The model of the decision-making support procedure on the example of criminal proceedings

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Abstract. Algorithms and mathematical models for the implementation of the decision-making support procedure in criminal proceedings to reduce subjectivity in decision-making are proposed. The results of simulation experiments for practical application of decision-making support procedure are presented.

1. Introduction

Currently, the automation of processes covers almost all spheres of life activity. A special role in the automation of processes plays in the field of law. Nowadays, we are facing with a contradictory situation: on the one hand, there is a clear invasion of information technology in a conservative sphere; on the other hand, this conservatism generates resistance to this phenomenon.

Today, there are widely used following information systems:
- legal-reference systems, like products made by state-owned corporations ("Etalon", "System"), made by private companies ("Guarantor" [1], "Consultant" [2], "Code");
- information-analytical systems ("LanFinance", ABFI expert system);
- document management systems (1C: document, BOSS Referent, Directum);
- expert systems ("Block", "Maniac", "Robber");
- business games ("Sales").

Special attention should be paid to information systems in the field of criminology [3], for example, in the field of detection and fixation (traces, digital forensic, lie detection and logging) and information retrieval systems for operational purposes [4].

The use of automated systems will minimize such issues as the inconsistency of standards, difficulties in the practice of their application. Also, it will be possible to avoid subjective interpretation of the law.

However, most information systems in the field of law cannot be classified as intellectual: they do not rely on a knowledge base, and decision-making support mechanisms are not implemented. This fact works to strengthen the subjective component in the field of law (for example, criminal proceedings).

To improve the effectiveness in law enforcement it is necessary not only the developing of the new software systems, accounting systems, integration with the data banks, but and the creation of procedures for decision-making support. Such systems will reduce the time to perform routine
functions (consideration and resolution of disputes, understanding of the will of the legislator, interpretation of norms) and will provide an opportunity for expert work (development of regulations, the formation of legal concepts, updating of existing institutions, etc.) [5].

Previously, were made attempts to develop an ontology of law [6]. Ontological modeling as a method of formalization of criminal law norms is an important means of achieving coincidence or correlation of the dictionary of a particular subject of crime qualification with the unified dictionary of criminal law terms [7]. Covering ontology of the key concepts and categories of all norms of criminal law, will be able to ensure the conceptual compatibility and unity of information and search language of various ontologies in the field of qualification of crimes, indexing in the process of qualification of data and search for the necessary information to assess the actions of persons who have committed socially dangerous acts [8].

Also, the group of researchers of the legal technology company "Simploer" [9] offers practical scenarios in the field of automation of law for business and for the state. After all, the lagging behind the modern legal system from public relations not only hinders the development of society, takes precious time from law enforcement officers to perform routine operations, but also makes the economy less efficient, because all these processes are interrelated.

The creation of intelligent automated systems based on knowledge will not only help to reduce the subjectivity in decision-making, but also optimizes the work in professional activities. Legal decision support procedures have an important implication. After all, the legal sphere is a complex subject area, in which there are not so many obvious logical connections and there is no naturally defined taxonomy, as in many natural sciences. Nevertheless, the growing practical need for legal systems of knowledge processing at the first stage of development entails the need to formalize such knowledge, solving problems of intellectual search and logical conclusion.

The need to create the model of determining dependencies and assessing the results of court decisions arose after the identification of the subjective component in the final measure of restraint in criminal proceedings. The subjective component consists of the difference in the final punishment in cases considered under the same paragraph of the same part of the same article of the criminal code [10]. In this situation, the task of creating a model of decision-making in criminal proceedings, which could become the basis of software, seems very relevant. Such means can act not only as a kind of "simulator", used for educational purposes but also serve to identify the "bottlenecks" of the legislation, thereby contributing to the improvement of legal technology.

Paragraph 28 of article 5 of the code of Criminal procedure (hereinafter-the code of criminal procedure [11]) contains the definition of the sentence – the decision made by the court at the hearing on the guilt or innocence of the defendant and the appointment of punishment or his release from punishment by the results of proceedings in the first or appeal instance.

In accordance with article 297 UPK of the Russian Federation, the sentence of the court must be lawful, reasonable and fair. The sentence is recognized as lawful, reasonable and fair if it is decided in accordance with the requirements of the criminal procedure code and is based on the correct application of the criminal law.

Implementation of all requirements specified in the law characterizes it as a judicial sentence.

