# On the Approach to Intelligent Data Analysis in the Social Sciences

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***Abstract*—The paper considers the intelligent data analysis in subject areas with open sets of empirical data, where formal apparatus is absent and the procedures for the theories' formation are heuristic. Approaches to solving these problems by means of the JSM Method of automated support for research are described. Implementing JSM Method intelligent systems are partner human-machine systems that automatically reproduce an imitation of the set of natural (rational) intelligence' abilities. In the interactive mode, it is possible to imitate such abilities as adaptation and correction of knowledge and the choice of reasoning strategy. JSM Socio intelligent system has been created to solve various problems of sociological data analysis. The generation of hypotheses on behavior prediction and its determinants, empirical regularities revealing in expanding empirical data give reason to consider the JSM Method as a tool for knowledge discovery in the social sciences.**

***Keywords*—knowledge discovery, JSM Method, formalized qualitative analysis, social data analysis**

## I. Introduction

Artificial Intelligence researches can be divided into two parts – an epistemological part and a heuristic part [1]. The first one means formalization and automatization (in computer systems) the cognition process as such. The heuristic problem of how to create constructive tools for knowledge acquisition has a variety of approaches. The most important result of practical realization of theoretical principles and procedures in intelligent systems (AI-systems) is the possibility of new knowledge generation as a result of intelligent analysis of empirical data.

It is important to distinguish data analysis as pattern extraction from data (data mining) from intelligent data analysis (IDA) as new knowledge generation (knowledge discovery). The final product of the empirical data analysis should be a new knowledge, which is provided by the full process of Knowledge Discovery [2]. Data Mining represents one of the stages of this process – application of specific algorithms for extracting models (patterns) from data. The most important principle of intelligent data analysis is the tools' adequacy to the subject domain and the nature of the problem in hand [3] – in contrast to the dominant role of the tools in data analysis.

Intelligent data analysis (knowledge discovery) is an inherent part of empirical research in areas where there are no developed formal tools and, accordingly, the procedures for theories formation are heuristic in nature. Approaches that formalize the relevant research heuristics with implementation in computer systems are considered to be fruitful for the purpose of discovering new (with respect to the existing fact bases, BF, and knowledge bases, KB) knowledge. Such systems using artificial intelligence (AI) methods can be a tool for automated research support in sociology.

## II. Problems of Epistemology and Heuristics of Social Sciences

The mass nature of many social phenomena and the obvious difficulties of taking into account the many factors influencing them led to the dominance of quantitative (statistical) methods of studying social reality. These methods are quite effective in the analysis of global and mass phenomena, but are of little use at the microsociological level, where mechanisms, motivation, and incentives of social behavior – individual and group – are considered. Insufficiency of Quantitative approach in AI design for social sciences is the main idea in contemporary research [4].

Studying the actions of human individuals (notably in their social relations with each other) is based on qualitative methods that transform subjective personal experience into typical models by informal means [5], [6]. Qualitative Comparative Analysis (QCA) [7], which is rather popular in sociological practice, can be considered as the certain approximation to the formalization of the typical qualitative methodology of case-study. The method is based on minimization of Boolean functions describing the dependence of the studied effect (presence or absence of phenomena, processes, structures) on presence or absence of some independent variables (possible causal conditions) and their combinations. Of course, formalism of this level seems obviously insufficient to study complex social phenomena [8].

The need for objectification of the results of qualitative analysis is to some extent satisfied due to the development of CAQDAS (computer aided/assisted qualitative data analysis systems) [9]. The use of these tools provides systematic nature, efficiency and reliability of standard procedures for processing qualitative data, thereby increasing the validity of conclusions.

However, this is far from solving the actual problem of formal imitation and computer realization [10] of the inductive strategy of qualitative analysis. In general, research heuristics of sociologists aimed at building theories based on revealing dependencies from an analysis of empirical facts can be represented by a universal cognitive cycle "data analysis – prediction – explanation". The formalization of this process – IDA – provides a transition from phenomenology to a knowledge system in the sciences with a poorly developed formal apparatus.

The irreducibility of human reasoning to axiom-based proof schemes has determined both the "cognitive turn" of modern logic – a departure from "antipsychologism" [11], and the emergence of ideas of "humanization" of AI systems among AI founders [12], [13]. At the current stage of AI development, the main goal of research in this area is constructive imitation (only to some extent) and the strengthening of human cognitive abilities in intelligent systems (IS) [14](pp. 256–277).

