«QUALITY ASSESSMENT INDICATORS OF THE SMART EXPERT SYSTEMS FOR ANALYSIS AND CONTROL ON THE SOCIOTECHNICAL LANDSCAPE»

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Summary. Rapid changes in the sociotechnical landscape (STL) make it necessary to control the process of its management, which is possible when using hybrid intelligence with automated decision support systems (ADSS). The system-forming core of ADSS is smart expert systems (SES). The problem arises of a comprehensive assessment of the quality of SES to satisfy the demands by social practices at the expansion of digital technologies. At present the regulated approach of quality assessment at the symbolic level is not sufficiently formalized. The purpose of the study was the development and testing of various indicators of the quality of SES, allowing for certain semantic groups and in general to assess the various properties of SES for an optimal choice. Described an ensemble of indicators of the quality: privates, complex (representing a group of private in the form of a symbol) and an integral indicators. The proposed methods of calculating indicators meet the requirements of SMART and 4C concepts. For the first time semantic groups proposed: risks of decision making, trust in circulating and input-output information, quality of diagnostics, quality of recognition, reliability and homeostaticity. For the first time, it is proposed to consider a complex quality indicator as a symbolic image including: a petal diagram, a tuple of private indicators and a quantitative assessment reflecting the area of the figure normalized. To calculate the integral index, a new system of formulas has been developed, based on Shortfly techniques. The results of testing the developed set of quality indicators over medical expert systems, which showed their acceptability, are given.

Key words: sociotechnical landscape, decision support systems, smart expert systems, performance indicators.

Introduction

Sociotechnical landscape [3] is formed on the basis of demands of social organizations of groups of people of different hierarchical levels for realization of certain functional goals, ensuring its existence as a biosocial species in conditions of noosphere. This leads to the synergistic emergence of various technical, and, especially, information and digital technologies that ensure the required functioning of various social practices. Most modern digital technologies of this direction use methodologies, technologies and software products of artificial intelligence to varying degrees, which determine the adequate functioning of automated decision support systems (ADSS) [24].

The system-forming core of ADSS is smart expert systems (SES) implemented on various platforms [26]. The coevolution of the various components of STL, the optimal existence of society and its parts and elements with, as a rule, poorly structured, not clear and voluminous information, in existing and predicted umvelt and umgebung, largely depend on the quality of the work of the SES [13].

The problem of ensuring the proper quality of ADSS is closely related to the problem of quality management of the development of social practices (medicine, education, culture, economy, etc.) [1, 9] in the context of the expansion of digital technologies in the information society Industry 4.0. This makes its technical solution of a humanitarian and social orientation relevant.

The problem of quality since the time of Aristotle [23] is considered in the philosophical aspect [14, 17, 10]. One of the first understandings of the system category of "quality" was later revealed by Hegel [11]. Currently, the philosopher Subetto A.I. defines quality as quintessential - qualitivism, the characteristics of which are measurability, controllability, systemicity and axiology, procedural [22].

The modern stage of the development of the sociotechnical landscape is characterized by the decision not only to observe the co-evolution of social practices and digital technologies, but also to predict the development of processes of demand and realisability of the latter, with the aim of management and correction. Many decision support systems (including expert systems) are emerging, mainly based on the network principle [4]. The problem arises of a comprehensive assessment of the quality of such systems, that is, the set of properties and/or the degree of satisfaction of the needs of certain social practices (or their individual components).

If you consider decision support systems as software and hardware products, then to evaluate their quality, for example, in the Russian Federation, the following methods [25, 27] are defined: measuring, registration, calculation, organoleptic, expert, sociological. The latter is based on a survey and analysis of information from potential consumers. The indicators obtained by different methods allow to solve the problem of SES and ADSS quality assessment at the system level. Meanwhile, at present, there is not a sufficiently formalized approach to assessing the quality of SES for implementation by computer technologies at the symbolic level and taking into account the homeostatic and synergistic features of the object of application. similar systems in social practices [25].

In this regard, the purpose of our research was to develop and exploratory testing of an ensemble of private, complex (group) and integral quality indicators of SES and ASPR capable of evaluating, comparing and choosing at the verbal-semantic level.

Materials and methods

Performance and quality measures are distinguished when assessing the functioning of the ADSS. In the philosophical and semantic aspect, efficiency can be considered as one of the integral indicators of quality [29]. Since the category of "quality" in relation to ADSS, oriented to application in the sociotechnical landscape, involves technical and humanitarian (socio-philosophical) aspects [5], the problem of their convergence arises.

