The Principles of Creation an Intelligent System for Solving Criminalistics Problems

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Abstract
Considered the features of the use of data mining methods and their computer implementation in the study of the influence of psychological characteristics of a person on the signature's attributes.

Keywords
Data mining, Galois closures, potential hypotheses, psychological characteristics, signature's attributes, two-level structure.

1. Introduction

Data mining methods allow you to discover new knowledge and identify patterns in subject areas with poorly structured data. Examples of such fields are sociology and criminalistics. Structuring the source data, determining the conditions for the applicability of data mining methods, forming a system of relations in the process of working together with an expert increases the level of formalization of knowledge representation.

Data mining tools and their implementation in computer systems for solving problems in the humanities must meet certain conditions. This is due to the specifics of the tasks and the presentation of data in these areas.

In computer systems that solve problems using data mining methods, there should be means to identify the causes of effects and interpret the resulting dependencies.

The specifics of the work of an intelligent system implementing the use of data mining methods are considered in relation to the task of identifying the influence of psychological characteristics on the execution of the signature. The fact of such an influence is recognized by both psychologists and handwriting experts, but no clear dependencies between psychological characteristics and signature features were revealed [1, 2]. In the majority of studies, the inverse problem is solved – the determination of personality characteristics by handwriting, and mainly graphological methods are used. Graphology has developed a rich system of handwriting’s attributes and accumulated practical experience, but it is more an art than a science and does not explain the conclusions obtained.

The use of data mining methods should not only determine the psychological factors affecting the manifestation of certain handwriting’s attributes, but also provide an explanation for the dependencies obtained. You can also use these methods to verify the validity of the graphological approach.

2. Formulation and specificity of the problem

The task of identifying the influence of psychological characteristics of a person on the attribute manifested in his signature is as follows. There is an array of data that contains descriptions of psychological characteristics and signature attributes for a group of respondents. It is assumed that these data implicitly contain dependencies between subsets of psychological characteristics of respondents and certain attributes of their signatures. It is required to identify these dependencies.

This task has features related to the selection and description of data.

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Psychological characteristics are described using psychological tests, signature's attribute are highlighted and described by a handwriting expert. However, there are a number of difficulties in presenting both psychological and handwriting data.

Different psychological tests reflect different aspects of a person's psychological profile. There are different tests to describe the same side. When choosing a test, it is assumed that the psychological traits described by it determine the characteristic features of the signature.

When describing signature's attributes, different experts identify different attributes, and try to minimize their number. The same attribute value found in the signatures of different respondents can be called by an expert in different ways [4].

There is subjectivism in the description of psychological and handwriting data.

Another specificity of the task is the lack of a research hypothesis about the nature of the influence. This further complicates the choice of psychological tests. Therefore, this choice should be iterative.

These specificity of the problem impose specific requirements on a computer system that implements methods of solving it with the help of data mining. The specifics of the problem impose requirements on the method of its solution and the computer system implementing this method. These requirements are aimed at minimizing subjectivity in the description of data. They should take into account the possibility of iteration based on the results of the system.

These requirements are as follows:

- the ability to work with multiple texts at the same time;
- the ability to delete and add tests and/or signature attribute based on the results of the system;
- the availability of a detailed list of signature's attributes in the database;
- the presence of an input subsystem that allows the expert to describe the signature as fully and unambiguously as possible using a list of attributes.

The input subsystem takes into account the hierarchical structure of the signature's attribute and offers the expert a choice of the name of the attribute and its value from the lists. These ensures unambiguity of the naming of the attribute. This eliminates subjectivism in the designation of signs, which introduces errors in determining the results of the operation of similarity of signatures.

The hierarchical representation of the signature's attribute, the list structure and the description of the input subsystem were described in [5].

3. The solution method

To solve the problem, a variant of data mining using the JSM-method of automated research support was chosen. There are a number of reasons for choosing this method.

The JSM-method was created as a formalization of methods of John Stuart Mill [6,7]. The JSM- method is constantly being improved. Now it implements automated research support, based on JSM-reasoning and JSM-research.

