science.kz)

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Address of printing house: ST "Aruna", 75, Muratbayev str, Almaty

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## **MULTI-AGENT BASED DISTRIBUTED INFORMATION SYSTEM OF INVESTMENT DECISIONS SUPPORT**

**Abstract.** Decision making in unstable economic condition is a challenge and requires new approaches and methods of information proceeding. The information system described in the paper aims to provide new tools of decision-making to small and middle business. These tools are based on the analysis of information from open Internet sources. Multi-agent based architecture is the most appropriate for such a kind of information systems. Multi-agent system paradigm includes a huge variety of approaches and technologies some of which are analyzed in the paper.

**Key words:** multi agent information system, investment analysis, decision making.

### **1. Introduction**

A multi-agent system (MAS) is a system formed by several interacting intellectual agents [1]. In 1975 the actor concept was described [2], which is considered to be the first attempt of creation of MAS-based decision support systems.

The paradigm of multi-agent architecture arose in the late 1990s, when the MASs were separated into an independent class, combining research in the field of distributed artificial intelligence [3-5]. In 1999 the modern concept, taking into account types of agents' tasks and the peculiarities of the environment where agents operate, has been defined and the first software framework for DSS has been described [6]. Besides, in the same year the term "multi-agent decision support" was introduced [7].

Today, MAS has received significant development and is used in such areas as Knowledge Mining [8], Natural Language Processing (NLP) [9], Natural systems modeling [10] and others. As a basic of DSS, MAS has been implemented in transportation management [11] and medicine [12].

Architecture is an essential component of MAS and should be consistent with its objectives. The architecture defines the principles of interaction and the structure of agents, the direction of information flows, the format of messages, etc. So at the first stage of the MAS development it is necessary to carefully evaluate all the advantages and disadvantages of various architectural solutions [13].

Under the intelligent agent in this case, we mean a program that independently performs the task specified by the user, for long periods of time. In our case, these are intelligent tracking agents that perform database monitoring and ensure the actualization of data and mathematical models.

### **2. Related work**

The comparative analysis of multi-agent architectures has been done for choosing a platform for developing a distributed information system of investment decisions support.

To date, a large number of different multi-agent architectures have been developed; among them the following groups can be distinguished: flat and hierarchical architectures, architectures with a management center and distributed, closed and open operating in an environment with high and low uncertainty, etc. In general, the flexibility and stability of a multi-agent system are mutually exclusive concepts. That is, to achieve the greatest flexibility of the system, to allow the dynamic addition of new agents, it is necessary to complicate the mechanisms of interaction, which naturally leads to a decrease in the reliability and stability of the system.

Among all the variety of architectures designed to implement the multi-agent approach, we will

consider only those that are recommended for decision support systems.

### 2.1 IMAP

IMAP architecture (Architecture for Intelligent Multi-Agents Paradigm) has been designed to create MAS that operates within a corporate network [14]. It consists of the following agents: Contractor's Agent-Interface, Client Agent-Agent, Agent-Coordinator, Agent-Report, Database Agent. These agents form three modules: Interface module, Processing module and Data module. The interface module interacts with users and other MAS agents. Users can not directly access the Processing Module and the Data Module if they do not have system administrator rights. This architecture is designed to operate in a closed environment without uncertainties. It does not have the ability to interact with the Internet.

### 2.1 A OCD

The abbreviation of the name stands for "Agent-Based Open Connectivity for Decision support systems" [15].

The peculiarity of this architecture is the presence of a unique component of the system - the Matrix, external agents can be connected dynamically, this does not require changing the structure of the system. In this architecture, the DSS is divided into subsystems, each of which is represented by at least one agent. The matrix is the central controlling element, which ensures the interaction of agents. The structure of the Matrix is standardized and does not depend on the development tools used. External agents are recognized by the Matrix after connecting to the system.