The conviction of the judge in his or her rightness on the sentence imposed is only one of the components of such a procedural action, which is the drafting of the sentence. But that can't mean its justice. A judicial sentence is a sentence imposed in compliance with all the requirements prescribed by law.

Thus, the adoption of a judicial decision is a subjective character. For example, in criminal cases, "the judge, jurors, as well as the Prosecutor, investigator, investigator evaluate the evidence on their internal conviction, based on the totality of available evidence in the criminal case, guided by the law and conscience" (part 1 of article 17 of the criminal code).

In this situation, taking into account other significant factors does not allow us to talk about any formalization of decision-making, and, as a result, about the creation of any automation tools that could be used in the field of training and professional activities. Therefore, any proposals for the
creation of research methods of the problem and the development on their basis of automation could help to minimize the subjectivity in the adoption of judicial decisions and reduce the corruption component. In connection with the provisions of the criminal code [10] with the lack of a number of articles of the lower limit of punishment, the relevance of the issue has increased.

2. Materials and methods

2.1. Goals of the study
The goal of the study is to develop mathematical models and algorithms for the implementation of decision support procedures at the stage of sentencing in criminal proceedings.

To achieve this goal, the following main tasks were solved:
- analysis of criminal cases of different categories of gravity;
- identification of the subjective component in the court decisions;
- the full list of mitigating and aggravating circumstances by analyzing the criminal code of the Russian Federation and Plenum of the Supreme court of the Russian Federation;
- assignment of weights to the circumstances by the method of pair comparisons and using own computational experiment;
- development of a mathematical model of assessment of circumstances in criminal cases;
- development of a mathematical model for the formalization of fuzzy statements in a given area;
- development of software architecture for the implementation of decision support procedures;
- study of the field of practical application of decision support procedures in the field of training and professional activities.

The formation of the decision support procedure is one of the topical issues in many subject areas, where the algorithm of decision-making depends on many factors: there are mainly qualitative criteria for evaluating alternatives; the presence of both quantitative and qualitative criteria for evaluating alternatives; evaluation criteria represent a hierarchical structure, when each of the quality attributes is detailed by specific sub-characteristics; the number of alternatives in decision-making is unknown or may vary; some of the criteria values are interdependent, there is a possibility to change the composition of evaluation criteria at any stage of decision-making.

For the criminal law sphere, it is especially important to adopt an objective judicial decision. The development of a formal procedure to support judicial decision-making can form the basis of professional training programs. In addition, the existence of such a procedure will allow the creation of expert advisory systems and make the procedure of judicial decision-making more transparent.

2.2. Mathematics methods and algorithms
It was decided to use the method of expert evaluation, the method of pair comparisons, and the method of analysis of hierarchies as mathematical methods. Special attention should be paid to the proposed approaches for the development of dependency models and evaluation of results (quantitative and qualitative), as well as the experimentally derived formula for measuring quantitative traits [12]:

\[ Y = x_{\text{min}} + (x_{\text{max}} - x_{\text{min}}) \times (k_1 + k_2 + \cdots + k_n) + \alpha \]  

(1)

The formula consists of two parts:
- \([x_{\text{min}} + (x_{\text{max}} - x_{\text{min}}) \times (k_1 + k_2 + \cdots + k_n)] – formal evaluation;
- \([\alpha] – subjective component;
- Y – final decision (in years);
- \(x_{\text{max}} – maximum penalty provided (in years);
- \(x_{\text{min}} – minimum prescribed punishment (in years);
- k_1, k_2, \ldots, k_n – coefficients assigned to the circumstances (-1, 1);
- \(\alpha – subjective component.

Due to the fact that many articles of the criminal code there is no lower limit of punishment, the formula will be as follows:
\[ Y = x_{\text{max}} \times (k_1 + k_2 + \cdots + k_n) + \alpha \]  

(2)

There are restrictions for the coefficients \( k_1, k_2, \ldots, k_n \). Thus, the sum \( k_1 + k_2 + \cdots + k_n \) - “addition operation”, which obeys certain rules:
- since there are 2 circumstances, the sum will look like \((k_1 + k_2)\);
- since the circumstances based on Art. 62 of the criminal code are equivalent, and the punishment does not change, if in a criminal case there are both circumstances, then \( k_1 = k_2 = k_1 \& k_2 \).

To measure quantitative features in the quantitative approach, it was decided to use the scale of intervals, ratios, differences and absolute scale. To measure the quality features used ordinal scale and scale names.