JSM-reasoning is applied to two fact bases (BF^+ and BF^-). They contain data about the relations "object shows effect" and "object does not show effect", respectively. As a result of the sequential application of rules based on the synthesis of cognitive procedures - induction, analogy and abduction, hypotheses are generated about the causes of the manifestation or non-manifestation of the effect (hypotheses of the I-th kind) and hypotheses predicting the manifestation / non-manifestation of the effect for objects about which it is unknown which of the two BF they belong to (hypotheses of the II-th kind).

JSM research studies the preservation of the truth values of the hypotheses obtained with the sequential expansion of the databases of facts and is a means of detecting empirical regularities [8].

The use of the JSM-method for solving problems in subject areas has led to the need to consider various options for presenting data in a fact base. The minimal predicates implementing induction were also extended. According to the way data is presented in the fact base, two options are distinguished - atomistic and non-atomistic. In the atomistic version in the fact base, each object has or does not have one property. If there are several properties, they are independent and can be considered separately. Positive and negative BF contain examples (facts) of the form: "Object *X* has property *Y*" and "object *Z* does not have property *Y*". The atomic variant is used to identify the reasons why objects have or do not have certain properties and predict, using these reasons, the presence or absence of these properties in new objects. The non-atomistic version is used in problems in which the influence of the characteristics of an object on the features of the effect it manifests is sought. In such tasks, the effect is described not just by the name, but also, like the object, has a complex structure. Therefore, examples of BF^+ and BF^- are: "object *X* exhibits effect *Y*". Examples are divided into positive and negative by an external factor, assuming that objects related to this factor in different ways exhibit different effects. It is important that in the atomistic version, the property in positive and negative examples is the same, and in the non-atomistic version, the effects in such examples are different.

Minimal predicates - simple positive and negative direct similarity predicates find the similarity *V* of at least two objects in BF^+ and BF^- as a result of a similarity operation (the operation is determined at the stage of creating a domain model). All objects containing *V* are taken (the condition of exhaustion). Predicates describe an empirical dependence of the type "similarity of objects in (+/-)-examples implies similarity of *W* effects and, moreover, for all objects under consideration. A hypothesis of the I-th kind (*V*,*W*) is assigned a truth value of +1 if it satisfies a positive similarity predicate, -1 if it satisfies a negative one, and 0 if it satisfies both.

The JSM-method with direct similarity predicates is used in the atomistic version. In the case of a nonatomistic variant, the JSM method with inverse similarity predicates can be used. In the inverse predicate, the condition of exhaustibility is imposed on the result of similarity of effects. Direct and inverse predicates differ in causal orientation. We can consider a mutual similarity predicate in which the exhaustibility condition applies to both objects and effects at the same time. The informativeness of descriptions of objects and effects determines the choice between these predicates.

In some tasks, the description of an object can be refined with additional parameters. An example of a fact base in such tasks is: "object *X* with additional parameters Z_1, ... Z_k exhibits the effect *Y*". In this case, the exhaustion condition can be imposed on the object along with additional parameters or only on additional parameters.

Simple similarity predicates are extended with various additions. The prohibitions of counterexamples, the uniqueness of the reason are examples of such additives. The Cartesian product of sets of positive and negative similarity predicates forms the distributive lattice of strategies of the JSM-method [9].

The presence of a set of strategies makes it possible to choose the most adequate for solving the problem. The abductive convergence test points the way to expanding the fact base. Analysis of the results allows you to adjust the data, the choice of strategy. Finding regularities can lead to the construction of a theory.

The participation of an expert is necessary at the level of developing a domain model and adjusting it based on the analysis of the results obtained. Therefore, a computer system for the implementation of data mining should be automated.

The JSM-method is a tool for automated research support. It generates knowledge as a result of extracting dependencies implicitly contained in arrays of empirical data. It is essential that these dependencies are meaningfully interpreted.

