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Search of innovations and management of industrial system evolution

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Abstract
The paper outlines the key elements of the approach to creating an intellectual information system to support innovations at the enterprise. The approach is based on the integration of mechanisms for innovative solution search as well as methods of industrial engineering system evolution management by making use of the created innovative solution storage, algorithms of consistent optimization and identification of process-dependent parameters. The authors look into possibility of using the proposed approach in respect to the basic version of a functional model for the industrial engineering system.

Keywords:evolution, industrial engineering system, innovation, subject search, genetic algorithm, functional model

1. INTRODUCTION

New methods of the advanced technologies and innovative ideas search and synthesis are one of the priorities in the development of a mechanism for effective management of the industrial engineering system evolution.

The paper outlines the key elements of the approach to creating an intellectual information system to support innovations at the enterprise. The approach is based on the integration of mechanisms for innovative solution search as well as methods of industrial engineering system evolution management by making use of the createdinnovative solution storage, algorithms of consistent optimization and identification of process-dependent parameters. The authors look into possibility of using the proposed approach in respect to the basic version of a functional model for the industrial engineering system.

2. INNOVATIONS AND MANAGEMENT OF INDUSTRIAL ENGINEERING SYSTEM EVOLUTION

Innovation is a new or improved product, production or application technology, developments or enhancements in the sphere of production engineering and (or) economics, and (or) marketing of products to provide economic benefits and conditions for such benefits, or to improve the customer appeal of products [1]. Innovative activity is a combination of technologies, application areas, markets and organizational arrangement.

In [4, 9, 11, 12, et al.] the authors considered the problem of the production evolution by the way of capitalization of knowledge, experience and intelligence of a production staff; they proposed and studied a formal model of the intelligent production evolution mechanism; lay down conditions for the progressive development of production in the light of abundantly used knowledge.

This article focuses on the objectives of information influence on the perception of decision-makers and the decisions to be made. Tools for the knowledge search and acquisition from various data stores and its involvement into decision support systems are the foundation of such information influence.

In this regard, we can say that R&D-management is very important. Its basic model includes competitive analysis and forecasting of the technological development based on scientometric and analytical services and systems of semantic search of commercially valuable information. In this case, a newish world trend – the efficient use of already existing global and innovative capacity – is evident.

3. FUNCTIONAL MODEL FOR INDUSTRIAL ENGINEERING SYSTEM

We represent the industrial engineering system as a set of center Z, and a set of agent groups A. Each active and autonomous agent $a_k \in A_n$ of any group $A_n \in A$ is involved into the running of a certain technological process stage. It is significant that Z includes a board of management (top managers), while *A* comprises an operational manager and staff (technicians, mechanics, instrumentation department specialists, etc.).

The plan of the whole active system is described by vector *x* in space *X*withdimension*N*, and the possibilities of agent a_k are described by technological set $X_k \subseteq X$ with dimension N_k. Thus, any feasible plan $x_k \in X_k$ for agent a_k is to meet local constraints *L* (for example, permissible temperature or pressure in the process, swiftness of a response, etc.) and general constraints *G* (for example, jobs for the production output, limited resources, allocation of material flows between production units, etc.). In managing the production system evolution there appears the task of reducing the actual vector of the system estimated parameters to the existing scheduled constraints L and G.

Let us assume that the agent may be in *m* states forming its model of constraints $y = \{y_i, \overline{1,m}\} \in Y(p) \subseteq R$ where *p* – the agent potential, its manifestation will depend on control $u \in U$ from *Z*, *R* – the advantages of a system, and *Y* (*p*) – a compact and convex set of agent's limitary abilities. Implementation of *p* can be represented as a countable system $Y(p_1) \subseteq Y(p_2) \subseteq \ldots \subseteq Y(p)$, where $p_1, p_2, \ldots$ – sequencing of agent's potentials increased by means of control *u* (Fig.1).

Control is provided at time *t* from center *Z*. It includes plan y_t which determines the agent's performance, consumed resources x_t, operational conditions of process α_t, management of agent's behavior u_t, and the interference known to agent and unknown to center *Z* at time *t*.

After analyzing the feasibility of possible operational conditions the agent selects state $y_t \in Y(p(u_t), x_t)$.

Center *Z* observes y_t and specifies α_{t+1}at time *t + 1* by using the assessment procedure of technological opportunities of agent $\alpha_{t+1} = I(y_t, x_t, \alpha_t)$. On the basis of agent's potential assessments, scheduling and regulating procedures, the center awards an agent for achieving targets.