SES in ADSS is a software product. This leads to the dominance of the technical level. Convergence into an integral indicator is proposed to implement by iteratively convolving complex indicators of different groups after rationing their values in the range [0; 1] for quantitative metric and determination of the coefficients of confidence for quality indicators in a similar range of values. In this case, similar to fuzzy set theory, quantitative evaluation of integral quality index is proposed to be calculated as convolution of complex group values, transforming Shortfly formulae [19].

Requirements [6] are made in the qualimetry for integral indicators: representativeness, monotonicity, efficiency, sensitivity (classification and variability of parameters), comparability (comparability).

When developing the ensemble of quality indicators, it was taken into account that they should have five properties and four requirements, corresponding to the concepts of SMART and 4C [7] (specific, measurable, achievable, relevant; Clearness, Comletemess, Complexity, Consistency). Each quality indicator is characterized by an average value and variability. In the case of using a qualitative metric, this is a fuzzy range of a linguistic variable. With quantitative metrics, variability is often estimated by a 5% deviation from the obtained value.

After determining the nomenclature of quality indicators, they were grouped by semantics to form a motorcade based on the opinions of experts.

Testing of the obtained quality indicators was carried out on SES similar in the social practice "Medicine": "Home Doctor" [12] and "Consilium" [8].

Results and discussion.

Given the wide variety of existing expert systems in the various social practices of STL and which are the basis of the ADSS, it is proposed to consider groups of quality indicators reflecting various properties, the calculation of values of which uses different methodological approaches, which allows a systematic, integrative approach to the issue of SES assessment. Note that if the value of the complex quality indicator in a group exceeds a certain threshold value or linguistic variable [28] identifying it has the necessary value of the belonging function, then when deciding on them can be used the philosophical category "truth of knowledge" [16].

The context of the analysis of various information allowed sources led to the formation of the following groups of private quality indicators.

1. *Risk assessment of proposed decisions.* The QCRi integrated quality indicator is a convolution of private indicators reflecting the risk of incorrect decisions as a result of the adoption of improper decisions on the management of STL in digital reality as a result of inadequately formed SES recommendations (error in the second kind). Private quality

indicators make up a array that reflects the risks of errors: selectivity (incorrect choice of an alternative solution to the SCL) - Sel, inadequate formation of SES of many alternatives - InForm, overdiagnosis ("overestimated hazard") - IverDia, hypodiagnostics ("underestimated hazard") - UnderDia: PrivQCRi={Sel, InForm, IverDia, UnderDia}. The numerical values of these indicators are evaluated by experts after experimental operation. If the SES solves problems for classification (or diagnostics), and its classification power (TPR - true positive rate) is known, then, in the first approximation, QCRi = 1-TRP. Since the metric of quality coefficients of different groups must correspond to one principle "from worst to best," as from "0" to "1," then the calculation should take the value of 1-QCRi (= TRP).

2. *Evaluation of confidence measures to information* – QCTi*:* input, circulating and output. QCTi is calculated as functionality from trust factors: to input information -CCin; to circulating information - CCci; to the output information - CCoi: QCTi=F(CCin,CCci,CCoi). The CCin coefficient determines the subjective trust of the decision maker to formalized information about the object, subject or process in the STL, in the thesaurus of the SES interface. The CCci coefficient determines the confidence of the decision maker in artificial intelligence procedures or strict mathematical methods based on algorithms that determine the functioning of the SES. The CCoi coefficient characterizes the adequacy of the generated information with respect to the previously made decisions. In the first approximation, it can be estimated by accuracy (ACC) if a classification or diagnostic problem is solved. Since these the particular quality indicators characterize independent processes, then: QCTi=kcc·CCin·CCci·CCoi, where kcc is a correction factor that takes into account the "dissenting opinion" of the decision maker (to increase or decrease the obtained QCTi value (if there is no such opinion, then kcc = 1). Thus, PrivQCTi={CCin, CCci, CCoi}.

3. *Typical statistical indicators of classification (diagnostics) quality* - QCSt. Это - TPR - true positive rate, SPC - true negative rate, ACC - accuracy, TS - threat score (or CSI - critical success index (CSI), odds ratio – OV= (1-TPR)/SPC. OV allows to estimate probability of occurrence of some event with its pre-probability (before application of SES) by special nomogram [21]. These specific values are determined during testing and/or simulation. We used diagnostic tests according to the book D. Nicoll [21]. Since OV is not normalized in the range [0;1], it is excluded from the QCSt calculation algorithm, although it is taken into account when analyzing quality. Thus, PrivQCSt={TRP, SPC, ACC, CSI}.

