Bionic-Oriented Information System for Innovation Activities

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Abstract

Background/Objectives: The paper regards the primary issues of the development of the intellectual information support system for research and development of the perspective bionical technologies and forming and early evaluation of ideas, providing user required information on biological systems, biological technologies and their analogs gained by utilization the new approaches to problem-driven information resources search. Methods/Statistical Analysis: Metadata is a form of information resource description, used to categorize all containing data. This kind of description can be used for the bionic information resources, intended for providing support for perspective research. The information resource descriptions are supposed to be created using the uniform representation standard. According to it, every resource description contains two categories of features: Compulsory and semi-permanent. It is worth saying that the developed intellectual support system does not have analogs, but it brings together the world-wide experience of building the bibliographical databases, search systems development as though as network-based expert systems. Findings: The complex of theoretical and practical results, obtained during the experimentation, makes it possible to form an intellectual bionics support system for serving user needs. This system will provide the representation data on the biological prototypes and the existing bionic technologies and their analogs by applying new approaches for problem-driven information resources search. Using the described system will promote forming new intellectual products in bionics. This will be achieved by ideas forming and early-time evaluation, what assumes individually formed idea being evaluated by co-workers and if required, been completed together. Applications/Improvements: The mechanism of collective generation and optimal solutions selection can obtain information from different participants, table the problems and solve them by the collective intelligence which is more powerful that separate individuals. Building an expert network, used for information analysis, ideas generation, situation evaluation and optimal solutions selection, requires the specific control, implemented by separate ideas forming subsystem. This, using the intellectual support system, allows ideas formation and estimation in early stages.

Keywords: Bionics, Bionic Technologies, Ideas Formation, Information Resources, Information Support, Innovational Process, Knowledge Base, Network Expertise

1. Introduction

Bionics, as a scientific direction which produces new technologies from their existing in nature analogs, is topical and perspective trend in social and innovational society development.

Traditional bionic technology combines empirical, theoretical and practical knowledge of the biological origin. This complex of knowledge is necessary and sufficient for building a relatively adequate model, which would serve as a basis for creating a technical prototype. However, in practice these requirements are hard to follow: Incompleteness, incorrectness and irrelevance of the biological prototype description lead to necessity of gathering more information. Such need, in turn, induces the evolution of the specialist’s creative thinking. Targeted

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Intellectual activities provide conditions for forming a set of mental tools such as guess, metaphor, fantasy, intuition, hypothesis and methods. All of above, taken in complex, lead to creation and development of new theories, methods, innovation technologies and techniques for engineering and innovational creativity.

It is worth saying that existing bionics reveal only a fraction of available humanity cognitive potential. The last decades, bionics was given an impulse to development. This can be explained by the possibility of using outcome, obtained by conducting research on micron and sub-micron (nano) levels. Such research makes it possible to reveal, examine and imitate natural mechanisms and constructions. Modern bionics allows inventing new innovative materials, technologies and devices, based on principles, gathered from the natural analogs on cell, sub-cell, molecular and in-molecular levels. The results of such research have far-reaching consequences. Thus we can conclude that the tasks of our scientific community are to explore, realize, comprehend and formulate new scientific knowledge and then use it for solving practical tasks for the sake of humanity.

Intellectual problem-driven research support system containing knowledge of biological systems and existing bionic technologies can facilitate the research and development of a wide range of perspective bionic technologies. That can be achieved by applying new approaches to the implementation of problem-driven information resources search and mechanisms of new ideas' formation and evaluation at the early research steps.

2. Primary Development Directions

For now there is a vast variety of data, describing biological systems from the bionics viewpoint, but it is widely spread amount different sources like libraries and of course, Internet. The purposeful problem-driven integration of different sources containing biological and bionic data into a single classification-based information resource will leverage the comprehensive and complex study by providing a researcher relevant information.

The developed intellectual information support system for the bionics study will provide:

- Adding new information resources, found among open-access data sources, to a knowledge base;
- Problem-driven pertinence-based search of information resources;
- Concise and responsive user interface with indexing algorithms, based on the ontological knowledge representation model (i.e. complex specification of the bionic information resources set in a conceptualized form);
- The possibility of producing new ideas and their further development using the retrieved expert knowledge.