## III. JSM Method in the Sociological Research

Examples of such systems are intelligent JSM-IS systems that implement the JSM Method of automated support for research [15]. The method reproduces research heuristics of mentioned type, using plausible reasoning with ampliative conclusions in the open world in the form of synthesis of non-elementary cognitive procedures: empirical induction (analysis), structural analogy (prediction), abductive acceptance of hypotheses. A formal language with a descriptive and argumentative functions [16] has been created for this purpose. Descriptive function provides initial data and knowledge structurization (with possibility of similarity determination) and formation of relation system. Argumentative function enables to formalize reasoning – analytic and prognostic procedures as well as procedures of explanation, falsification and possible verification of the results obtained [14](pp. 170–231). The induction is represented by formal elaborations and extensions of J.S. Mill's inductive methods [17], abductive acceptance of hypotheses is based on the initial data explanation [18]. This kind of abduction solves the problem of forming a criterion for sufficient reason for inductive hypotheses acceptance and has a fundamental importance for open areas with poorly developed (or completely absent) formal apparatus.

The realization of JSM-procedures and their combinations – strategies – in IS-JSM for the analysis of sociological data JSM Socio [19] is aimed at building a theory based on empirical facts which correlates with the methodological approach of qualitative analysis (using informal inductive inference). JSM Socio is considered to be a tool for formalized qualitative analysis of sociological data (FQASD). Expert-sociologist requirements reflected in the principles of formation of the information environment (fact base BF and the knowledge base KB) and the features of the user interface. Knowledge base includes both a priori (conventional) and obtained new knowledge as a result of the application of procedures. According to the microsociological paradigm, the social interaction of individuals is forced by internal motivation and possible external influences, which necessarily requires a multiparametric description [20]. This circumstance, coupled with the discrete nature of qualitative variables and the need to form a relational system that displays the semantics of the subject area, is taken into account by the descriptive function of the JSM-language intended for the FQASD.

The procedural semantics of the JSM Method can be formulated for various data structures that preserve the algebraic expressibility of similarity. The basic representation is the Boolean data structure. Accordingly, finite sets $\mathbf{U}^{(i)}$ and Boolean algebras defined on them $B_i = \langle 2^{\mathbf{U}^{(i)}}, \varnothing, \mathbf{U}^{(i)}, —, \cap, \cup\rangle, i = 1,2,3$, are considered. Thus, subjects of behavior are characterized by a set of differential indicators $\mathbf{U}^{(1)} = \{d_1, \dots d_{r_1}$ that include elements of a social character (including value-normative attitudes), individual personality characteristics and biographical data. $\mathbf{U}^{(2)} = \{a_1, \dots a_{r_1}\}$ is a set of behavioral effects (actions and attitudes), $\mathbf{U}^{(3)} = \{s_1, \dots s_{r_1}\}$ is a set of situational parameters.

The individual variables $X, Z, V, \dots$ of the 1-st kind (perhaps with sub-indices) and constants $C, C_1, C_2, \dots$, being the values of the variables for objects and subobjects $X, Z, V$, etc., are introduced to represent persons (subject of behaviour) in the language, $X \in 2^{\mathbf{U}^{(1)}}$ The objects properties (for example, subjects' behavioural effects) are represented with the individual variables of the 2-nd kind $Y, U, W, \dots$ (perhaps with lower indices) and constants $Q, Q_1, Q_2, \dots$, $Y \in 2^{\mathbf{U}^{(2)}}$. The variables $S, S_1, \dots, S_n$ and the constants $\bar{S}, \bar{S}_1, \dots$ , $\bar{S}_n, S \in 2^{\mathbf{U}^{(3)}}$ of the 3-rd kind are introduced for the context (situational) parameters.

