Software in the field of information and analytical support for territorial management: a methodological approach to assessment

P V Senchenko and A A Sidorov
Tomsk State University of Control Systems and Radioelectronics, 40, Lenina Ave., Tomsk, 634050, Russia

E-mail: pvs@tusur.ru

Abstract. The article considers the approach to software evaluation, which is used for information and analytical support of the territorial administration. It is proposed to use a computational procedure based on determining the correspondence of the functional completeness particular alternative to a reference sample. A set of parameters has been formed that needs to be taken into account to select a specific information technology solution for the intended purpose. The proposed tools can be adapted to compare software systems for other purposes.

1. Introduction
Today's software market has developed a segment of standard design solutions for information analysis support of public administration, with a focus on management of social and economic territorial development. As expected, this results in the following situation: on the one hand, the development of such solutions allows customers to choose information systems that meet their needs best, while on the other hand, developers strive to integrate their systems with as many services as possible, with many of them completely irrelevant for the user, which results in a rather expensive product with excessive functionality. The authors propose to base the comparative analysis on a method for evaluation of automated information systems and technologies that checks the functional range of any solution against user requirements, a certain standard, or a technology that is being developed.

Today, there are several basic methodological approaches to the assessment of complex systems. They can conditionally be divided into general and specialized tools for the nature of objects. The first group may include classical and based on them modifications decision-making methods [1-4]: methods of the main criterion, composite (integral) criterion, ideal point, evidential reasoning approach. Their application requires additional research regarding the development of models for assessing the object. The second group is formed by methods originally intended for software research, which include Russian standards (GOST 28195-89, GOST R ISO/IEC 25010-2015) and actual international standard for evaluating the quality of software products [5], as well as methods for assessing the quality and comparison of software products according to various criteria [6-8].

The research purpose is the description of the methodological approach to comparing complex software systems by the criterion of functional completeness. Our main contributions are to create a software evaluation model for information analysis support of regional development management with
defining a set of key functions.

2. Software evaluation model

The methodology for evaluating automated information systems and information technologies for comparative analysis was adapted. The technique is based on verifying that the functional completeness of the solutions under consideration meets the user’s requirements, a certain standard, or the technology being developed [9]. For comparison, it is proposed to use a ‘reference’ information system, which has functional software solutions characteristics available on the market that are significant in terms of managing the socio-economic territories development, and services that are based on new methodological and instrumental approaches (according to the paper authors software solutions include areas such as: information system’s development and analytical support for the activities of authorities and management; an unified interdepartmental information and statistical system development; a state geoinformation portal creation providing the publication of basic spatial data and basic spatial information and metadata; provision of electronic state digital maps and plans). The above goal-determining provisions allow us to state the priority development of such functionalities as spatial analysis, which can be implemented using geoinformation technologies, and decision support based on both classical methods and data mining methods, developing, in turn, on the basis of the apparatus fuzzy logic.

Let \( Z = \{Z_i\}, i=1,2,..., n \) be a set of software and hardware solutions selected for comparison; \( R = \{R_j\}, j=1,2,..., m \) be a set that represents the dictionary of functions (features) implemented in solution \( \{Z_i\} \). The initial information is represented in the form of a matrix \( X = \{X_{ij}\} \), with its elements defined as follows:

\[
X_{ij} = \begin{cases} 
1, & \text{if the function is implemented} \\
0, & \text{if the function is no implemented} 
\end{cases}
\]

Assume that \( Z_k \) is the reference solution. The case makes use of the following designations:

- \( P_{ik}^{(11)} \) is the number of functions implemented both in \( Z_i \) and in \( Z_k \), i.e. \( P_{ik}^{(11)} = |Z_i \cap Z_k| \) is the size of the intersection of sets \( Z_i = \{X_{ij}\} \) and \( Z_k = \{X_{kj}\} \);
- \( P_{ik}^{(10)} \) is the number of functions implemented in \( Z_i \), but not in \( Z_k \), i.e. \( P_{ik}^{(10)} = |Z_i \setminus Z_k| \) is the size of the difference of sets \( Z_i = \{X_{ij}\} \) and \( Z_k = \{X_{kj}\} \);
- \( P_{ik}^{(01)} \) is the number of functions implemented in \( Z_k \), but not in \( Z_i \), i.e. \( P_{ik}^{(01)} = |Z_k \setminus Z_i| \) is the size of the difference of sets \( Z_k = \{X_{kj}\} \) and \( Z_i = \{X_{ij}\} \);
- \( P_{ik}^{(00)} \) is the size of the union of \( Z_i \) and \( Z_k \), i.e. \( P_{ik}^{(00)} = |Z_i \cup Z_k| = P_{ik}^{(11)} + P_{ik}^{(10)} + P_{ik}^{(01)} \).