Implementation of the described features requires research in:

- Principles and methods of information resource description;
- Methods and algorithms of knowledge base engineering;
- Methods of information resource search;
- Methods and algorithms of bionic knowledge base population;
- Bionic technologies formulation and estimation.

It is worth saying that the developed intellectual support system does not have analogs, but it brings together the world-wide experience of building the bibliographical databases, search systems development as though as network-based expert systems.

3. Information Resource Description

Metadata is a form of information resource description, used to categorize all containing data. This kind of description can be used for the bionic information resources, intended for providing support for perspective research.

The information resource descriptions are supposed to be created using the uniform representation standard. According to it, every resource description contains two categories of features: Compulsory and semi-permanent.

Compulsory features include the unique resource identificator, its name, type, definition, source link, relative resource and so on. It is advisable to use a Dublin Core approach for defining the compulsory features. In Dublin Core metadata elements are splitted into three groups: Definitive, intellectual property and resource identification.

It is needed to provide multivariable information search but the further study revealed that sole Dublin
Core is not sufficient, so the new approaches to forming the extended meta-description are developed. It is intended to add more data, which will provide running more detailed search queries containing semi-permanent resource features².

4. Knowledge base Engineering

The knowledge base architecture is being developed³ for solving the task of information resource storage. It is supposed to use three interconnected databases: System, model and object.

The system database will contain all data about users and system settings.

The model database will contain the bionic resources definition in a form of a knowledge representation model⁴.

The support system will obtain a model interconnection mechanism, which would unify:
- Entities (objects, links and so on);
- Entity relations (“Is-A”, “Extends” and so on).

The object database stores the information about already indexed entities which are classified according to model database.

Ill-structured information is supposed to be stored in a file-based storage which is formed according to the model and object databases.

In general, the architecture model of the knowledge base consists of several databases and file storage (Figure 1).

![Figure 1. Knowledge base architecture model.](image)

During the study authors proposed several solutions to a task of building semantic field model by extracting the lexical units from ill-structured or non-structured text documents⁵. The foundation of a proposed model is formed by cognitive psychology and psycholinguistics. This approach allows organization of the knowledge base according to user requirements.

5. Information Resources Search

The knowledge base is represented by a graph what makes possible to use the graph-based search algorithms:
- Full breadth-first search;
- Full depth-first search;
- Backtracking;
- Depth-limited search;
- Iterative deepening search;
- Heuristic search⁶.

Breadth-first search is a simple graph traversing technique, which assumes the consistent node exploration level by level. This type of search guarantees that firstly added nodes will be checked first. The advantage of this method is in its completeness, so every node will be checked. Its main drawbacks are in high time and memory-consumption.

Depth-first search starts with the root and goes to the deepest node in graph. Then, the already checked node is removed from the search field and the algorithm goes a step upper. The complete depth-first search can be implemented by using a recursive function which is applied for any node of graph. The advantage of this approach is in memory economy because it stores only current path. Its main disadvantage is in sufficiently huge (or infinite) number of steps, needed to find an element in the middle of a graph.

It's worth saying that there are several improved methods based on depth-first search: Backtracking, depth-limited search, iterative deepening search.

The idea of backtracking is that not all the child nodes are revealed. This approach saves memory by saving only the current state.

Depth-limited search requires some heuristics for limiting the traversing depth, what requires the additional search tree.

Iterative deepening search is a modification of depth-limited search and differs from the origin by increasing the maximum depth. This is the most optimal uninformed search algorithm because it is complete and has optimal memory and machine time consumption.

Heuristic (informed) search consists of two repeated steps: The estimation function f (n) defines the next node and the heuristic function h (n) estimates the “cheapest” arc from the current node to target. In some implementations these functions may be merged together. This kind
of search is consimilar to depth-first search and shares its advantages and disadvantages, but a quality heuristic function can positively influence the results, depending on the task complexity.

Besides that, the search can be accelerated by applying pertinence-aware search algorithms, which take user preferences into account.

The distinguishing feature of the developed approach is the possibility of iterative search rule formation for problem-driven information.

It is assumed that information resource search would take user preferences into account. In this case, user must mark the relevance of found documents, providing a feedback. This would give some additional heuristics for the next iteration of data storage and obtaining procedures.