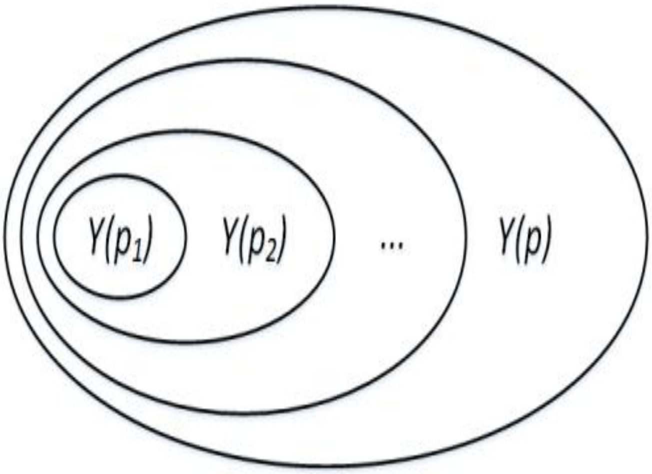

Fig.1. The growth of agent's limitary abilities.

A more detailed description of the proposed functional model of industrial engineering system is given in [2].It is virtually impossible for center Z to get an unambiguous and universal representation of agents' technological abilities and to make relevant decision. All these require the development of special procedures for the exchange of expert information

4. INFORMATION SUPPORT OF INNOVATIONS

Currently, there has been an increased demand for such services as the development of integrated control systems, practical implementation of new financial technologies, the business appraisal, the market research. More detailed investigation [3, 4] revealed a number of problems in the consulting services market, for example, the lack of a clear pricing policy, duplication of consulting programs, underdeveloped scientific and methodological base.

In this context, efficient algorithms oriented to the expert subject search of innovative solutions in global and local specialized data stores can play the lead role. When running a subject search, users inevitably face the following hard problems:

- Difficulty in selection of the consistent key concepts for formulating search queries.
- Boundaries of the structural complexity of search queries.
- Fragmentation and non-uniformity of the required information, the availability of alternatives with comparable relevance.

Solving these problems, one is to interpret correctly the search results with the view of a simultaneous relevance estimation of documents found by different queries, with due regard for correctness of search engine rankings, availability of all the relevant results to be estimated, effective solutions in other areas for successful use in the field in question. Project [5], [6] offers the technology of search queries generating, filtering, and search results ranking to create storages of innovative solutions.

The basic idea of generating search queries is engineering the evolutionary process with a special genetic algorithm. For the purpose of obtaining highly relevant results, it is to form a stable and effective query population in a search engine. In the process the encoded queries sequentially undergo genetic changes and start up at a search engine. The semantic relevance of intermediary search results is estimated, values of the objective function are calculated, and the most suitable queries are selected.

The initial population of search queries N can be represented as a set Q,with $|Q| = N, N < |Q_0|/2$, $q \in Q$. Assume that the search query $q = \{k_1, k_2, ..., k_m\}$ is a random combination of key notions from search image Q_0. The result of a search query is a set of documents R, $|R| = D$. The value of fitness function w_i determines the quality of queries and is calculated for every found i-th document (query result) $r_i \in R$: $w_i = F(g,p,s,a)$, where $g = g(R)$ is determined by the position in the ranked list of query results; $p = p(R_1, R_2, ... R_N)$ is determined by the occurrence of this result in the result lists of the majority of queries; $s = s(r_i, Q_0)$ is determined by the semantic similarity to adaptively modifiable Q_0; a is an environmental factor. The objective function for each query is $\bar{w} = \frac{1}{D}\sum_{i=1}^{D} w_i$ where D – the number of query results. The evolutionary operation of crossover is realized through the discrete recombination, i.e. term communication between queries; a genotypical outbreeding is used for the query reproduction. The most appropriate mutation operation is a probabilistic replace of the randomly selected query term with a synonym. An elite search is used in forming a new population of queries. A stable population is generally considered as the condition for stopping an algorithm. This genetic algorithm is described in [6, 7], particular research results on its effectiveness are given in [10].

[8] introduces the software implementation prototype of the described genetic algorithm. In particular, main algorithm steps and parameters, software components are determined and results of the algorithm preliminary study are shown.The prototype is implemented as Genetic Algorithm Framework (GAF) with the following main components: a user interface; GAF main library; a morphological analysis and lemmatization module; a text analogy semantic analysis module; a search module; a database management module; a metadata management module (Fig. 2).