4. *Reliability indicators* - QCKe characterize probability of failure or loss of SES operability during operation (uptime probability UP(t)) and failure rate. These indicators are determined by the characteristics of computers, operating systems and software compatibility. If the time of failure-free operation of the SES is long compared to the time of making decisions of the SCL, then this complex indicator is not taken into account when calculating the proposed integral indicator.

5. Recognition quality indicators reflecting the quality of recognized images (classes) of situations to be analyzed, predicted and corrected (controlled) - QCCl: in terms of reliability of recognition RecRel - (analogue of accuracy in QCSt), in terms of prediction strength PredPow, in terms of efficiency of classification EfCl, in terms of learning ability - AbLe, in terms of labor intensity of SCL with SES - LabInt. Thus, PrivQCCt ={PredPow, EfCl, AbLe, LabInt}.

6. Homeostatic quality indicators [28] (QCGo) make it possible to assess the level of quality of maintaining homeostasis (MainHom) and the level of quality of suppressing penetrating

interference (informative noisiness of input information - PenInt). Thus, the set PrivQCGo={MainHom,PenInt}.

Integral convolution of quality indicators most often uses an additive or multiplicative structures with parameters that determine the weight coefficients of the "importance" of arguments. The Integrated Quality Measure (QIC) is proposed to be defined as a rollup of complex measures as follows. The decision-maker using hybrid intelligence (DMHI) [5], based on the objectives of the analysis, determines the importance of the groups for which the tuple of complex indicators is compiled. Then lower and upper thresholds are introduced, which determine application of certain formulas - por1 n por2, presented in Table 1 (Obtained by transformation of formulas of calculation of Shortleaf confidence coefficients of decisive rules of knowledge base of MYCIN expert system [20] and its subsequent modifications.)

As a complex indicator for the CIg group, it is proposed to use the image of deviations of values of partial criteria from nominal ones (on the lobe diagram) and its quantitative characteristic - deviation of this image from nominal or optimal (in this case - "1"). The axes of the diagram are evenly distributed in a circle. Then the complex indicator is a set: CIg={image, array, normrea, corteg}. (Here: image - the shape of a petal diagram, array - a set of private criteria, normrea - the normalized area of the figure on the diagram, corteg - a tuple of private indicators, ordered in descending order).

Table 1. Formulas for calculating the integral quality index QIC.

	u_i < por1	$u_j \subset [por1; por2]$	u_i > por2
u_j < por1	$\min(u_i,u_j)$	$\min(u_i,u_j)+\frac{\lvert u_i-u_j\rvert}{1+\min(u_i,u_j)}$	$\max(u_i,u_j)-\frac{\lvert u_i-u_j\rvert}{1+\min(u_i,u_j)}$
$u_j \subset [por1; por2]$	$\min(u_i,u_j)+\frac{\lvert u_i-u_j\rvert}{1+\min(u_i,u_j)}$	$\{\max(u_i,u_j)+\min(u_i,u_j)+\frac{\lvert u_i-u_j\rvert\cdot[\max(u_i,u_j)-\min(u_i,u_j)]}{[1+\max(u_i,u_j)]\cdot[1+\min(u_i,u_j)]}\}/2$	$\max(u_i,u_j)-\frac{\lvert u_i-u_j\rvert}{1+\max(u_i,u_j)}$
u_j > por2	$\min(u_i,u_j)+\frac{\lvert u_i-u_j\rvert}{1+\max(u_i,u_j)}$	$\max(u_i,u_j)-\frac{\lvert u_i-u_j\rvert}{1+\max(u_i,u_j)}$	$\max(u_i,u_j)$

Where: u_i, u_j - values of complex indicators of groups i and j; u_j follows u_i in the tuple.

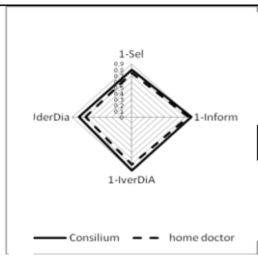
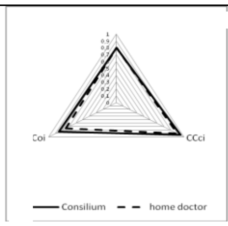
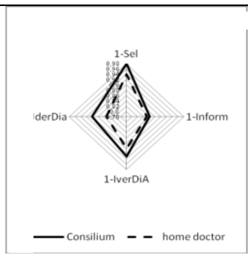
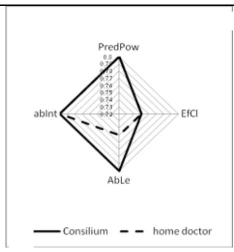
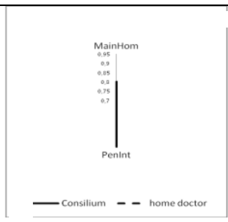
This presentation allows for the assessment of a comprehensive indicator at the verbal level. The dev order of axes in array is not clearly defined, normrea in the complex quality indicator by group is proposed to be calculated using the formula:

$$normrea = \sqrt{\frac{2\cdot\sum_{i=1}^{n}\sum_{j=1/j\neq i}^{n}(x_i\cdot x_j)}{(n-1)\cdot n}}, \quad (1)$$

where: x_i, x_j, n - values and number of private quality indicators in the group, respectively.

As a test of the selective capabilities of the proposed ensemble of quality indicators (private, complex and integral), two automated diagnostic medical systems currently used in medical practice were investigated: "Home doctor" and "Consilium." With the help of experts, specialists in the field of artificial intelligence (2 professors, 4 candidates of sciences, engineer - cognitologist, software engineer, one head of the enterprise, two sociologists, two philosophers), the motorcade {QCRi; QCCl; QCTi; QCSt;QCGo} and thresholds according to the "golden section" principle: por1=0,237 & por2=0,856. The results are shown in Table 2.

Table 2. SES quality indicators

Group, complex indicator	Private indicator	SES «home doctor»	SES «Consilium»	Image character, tuple, value
QCRi Risk Assessment	Sel InForm IverDia UnderDia	0,25 0,25 0,2 0,3	0,2 0,1 0,1 0,2	 Complex indicators home doctor 0,97 Consilium 0,99 Tuples home doctor: IverDiA, Sel, InForml, UderDia Consilium: Inform, IverDiA, Sel, UderDia
Assessing confidence in QCTi information	CCin CCci CCoi	0,8 0,9 0,75	0,8 0,95 0,85	 Complex indicators home doctor 0.82 Consilium 0,87 Tuples home doctor: CCci, CCin, CCoi Consilium: CCci, CCoi, CCin
QCSt classification	TRP SPC ACC CSI	0,94 0,85 0,9 0,85	0,98 0,86 0,93 0,9	 Complex indicators home doctor 0,88 Consilium 0,92 Tuples home doctor: TRP, ACC, SPC, CSI Consilium: TRP, ACC, CSI, SPC
PrivQCCt recognizers	PredPow EfCl AbLe LabInt	0,8 0,75 0,75 0,8	0,8 0,75 0,8 0,8	 Complex indicators home doctor 0.77 Consilium 0,79 Tuples home doctor: PredPow, LabInt, EfCl, AbLe Consilium: PredPow, LabInt, AbLe, EfCl
Maintaining homeostasis PrivQCGo	MainHom, PenInt	0,8 0,7	0,9 0,9	 Complex indicators home doctor 0.77 Consilium 0,82 Tuples home doctor: PenInt, MainHom Consilium: MainHom, PenInt
Integral index QIC		0,815	0,917	

Thus, both analyzed POS are suitable for use as part of the ADSS because QIC>0.62 (upper threshold of the "golden section"), but the "Consilium" of the ADSS is preferable, since its QIC is 12.5% more and QIC > 0.856 (the previously selected upper threshold of the "rigid" classification criterion "[15]).

Conclusion. In the course of the study, an ensemble of indicators of the quality of the work of the expert system was determined as the main module of the ADSS, designed to analyze, predict and manage sociotechnical landscapes in modern conditions of digital intelligence of social practices. The scientific and practical novelty of the study is determined by the following:

Conclusion.

In the course of the study, an ensemble of indicators of the quality of the work of the expert system was determined as the main module of the ASPR, designed to analyze, predict and manage sociotechnical landscapes in modern conditions of digital intelligence of social practices. The scientific and practical novelty of the study is determined by the following:

1. It is shown that the quality of functioning of the SES can be estimated using an integral indicator calculated as the functionality of complex group indicators, which are a symbol-image of partial indicators in a certain semantic group.

2. Formed groups of private indicators include assessment of SES properties: risks of decision making, trust in circulating and input-output information, quality of diagnostics, quality of recognition, reliability and homeostaticity.

3. To calculate complex and integral indicators, methodologically different concepts were used, which corresponds to the basic principles of self-organizational modeling: synthesis of a symbolic quality image and a modified Shortfly method.

Exploration testing of the ensemble of quality indicators on medical smart expert systems showed their acceptability when choosing the toolkit for solving the problems of the best choice of the best SES for ASPR of STL management in digital reality.

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