ENGINEERING MANAGEMENT OF INTELLIGENT CONTROL SYSTEMS: INFORMATION TECHNOLOGIES OF KB-DESIGN, CREATION AND PROTECTION PROBLEMS OF THE INTELLECTUAL PROPERTY

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Abstract: Present problems in engineering management in domain of intelligent control systems and concrete practical ways in intellectual property (IP) creation on intellectual product as an information design technology of *integrated intelligent control systems* (IICS) are considered. Important technology components as software and hardware (SW&HW) support are including. The considered knowledge base (KB) -technology is based on new kinds of modeling and calculus such as soft computing, quantum computing and quantum soft computing. These types of calculations could be also considered as intellectual products. We consider as an intellectual products as source information products. The decision-making of the problem in practical and commercial application have special value at creation of information technology. Concrete recommendations regarding on IP creation and practical protection on intellectual products are given.
Keywords: *Integrated intelligent control systems*, *Intellectual property*, *Design technology*

1. Statement of the problem and substantiation of its importance

From engineering management point of view, creation of the IP on high-level information technologies developed on the basis of an appropriate intellectual products has a ground importance in 21 century [1-6]. The World Intellectual Property Organization (WIPO) revealed that 90% to 95% of all the world's inventions are found in patent documents. Additionally, the European Patent Office (EPO) also disclosed that "patents reveal solutions to technical problems, and they represent an inexhaustible source of information: more than 80 percent of man's technical knowledge is described in patent literature." Patents are an important source of technological intelligence that companies can use to gain strategy and computational patent mapping is a methodology for the development and application of a technology knowledge base for information design technology and competitive intelligence [6]. Further analysis would reveal more insights into the technology and business strategies that these companies have for their patents portfolio. Therefore, leading international companies, especially from USA, Japan, UK, Canada, Germany, France, Italy, Holland, Russian Federation etc., concentrate their great attention on the following important issues: (1) creation of the intellectual basis for developed information technology; (2) development of the flexible structure of technology taking into account the evolution in adjacent areas (such as computer science technologies, SW&HW support of design processes and industrial processes of manufacturing etc.) and (3) creation of SW&HW support for corresponding industrial and information environment.

At least five-ten years and highest risk capital investments are needed for the technology development and application, and during this development stage process there is an objective necessity in IP protection against industrial espionage and piracy. The practice shows that the best way of the protection is a creation of IP on all development period stages [1 - 6].

As an example confirming the above statement, consider new computer science technology concerning quantum computer structure and architecture design. According to expert's estimations, the first industrial sample of such kind of computers is expected (under certain condition) approximately in 35 - 50 years (a cost of development of the technology on two order exceeding cost of the project on creation of the atomic bomb). At the same time, there is a necessity to resolve many complex scientific and technical problems such as decoherence,

nanotechnology equipment's design, control of cooled atoms, and so on. In the case of success in solution of mentioned above problems, one quantum computer with one thousand atoms will be enough to keep all the information available in the universe, or to process huge data files of the information like about 2^{1000} bits, and to solve unsolvable computational problems like cryptography, code braking, integer number factorization, fast data base (DB) search, secure communications and so on, by quantum algorithms. Such complicated computational problems cannot be solved on a classical PC or their solution is too expensive. For these reasons, the great attention is given by leading companies and research institutes to the information technology research, design and protection. For past 15-20 years many corporations and leading universities prepared specific proposals on IP development and its protection [7]. Now they give grant attention to the interrelation between business-programs, business-plans and IP on intellectual product, as background of the appropriate programs for decreasing of risk.

Remark. The analysis of given offers and existing practical experience in IP creation on intellectual product has shown that efficiency of the process depends on the problem-oriented area. The way of IP protection, on the intellectual product, essentially depends on the scientific and technical bases developed in these specific business areas. In this article some issues regarding IP development in the concrete problem-oriented area of *information design technology of IICS* are considered.

Figure 1 shows the basic components and interrelations of information design technology of IICS based on new kinds of computing (such as soft and quantum computing).