The base data warehouse component specified for storing innovative technological decision descriptions in order to assess their feasibility in production is Apache Lucene/Solr platform being a high-performance system with advanced features for text search. The cross-platform technologybeing recognized and acknowledged globally has significant advantages such as facet search, hit indication, and result clusterization. To rank search results Lucene uses an adaptive vector space model of the standard weight function documentsOkapi BM25.

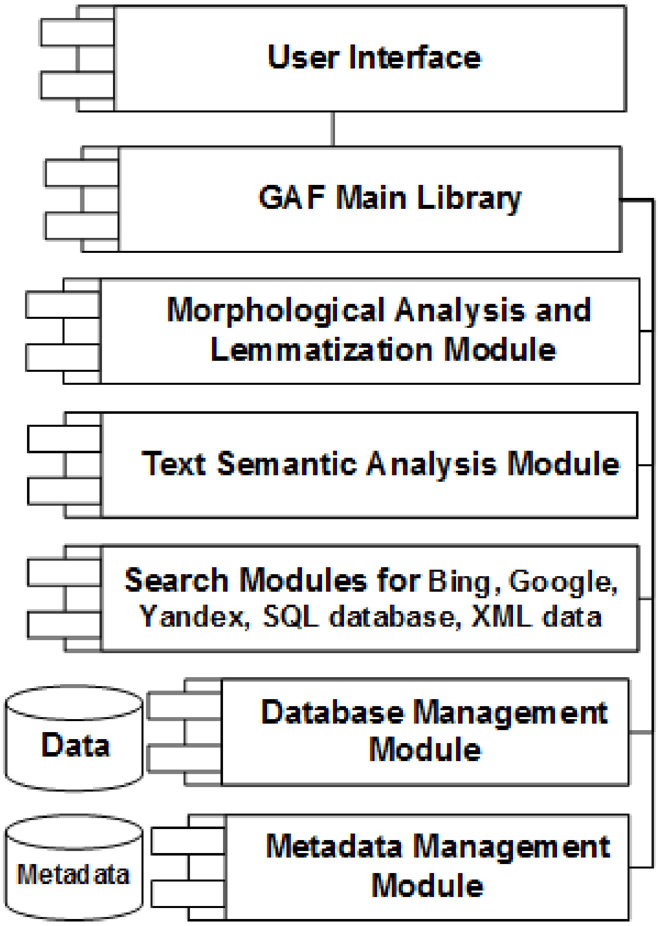

Fig. 2. Main components of the application realizing genetic algorithm GAF.

Main data warehouse problems being solved are the following: the unification and specification of file and index data collection, storage, transfer, and representation; the development of data collection and processing regulations.

5. MANAGEMENT OF INDUSTRIAL ENGINEERING EVOLUTION

It is expedient for centre*Z* to construct technological preferences with the locally optimal tasks already solved by agents $a_k$andwith the additional datareceived from them, the latter helping the agent to specify their capabilities and make the final decision.

The whole cycle of the agent's generating information about their capabilities consists in the following stages:

1. At the *r*-th step the agent receives centre*Z*'s alternative plan and control action. Therefrom the agent generates the set P_k^r of their capabilities and the set X_k^r of limit technology opportunities. The generation of $p^r \in P_k^r$, $x^r(p)$ and $y^r(x)$ takes place at this moment.
2. The task of potentially preferred series of activities $x^* = x(p)$ is solved.In case of the solution absence a trade-off decision (see below) should be found. The decision should correspond to initial sets P_k^r and X_k^r and lead to Stage 3 or otherwise – to Stage 5.
3. At this stage the directions of possible enhancement P_k^r are analyzed through the study of environment behavior and the search of new information (knowledge) for $P_k^{r+1} \supseteq P_k^r$.
4. If enhancement P_k^r is possible and there is P_k^{r+1} obeying Stage 3 condition, go to Stage 1.
5. When sets P_k^{r+1} и X_k^{r+1} are constructed, the procedure of searching a minimally preferred point in the space of state value assessments is carried out.
6. Based on the additional information search the enhancement possibility of sets P_k^{r+1} и X_k^{r+1} is determined. If the outcome is positive, go to Stage 1.

