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Review Article

Ensembles of Intellectual Agents with Decision-making

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Abstract

An ensemble of intelligent decision-making agents is a cognitive information system that makes a decision based on an objective analysis of available data in difficult situations, in an interactive mode, taking into account performance criteria and resource-time constraints. Decision-making criteria are functionalities that express preferences and allow ranking the quality of decisions. The lower bound of the resulting solutions is the lower measure of their quality. The upper limit of the resulting solutions is the norm of their quality. Resource-time ranking and by the preferences of the resulting solutions determines the levels of their quality. Ensembles of intelligent decision-making agents control resource-time risks of managing indicators of accuracy of qualitative parameters of decisions. In the course of their work, they use communicative-associative principles of imitating human reasoning, implemented through artificial intelligence technologies. Decisions are made on the basis of rules. Decision rules are a set of logical constructs used to produce a knowledge-based solution. The input data is converted into a solution using the knowledge base. Intelligent decision agent ensembles provide an explanation of how the system received the solution or alternative solutions to the problem and what knowledge was used during this process. The explanation represents the progress of a result in a graphical, tabular, or textual form that a person can understand.

Keywords: Ensembles of Intellectual Agents; Quality of Decision-making; Criteria of Preference; Resource-Time Ranking; Measure and Quality Norm

Introduction

The decision-making system is designed for multi-criteria decisions in a complex information environment. The results of decisions made are assessed not on one, but on the totality of many criteria considered simultaneously. Information complexity is determined by the need to take into account a large amount of data, the processing of which without the help of modern computer technology is almost impossible. Under these conditions, the number of possible solutions is usually very large, and the choice of the best of them requires comprehensive analysis, optimization and ranking. A fundamental point is the choice of a set of criteria on the basis of which possible solutions will be selected and compared.

Various methods are used for the analysis and workings of proposals: data mining, knowledge search in databases, precedent-based reasoning, simulation modeling, evolutionary calculations and genetic algorithms, neural networks, situational analysis, cognitive modeling and artificial intelligence methods.

The decision-making system is a set of software tools for data analysis, modeling, forecasting and management decision-making.

The decision-making system allows you to choose the right solution from the maximum possible options.

There are specialized decision-making systems.

Analytics Integrad is a data visualization software platform that allows you to process and summarize information from heterogeneous automated systems.

Forsyth. The Analytics Platform is a data mining software suite that effectively visualizes information to enable business decision-making based on reliable data.

Microsoft Power BI is a business intelligence program that provides insights for quick and informed decision-making by managers.

Contour BI is a business intelligence computer program for collecting, storing, analyzing statistics and preparing business reports.

Business Scanner is a cloud-based solution for business analytics in sales, financial management, retail and marketing.

Visary BI is an importo-independent advanced analytics system for multidimensional analysis and visualization of big data for making informed and strategically important management decisions.

The Visiology Analytics Platform is a business intelligence system for creating visual representations of large data sets in an intuitive way that allows you to more accurately analyze business information.

QlikView is an analytical solution for the rapid development of highly interactive analytical applications and dashboards that provide information on business tasks.

Loginom is a low-code analytics platform that enables data integration, cleaning and analysis to make better management decisions.

Domo is a cloud-based analytical business management software solution that can connect multiple heterogeneous data sources, including spreadsheets, databases, social media, and any existing cloud or local software solution.

The BIPLANE24 System is a business analytical tool that allows you to manage business reporting and monitor the implementation of key performance indicators for an average or large enterprise.

Krista BI Information and Analytical System is a tool for business analytics tasks, reporting and comprehensive monitoring of key performance indicators of business processes.

Captain Analytics is an online service for collecting and visualizing business data from disparate sources.

Tableau Public is BI software that allows you to connect to a spreadsheet or file and create interactive data visualizations.

Yandex DataLens is an online service for analytics and visualization of business data from various sources.

Looker is an analytics platform that integrates business data and business team, enabling each specialist to explore and understand data to support effective decision-making.

The article proposes an approach to creating universal decision-making systems based on ensembles of intelligent agents by combining many functionalities [1-7].

Structural and functional hierarchy of intelligent agents in the ensemble

By structural hierarchy, intelligent decision agents have a user interface, databases, and scale modeling tools.

The principle of operation is based on four sequences:

- Intelligent definition of the environment in which the decision is made;
- Design and development of possible alternatives;
- Derivation of the algorithm of actions;
- Adapts the selected solution to specific conditions.

All management decisions are built on this principle.