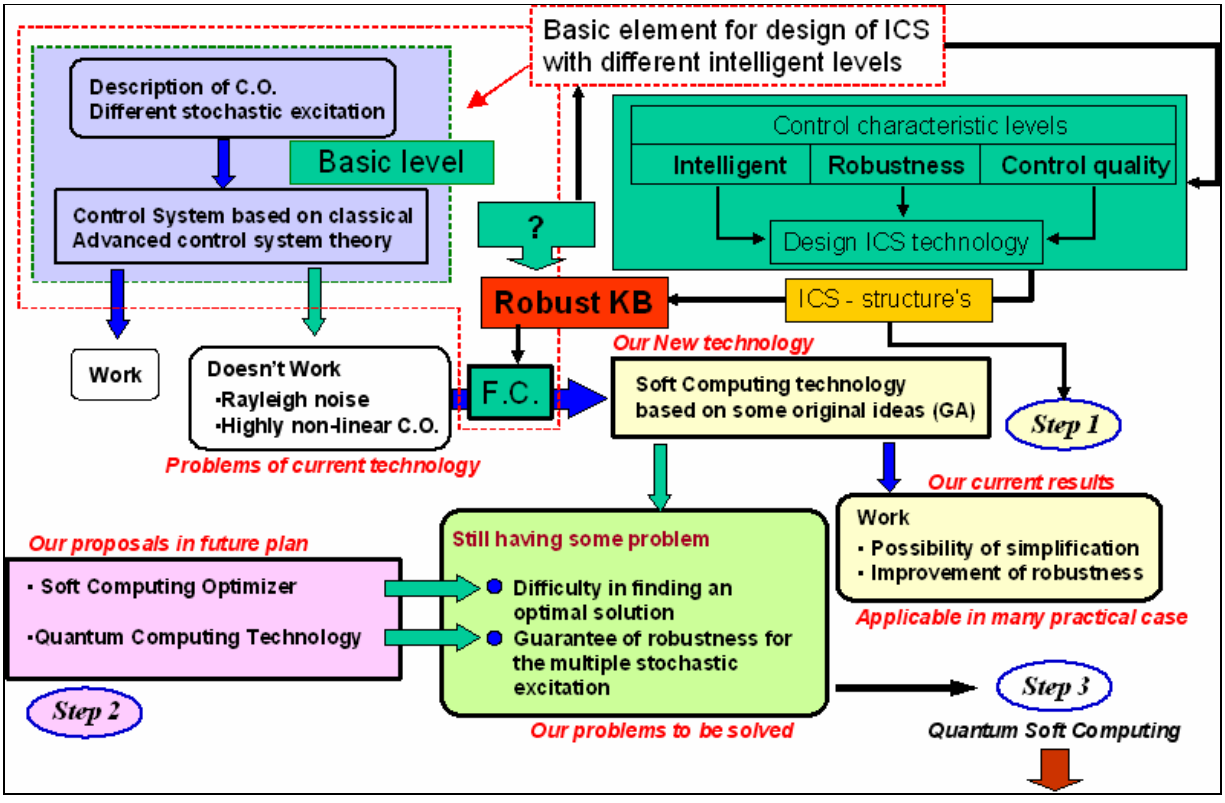

Figure 1: *Control process by creation design technology of IICS*

The key point solved by using this technology is the extraction of the objective knowledge independently from experience of experts and design of smart KB for fuzzy controllers as the main part of robust ICS [8, 9]. The technology has wide practical applications and its role and importance in scientific and technical processes is great. Therefore, IP creation and protection plays a special role during R&D of the technology.
In this paper, examples of legal protection of concrete IP in the area of ICS design are given. I hope that given examples allow ICS developers use given experience of IP protection in their professional work. In the following section, the differences of acts regulating legal relations between IP creation and ways of its protection accepted in the various countries are considered.