Stage 2 of the algorithm described above uses three types of mechanisms with generating an interactive process for making a trade-off decision of the technology management problem:

- The analysis mechanism. Here, at the *r*-th step, agenta_i, processes the data and compares them with the outcomes received at the (*r*-1)-th step for constructing sets P_k^r and X_k^r. The preliminary idea of the desired activities values is formed.
- The target-setting mechanism. In view of the analysis results the conditions of achieving desired preferences (trade-off decisions) are determined. To do it the ideal point of the assessment space $\tau_i^* = max\, \tau_i(x(p)),\ i = \overline{1,L}$ is calculated where maximization is done with $p \in P_k$, $x \in X_k$. That is, τ_i^* is the maximum assessment valuefor coordinate *i*which may be derived with the target activities. It is the point that forms the centre of the preference search area.
- The self-organization mechanism for preliminary conditions provides the new knowledge about the enhancement rules of sets $P_k$and X_k. The mechanism can be of different forms: the object experimental survey, the *k*-th agent environment analysis, the experts' advice on process condition improvement, the personnel interrogation procedures, etc.

6. IIMPLEMENTING TECHNIQUE TO PROVIDE INFORMATION SUPPORT OF INNOVATIONS

The techniquetoconstruct the system of information support of innovations for managing theindustrial engineering system evolution is implemented as an example of managing the *n*-stage technological processing of feedstock C_0 into finished product C_n (Fig. 3).

Each stage$c_i$is managed by a group of agentsa_i.The centre*Z*,with local *L* and general constraints *G*in mind and based on the analysis of information received with the subject retrieval, develops plan *x*. Agent $a_k$has general knowledge *d*(shared by agent a_k and centre*Z*), knowledge *b*(only known by agenta_k)and knowledge obtained as a result of applying search algorithms in generating the information about the agent's capabilities in performing engineering functions.

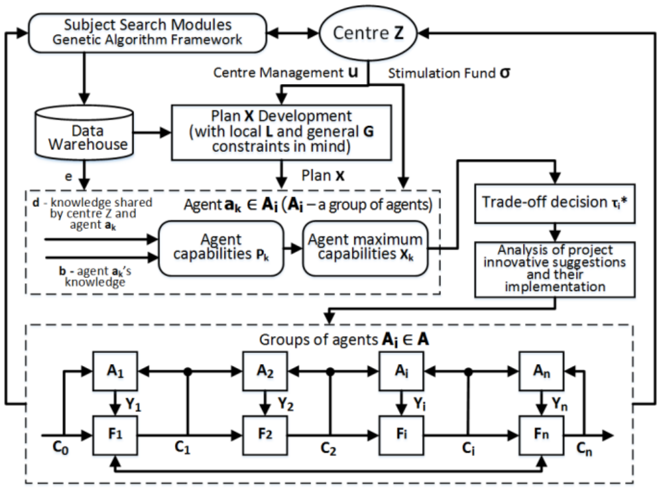

Fig.3. The formal scheme of n-stage process management.

The centre performs the agent P_k' capability growth management *u* (e.g., on the basis of newly found methods of motivation and stimulation management) andmaximum engineering capabilities X_k(e.g., the introduction of new modes and possibilities of equipment and engineering unit maintenance; available equipment upgrading; the adjustment of technological stages).

The information obtained with the subject retrieval is used in (a) managing by centrethe growth of an agent's capabilities and maximum engineering capabilities; (b) developing a production plan (e.g., introducing the decisions influencing the constraints); (c) an agent's generating the information about their capabilities (studying the experience of other similar enterprises; professional development and further training, studying professional literature).

Assume that the analysis of innovation approaches found and suggested by process engineers (a group of agents A_i being responsible for stage F_i operation) makes the head of production development (centre*Z*) decide on the change of some manufacturing process components at stage F_i,with the others having enhanced performance. This results in raising the final product quality performance, with the final product cost$C_n$decreasing owing to the reduction in purchase expenditure on the accessory parts also used at this stage.

The plant manager (centre*Z)*with the assistance of the analytical service using the system of information support of innovations found and made the decision on including additional operations and feedstock processing stages C_0 in the process flowsheet thus making it possible to push up the final product volume C_n without decreasing the target level of its quality.The improvement of engineering and economic performance results in 19.2% increase of the enterprise profit (the experimental observation was carried out during six quarters).In addition the increase of the enterprise motivation fund σresulted in searching other innovation decisions.

7. CONCLUSION

The intelligent information support of innovations at the enterprise based on the integration of innovation decision search mechanisms, models and methods of industrial engineeringevolution management, applications of the algorithms of coordinated industrial engineeringparameter optimization and identification helps stimulate innovation search and, thus, improveindustrial engineeringperformance of the enterprise.

CONFLICT OF INTERESTS

The author declares that there are no conflicts of interest in the research.

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