In terms of functionality, intelligent agents are divided into orientation categories:

- Documentation focus - read and process data from documents of various formats and content;

- Model focus - generation of solutions based on situational, analytical, financial, simulation and other business models;
- Focus on databases - decision-making is based on digital storage of information of a particular company;
- Focus on knowledge bases - the decision is made on the basis of performing similar tasks, taking into account laws, dependencies and established rules;
- Communicative Focus - Used to enable the interaction of multiple intelligent agents working on a single task.

Ensemble sources are factors and processes relating to the activities of a particular object. The experience of employees in the subject area is taken into account. The output is data analytics and a simulation model of events necessary to make a balanced decision in this situation, taking into account all primary and secondary factors.

Functional intelligent agents work with enterprise operating systems and databases to enable rapid ensemble integration and optimal model building. The ensemble functions on the same platform.

Thematic intelligent agents are focused on a certain range of tasks, which simplifies the processes of analytics and data processing, increases performance.

Intelligent agents with unified information processing provide information consolidation at the level of many tasks.

Intelligent agents with tiered storage and configurable access have a single and standardized source of data acquisition. The enterprise decision-making model is able to expand storage volumes with heterogeneous data. Standardization allows you not to reconcile the synchronization of all areas of the database.

Knowledge-focused intelligent agents provide specialized, evidence-based solutions to problems.

The ensemble's corporate intelligent agents are directly involved in the development of the solution. The decision put forward by the ensemble can be finalized, improved by the user, and then sent back to the ensemble for verification. After that, the decision is again presented to the user, and so on until he approves the decision.

Communication-based model-oriented intelligent agent ensembles support the work of two or more users engaged in a common task. They process unstructured information in a variety of electronic formats.

Strategic management and decision-making ensembles enable dynamic process modeling. When using dynamic modeling methods, the activity of intelligent agents is described in the form of a mathematical model, in which all tasks and processes are presented as a system of interconnected calculated indicators.

To ensure the activity of ensembles of intelligent agents, it is necessary to form a number of alternatives:

$R = \{Aj, Sj\}$,

where A is an alternative represented in the form of a set of control actions;

j is the level of preference (rank) of the alternative;

S - description of the alternative, explanation of why it is preferredbefore the preferences following her in the motorcade.

The use of an ensemble of intelligent agents to solve this problem is determined by the following stages of its functioning:

- Sets the user's action target and creates constraints. Restrictions that form the boundaries of the area of permissible solutions to the problem can be set by the higher control body, determined by the conditions of the situation, or formed directly by the operator.
- Forming a plurality of alternatives Aj, consisting in a sequential setting the objective function and finding some of its parameters that determine the strategy the use of managed tools and the allocation of their resources within the established limitations. The susceptibility of ensembles to self-organization processes allows the use of internal reserves in their management, i.e. to achieve the intended state or structure without direct influence from the management entity. The parameters of such management are: management rules, quality of solutions and risks.
- Ranking and clarifying alternatives. The latter is an important step in the use of ensembles, since explanations of the preference of alternatives not only help the user in choosing,

but also increase the level of confidence in the results of the ensemble of intellectual agents.

When implementing this cycle, there is a need to formalize the data and structure the task of forming alternatives. To form a set of management alternatives, you must first structure the control process, then formalize the conditions for its flow, and only then use the mathematical apparatus to optimize the behavior of the controlled system. These are quite complex processes, for the implementation of which it is necessary to provide for appropriate software and technical means as part of ensembles.

The software tools of decision-making ensembles are intended for a formalized description of the situation: description of selection criteria, formation of alternatives, selection of solutions according to a predetermined method.

Management decision-making software products are based on formal methods developed within the framework of game theory and optimization theory. The methods of choosing alternatives provided to entrepreneurs, executives, analysts and consultants in such software are quite diverse - from scenario analysis, costs and benefits, to consensus tracking and previous decisions.

Users of these systems and services can extract or enter relevant data for analysis in order to support local decision-making in distributed teams that work in different places.

The administration option allows you to configure and manage the functionality of the system, as well as manage accounts and access rights to the system.

The ability to import and/or export data in the product allows you to download data from the most popular file formats or upload work data to a file for further use in other software.

The ability to multi-user access to the software system ensures the simultaneous operation of several users on the same database under their own accounts. In this case, users may have different access rights to data and software functions.

Often, when using modern business software, there is a need to automatically transfer data from one software to another. To provide such and similar interfaces, software systems are equipped with special API application software interfaces. With such APIs, any competent programmer will be able to link two software products to each other for automatic information exchange.

The presence of reporting and/or analytics functions in the product allows you to receive systematized and visualized data from the system for subsequent analysis and decision-making based on data.