2. Features of IP legal protection in the field of high information technologies

Present mechanism of a legal protection (basically, as the copyright) is insufficient for protection of interests of developers of the high-level technologies especially such concepts as mathematical algorithms, new kinds of modeling and the computing, new structures of intelligent systems [1-3, 7]. The problem happens because the basis the development is distributed in many scientific disciplines such as mathematics (algorithms and programs), physics (quantum computation), and biophysics (DNA computation) and so on. Modern legal laws and forms of IP protection do not cover calculus models in the given concepts, and also do not contains precise recommendations for the decision making of these problems (see one of example in [10]). Intensive introduction of high-level technologies in the advanced countries has resulted in necessity of solution of the problem.
Remark. It is enough to note, that Patent Office of Japan in 2001, having lead carried out the analysis of a situation in the intellectual market, has declared the new national program on preparation of experts in the field of in IP formation and protection. The purpose of the program: to become by 2010 on the first place in the world in this area. The report submitted by the president of Patent Office of Japan H. Arai to the government of the country (CSTP - *Council for Science and Technology Policy*) on 60 pages of the text contained 55 concrete items on reconstruction of the existing system in the domain of IP formation on high-level technologies [11]. In the submitted report, the current situation is described. At the Japanese Patent Office there are no qualified experts having PhD degree whereas in USA more than 500 experts have it [11]. The base for realization of the planned program is the amplification (strengthening) of cooperation « *university - industrial company* » with assistance and coordination on the part of public sector. It is enough to note one of features of this program: financial support of university in direct ratio the vigorous activity of university also will be estimated with 2004 on a new parameter - IP formations (patents) and the effective utilization [11].
In conditions of the legislation existing in the world and experience of application there are certain features and difficulties during IP formation and protection on the intellectual product by virtue of dynamic development of high-level technologies behind which evolutionary development of the appropriate legislation is out of date. Distinctive feature of the discussion concerning these problems is necessity in taking into account the problem orientation of the considered technology (in a view of a history of the development and a modern condition) for allocation of novelty component and revealing of forms of IP protection by existing legal means of the concrete country [1 – 7, 11, 12].
The patent on intellectual product is the maximum protection form of IP. However, in connection with development of information technologies based on the high-level technology product including the knowledge from different areas of a science and engineering, and using new concepts of a computer science and an artificial intelligence (AI) (such as soft

computing, fuzzy algorithms and fuzzy control, quantum computing and quantum algorithms etc.), there was a certain objective conflict between formal definition of patentability and high technology intellectual product. The conflict was successfully solved by the US Patent Office given precise definition of the patentability of the computer software (SW) and mathematical algorithms [2, 3, 7].

Let's consider one of variants of definition of patentability high-level technology intellectual product, considering as, an example, soft computing and quantum soft computing.

Definition of patentability of such kind of technology as an intellectual product makes it difficult for experts in reviewing of such patents.

Frequently many developers of high-level technology intellectual product do not pay the necessary attention to IP creation on the intellectual product at an initial stage of development. Vivid examples of the kind are given in [13].

One competent example of a modern approach to IP protection in high information technology area is the Grover's patent on quantum search algorithm (for search in unstructured sizable databases). In this case, intellectual product as a quantum algorithm (by virtue of the novelty and applied value) has the raised patentability as it is based on high-level technology intellectual product and mathematical tool such as quantum computing which is a new steps in computer science technology [14].

As we can see from Figure 1, variation of the computational types and models (Steps 1-3), results with an automatic increment of the intelligence of the designed ICS. Based on this approach an IP was created in a form of patents, protecting the IP [14-18].

After IP formation on intellectual product a trademark creation (TM) on an industrial sample is required. In our example, KB-optimizers with new kinds of computing are the base of the developed information technology. In this case, first of all, it is necessary to create a TM on the basic components of the technology. It is necessary also to emphasize, that TM should include also some semantic content of intellectual product itself.

3. Features of creation of high-level information design technology of intelligent control systems

As abovementioned modern design technologies based on high technology intellectual product, contain in the concentrated kind, the valuable information and results from many areas of a science and engineering. Such creation of technologies represents long and creative process. Besides the general laws describing formation such intellectual product, there is a set of the additional hardly formalized factors arriving from concrete application area.

One of such typical and vivid example is a development of information design technology of robust IICS. The carried out research [19 - 22] had demonstrated that the ICS have the following features and advantages: (1) Keep the basic advantages of traditional feedback control systems such as stability, controllability, observability etc., that make a basis for design technology of ICS; (2) Have optimal KB (from the view point of the given criterion of control quality), and also have an opportunity of correction and adaptation to a varied unpredicted situation of control; (3) Guarantee robustness of required quality of control on the basis of designed KB; and (4) Are open systems and allow to enter additional criteria of control quality and restriction on qualitative characteristics of control processes.

The listed features of ICS design technology characterize the given technology as the high level one and show that it has elements of essential novelty (as one-by-one components, and structurally as a whole).

Figure 2 shows the design process of robust ICS structures (scientific and technical features is submitted [8]).

Apparently from Figure 2, the basis of development of the high level technology is the high information technology, intellectual product made in the field of mathematics (algorithms, programs), physics (quantum computing), biophysics (DNA computing) etc.
Let's consider a role of the marked features in formation of information technology as integrated intellectual product, containing as the fragments separated independent intellectual products.

