Qualitative analysis relations

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Abstract. The object of this paper is to introduce relationship models into qualitative analysis to simplify this analysis. The article proposes a set of relations based on the predicate calculus. The concept of "quality relations" is introduced. The relations content is revealed: proportionality, complementarity, connectedness, opposition and dichotomy. Single, double and triple predicates are used. It is shown a qualitative difference between oppositional and dichotomous relations. The principles of qualitative analysis are described. The presence of two directions in the qualitative analysis is shown: social and intellectual. It is shown that qualitative relations are the basis for qualitative analysis and finding cause-and-effect relations. Methods of carrying out qualitative analysis are shown: discrete values, qualitative values, ambiguous values, qualitative process simulation.

1. Introduction
The state of qualitative analysis is characterized by ambivalence. The first direction can be called social. It uses qualitative analysis in the fields of sociology, medicine, linguistics, psychology [1]. There are certain research principles in these areas. They are characterized by the terms: "qualitative analysis" (QA) [2, 3], "qualitative data analysis" (QDA) [4], qualitative research (QR) [5]. The second direction can be called intellectual. It uses qualitative analysis in the field of artificial intelligence. This area is characterized by other terms: qualitative reasoning (QR) [6] and qualitative simulation (QS) [7, 8]. There is no tendency of convergence between these directions. For the first direction it is typically that a direct definition of a qualitative analysis is practically not given but its properties and comparative characteristics are described. Here is a description from Wikipedia [9] “Qualitative research is based on data obtained by the researcher through direct observation, interviews, questionnaires, focus groups, participatory observation, field notes, documents and artifacts. Data is usually not numeric.” The core of qualitative analysis is coding. Its interpretation [9] is given as follows. “In general coding refers to the process of associating meaningful ideas with relevant data.” Qualitative analysis methods are recognized as: coding recursion, pattern analysis.

It is noted that [10] “Qualitative analysis is rather inductive than deductive. Instead of working with specific hypotheses and predefined codes the researcher encodes the data during or after it has been collected. Coding schemes can often be very complex but they are the key to data analysis” in this work. There is no direct definition in this interpretation.
In [11] the main methods of QDA are described in a popular form: qualitative content analysis, narrative analysis, speech analysis, grounded theory (GT), interpretive phenomenological analysis (IPA). An explanation is given below.

Content Analysis is the most common and simplest type of QDA. It is used to assess patterns in content (words, phrases or images) or in sources of communication, for example from photographs in newspapers to political speeches. Grounded theory is a methodology in which the explicit intent is to create a theory using data through a series of “tests” and “fixes.

The IPA is designed to understand how a subject (e.g. a person) feels in connection with an important life event, experience, or situation (which we call a phenomenon — letter “P” in IPA). These phenomena can range from common (such as motherhood or the aftereffects of a car accident) to rare (such as a subject's experience in a refugee camp). Thus, the existing methods do not meet the requirements of creating preferably objective theory of qualitative analysis. In the encyclopedic dictionary "Mathematics" the term "qualitative analysis" is absent. This indicates the state of this direction and makes the study of this problem urgent.

The coding method in qualitative analysis is used mainly to describe entities and processes between them. In this paper the coding method is used to describe relationships in qualitative analysis.

2. Research methodology

The research is based on qualitative analysis, logical analysis, comparative analysis and systemic analysis. The main method is the qualitative analysis coding method. The materials used are publications in the field of qualitative analysis and qualitative reasoning from the field of social sciences and artificial intelligence.

3. Research results

3.1 Quality relations systematics

For relations in the field of qualitative analysis it is advisable to introduce a special term "qualitative relations". These relations have no numerical values and is way are different from relations in mathematics. For example, in qualitative terms the relations "greater" is acceptable but it does not apply quantitative values.

In qualitative analysis qualitative relations are used primarily while in mathematics and quantitative analysis relations are used primarily. In accordance with the basic concept of coding in qualitative analysis it allows the introduction of symbolic notations. We will use this to describe the relations used in qualitative analysis. Logic is a type of qualitative analysis. Therefore, to introduce qualitative relations we use the theory of logic and in particular predicate concept. All qualitative analysis relations are single, double, and triple predicates. For simplicity, some examples will be numerical but with a qualitative characteristic.

3.1.1. Unitary predicates. Unitary predicates express a property. Let us introduce the concept of integrity relation and denote it by the symbol (©), similar to "copyright". The designation A© means that A (object, system, process) is an integral object.

Let us introduce the concept of latency relation (∸) in the form of points corresponding to the vertices of a symmetric triangle. The notation A× means that A (object, system, process) is a latent object.