The portion (share) of functions of solution \( Z_i \) that are also implemented in \( Z_k \) can be assessed using the value \( H_{ik} = \frac{P_{ik}^{(11)}}{P_{ik}(P_{ik}^{(11)} + P_{ik}^{(10)} + P_{ik}^{(01)})} \). Correlation between \( Z_i \) and \( Z_k \) is assessed based on the values \( P_{ik}^{(11)} \) and \( G_{ik} = \frac{P_{ik}^{(11)}}{P_{ik}^{(10)}} - \frac{P_{ik}^{(00)}}{P_{ik}^{(11)}} \) \((0 \leq G_{ik} \leq 1)\), where \( G_{ik} \) is the “similarity measure”.

By choosing various threshold values \( (\varepsilon_h \) and \( \varepsilon_g \) one can construct logic absorption \( H^0 \) and similarity \( G^0 \) matrices for matrices \( H \) and \( G \):

\[
H_{ik}^0 = \begin{cases} 
1, & \text{if } H_{ik} \geq \varepsilon_h, \ i \neq k; \\
0, & \text{if } H_{ik} < \varepsilon_h \ Or \ i = k \end{cases}; \quad G_{ik}^0 = \begin{cases} 
1, & \text{if } G_{ik} \geq \varepsilon_g, \ i \neq k; \\
0, & \text{if } G_{ik} < \varepsilon_g \ Or \ i = k. 
\end{cases}
\]

We propose six groups for comparison of software and hardware solutions for information analysis support of territorial development – more than 40 different parameters as examples of key functions (Table 1-6).
### Table 1. Example of properties of software and hardware solutions

(Group of parameters ‘Analysis and forecasting of social and economic development of territories’)

| #  | Parameter                                                                                       | Software and hardware solution |
|----|-------------------------------------------------------------------------------------------------|--------------------------------|
| 1  | Monitoring of key indicators of social and economic development in the region, implementation of targeted investment programs, and delivery of key indicators of economic development |                                 |
| 2  | Integrated assessment for social and economic, tax, investment operations of territories         |                                 |
| 3  | Multivariate scenario forecasting of social and economic development of the region              |                                 |
| 4  | Generation of standard reports                                                                  |                                 |
| 5  | Specification of algorithms for calculation of indicators                                       |                                 |
| 6  | Visualization of social and economic information using business graphics                        |                                 |

### Table 2. Example of properties of software and hardware solutions

(Group of parameters ‘Performance appraisal for governance and administrative bodies’)

| #  | Parameter                                                                                     | Software and hardware solution |
|----|-----------------------------------------------------------------------------------------------|--------------------------------|
| 7  | Generation of summary reports on results and main activities of executive authorities in the region |                                 |
| 8  | Evaluation of inefficient spending of regional authorities                                     |                                 |
| 9  | Calculation of indicators for monitoring and evaluating the government activities effectiveness in the subject of the Russian Federation |                                 |
| 10 | The ineffective expenses amount of the government in the subject of the Russian Federation      |                                 |
| 11 | Medium-term variant forecasting of regional government's performance indicators                |                                 |

### Table 3. Example of properties of software and hardware solutions

(Group of parameters ‘Territory passport support’)

| #  | Parameter                                                                                   | Software and hardware solution |
|----|---------------------------------------------------------------------------------------------|--------------------------------|
| 12 | Presentation summary information on various fields of activity in the region                 |                                 |
| 13 | Monitoring the status of management objects                                                 |                                 |
| 14 | Information about socio-economic development in the region, municipalities and enterprises representation |                                 |
| 15 | Attributive information about objects on the territory representation                         |                                 |
| 16 | Information on the political situation and the results of opinion polls                      |                                 |

### Table 4. Example of properties of software and hardware solutions

(Group of parameters ‘Decision support system’)

| #  | Parameter                                                                                           | Software and hardware solution |
|----|----------------------------------------------------------------------------------------------------|--------------------------------|
| 17 | Maintaining the function of formal logical inference and decision making based on the information available in the database, reference and information block and the results of spatio-temporal analysis and modeling |                                 |
| 18 | Analysis based on fuzzy modeling                                                                     |                                 |
| 19 | Conducting medium-term and long-term forecasting the performance of regional government using elements of fuzzy logic |                                 |
| 20 | The user preferences function formation                                                              |                                 |
| 21 | Use of formal optimization and ranking methods by vector criterion                                   |                                 |
Table 5. Example of properties of software and hardware solutions
(Group of parameters ‘Geoinformation functionality’)

| #  | Parameter                                                                 |
|----|---------------------------------------------------------------------------|
| 22 | Using the GIS module                                                      |
| 23 | Attribute information maintenance                                         |
| 24 | Layer Support                                                             |
| 25 | Maintaining the spatial analysis function                                 |
| 26 | Maintaining spatio-temporal modeling                                     |
| 27 | Geographic information analysis problems solution                          |
| 28 | Evaluation and interpretation of relationships between geographic features|
| 29 | Display on the map several indicators for the cause-effect relationships analysis |
| 30 | Service oriented architecture availability                                |
| 31 | The ability to dynamically expand the functionality of analytical data processing |