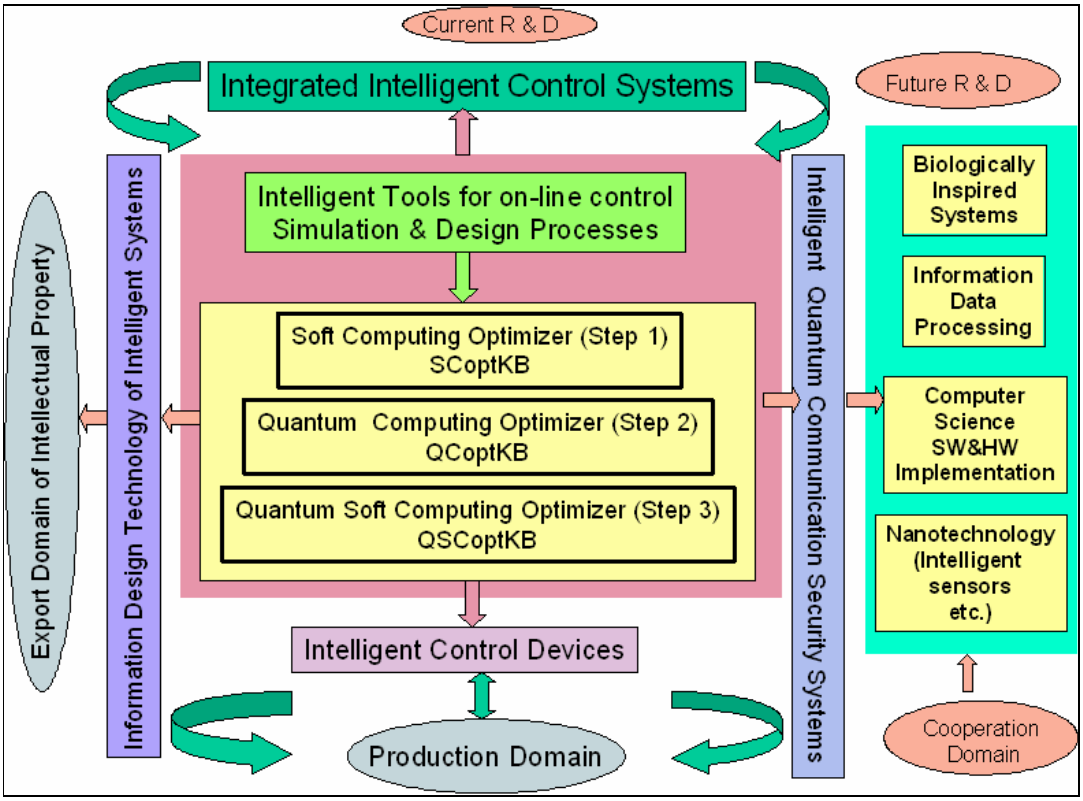

Figure 2: *Design process of robust structures IICS*

One of the essential attributes of novelty intellectual product is the patentability that entails necessity of protection. As example, we describe process of IP creation on high information design technology of IICS having scientific and technical features.

4. Example of IP formation for the technology stage

Let's consider a concrete actual problem for the modern theory of control: robust KB design of IICS.
The basic problem here is optimization of the design process of optimal KB for fuzzy controller (FC) (see Figure 1). We shall describe experience of IP formation for the technology stage.
As it was mentioned, a process of extraction, processing and formations of knowledge represents one of the central problems of the AI theory. The expert during design of the KB for ICS introduces subjective attributes in KB and consequently there is a problem of KB objectiveness. With new methods of computing such as soft computing (based on GA), quantum and quantum soft computing, it is possible to formalize and optimize objective process of KB extraction, processing and formation of the KB avoiding expert subjectiveness.

4.1. *Separate features of the KB design*. Let's consider separate features of design process of KB representing central problem in the AI.

1. Distinctive feature of ICS is a property of robustness. Thus, each intelligent level of a control system has the appropriate level of its robustness. For increasing of ICS robustness, the "principle of intelligent feedback" was introduced. It allows to use the information extracted from an output of a classical PID-controller and from control object (CO) output for construction of KB for designed FC.

2. Modern design technologies of ICS are based on a fuzzy neural network (FNN) as a tool of learning process. In general, FNN does not guarantee achievement of desired accuracy of approximation of learning signal and, as a consequence, the sensitivity to CO dynamic behavior is increased (reducing robustness). It was demonstrated at various classes of stochastic disturbances and CO. For elimination of FNN defects the program toolkit is based on GA was developed. This has allowed to establish a necessary level of accuracy of approximation and to guarantee accessibility.