3.1.2. Double predicates. Double predicates express relations between a pair of objects. An important relation for qualitative analysis that is not used directly in mathematics and logic is the proportionality relation. Let us introduce the concept of the relation of qualitative proportionality (⇔) [16] and non-proportionality (↓). The designation A⇔B means that A and B (object, system, process) are proportional. They are followed by the possibility of their comparison, juxtaposition, replacement or transformation of one into another.
Relation of non-proportionality A↛B means that A and B (object, system, process) are not proportional. This is followed by the inadmissibility of their comparison, juxtaposition, replacement and transformation.

Qualitative similarity relations are indicated by a symbol (≈). The designation A≈B means that A and B have signs of similarity in most of the signs or in all signs. Similarity does not mean equality but means similarity.

Qualitative difference relation (≠). The designation A≠B means that A and B are different objects although they can be proportional. For example, the numbers 8 and 10 are different but proportional.

Complementarity relation (≜). The notation A≜B means that A and B are complementary. This means that the sum of their properties enhances their combined action or influence A + B > A; A + B > B.

Qualitative entailment relation (⇒). The notation A⇒B means that A implies B or B follows from A. In the event that the implication sign is already used in the expressions the symbol (⇔) can be used to denote a qualitative entailment.

Connectedness relation (⇑). The notation A⇑B means that A and B are linked. Either they are related by common features, or they are related by the following relationship. In this case [(A∩B ≠ ∅)⇒(A→B)].

Opposition relation (Θ). The notation AΘB means that A and B are proportional, different and opposite. In this case, for a hard opposition (A = ¬B) or A + B = 0. For a soft opposition, A and B are opposite in a larger number of signs or A + B ≠ 0.

Membership relation (⸦). The notation A⸦B means that A belongs to B and is a part of it.

Similarity relation (►). The designation A►B means that A differs from B but B is similar to A in a number of ways. For example, two equilateral triangles may have different areas but are similar in shape. The same is the case for squares. For rectangles the similarity exists if the proportions are equal between the corresponding sides.

3.1.3. Triple predicates. The dichotomy relations hold for parts and for the whole. It is indicated by the symbol (↑↑). The notation ↑↑(A B C) means that A, B - are parts of C - the whole that unites them. The following properties hold: A∪B = C and, moreover, A ∪ = B∅. Thus, dichotomy relation is qualitatively different from opposition relation by the inclusion of a third object in the scheme of analysis.

Not all are considered but only the basic relations. For example, the trivial relations more / less and farther / closer. They also have a qualitative coloration and refer to qualitative relationships provided that they operate with qualitative variables. All considered relations are qualitative and do not need quantitative values for analysis.

3.2. Qualitative scales in qualitative analysis

Variable scales perform important functions in qualitative analysis [12, 13]. They set the basis for analysis, define the units of analysis, set the categories for analysis, qualitatively highlight the area of qualitative analysis, set the comparability of the parameters of the qualitative analysis or their proportionality. The quality scales are nominal and ordinal. The nominal scale and nominal values are used for identification (John, Smith), for discrimination (a ball is not a cube) or for qualitative classification (John - belongs to the class of names, cube - belongs to the class of geometric shapes).

Nominal variables make it possible to recognize, classify, distinguish and identify an object. Their use is based on the axioms of identification 1, 2, 3.

1. A is B, or A is not B.
2. If A is B, then B is A.
3. If A is B and B is C, then A is C.

Axiom 1 is the axiom of the "either yes or no" alternative. It supposes either similarity or difference. Axioms 2 and 3 are the axioms of similarity. Axiom 2 describes the similarity between two objects.

3.
Axiom 3 describes the similarity between three objects and defines a recursive formula for comparing any number of objects. In logical form, the axioms of identification look like this.

\[ (A = B) \oplus (A \neq B). \]  \hspace{1cm} (1)

\[ (A = B) \rightarrow (B = A). \]  \hspace{1cm} (2)

\[ ((A = B) \land (B = C)) \rightarrow (A = C). \]  \hspace{1cm} (3)

This provides a basis for qualitative analysis on a nominal scale in the absence of uncertainty. Nominal variables are also called categorical because they define categories or class names.

Ordinal scale is used for qualitative comparison of objects or for ordering objects. It is actually a comparison mechanism. The comparison can be qualitative or quantitative. Qualitative analysis uses only qualitative variables.

Ordinal variables can be denoted by integers but they are not numbers. For example, the first place and the first grade can be designated by the number 1 which corresponds to the logic of coding the qualitative analysis. Ordinal variables provide only qualitative characteristics of the comparison. They indicate the rank of an object or parameter in the compared population.