The A OCD architecture is a hybrid of centralized and decentralized MAS topologies. A similar hybrid topology is represented by Nelson Minar [16]. In this topology, agents are partially interconnected. In A OCD, each agent can connect directly to another agent, however, it is often not feasible to maintain such a connection, therefore, in A OCD, such connections are established upon request, and after its execution cease to exist. The agent interaction language is based on the FIPA model [17], but it has its own peculiarities. This architecture is called "hybrid" because it has a single processing center, but at the same time, agents are connected. However, in fact, agents are not able to interact independently and transmit information directly to the user. Consequently, if the interaction center - the Matrix fails, the system will be completely inoperative.

### 2.2 RETSINA

RETSINA (Reusable Task Structure based Intelligent Network Agents) [18] is a multi-agent infrastructure designed to gather information from various Internet resources and support decision-making. RETSINA includes a distributed MAS architecture, agent interaction protocols, and a set of agent creation software.

The infrastructure consists of 3 types of agents. Interface-Agents interact with the user, receiving tasks and sending the result of work. Agents-Executors provide execution of tasks by drawing up a plan for solving the problem and its execution. Informant agents provide intelligent access to heterogeneous information on the Internet. Tasks that cannot be executed by a single agent are performed by an agent team that is generated on the basis of a request.

In an open MAS, agents should be able to find each other. In such systems, distributed on the Internet, where agents can be dynamically connected and disconnected, broadcast-based communication is used. In RETSINA, it is implemented with the help of special Agents-Mediators.

Thus, the RETSINA infrastructure allows the creation of flexible, dynamic MAS with a flat organization operating in an open environment. It provides code reuse, stability and asynchronous agents. However, it requires code redundancy. This is an unavoidable price for the ability to adapt to a changing external and internal environment.

## 3. Information system of investment decisions support

### 3.1 The aim and services

The information system is aimed to suggest new investment analysis tools for small and middle business enterprises. Today investment analysis doesn't allow to take into account great amount of information about internal and external environment. Thus the objectives of the IS are as following: find the information resources, develop the methods of the information proceeding and provide them to the final users, investors and decision makers.

The first method has been developed based on the analysis of the unique database containing the information about investment projects implemented in Kazakhstan. The database is an Excel table with the following columns: “Sum”, “Start Date”, “Finish Date”, “Economic branch”, “Region” and “Problems arisen” (Figure 1).

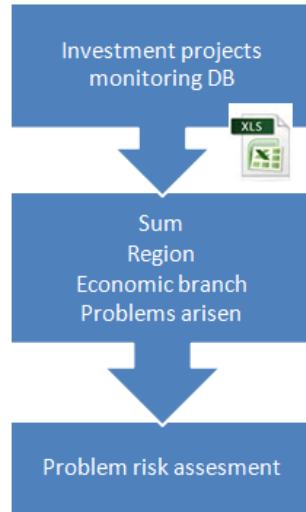


Figure 1 – Data source for the method of risk assesment

Despite the fact that DB contains limited number of projects we succeeded to create the mathematical models of high quality for risk assessment. This is described in details in the previous publication [19].

Another method has been developed based on the analysis of official statistical data of the Republic of Kazakhstan and the Russian Federation. The aim of the method was to create a tool for comparative assessment of the regions. Statistical data are stored in different formats and actualized in different periods of time, so the main goal was to define corresponding statistical indexes and harmonize their updates (Figure 2).