3. In a basis of the given design stage of robust KB for IICS, physically proved the principle which determines the robustness level depends on the value of the information incorporated in the KB. It enables to determine a necessary level of intellectuality depending on complexity of the concrete control problem.

We shall consider briefly the basic physical principles allowing establishing the interrelation between mechanical characteristics of CO dynamic behavior, stability, controllability and robust control. For this purpose was used information and thermodynamic approaches connecting dynamic stability (Lyapunov function), controllability and robustness by the uniform condition.

Let's consider dynamic system of the control object, described by the following equation

$$\frac{dq}{dt} = \varphi\ (q, t, u), \tag{1}$$

where q - a vector of generalized coordinates and u - force of control, t - time.

Necessary and sufficient conditions of asymptotic stability of dynamic system described by the equations (1) are determined by Lyapunov functions that have two important properties:

- it is strictly positive function from the generalized coordinates, i.e., $V > 0$ (condition 1),
- the full derivative on time from Lyapunov function less or is equal to zero (condition 2). $\frac{dV}{dt} \le 0$.

According to the listed requirements to Lyapunov function we shall choose (as Lyapunov function) the following function:

$$V = \frac{1}{2}\sum_{i=1}^{n} q_i^2 + \frac{1}{2}S^2,$$

Where $S = S_p - S_c$ - entropy produced in open system; S_p - entropy of CO, S_c - entropy of PID-controller.

The first condition is carried out automatically. We shall demand performance of the second condition $\frac{dV}{dt} \le 0$. We shall take a full derivative on time from Lyapunov function described above:

$$\frac{dV}{dt} = \frac{1}{2}\sum 2\dot{q}_i q_i + \frac{1}{2} 2S \cdot S = \sum_{i=1}^{n} \dot{q}_i q_i + SS = \sum_{i=1}^{n} q_i \cdot \varphi(q,t,u) + \left(S_p - S_c\right)\left(\dot{S}_p - \dot{S}_c\right).$$

Thus [19]

$$\underbrace{\frac{dV}{dt}}_{stability} = \underbrace{\sum_{i=1}^{n} q_i \cdot \varphi(q,t,u)}_{controllability} + \underbrace{\left(S_p - S_c\right)\cdot\left(\dot{S}_p - \dot{S}_c\right)}_{robustness} \le 0 \qquad (2)$$

Figure 3 shows the interrelation between Lyapunov function and entropy production in CO and in control system.

Closed System	Open System
$\frac{dV}{dt} = -\frac{1}{T}\frac{dS_P}{dt}$	$0 > \frac{dV}{dt} = \sum_i q_i \varphi(q_i, u, t) + (S_P - S_C)\left(\frac{dS_P}{dt} - \frac{dS_C}{dt}\right)$ Stability Condition ≡ Mechanical Motion Part (Controllability) ⊕ Thermodynamic Behavior Part (Robustness)

Figure 3*: Interrelation between Lyapunov function and entropy production in control object and control system.*

The equation (2) describes the physical law of control quality and connects in a single whole different control quality measures such as: *stability*, *controllability* and *robustness*.

Thus, the mutual relation between Lyapunov stability and robustness described by the equation (2), is the basic physical law for ICS design. This law is the base for applied KB-design technology at robust IICS (with the increasing intelligent levels) based on soft computing.

4. Soft computing creates an opportunity to develop the universal approximator of intelligent control system, which takes the minimum necessary information from the data from CO.

Thus, the information design technology includes physically proved characteristics of quality of control processes. Therefore, the definition of robustness, so important for control processes, can be determined correctly (see below, Figure 4) and represents a minimum of the necessary initial information for achievement and preservations of required control quality.

Thus, data extraction process, information processing and KB formation represents high-level technology intellectual product, demanding IP creation and its protection.

Process of KB design is realized *by a new* kind of intelligent feedback. Figure 4 shows in detail this process.

And thus owing to the novelty the process is patentable. The tool of KB design and optimization is patentable according to their novelty. Changing model of CO (see Figure 4), we receive a variety of applications of the universal circuit realizing process of extraction, data information processing and formation robust KB for IICS of the given class.