As already mentioned, the description of the psychological characteristics of the respondent using psychological tests requires the use of several tests with the possibility of replacing them with others. One of the tests is designated as the main one, and the rest are considered as additional parameters. In the course of the system operation and analysis of the results, it may be necessary to replace the main test with one of the additional parameters or with a new test. Descriptions of the object, additional parameters, and the effect are informative.

The nature of the data requires the use of a non-atomistic version of the JSM method with additional parameters.

4. Theoretical approach to solving the problem

The informativeness of the description of all parts of the example of the fact base and the presence of additional parameters complicates the preliminary choice between the direct and reverse versions of the JSM method. To solve this problem (without taking into account additional parameters), potential hypotheses were introduced in [10].

If a pair (*V*, *W*) satisfies the predicate of a simple direct similarity method, then *V* is the result of a similarity operation for an exhaustive set of examples containing *V*. If (*V*,*W*) is the hypothesis of the inverse method, then *W* is the non-empty result of the operation of the similarity of the exhaustive sets of examples containing *W*. We denote by *N* the set of all names of examples of BF, through N^+ - the set of names of examples of BF^+, by N^- the set of names of examples of BF^-.

Positive potential hypotheses generated by examples with the names $\{n_1, ..., n_k\}$ from the set N^+ are pairs (*V*,*W*) such that:

$$(Xn_1\cap...\cap Xn_k=V)\&(Yn_1\cap...\cap Yn_k = W)\&\forall Xm\forall Ym((V\cap Xm\neq V)\vee(W\cap Ym\neq W)\&(m\notin\{n_1,..., n_k\})), \quad (1)$$

where X_i are objects, Y_i are effects.

The exhaustion condition can be satisfied in a potential hypothesis for *V*, for *W*, or for *V* and *W* together. Or it may be that this condition is not satisfied either for *V* or for *W*. This follows from formula (1). Consequently, the set of potential hypotheses contains all the hypotheses obtained by the direct, inverse, and reciprocal similarity predicates. But some potential hypotheses may not be real hypotheses.

To find potential hypotheses (in the case without additional parameters), the fact base was presented in the form of a similarity space. It is associated with Galois correspondences and Galois closure operators. It is shown that potential hypotheses are closed sets in this space [10].

In [11] for problems in which objects in the fact base have one property, it is shown that all closed sets of the formal context are hypotheses of the direct version of the JSM method. So a closed set is an exhaustive similarity result. The method of finding potential hypotheses and their classification is consistent with this. For the case without additional parameters, it was proposed in [12]. This method uses subdivision of the fact base for each set of objects and set of examples. Subbases are presented as spaces of similarity. Closed sets are searched in them. Examples whose names are included in their intersection generate potential hypotheses. If $V = \cap \pi_i \setminus \cup \pi_j$, where $\pi_i \in \Pi$, $\pi_j \in \Pi \setminus \Pi'$, then V is the kernel of the similarity space [13]. In this case, the hypothesis is minimal. (Likewise for W).

The principle of finding the set of potential hypotheses as a system of Galois closures also applies to the case when the examples of the fact base contain descriptions of objects, effects and additional parameters. For the problem under consideration, the base of facts is divided into sets of values for the scales of the main test, signature attributes and values for scales of additional parameters. The similarity space in this case has the form:

$$\Sigma = <U, \Pi>, \Pi=\{\pi_1,\ldots, \pi_n\},\ U = \cup_{i=1}^{n} \pi i, \tag{2}$$

where $\pi_i = u_{i0} \times u_{i1} \times\ldots\times u_{ik} \times u_{i00}$, u_{i0} – part of the example related to the main test, u_{ij} (j=1,…, k) – parts of examples related to additional parameters , u_{i00} is the part of the example related to the description of the signature, i is the number of the example, n is the quantity of examples in the fact base. The Galois correspondence is defined between the set of example names and the set U. The similarity space Σ is divided into k +2 similarity spaces $\Sigma_0, \Sigma_1,\ldots, \Sigma_k, \Sigma_{00}$, in each of them closed sets and their intersections are sought. Since the intersection of closed sets is closed, it is a potential hypothesis.