The formation of the decision support procedure involves the sequential implementation of the following steps (figure 1):

**Phase 1.** Analysis of articles of the special part of the Criminal code of Russian Federation

**Phase 2.** Analysis of criminal cases of different categories of severity and taken of them decisions.

**Phase 3.** Determination of the list of mitigating and aggravating circumstances, which be taken in adjudication (decision).

**Phase 4.** Application of the method of expert evaluation and the method of paired comparisons to determine the weight of the severity of each circumstance.

**Phase 5.** Development of production rules for each article of the criminal code

**Phase 6.** Application of Mamdani’s algorithm to determining the type of punishment and its degree.

**Phase 7.** An algorithm for calculating the final penalty.

**Phase 8.** Development of the program to use in the field of professional activity.

**Figure 1.** Phases of implementation of the decision support procedure.

To achieve a reliable assessment of the circumstances, the method of paired comparisons is used. At first, all mitigating and aggravating circumstances were compared in pairs, how each of them can
have a minimal impact on the decision-making in any case. Earlier circumstances and calculations of them on specific criminal cases were considered. The list of circumstances was compared by experts, regardless of the case in which they would appear.

The sum of the estimates of each circumstance is treated as its rank, which is written in the column of the corresponding expert advisor. Ranks are averaged with account opinions of all experts. The total relative assessment of each circumstance is divided by their sum, the normalized relative importance of each circumstance which is written down in the last column turns out.

2.3. Mamdani fuzzy inference system
To formalize fuzzy statements, in order to determine the truth of judgments and give them an estimate, the variables are used \((x, U, A)\):

- \(x\) – the value of the variable;
- \(U\) – universal set, the domain of definition \(x\);
- \(A\) – fuzzy set on \(U\) that interprets the value of \(x\) using the membership function \(m(x)\).

The concept of "bribe" can be represented by the linguistic variable, if it does not take numerical values, for example, "significant size", "large size", "especially large size". In this case, such a linguistic variable is described as follows: \(X, T(X), U, G, M\), where:

- \(X\) – variable name, "bribe";
- \(T(X)\) – term-the set of \(X\), given by the enumeration of values, i.e. "significant size", "large size", "especially large size", using the syntactic rule \(G\), generating terms of the set of \(X\);
- \(U\) – universal set, that is, the size from 25 000 to 1 000 000;
- \(M\) – a semantic rule that interprets the meaning of \(X\), with \(M(X)\) denoting a fuzzy subset of the set \(U\) that is, the term "large" is interpreted by the following fuzzy subset \{25000/0.3; 50000/0.55; 150000/0.75; 500000/0.55; 1000000/0.3\}.

Example 1. The statement \(X = \text{"bribery on a large scale"}\) defines a fuzzy variable "large size". We specify for this variable a universal set in discrete form {up to 25000, up to 150 000, up to 1000000} and on this set we set the membership function in the following form (figure 2):

\[
\begin{align*}
M(X) & \quad 25000 & \quad 150000 & \quad 1000000 \\
\end{align*}
\]

![Figure 2. The membership function of the simple statements.](image)
Also, the use of the algorithm is due to the fact that it is possible to use elements of fuzzy logic and the theory of fuzzy sets at intermediate stages, to introduce linguistic variables, to assign them numerical ranks, at the output, to obtain quantitative values. For example:

- \( a_1, a_2, \ldots, a_n \) – data on the committed crime and its qualification;
- \( b_1, b_2, \ldots, b_n \) – the existence of mitigating circumstances and their types;
- \( c_1, c_2, \ldots, c_n \) – the existence of aggravating circumstances and their types;
- \( k_1, k_2, \ldots, k_n \) – the coefficients of the gravity of the circumstances;
- \( \text{max} \) – the maximum amount of punishment;
- \( \text{min} \) – the minimum size of punishment.

There is an expert assessment of the significance (influence) of mitigating and aggravating circumstances on the amount of punishment. It can be obtained from judges or investigators (acting as experts) who deal directly with the assessment of circumstances. To formalize this evaluation by using a linguistic variable \( \langle \beta, T, X, G, M \rangle \), where

- \( \beta \) – mitigating (aggravating) circumstance;
- \( T \) – "factor is not affected (minimally affected) to the amount of punishment" that "circumstance, and influences the amount of punishment", "the fact greatly affects the amount of punishment";
- \( X = [-1; 1] \);
- \( G \) – the procedure of formation of new terms by means of logical sheaves and modifiers. For example, "the circumstance has the maximum effect on the amount of punishment";
- \( M \) – the procedure for setting the universe \( X = [-1; 1] \) values of the linguistic variable, ie, terms from the set \( T \).