Social phenomena reflect the interaction of motivated, purposefully acting individuals taking into account important factors for them. Accordingly, the most important component of the JSM-language for FQASD is the representation of the opinion $\varphi$ – the individual's personal perception of various aspects of social reality. Opinion is formed on the basis of the respondent's evaluation of the statements $p_1 \dots p_n$, characterizing the situation of interaction and argue the attitude towards it [21]. Statement $J_\nu p_i$ is the answer to the question "what is the value $v$ of the statement $p$?" $(i = 1, \dots, n)$; $J_\nu p_i = t$ if $v[p_i] = \nu$; otherwise, $J_\nu p_i = f$; $t$ and $f$ are truth values of two-valued logic "true" and "false", respectively. In the general case of an $m$-valued poll (if there are $m$ variants of sociologically interpreted estimates of statements $p_1 \dots p_n$) the evaluation function $v[p_i]$, $(i = 1, \dots, n)$ takes values $\nu \in \left\{0, \frac{1}{m-1}, \frac{m-2}{m-1}, 1\right\}$, $v[p_i] = \nu$. The $j$-th individual's opinion is the maximal conjunction $\varphi_j = J_{\nu_1^{(j)}} p_1 \& \dots \& J_{\nu_n^{(j)}} p_n$, where $\nu_i^{(j)}$ is corresponding evaluation of statements $p_i$ $(i = 1, \dots, n)$, $\nu_i^{(j)} \in \left\{0, \frac{1}{m-1}, \frac{m-2}{m-1}, 1\right\}$, $j = 1, \dots, m^n$. Let's $[\varphi_j] = \left\{J_{\nu_1^{(j)}} p_1, \dots, J_{\nu_n^{(j)}} p_n\right\}$ be the set of corresponding conjunction's atoms.

Thus, the subject of social interaction is defined by the term $\bar{X}$ (complete object), $\bar{X} = \langle X, S, [\varphi]\rangle$. The complex multi-parameter structure of social systems and the various mechanisms of social interactions require an epistemologically adequate language for data representation (in particular, their parametrization), the choice of effective analysis procedures and strategies, and the conscious formation and enlargement of empirical facts set. In general case initial data are represented by $(+)$-facts $FB^+ = \left\{\langle \bar{X}, Y\rangle \,|\, J_{\langle 1,0\rangle}(\bar{X} \Rightarrow_1 Y)\right\}$ ("object (person, for example) $\bar{X}$ possesses the set of properties (effect of behavior) $Y$"), $(-)$-facts $FB^- = \left\{\langle \bar{X}, Y\rangle \,|\, J_{\langle -1,0\rangle}(\bar{X} \Rightarrow_1 Y)\right\}$ and facts that describe objects with previously undefined properties, $FB^\tau = \left\{\langle \bar{X}, Y\rangle \,|\, J_{\langle \tau,0\rangle}(\bar{X} \Rightarrow_1 Y)\right\}$, $FB = FB^+ \cup FB^- \cup FB^\tau$. This allows us to vary the relational structure depending on the sociological model [19], [22]. Types of truth values in JSM Method are $1, -1, 0, \tau$ (factual truth, factual falsity, factual contradiction ("conflict"), uncertainty) correspond to the semantics of the four-valued logic of argumentation [14](pp. 312–338).

The JSM-research strategies are formed taking into account the empirical situation of the study. The key procedures for inductive generation of causal hypotheses are formalization of Mill's inductive methods, as well as their extensions and elaborations [15]. The minimal predicates representing the inductive similarity method are the predicates $M^+_{a,n}(V, W)$ and $M^-_{a,n}(V, W)$ for generating possible hypotheses on the causes of $(+)$- and $(-)$- facts, respectively (parameter $n$ shows the number of applications of the rules of plausible inference to the $FB$, $a$ – agreement – is the "name" of the Mill's inductive similarity method). The premises of the inductive inference rules $(I)^\sigma_n$, $\sigma \in +, -, 0, \tau$ include the corresponding Boolean combinations of the predicates $M^+_{a,n}(V, W)$ and $M^-_{a,n}(V, W)$. Thus, induction in the JSM Method includes an argumentation condition that ensures mutual falsifiability of conclusions and constructiveness of their truth values generating.

The similarity predicates can be strengthened by additional conditions, including those allowing formalizing other Mill's inductive Methods. Let $I^+$ be the set of $M^+_{a,n}(V, W)$ strengthening (indices), $I^-$ be the set of $M^-_{a,n}(V, W)$ strengthening. Then the JSM strategies $Str_{x,y}$ will be the sets of rules