A potential hypothesis can be written as:

$$N': (C, \{Q_i\}, W),\ N' \subseteq N,\ C = (u_0^1 \cap \ldots \cap u_0^m),\ Q_i = (u_i^1 \cap \ldots \cap u_i^m),\ W = (u_{00}^1 \cap \ldots \cap u_{00}^m),$$
$$((C \neq \emptyset)\ \&\ (W \neq \emptyset)),\ m = |N'|,\ i = (1,\ldots,k). \tag{3}$$

For any i, the set Q_i can be empty.

In the case when additional parameters are present in the base of facts, the set of all potential hypotheses gives a complete picture of all possible hypotheses of the direct and inverse methods of similarity with the fulfillment of the exhaustion condition both for each of the elements of the example π_i, and for all their possible combinations. Obviously, in order to analyze the set of potential hypotheses, it is necessary to give their classification, the basis of which is the fulfillment of the exhaustion condition. If N' is closed in Σ_j, then this is a conjecture with exhaustibility with respect to the j-th element of examples of the fact base. The classification of potential hypotheses refers each hypothesis to the method by which it was obtained (by the condition of exhaustion). As the number of additional parameters increases, the number of classes of this classification grows exponentially. This limits the number of additional parameters that can be used at the same time.

The classification of the set of potential hypotheses is somewhat complicated by the fact that, unlike problems without additional parameters, where all parts of a potential hypothesis are not empty, potential hypotheses with empty values of additional parameters are admissible. Generally speaking, we can consider the option when an empty value is permissible for the main test, provided that at least one value of the additional parameters is nonempty. The meaningfulness of such dependencies may indicate the need to replace the main test with one of the additional parameters.

Within a class, hypotheses are not the same type. In the same class there can be hypotheses with and without uniqueness of cause, with the influence of additional parameters and without influence. Therefore, each class can be subclassed. The classes and subclasses of the classification of the set of potential hypotheses are the result of data mining as applied to the solution of the indicated problem.

5. Algorithmic and software principles of searching and classifying potential hypotheses.

Dividing the fact base into subbases and finding closed sets in each of them makes it possible to combine the finding of potential hypotheses and their classification in a single algorithm. The operation of the algorithm is preceded by the procedure for automatically calculating the assessments of the respondents after they have completed psychological tests.

In essence, the algorithm for finding potential hypotheses and their classification can be described as follows.

1. Splitting the base of facts into subbases corresponding to the main test, additional parameters and description of signature features.
2. Finding all the similarities in each subbase.
3. Filtering, that is, the selection of similarities that satisfy certain conditions (filters). In this task, these filters are:

- the number of examples that generated similarities;
- the number of description features included in the similarity result;
- informativeness of the values of common attributes (to describe the signature).

4. Finding potential hypotheses $\{N'_j: (C_j, \{Q_j^i\}, W_j)\}$, where $\{N'_j\}$ are the intersection of subsets of example names that generated similarities on subbases, C_j, $\{Q_j^i\}$, W_j are the results of similarities of examples with names from N'_j, $N'_j \neq \varnothing$, $C_j \neq \varnothing$, $W_j \neq \varnothing$.

Subbases in which the subset of the names of examples that generated the similarity coincides with N'_j indicate those parts of the examples for which the exhaustiveness condition is realized. If none of the subsets that generated similarities in the subbases coincides with N'_j, this means that the potential hypothesis is not a real hypothesis.

The sums of points on scales of psychological questionnaires can be divided into standard intervals of values - high, medium, low, or you can choose a more fractional breakdown. With standard subdivision, only the same scale values are similar. Fractional partitioning allows you to enter a similarity operation, the result of which is the adjacent values of the scales. In this case, the values of the scales and the results of the operation of similarity are conveniently represented as a bit string. The similarity operation is then implemented as bitwise string multiplication (see [14]). At the output of the algorithm, we obtain a classification of potential hypotheses according to the fulfillment of the exhaustion condition.