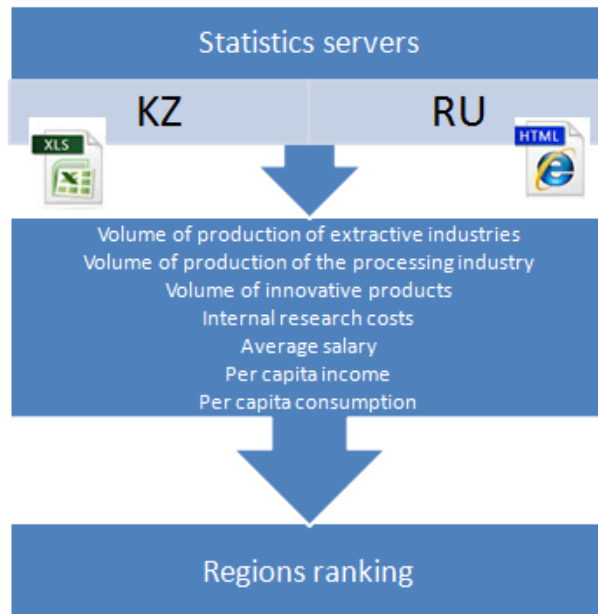


Figure 2 – Data sources for the method of regions ranking

As a result new tools of investment analysis allowing to take into account internal and external factors have been created.

3.2 The architecture and the potential for its expansion

First of all, it is necessary to determine the environment of IS functioning, since the complexity of the architecture and communication protocols depend on this. Besides the important question is whether it is necessary to implement the possibility of dynamic connection of agents.

The operating environment of the planned IS is supposed to be open, because it monitors Internet resources such as statistical servers and monitoring databases. However, the level of uncertainty in this environment is low. Basically, a change in the environment can occur due to the termination of access or change of information resources location. However, this is not the reason for creating special agents to search new sources, because, firstly, such situations arise infrequently, and secondly, access to information sources due to the specifics of their updates occurs no more than once a year. Therefore, in the abnormal situation it is enough for agents to inform the expert about it, and let finding new sources to service specialists. They are only able to assess whether new information resources correspond to the needs of the system, as well as ensure the correspondence of data format.

Taking all this facts into account, it is possible to create an architecture based on IMAP architecture, adding a module for Internet interaction.

Since there is no need for centralized data processing, it is proposed to use a flat architecture without a single processing center, besides the proposed architecture has 2 types of interfaces (Figure 3): the Client for final users and the Expert for service specialists. These specialists must be able to evaluate the predictive accuracy of risk assessment models retrained and check whether the updated ranking contains gross inconsistencies caused by possible data transfer and processing errors.