$(I)^{\sigma}_{n}$, $\sigma \in \{+,-,0,\tau\}$ such that they are formed by possible combinations of $M^{+}_{x,n}(V,W)$ and $M^{-}_{y,n}(V,W)$ predicates. The partial order relations based on the relation of logical deducibility are generated on the sets of predicates $M^{+}_{x,n}(V,W)$ and $M^{-}_{y,n}(V,W)$. The partially ordered sets of predicates $M^{+}_{x,n}(V,W)$ and $M^{-}_{y,n}(V,W)$, as well as the rules of plausible inference including them, form distributive lattices, and the direct products of these lattices form possible strategies $Str_{x,y}$ of JSM reasoning [23]. Thus, the strategies of the JSM Method have an algebraically definable structure, and the difference in the plausibility degrees of the hypotheses generated as a result of application of various strategies is given constructively. The use of various strategies characterizes the mechanism of causal forcing of the studied effects, which means the realization of the idea of syntax adequacy to the semantics of the subject area and the method's adaptability to the class of problems being solved.

A characteristic feature of empirical sociological research is the incompleteness (openness) of knowledge about the world, facts available to the researcher and describing their data. Developed logical means of the method provide the research possibility: empirical regularities ($ER$) (nomological statements) discovery. $ER$ are inductive operationally definable (non-statistical) generalizations of the results of formalized JSM heuristics when enlarging (changing) data. $ER$ are defined as regularities in sequences of embedded $FB(p)$, $p = 1,\ldots,s$ using various JSM strategies from the set $\overline{Str} = \{Str_{x,y} \,|\, x \in I^{+}, y \in I^{-}\}$ [15]. Semantically, this means recognition of the conservation of the cause – effect relation, i.e. the constancy of the truth values type in inductive hypotheses about $\pm$-causes and hypotheses-predictions obtained using causal hypotheses in the conclusion by analogy. Acceptance of the results of the JSM study on the basis of a non-singular assessment of the quality of reasoning and hypotheses allows correction of open (quasi-axiomatic) empirical theories. In combination with falsification tools built into the JSM procedures, this forms a enhancement of the K.R. Popper demarcation criterion [16], which separates the completed scientific research from the pre-research and provides sufficient reason for grounded decision-making.

## IV. Application experience

The most complete analysis of the social behavior of individuals is realized when considering the relational structure $\bar{X} \Rightarrow_1 Y$. The representation of the initial fact base by the predicates $\langle X, S, [\varphi]\rangle \Rightarrow_1 Y$ was used in the analysis of the constructive social activity, performed in collaboration with the Institute of Sociology, RAS. The chosen representation is related to the complex and multiple influence of the society characteristics on social activity. The focus of the study was the problem of society typology, based on the generation of determinants of political or civil forms of social activity.

A concept and model for the study of the determinants of social behavior (political/civic participation/non-participation) was formed, parameterization of the initial data with the inclusion of situational parameters – a set of socio-economic and functional characteristics of the respondent's area of residence (administrative status of the city, population income, cultural status, etc.), representing the territorial context of actions was proposed. The set of potential determinants included individual characteristics of the respondents' status; opinions, assessments that characterize the civil position. Different levels of determinations (situational, value, normative) were taken into account. Political activists – participants in political actions, (+)-examples in the JSM Method language – opposed (was considered as (–)-examples) civil activists (members of public organizations, do not participate in political activities), as well as helping individuals and nowhere involved passive citizens.

Visualization of the results of a computer experiment in the form of a "hypothesis tree" provides the sociologist with the opportunity to interpret the results and build a typology based on the revealed determinants. The basis of typologization – the "core" – is formed by the maximal intersections of respondents' descriptions. Similarities of subsets of respondents included in the maximum intersection allow to identify additional "peripheral" features. Peripheral features in different combinations form subtypes, which makes it possible to characterize the nuances of the position of subjects belonging to the same type of behavior, i.e. to suggest typology clarification.

As a result, the characteristic features of social types that implement various forms of social activity – political, civil, individual and passive – were described, and the features of interaction between these types were revealed. A non-trivial meaningful conclusion concerns the self-reference of "political activists" and "active citizens". Political activists consistently attribute the status of the subject of social action to themselves, denying this status to others. In other words, a feature of all political activists (who are representatives of systemic political parties in Russia regions) is the "leader" ideology, which is transmitted from political authorities to political activists. This seems to be due to the fact that the recognition of civic partners as social actors is uncomfortable for political activists, since it implicitly calls into question their social role. However, the rejection of partnerships with active citizens, attributing them the role of followers destroys the civil dialogue. On the contrary, active citizens ascribe to citizens the status of subjects of social action and declare their own readiness to participate in solving social problems and to unite.