Table 6. Example of properties of software and hardware solutions
(Group of parameters ‘Technical implementation’)

| #  | Parameter                                                                 |
|----|---------------------------------------------------------------------------|
| 32 | Using Data Warehouse                                                      |
| 33 | Enabling multi-dimensional data cubes                                     |
| 34 | Setting a data slice: adding/deleting measurements, changing the sequence of measurements in a slice |
| 35 | Configuring the display of hierarchies in dimensions                      |
| 36 | Data slice graphical representation: setting the type of chart, facts to be displayed, scale, legend, signatures, etc. |
| 37 | Setting the database structure in accordance with the additional requirements of specific executive bodies of the constituent entity in the Russian Federation |
| 38 | Tools availability for creating and changing arbitrary reporting forms    |
| 39 | Reporting using templates                                                 |
| 40 | Exporting data to various formats availability (Excel, XML, etc.)          |
| 41 | Web-interface’s availability                                              |
| 42 | Direct interface with Google Earth map services, Yandex map               |

Similarity (Figure 1) and absorption (Figure 2) graphs based on the logic matrices $G^0$, $H^0$ offer a visualization of interrelation of the solutions in question (in terms of their functionality). The bidirectional edge of the graph between vertices $Z_k$ and $Z_l$ means that systems $Z_k$ and $Z_l$ are mutually absorbing, i.e. the functionality of system $Z_k$ is completely absorbed by system $Z_l$ and contrariwise: the functionality of system $Z_l$ is completely absorbed by system $Z_k$. 
3. Results and Discussion
Despite the overall transparency of the approach, the result will largely depend on the assumed values $\varepsilon_h$ and $\varepsilon_g$, as defined by the expert. Therefore, overestimated similarity and absorption coefficients will lead to the impossibility of correlating the systems under consideration with the reference system. The opposite situation, when these coefficients are underestimated, they can also lead to the impossibility of choosing the best system, since all the systems under consideration will be similar to the standard and mutually absorbed, which devalues the entire comparison methodology. Thus, a significant role is assigned to the decision maker, both in terms of compared indicators selection and in determining the most suitable similarity and absorption coefficients. In case if the choice of the system will be difficult and/or impossible with rather high values of $\varepsilon_h$ and $\varepsilon_g$, it is advisable to use additional selection criteria to make a definitive final one, for example, to evaluate the cost indicators, warranty obligations and support conditions.

4. Conclusion
The considered comparison technique can be used when choosing complex software products (for example, [10]). It should be noted that the adequacy of the method directly depends on the number of compared functions (parameters) and with a small number of functions will give an unreliable result. In this case, one must either decompose the functions into elementary processes or use additional comparison parameters, such as cost indicators, reliability, maintainability, productivity.
Acknowledgments
This paper is designed as part of the national project ‘Methodological and instrumental support for decision making in the tasks of managing socio-economic systems and processes in a heterogeneous information environment’ of the Ministry of Science and High Education of the Russian Federation.

References
[1] Spiegelhalter D, Best N, Carlin B and Van Der Linde A 2002 Bayesian measures of model complexity and fit. Journal of the Royal Statistical Society. Series B: Statistical Methodology 64 (4) 583-616
[2] Slovic P, Fischhoff B and Lichtenstein S 1977 Behavioural decision theory Annual review of psychology 28.1 1-39
[3] Berger J 1985 Statistical decision theory and Bayesian Analysis (2nd ed.) (New York: Springer-Verlag) p. 617
[4] Pelissari R, Oliveira M, Ben Amor S, and Abackerli A 2019 A new FlowSort-based method to deal with information imperfections in sorting decision-making problems. European Journal of Operational Research 276 (1) 235-246
[5] ISO/IEC 25000:2014 Systems and software engineering – Systems and software Quality Requirements and Evaluation (SQuaRE)2014 (ISO/IEC JTC 1/SC 7 Software and systems engineering)
[6] Gavrilov A and Kubasheva E and 2013 Estimation Procedures of Website Qualities Vestnik of Volzhsky University after V.N. Tatischev 17 138-140
[7] Lipaev V 2005 Problems of the development and quality control of large software systems Programming and Computer Software 31 (1) 47-49
[8] Shcherbakov S and Aruchidi N 2008 Economic aspects of building Internet applications: methods of comparative analysis and selection of Internet technologies Economic Sciences 43 381-387
[9] Khubaev G 1999 Complex systems: expert comparison methods News of higher educational institutions. North Caucasus region. Series: Social Sciences 3 7-24
[10] Senchenko P V, Zhukovskiy O I, Gritsenko Y B, Senchenko A P, Gritsenko L M and Kovaleva E V 2017 The web-based information system for small and medium enterprises of Tomsk region. IOP Conf. Series: Journal of Physics: Conf. Series 803