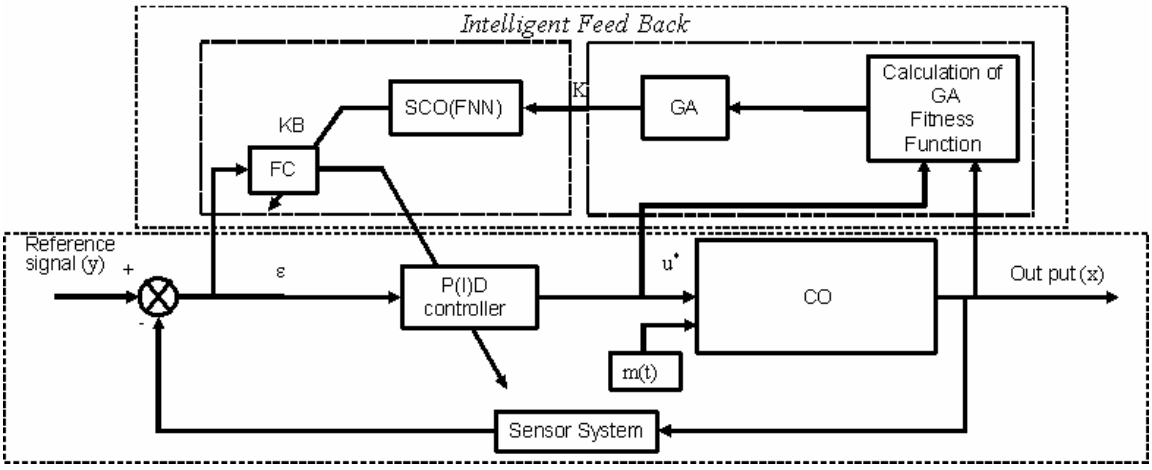

Figure 4: *Structure of an intelligent control system with new intelligent feedback based on soft computing*

4.2. *Intellectual product protection*. In connection with stated items there is a following problem:

How to protect intellectual product submitted on a Figure 4?

For this purpose first of all it is necessary to denote types of novelty in developed intellectual product.

Firstly, the intellectual product consists of IICS structure with new type of intelligent feedback and includes a new type of GA with discrete or continuous constraints on variables. The structure contains also soft computing optimizer (SCO) for approximation of teaching signal (TS) and KB formations for FC.

A new kind of computing (in applied mathematics) and the physical control law based on a principle of a minimum of entropy production, both in CO, and in a traditional controller are the background of objective KB design processes for smart FC.

Therefore, on the base of developed IICS structures we can create an IP which is protected by the following patent [16]

Secondly, the attraction of new kinds of computing, such as soft computing, has allowed to develop a program support of KB design processes.

The program tool is realized as a sequence of GAs for rough and thin adjustment of parameters of production rules in KB, and to optimize its structure. The description of use of the given product is in detail considered in [8]. Thus, the program tool represents patentable intellectual product.

The process of KB design can be divided into two sub-steps: 1) data processing and formation of knowledge; and 2) program and tool support of design processes with the purpose of optimization of KB structure.

Thus, creation of IP on intellectual product is possible under condition of novelty of components in modeling system or in program support tool.

Next important step during a legal IP protection is the creation of trademark (TM) on industrial sample. In Table 1, TM for the developed tool is shown.

The semantic content of KB Optimizers is included in their TM titles. Thus, the logical result of developed TM is as follows:

(1) **SCOptKB™**; (2) **QCOptKB™**; (3) **QSCOptKB™**

The next stage of IP protection is the creation of protection of the copyright to duplicating created intellectual product [23, 24]. Thus, on the given example we have shown that creation

of a uniform chain «the Patent - TM - the Copyright» is a necessary and sufficient condition of legal protection program intellectual product.

Table 1: *Logic process of TM formation on KB optimizers*

№	Computations and abbreviations	Operations and abbreviations	Object of optimization	TM
1	Soft Computing (SC)	Optimization (Opt)	Knowledge Base(KB)	SCOptKB
2	Quantum Computing (QC)	Optimization (Opt)	Knowledge Base (KB)	QCOptKB
3	Quantum Soft Computing (QSC)	Optimization (Opt)	Knowledge Base (KB)	QSCOptKB

5. Conclusions and recommendations

1. Problems of patentability regarding software and mathematical algorithms are solved in USA, Japan and in EU countries.

2. The Russian legislation in the field of protection of the intellectual property [23, 24] allows to carry out copyrights to software. Taking into account growing interest to high information technologies in various spheres of the Russian economy, it is necessary to develop the experience of legal protection of intellectual product described in patents, protected in USA.

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