For ordinal variables the identification axioms 1, 2, 3 are valid. Additionally, the ordering axioms hold for them. Ordering axioms 4, 5.

4. If A precedes (or is equivalent to) B then B does not precede (or is equivalent to A; either A precedes (or is equivalent) to B; or B precedes (or is equivalent) to A.

5. If A precedes (or is equivalent to) B and B precedes (or is equivalent to C, then A precedes (or is equivalent) to C.

The logical form of these axioms is as follows.

\[ [(A \geq B) = (B \leq A)] \oplus [(A \leq B) = (B \geq A)] = 1 \]  \hspace{1cm} (4)

\[ (A > B) \land (B > C) \rightarrow (A > C) \]  \hspace{1cm} (5)

Axiom 4 is called the sorting axiom. Axiom 5 is called the axiom of transitivity or property transfer. It is one of the key points in logical reasoning.

3.3. Qualitative reasoning

The variable scale axioms are a simple tool for qualitative analysis. Qualitative reasoning is a more versatile tool for qualitative analysis. Syllogisms are a special case of qualitative reasoning. Qualitative reasoning forms the basis of qualitative analysis. Common to many types of reasoning is the construction of formal structures that can be investigated qualitatively and objectively. Qualitative reasoning is based on logical analysis which includes not only mathematical logic but also spatial logic [14-16]. The spatial aspect of reasoning distinguishes qualitative spatial reasoning [17, 18].

The QR principles used simulate human thinking and reasoning. Principles of qualitative reasoning include [19]: discrete values, qualitative values, ambiguous values, qualitative process simulation.

The discrete value method consists of replacing continuous values with discrete characteristics for reasoning. For example, instead of quantifying the change in speed in terms of dynamics you can use three discrete values: increases, decreases, unchanged. Instead of quantifying the change in speed in terms of the timetable two discrete values can be used: compliance with the norm, not meeting the norm. Instead of quantifying the trajectory of the body you can use two discrete values that correspond to the calculated trajectory, does not correspond to the calculated trajectory. These examples show that qualitative variables and the relations between them allow you to make decisions quickly eliminating unnecessary quantitative analysis. Summing up, it should be stated that the method of discrete values consists in identifying qualitative or quantitative groups according to a given attribute and replacing quantitative values in the group with a generalizing qualitative attribute.

The qualitative value method consists in the selection of criteria for assessing the situation based on the conditions of the situation. For example, if a spacecraft enters the atmosphere of planets, it is
necessary to calculate the correspondence of the tangent in the trajectory to the safety angle but if the motion occurs in open space, the safety angle may not be calculated.

The method of ambiguous meaning is to form several goals instead of one. For example, in discrete optimization problems or problems of the second kind instead of one optimal solution, rational solutions can be determined.

Process simulation method consists of qualitative representation of process states and transitions between states. Qualitative simulation is a complement to, and sometimes the basis for, qualitative reasoning using artificial intelligence methods [20]. Qualitative simulation serves as the basis for smart inference, but using qualitative variables. Qualitative simulation manipulates symbolic descriptions of objects and symbolic descriptions of the relations between them. Qualitative simulation is the main process of finding causality.

Qualitative simulation (QS) is defined as a method of reasoning using simulation, and it generates possible values and directions of their change, which are defined as the state on the time axis for systems with continuous events, using qualitative information about the simulated system and the states following each of the them others by time points and time intervals of the sequence make up behavior trees [21]. The quality differential equations (QDE) used by QS represent a family of functions, not a specific function; they contain a set of functions. The time axis in the QS is formed by time points and the interval between time points. Qualitative state descriptions are computed for both time points and intervals, and they constitute the simulation trajectory. Due to the incompleteness of the information used by QS each qualitative variable gives the next set of values rather than one value. As a result, running the simulation provides possible alternative paths.

4. Conclusion
Qualitative analysis is aimed at finding qualitative relations firstly, at building qualitative descriptions secondly and at finding causal relationships thirdly. This implies the importance of quality relations. They serve as the basis for the description and the basis for finding a causal relation. Qualitative analysis is an operational method for analyzing objects, their properties, states and relations between them. An object can be compared by itself based on recursion. In doing so the comparison should be appropriate or proportionate. Proportionality is an important condition for qualitative analysis. There are different types of qualitative analysis. The object comparison aspect leads to object qualitative analysis or object qualitative analysis. Object qualitative analysis is based on comparing two or more objects by highlighting the common and the different in them, if such a comparison is proportional. The aspect of considering the characteristics of objects leads to a qualitative analysis of characteristics or an attributive qualitative analysis. Attributive qualitative analysis is based on the comparison of two or more characteristics (attributes) by highlighting the common and the different in them, if such a comparison is proportional.

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