3. Results and discussion

For example of the use of the method of pair comparisons in table 1 the results of the comparison of mitigating circumstances, in the same order, were compared aggravating circumstances.

| Bi | Sum of points of the 1st expert | Sum of points of the 2nd expert | Sum of points of the 3d expert | Sum of points of the 4th expert | Sum of points of the 5th expert | The average amount of points | Weight of circumstance |
|----|--------------------------------|--------------------------------|--------------------------------|--------------------------------|--------------------------------|------------------------|----------------------|
| b1 | 2                              | 2                              | 2                              | 2                              | 2                              | 2                      | 0.02                 |
| b2 | 5                              | 6                              | 5                              | 4                              | 5                              | 4.1                    | 0.04                 |
| b3 | 6                              | 6                              | 6                              | 7                              | 6.2                            | 0.05                   |
| b4 | 8                              | 7                              | 8                              | 8                              | 8                              | 7.8                    | 0.07                 |
| b5 | 7                              | 7                              | 7                              | 7                              | 7                              | 7.2                    | 0.06                 |
| b6 | 7                              | 7                              | 7                              | 8                              | 7                              | 7.2                    | 0.06                 |
| b7 | 11                             | 11                             | 11                             | 10                             | 12                             | 11.8                   | 0.09                 |
| b8 | 1                              | 1                              | 1                              | 1                              | 1                              | 1                      | 0.01                 |
| b9 | 12                             | 12                             | 11                             | 13                             | 11                             | 11.8                   | 0.1                  |
| b10| 1                              | 1                              | 1                              | 1                              | 1                              | 1                      | 0.01                 |
| b11| 13                             | 13                             | 13                             | 12                             | 13                             | 12.8                   | 0.1                  |
| b12| 4                              | 4                              | 5                              | 4                              | 4                              | 4.2                    | 0.04                 |
| b13| 9                              | 10                             | 10                             | 9                              | 9                              | 9.4                    | 0.08                 |
| b14| 15                             | 14                             | 14                             | 15                             | 14                             | 14.4                   | 0.12                 |
| b15| 5                              | 5                              | 5                              | 5                              | 5                              | 5                      | 0.04                 |
| b16| 14                             | 14                             | 14                             | 14                             | 15                             | 14.2                   | 0.11                 |

The next step is to assess the degree of preference (significance) of one circumstance over another. To do this, the scale of relative importance is used. As in the first case, the expert (in our particular case, the judge) conducts a paired comparison of circumstances on the proposed scale.
After the creation of matrices for each expert (one case of one judge), a single matrix of paired comparisons for all experts (judges) is developed. In the case where experts have different opinions on the significance of the circumstances, the geometric mean for each cell, the arithmetic mean and other methods are used as a method of averaging the significance.

The method of paired comparisons is suitable for both quantitative and qualitative types of punishments. Taking into account that for qualitative types of punishments calculation of weights of circumstances and the formula of calculation are inapplicable, in this case, the method of pair comparisons deserves special attention, in this way all circumstances brought in the law are worked out.

To implement the algorithm, the production rules are formulated on the basis of the following information:

1. Data on the committed crime (crimes).
2. Qualification of crime (article of the criminal code).
3. The presence of mitigating circumstances and their types.
4. The presence of aggravating circumstances and their types.
5. The coefficients of the gravity of the circumstances.
6. The minimum penalty for this type of crime.
7. The maximum penalty for this type of crime.

For all articles of the Criminal code, the general rules can be divided into two groups: for quantitative and combined punishments (quantitative and qualitative).

For quantitative punishments (arrest, imprisonment (in years, months)).

\[ a_1, a_2, \ldots a_n \] – data on the committed crime and its qualification;
\[ b_1, b_2, \ldots b_n \] – extenuating circumstances;
\[ c_1, c_2, \ldots c_n \] – aggravating circumstances;
\[ \text{min} \] – the minimum amount of punishment;
\[ \text{max} \] – the maximum amount of punishment;
\[ k_1, k_2, \ldots k_n \] – the weight of circumstances (mitigating);
\[ t_1, t_2, \ldots t_n \] – the weight of circumstances (aggravating).