The researcher must analyze these classes and choose the class that defines the version of the JSM-method that is most adequate to the problem being solved. The selection criteria, in addition to the content side, may include the number of hypotheses in the class, the number of examples from which the hypothesis is derived, and so on.

For the convenience of working with the results of data mining, the system should offer a user-friendly interface. Here are some techniques for such an interface:

- abbreviated names of scales and attributes to fit more information on the screen; the full name appears when you click on the short designation;
- list of options for view: hypotheses of all classes, hypotheses of one or several selected classes, hypotheses of classes that do not contain empty values for additional parameters, etc.;
- list of the number of hypotheses in classes, so as not to consider classes where there are very few or very many hypotheses;
- displaying positive and negative hypotheses together or separately.

The key principles of program implementation of the system include the following provisions:

- simultaneous access from different computers to enable different users to work;
- two-level structure - a database on a remote server, logic and interface in a web application;
- working with database entities in the concept of object-oriented programming;
- dynamic formation of the user interface depending on the context.

At this stage of system development we used MySQL as a database management system, Django web framework with the use of Python, JavaScript languages to create a web application. The DTL (Django Template Language) embedded in Django was used to form context-sensitive interface.

6. Conclusion

The considered methods of intellectual analysis of forensic data organize the search for dependencies that allow studying the interrelation between the psychological characteristics of a person and individual signature features. The introduction of several tests as additional parameters makes it possible to conduct a study of the complex influence of diverse psychological aspects on the attributes of the signature and highlight the main of these aspects. The high information content of the data in the fact base generates dependencies of various types, which requires their classification. This imposes requirements on the algorithmic and software components of the system that implements the data minig.

Experiments were carried out on a data array containing general and particular attributes of signatures and test results for one main and three additional psychological questionnaires of thirty respondents. The fact base is divided into positive and negative parts by gender. When conducting experiments, an expert has the opportunity to choose a variant of the JSM-method based on an analysis of a variety of potential hypotheses. Hypotheses that satisfy the direct and inverse methods simultaneously ensure the uniqueness of cause and effect, so they should be considered first. It was the hypotheses from this class that gave logically meaningful empirical relationships between some features of the main questionnaire ("temperament structure questionnaire"), with the use of an additional questionnaire ("well-being, activity, mood") and the features that manifested themselves in the signature samples.

A high level of such traits of temperament as *working capacity, activity, initiative, speed of switching from one type of activity to another, motor-motor speed, self-confidence*, and a high level of all three scales of the "well-being, activity, mood" questionnaire is manifested in a small variability of particular signature attributes, i.e. attribute values are the same in all signature samples. General attributes in men are characterized by mobility, heterogeneity: *degree of development of handwriting and coordination is from medium to above average, the length of vertical movements is from medium to large, the direction of the signature line is from horizontal to ascending,* the shape of the base of the signature is arcuate-winding or rectilinear-winding .

Women with the same psychological characteristics have the same signature features with a slight difference.

In women, the values of *degree of development of handwriting coordination and pace* are more stable - above average or high. A higher, in comparison with men, level of values of these attributes is generally characteristic of women.

The significance of the obtained dependencies is confirmed by the presence of empirical dependencies, in which respondents with the same traits of temperament and general condition, but expressed at the average level, the values of the particular attributes of the signature are variable, and the general attributes become more stable.

The same empirical dependence in men and women indicate a lack of gender influence.

Thus, the principles of creation the system - the use of the JSM-method of automated research support in a non- atomistic version with additional parameters, the identification and classification of potential hypotheses allow conducting psychological and handwriting studies. The software approach used makes it possible for several researchers to work with the system simultaneously and facilitates the laborious process of data entry.

An analysis of the experimental results showed the need to expand the base of facts, taking into account the diversity of the age and professional composition of the respondents, the need to expand the list of particular attributes that allow comparing signatures that do not have the same elements (letters, strokes, etc.). The creation of tools for identifying regularities and trends from the set of obtained dependencies, as well as tools for supporting the interpretation of results, are priority direction in the development of the system.

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