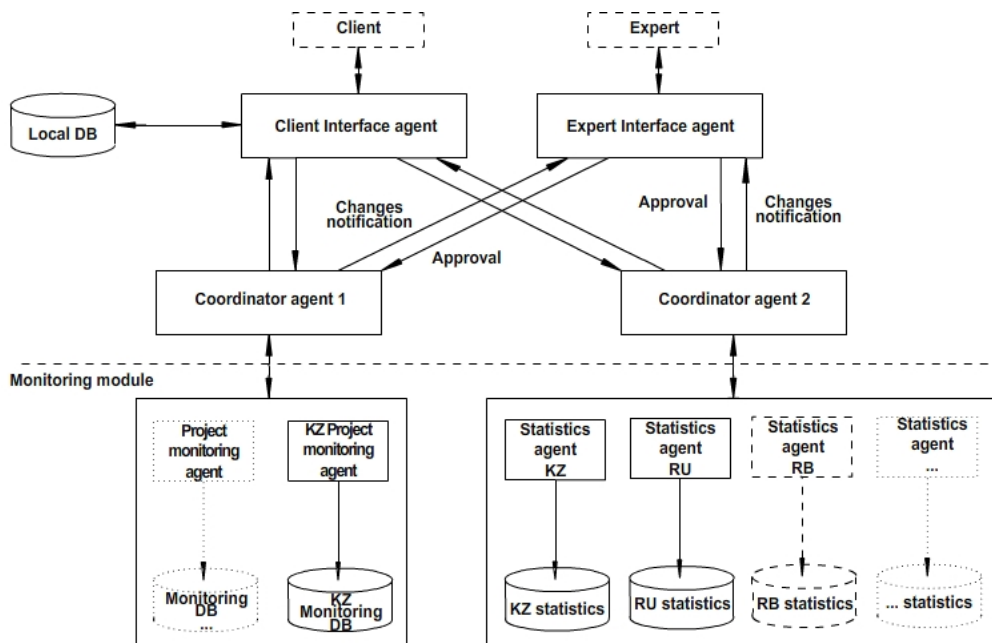


Figure 3 - Multi-agent architecture of IS

The IS architecture is not open, because it does not allow a dynamic connection of new agents without restarting the system. However, the addition of new agents is inevitable. The Monitoring module that provides IS interaction with Internet resources is highlighted in Figure 3. The Monitoring module consists of two groups of agents. However, this division is nominal and corresponds to the types of monitored information sources. Accordingly, Statistics Agents monitor the changes in the statistical information available on the official websites of the Statistics Agencies of the Eurasian Economic Union participants. Project Monitoring Agents track changes in the investment projects monitoring databases. Today the following information sources are identified: official statistics servers of the Republic of Kazakhstan and the Russian Federation and the database, monitoring the implementation of investment projects in the Republic of Kazakhstan. However, new monitoring agents can be created in order to



calculate ranking of the other countries' regions. These countries are other participants of the Eurasian Economic Union. According to EAEU legislation businessmen can operate in every country of the Union without limitations, so it is important to have an opportunity to compare conditions in regions of different countries. Dotted lines in figure 3 mark potential monitoring agents for statistics servers as well as databases monitoring the implementation of investment projects in other countries, although today such a database exists only in the Republic of Kazakhstan. It is clear that such geopolitical and organizational changes do not occur often. Therefore restarts of IS, necessary to add new agents, cannot impair its performance substantially, while providing the ability to dynamically add agents lead to unnecessary complication of the architecture.

The next level is composed of two Coordinator Agents. They process the information obtained from the monitoring agents, i.e. calculate the regional ranking and retrain risk assessment models. At this level, it is also possible to add new agents that implement some new functions. New Coordinator Agents may use the information obtained from existing monitoring agents, since the interaction occurs through broadcasting.

The Interface level is presented by two types of agents: Client Interface and Expert Interface. The possibility of adding new agents at this level is low. Interface Agents provide the users with access to the IS services. In addition, the Client Agent interface provides a connection to the local database, which stores information about registered users, projects analyzed, etc.

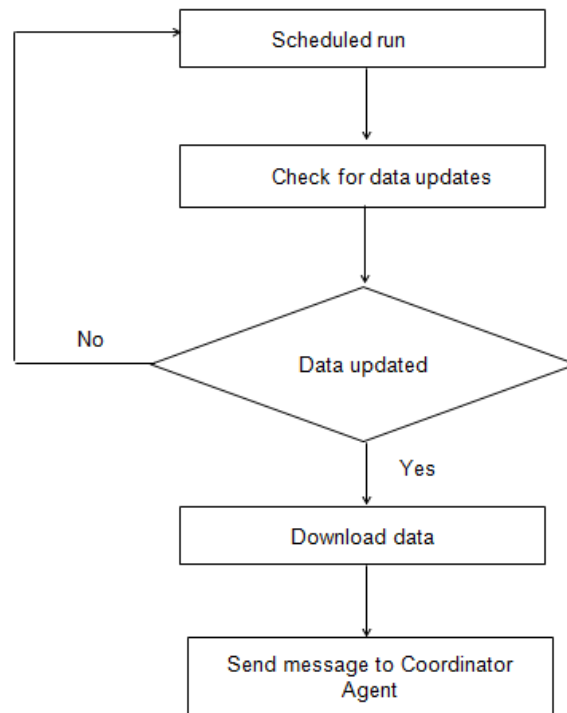


Figure 4 - General algorithm of Monitoring Agent

Figure 4 shows a flowchart of monitoring agent's actions. Setting a schedule is made depending on the frequency of changes in the observed data. It is known that the statistical information is updated once a year and the new statistics become available in a few months after the beginning of the year, thus the agent should be run in April or May, setting a weekly expectant interval if new data is still not available until you can get the updated information. On the other hand the frequency of updating the database of investment projects monitoring is unknown. Therefore it is enough to run agent once a month.