6. Knowledge base Extension

In context of knowledge base expansion its main aspect is the information resource classification (categorization) based on document context analysis.

Information Retrieval\textsuperscript{7-9} and Machine Learning\textsuperscript{10,11} methods are used for solving tasks of automated text document classification.

It is intended to apply automatic classification based on pre-defined categorization scheme\textsuperscript{12} with the certain amount of classified documents.

Furthermore, the approach based on ontological model of bionics scope is being developed. Such models are, in fact, a combination of a frame-based class and object descriptions\textsuperscript{13} and semantic network, representing the class hierarchy. Applying the ontological knowledge representation model gives, as a result, relatively simple but flexible document classification which can be edited by various GUI-based editors\textsuperscript{14}.

The classification task is also solved with a help of a special knowledge base, based on ontological model\textsuperscript{15} and description logics\textsuperscript{16} and a symbolic inference algorithm (solver).

Thus, solver and its knowledge base form a subsystem, which primary tasks are in storing and accessing the knowledge base by the queries of the classification algorithm\textsuperscript{17,18}.

It is worth saying that this classification task can be regarded also as pattern recognition. This approach requires distinguishing a set of attributes for every single object. For textual data a set of attributes is formed by words and word combinations with a help of linguistical and statistical methods. These attributes are gathered into a table (information matrix), where a row corresponds to a class and every row element – to its specific attribute, which value is defined during the learning. When learning is completed, text relation to the specific class is defined by the attribute analysis according to their values. The described algorithms make it possible to conduct a relatively precise classification but these results can be achieved only by using huge information matrix with a large amount of descriptors.

7. Ideas on Bionic Resources Formation and Estimation

As a form of human activity, scientific communication is a driving force in the development of science. Any research somehow or other requires analysis of external intellectual product followed by new intellectual product synthesis. It is absolutely clear that the quality of new intellectual product depends on various factors, e.g. relevance and integrity of initial data, personal proficiency and skills of a researcher, quality of feedback. Thus, the research success depends strongly on the informational environment, while the knowledge exchange relies on modern informational and communicational systems and influences the whole scientific potential. That’s why it is advisable to leverage the synthesis of new intellectual products by using modern technologies.

The mechanism of collective generation and optimal solutions selection can obtain information from different participants, table the problems and solve them by the collective intelligence which is more powerful that separate individuals. Building an expert network, used for information analysis, ideas generation, situation evaluation and optimal solutions selection, requires the specific control, implemented by separate ideas forming subsystem. This, using the intellectual support system, allows ideas formation and estimation in early stages for:

- Forming the favorable conditions for idea generation;
- Expert rate estimation according to his/her current competence level;
- Complex idea estimation;
- Individual idea generation and collective development;
- Mutually relevant ideas search;
• Information support for creating an innovative project.

Thus, the user research activities will be supported, in the one hand, by relevant and pertinent bionic information resources, in the other hand, by the feedback of other expert’s estimations, according to their trust level. (Figure 2a, Figure 2b)

**Figure 2a.** Outline of network expertise for ideas formation and evaluation.

**Note:**

*1. Researcher, who initiates the discussion.

*2. Motivational factors.

*3. Analyst (discussion leader) possesses a higher weight of assessments within a current discussion, generalizes the final decision and submits its results to administrator.

*4. Statistical data calculation taking into account the weights of expert assessments.

*5. An expert has no access to the offers and comments of colleagues prior to creating its own offer.

*6. An expert has no access to information about the author of an offer prior to assessing it.

*7. It is possible to introduce an offer rejection system so that further analysis of offers in decision-making becomes prohibited (except the cases of offer reactualization).

*8. The scale system may have the following form: “the offer is topical and agreed” / “agreed, but the offer is not topical” / “the offer is topical, but disagreed” / “disagreed, and the offer is not topical”.

*9. Indices applied to assess individual data.
**8. Conclusions**

The complex of theoretical and practical results, obtained during the experimentation, makes it possible to form an intellectual bionics support system for serving user needs. This system will provide the representation data on the biological prototypes and the existing bionic technologies and their analogs by applying new approaches for problem-driven information resources search.

Using the described system will promote forming new intellectual products in bionics. This will be achieved by ideas forming and early-time evaluation, what assumes individually formed idea being evaluated by co-workers and if required, been completed together.

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