The software product of decision-making ensembles shall:

- Provide scenario analysis;
- Have built-in tools for collecting feedback;
- Analyze and visualize input data;
- Generate multiple selection criteria, multiple alternatives, and help produce solution choices;
- Allow sharing of possible options and final decisions with internal and external stakeholders.

The main functionality of decision-making systems is:

- Information search;
- Intelligent data analytics;
- Situational analysis;
- Simulation and cognitive modeling;
- Building logical chains based on precedents.

Means and methods for identifying risks and analyzing problems should ensure monitoring of the functioning of the managed system in the normal mode and analysis of possible risks and threats that require decision-making.

One of the most important functions of the ensemble software is to predict the development of the situation and assess the possible results of decisions made.

Synergistic self-organization of large ensembles of intellectual agents according to the law of gold ratio

The golden ratio is a universal manifestation of structural harmony. Scientific research and practice show that in order to ensure systemic and structural stability and synergy of systems in technology, it is necessary to establish ratios corresponding to the golden proportion between the main indicators of the system. The law of the golden ratio is an objective law. Gold section technology serves

as a mechanism for self-organization of large ensembles of intelligent agents.

Self-organization is the formation of a spatial, temporary, information or functional organization, structure (more precisely, the desire for organization, for the formation of a new structure) at the expense of the internal resources of the system as a result of goal-setting interactions with the environment of the system. We are talking about information interaction with the external environment. In recent decades, methods and algorithms have appeared that allow you to work with large information flows.

They are important in the modern theory of systems, the diagnosis of their qualitative states, in synergetics as the theory of self-organization, cooperative action, the emergence of new qualities, integrity.

The process of self-organization of ensembles of intellectual agents is carried out according to the law of structural harmony of the system: "Generalized golden sections are invariants, on the basis and by means of which, in the process of self-organization, systems acquire a harmonious structure, a stationary mode of existence, structural and functional stability" [8-15]. The harmonious state of the system is not the only one and for the same system there can be an infinite number of harmonious states corresponding to golden proportions. The organization of the system involves certain coordination of the states and activities of its subsystems and components. The ability to organize itself is based both on the multiplicity of system elements and the branching of connections between them that contribute to the emergence of integrity, and on the presence of flexible interaction between elements in the type of feedback. Negative feedbacks (OS) ensure the stability of the system functions, the constancy of its parameters, resistance to external influences. Positive OSs play the role of process amplifiers and are of particular importance for the development and accumulation of changes. The presence of negative and positive OS leads to the possibility of development according to the law of the golden ratio using external and internal relationships.

The intelligent agent ensemble has many interconnections through wireless and mobile networks between competent agents. In order to make these connections effective, to establish an optimal interaction mode, a functional organizational structure is required. It organizes connections, distributes powers, establishes the circle of decision-making agents and agents executing them. The ensemble of intellectual agents is characterized by a high number of variants, this is due to the variety of external conditions in which intellectual agents function. The high many variability of large ensembles of intelligent agents with smart hybrid competencies requires their effective self-organization mediated by cognitive limits, associated with the volume that a person can effectively master and use, with the number of addressees with whom he can interact, with the organization of work in networks. Ensemble self-organization processes are carried out on the cooperation of intelligent agents with smart hybrid competencies with adaptive flexible infrastructure. At the moment of self-organization of the ensemble, a qualitative transition occurs, intellectual agents begin to function as a single whole, organizational stability begins.

A fundamental step in the description of such systems was taken by the Danish scientist, who worked for many years in America, Per Buck in the theory of self-organized criticality [16]. The name emphasizes that the system self-organizes into a critical state in which its dynamics acquire large-scale invariance in collective interaction in the network that develops as a result of self-organization.

The stable distribution of positive and negative responses of interacting bonds according to the law of the golden ratio determines the critical value of intellectual agents of the ensemble. An ensemble having an amount of necessary intelligent agents of equal or more critical value is capable of self-realization and obtaining the desired result. Determining critical values of ensembles of intellectual agents for the implementation of various sets of functions and competencies will help create a universal large ensemble with smart artificial intelligence. To implement and maintain large ensembles of intelligent agents with synergistic functional self-organization, powerful supercomputers are required [17].

Conclusion

Intelligent decision agent ensembles are an important information technology tool for practical tasks in various areas of knowledge. The synergistic use of intelligent agent ensembles allows us to find many solutions to problems arising in various areas of activity. Thoughtful solutions based on ensembles of intellectual agents, adequate actions, qualified execution, as a result lead to success.

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