Coordinator agents collect data from corresponding monitoring agents and then produce the programmed calculations (Figure 5). They need to make sure that all the required data are updated, because the regions ranking, for example, obviously is not relevant if the statistics in Kazakhstan are taken in the current year and in Russia in the past year.

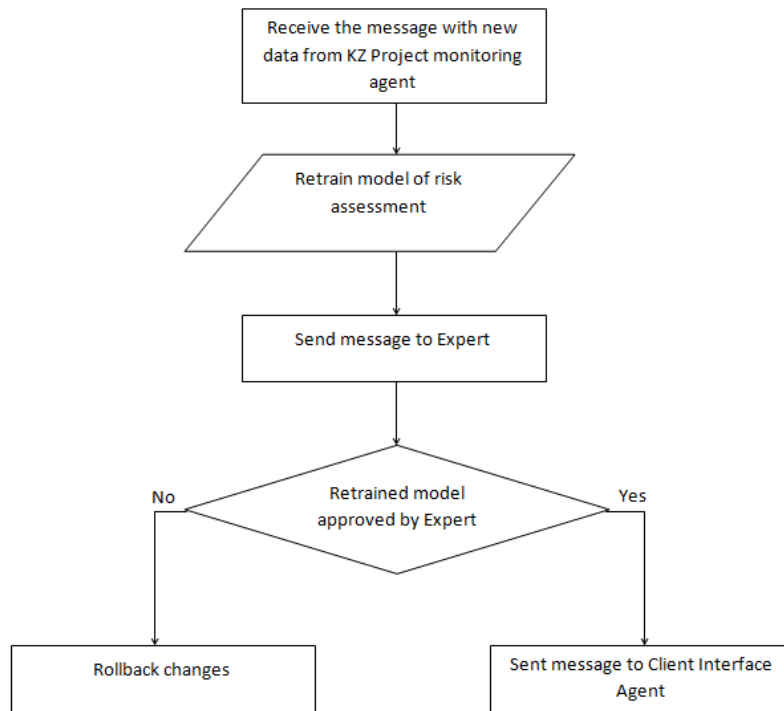


Figure 5 - General Algorithm of Coordinator Agent

The calculation results are transferred to the Expert Interface Agent. If the Expert approves updating retrained models and new ranking become available to the final IS users. Otherwise the new data is blocked pending resolution of problems from IS Administrators and Client Interface Agent continues to work with the old data.

### 3.3 The software used

A mechanism of interaction of software components has been developed to implement the proposed architecture. The scheme is presented in Figure 6.

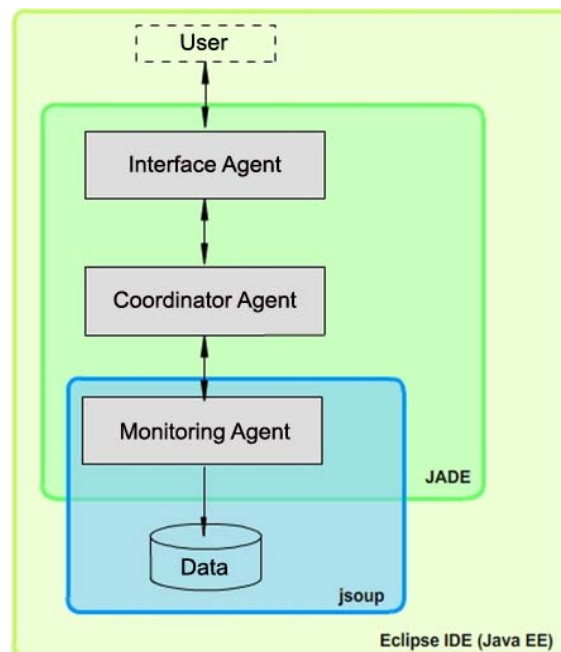


Figure 6 - Scheme software interaction

Below is a short description of the software technologies and applications used.