A significant contribution of the regional context to the difference in forms and degrees of civic engagement was identified. This allows us to talk about the influence of the social system on the formation of individual behavioral strategy and the danger of transferring contextual features to the individual level.

The results aroused interest in the study of various forms of non-political (civic) activity. The material was a study of helping (prosocial) behavior, including semantic opposition "private helping behavior – volunteering". The first is situational, sporadic, i.e. is an act of social action. The second is a reflective, prolonged social activity, value collective behavior that creates the phenomena of practical solidarity. The work is also carried out in collaboration with researchers from the Institute of Sociology on the empirical data provided by them.

Based on the proposed conceptual model of the research object, a structure of empirical data (a set of variables and indicators) was formed on the basis of a sociological study in different organizations and different regions of the country. Respondents are described by socio-demographic and status characteristics, situational characteristics represent the development of the locality and other parameters of the regional context, opinions and assessments characterize the value aspects of relations between people, their attitude to volunteering and to the organization of this activity where respondents work.

The similarity of socio-demographic characteristics and the similarity of basic signs of social behavior of corporate, independent and combining both types of civil activity of volunteers, in particular, a high level of interpersonal trust, was found. The phenomenon of "open social borders" between "systemic" and "non-systemic" civil activists, discovered by means of the JSM Method, turned out to be interesting. A rather intense mobility between these groups was revealed, which indicates that there is no value confrontation among

representatives of different socially active communities. This effect is difficult to detect by statistical methods. Further work is aimed at identifying the motivation of various forms of volunteer movement, determining complexes of value, socio-demographic and ideological characteristics that distinguish corporate volunteers from individuals, and those and others from those who refuse to help behavior

## V. Conclusion

IDA (knowledge discovery) is performed by computer systems that implement an intellectual process represented by the interaction of the mental process and the cognitive process controlled by it [24]. The formal representation of the universal cognitive process "data analysis – prediction – explanation" provides imitation of natural (rational) intelligence abilities (reasoning, argumentation, learning, explanation of the results obtained) and allows reproduction in intelligent computer systems in automatic mode. However, a poorly formalized mental process, including attitudes, imperatives, goal-setting, the formation of open empirical theories and their adaptation in the context of data and knowledge correction, requires human participation and can be implemented in such systems only in an interactive mode.

It obviously follows that the IDA effective implementation is possible only by means of partner human-machine intelligent systems (see, for example, [25], p. 64). Even the successful implementation of the descriptive function of a formal language depends (to a large extent) on the meaningful interpretation of the cognizing subject (expert). Interactive pre-processing of open empirical data, control of the use of formalized heuristics, expert evaluation of generated empirical regularities ensure meaningfulness of the results obtained and determine the effectiveness in a specific study of the argumentative function of the language. The interpretability and explainability of the results generated by the IS tools play a fundamental role in the acceptance of IAD results, since the responsibility for final decisions is the human prerogative. This is confirmed by the attention to research in Explainable Artificial Intelligence [26], which arose in the context of spectacular successes of AI methods, the results of which are not interpreted.

Intelligent systems that implement the JSM Method are a technological means of exact epistemology and are partner human-machine systems. They effectively implement the generation of new knowledge, but at the same time do not replace, but support and strengthen the meaningful work of the researcher in various subject areas, including social sciences.

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## Об одном подходе к интеллектуальному анализу данных в социальных системах

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Рассматриваются проблемы интеллектуального анализа данных в областях с открытыми множествами эмпирических данных, где отсутствует формальный аппарат и формирование теорий носит эвристический характер. Описаны подходы к решению этих проблем средствами ДСМ-метода автоматизированной поддержки исследований. Реализующие ДСМ-метод интеллектуальные системы являются человеко-машинными системами, воспроизводящими в автоматическом режиме имитацию ряда способностей естественного (рационального) интеллекта. В интерактивном режиме возможна имитация таких способностей, как адаптация и коррекция знаний и выбор стратегии рассуждений. Для решения задач анализа социологических данных создана интеллектуальная система JSM Socio. Порождение гипотез о детерминантах поведения и его прогнозе, обнаружение эмпирических закономерностей в расширяющихся базах эмпирических данных дают основание считать ДСМ-метод инструментом интеллектуального анализа данных в науках о человеке и обществе.

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