Rule 1:
If \((a_1\text{ and } a_2\text{ and } \ldots a_n)\text{ and } (b_1\text{ and } b_2\text{ and } \ldots b_n)\) then (\text{min});

Rule 2:
If \((a_1\text{ and } a_2\text{ and } \ldots a_n)\text{ and } (c_1\text{ and } c_2\text{ and } \ldots c_n)\) then (\text{max});

Rule 3:
If \((a_1\text{ and } a_2\text{ and } \ldots a_n)\text{ and } (b_1\text{ and } b_2\text{ and } \ldots b_n)\) then (\text{max} - (\text{max} - \text{min}) \times (k_1 + k_2 + \ldots k_n));

Rule 4:
If \((a_1\text{ and } a_2\text{ and } \ldots a_n)\text{ and } (b_1\text{ and } b_2\text{ and } \ldots b_n)\text{ and } (c_1\text{ and } c_2\text{ and } \ldots c_n)\) then (\text{max} - (\text{max} - \text{min}) \times (k_1 + k_2 + \ldots k_n) + (\text{max} - \text{min}) \times (t_1 + t_2 + \ldots t_n));

For combined punishments – quantitative with qualitative (for example, deprivation of liberty + deprivation of the right to engage in certain activities).

\[ a_1, a_2, \ldots a_n \] – data on the committed crime and its qualification;
\[ b_1, b_2, \ldots b_n \] – extenuating circumstances;
\[ c_1, c_2, \ldots c_n \] – aggravating circumstances;
\[ \text{min} \] – the minimum amount of punishment;
\[ \text{max} \] – the maximum amount of punishment;
\[ k_1, k_2, \ldots k_n \] – weight of circumstances (mitigating);
\[ t_1, t_2, \ldots t_n \] – weight of circumstances (aggravating);
\text{quality} – quality punishment.

Rule 1:
If \((a_1\text{ and } a_2\text{ and } \ldots a_n)\text{ and } (b_1\text{ and } b_2\text{ and } \ldots b_n)\) then (\text{min});

Rule 2:
If \((a_1\text{ and } a_2\text{ and } \ldots a_n)\text{ and } (c_1\text{ and } c_2\text{ and } \ldots c_n)\) then max and quality;
Rule 3:
If \((a_1 \text{ and } a_2 \text{ and } \ldots \text{ and } a_n) \text{ and } (b_1 \text{ and } b_2 \text{ and } \ldots \text{ and } b_n) \text{ and } (c_1 \text{ and } c_2 \text{ and } \ldots \text{ and } c_n)\) then \(((\text{max}-(\text{max}\text{-}\text{min})) \cdot (k_1 + k_2 + \ldots + k_n)+(\text{max}\text{-}\text{min}) \cdot (t_1 + t_2 + \ldots + t_n)) \text{ and quality } \cdot (k_1 + k_2 + \ldots + k_n));

Rule 4:
If \((a_1 \text{ and } a_2 \text{ and } \ldots \text{ and } a_n) \text{ and } (b_1 \text{ and } b_2 \text{ and } \ldots \text{ and } b_n)\) then quality;

Rule 5:
If \((a_1 \text{ and } a_2 \text{ and } \ldots \text{ and } a_n) \text{ and } (b_1 \text{ and } b_2 \text{ and } \ldots \text{ and } b_n)\) then min and quality;

Rule 6:
If \((a_1 \text{ and } a_2 \text{ and } \ldots \text{ and } a_n) \text{ and } (b_1 \text{ and } b_2 \text{ and } \ldots \text{ and } b_n)\) then \((\text{max}\text{-}\text{min}) \cdot (k_1 + k_2 + \ldots + k_n)).

There are difficulties with the definition of production rules for articles of the criminal code with a large number of points and a difference in punishments. Therefore, additional rules should be formulated for each article of the criminal code. Also will be separately actions for the qualification of crimes under a set of articles.

The fuzzy inference algorithm provides flexibility in decision-making because it is possible to adjust the evaluation criteria and inference rules.

The final step in the decision-making model is software implementation. The following structure is used for this:

4. Conclusion
The developed model of decision – making is universal and can be applied not only in the field of criminal proceedings but also in other subject areas when changing the list of alternatives to decisions, evaluation criteria and possible changes (additions) to the rules of withdrawal.

In the field of law, the model is the basis for creating a knowledge base of expert systems [15], which can be used in the field of training, as well as in professional activities. Research in the field of automation of decision – making in criminal law is currently quite promising. In addition, the study of the problems of decision-making in law has a positive impact on the improvement of legal technology and leads to the creation of training programs for students, training for professional activities, control the development of material, the development of a specialized modeling language, as well as the creation of support procedures for judicial decisions.
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