As the development environment IDE Eclipse has been chosen. Eclipse is an integrated development environment with open source software. The main language of Eclipse software is the Java, however, a variety of plug-ins allow to use other programming languages: Ada, ABAP, C, C ++, COBOL, Fortran, Haskell, JavaScript, Lasso, Natural, Perl, PHP, Prolog, Python, R, Ruby, Scala, Clojure, Groovy, Scheme, Erlang.

For the organization of agent-based interaction JADE technology is used. JADE is a software suite for the development of multi-agent applications, based on the FIPA specifications [20]. FIPA specification defines the language of agents' interaction, the key agents required to manage the system, ontology interoperability and transport layer protocols.

Jsoup is a Java library designed to work with HTML. It provides a convenient API functions to retrieve and manipulate web page data. Jsoup is based on HTML5 specification and performs parsing, using the same document object model that modern browsers.

#### 4. Conclusion and future work

There are a number of MAS architectural solutions designed for the implementation of decision support systems. Developing MAS architecture we must take into account the environment, since the increase of adaptability and openness leads to a complication of communication agents.

IMAP based architecture satisfying the requirements of the information system, operating in an open environment, but does not allow a dynamic connection of new agents.

The software communication scheme of the IS is based on the IDE Eclipse, using JADE platform of agents' interaction and Jsoup library for working with HTML.

One of the future work directions has been mentioned above and supposes searching for new sources of information and developing of new investment analysis methods on their basis. Besides regions of other EAEU participants should be added to the regions ranking.

Other important objective is dissemination of the information for the potential users' awareness about possibilities and advantages of the IS.

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### **ИНВЕСТИЦИЈАЛЫҚ ШЕШІМДЕРДІ ҚОЛДАУДЫҢ ТАРАЛҒАН КӨПАГЕНТТІ АҚПАРАТТЫҚ ЖҮЙЕСІ**

**Аннотация.** Тұрақсыз экономикалық жағдайда инвестициялық шешімдерді қабылдау ақпаратты өңдеудің жана тәсілдемелері мен әдістерін ойластыруды талап етеді. Мақалада кіші және орта бизнес үшін инвестициялық талдаудың жана құралдарын беретін ақпараттық жүйе қарастырылған. Мұндай ақпараттық жүйелер үшін ең оңтайлысы көпагентті тәсілдеме болып табылады. Көпагентті жүйелер парадигмасы тәсілдемелер мен технологиялардың сан алуан түрлерін құрайды, солардың кейбіреулері мақалада қарастырылған.

**Түйін сөздер:** көпагентті ақпараттық жүйе, ақпараттық жүйе, инвестициялық талдау, шешімдер қабылдау.

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### **РАСПРЕДЕЛЕННАЯ МНОГОАГЕНТНАЯ ИНФОРМАЦИОННАЯ СИСТЕМА ПОДДЕРЖКИ ИНВЕСТИЦИОННЫХ РЕШЕНИЙ**

**Анотация.** Принятие инвестиционных решений в неустойчивой экономической ситуации требует разработки новых подходов и методов обработки информации. В статье рассмотрена информационная система, предоставляющая новые инструменты инвестиционного анализа для малого и среднего бизнеса. В основе данных инструментов лежит анализ информации из открытых источников в интернете. Многоагентный подход является наиболее предпочтительным для подобных информационных систем. Парадигма многоагентных систем включает большое разнообразие подходов и технологий, некоторые из которых проанализированы в статье.

**Ключевые слова:** многоагентная информационная система, инвестиционный анализ, принятие решений.

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**ISSN 2518-1483 (Online), ISSN 2224-5227 (Print)**

<http://www.reports-science.kz/index.php/ru/>

Редакторы *М. С. Ахметова, Д. С. Аленов*  
Верстка на компьютере *А.М. Кульгинбаевой*

Подписано в печать 13.10.2017.  
Формат 60x881/8. Бумага офсетная. Печать – ризограф.  
9 п.л. Тираж 2000. Заказ 5.