On connection of the social choice problem with an opportunity of authors’ speech behavior evaluation

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Abstract. The article looks into an opportunity of the philological data processing automatization for the chosen group of authors. A tool for data formalization for each individual author is given as well as a ranking algorithm for the groups of authors. The group choice theory and the expert evaluation theory proved applicable for the goal stated.

1. Introduction

Automatization is extensively used in many fields including linguistics; however philology (literary text analysis) appears to be excluded from the process. Automatization in this field assumes mathematical formalism. A form of such formalism implementation is described in this paper.

Within humanities and social studies the problem of writers’ spiritual life has become the issue of a large body of research. The reality created by authors is analyzed as well as authors’ speech behavior. The problem of the author has become one of the central ones; it remains acute and is witnessing further extension and development. The authors’ speech behavior traced inside a piece of writing (a story, a novel, etc.) can turn to be key to understanding their view on the real world surrounding them, the events, and their assessment. As V. Vinogradov once noted, a narrator’s unique language absorbs their characters’ language and outlook as well as feelings and reflection on these events. Not only is an authors’ personality expressed through narration but also different voices of their time sounding loudly become heard [1]. The authors’ speech behavior studies are multivector ones and based upon different theoretical grounds depending on a researcher’s scientific interest and a subject field [2–6]. This research rests upon a relatively new scientific field — linguistic prognostication [7] having its method, which among other opportunities, adds to text analysis studies and big data analysis. It also gives tools for qualitative interpretation of quantitative results. The conclusions drawn are empirical rather than theoretical. However, to further boost efficiency of quantitative results’ analysis an appropriate algorithm is needed, whose development presupposes a choice of an adequate mathematical apparatus.
2. The procedure of the research and the problem raised

The research is done within the field of external linguistics and touches upon a number of factors which can have potential impact on writers’ mindset. Among those are geographic, historic, social, economic, religious and cultural ones. Chronological boundaries are: for the British writers — 2nd half of the XVI–XX cent. [8]; for the German writers — VIII–XX cent. [9]; for the American writers — XIX–XX cent. [10]. A. Kretov [11] argues that a society’s spiritual life is reflected in the texts created; a text itself is nothing but a reflection of its author’s mindset. A. Kretov outlines that a correlation exists between the verbs of visual perception and an author’s outlook. Defining the subject of his research he sets certain limitations and stresses that not all situations of visual perception should be selected for further analysis. He includes, firstly, the ones only where the subject of visual perception is active, not the object; secondly, the linguistic means describing such situations should be verbs or verb-noun phrases (cast a look, fix eyes, make eyes at etc.). Thus, the description should unfold from the situation of visual perception to the linguistic means of its expression [7]. So, relative frequency of verbs look and see (and their synonyms) is in focus. Developing the ideas above Y. Silina and A. Kretov [12] proposed to use an index — World Perception Index (WP Index). They argue that as the verb to see (and its synonyms) signifies an inward-directed action, that is an action directed towards the subject from the outside, while the verb look (and its synonyms) signify the opposite action vector, the one directed from the subject, that is an outward-oriented one. Y. Silina and A. Kretov explain that in case with a see-group the subject/person trusts the world, lets the visual images penetrate, and accepts them. So the WP Index positive value is higher than that of the look-group. The look-group is marked by unwillingness to accept the world, on the contrary, the subject’s/person’s will is to actively influence the world, bring changes to it. Y. Silina argues there is a correlation between the WP Index and the groups above. Negative values of the WP Index indicate that a person is not satisfied with the surrounding environment. Formula for calculating is as follows:

\[ WPIndex = FL_{see} - FL_{look}, \]

where \( FL_{see} \) is the functional load on the see-group, \( FL_{look} \) is the functional load on the look-group. The objectivity of the WP Index is secured by the assumption that the use of either see or look for a situation description is beyond a narrator’s control, with their use resulting from typical humans’ behavior described by the author. Such typical behavior is determined by the conditions people live in and their attitude towards them. Thus, the WP Index turns out to be an indirect and, consequently, an objective indicator of people’s attitude towards the surrounding world [13].

As is seen, WP Index is an important source of information about an author’s individuality, however, it is not exhaustive. In our research based upon WP Index data we expect to identify the reasons for the Index alterations. To do this we add other important factors influencing the author’s outlook, namely, the period the novel was created, its genre, the historical, political, socio-cultural environment. To reach the aim we analyze several time periods (50 years each) for every country under research with a view to outlining the factors we find most influential for the group of authors in each period envisaged. To better understand the authors’ world perception we analyzed a wide range of sources: biographies, autobiographies, letters, notes on history — all giving a panoramic view on the socio-cultural landscape of each period. All described above let us outline the listed below factors, observe the changes and see the hierarchy of those, with the dominant one at the top for each individual author and for the whole period. The factors influencing the WP Index are:

- faith (religious belief) / atheism;
- wealth / poverty;
- happy marriage / unhappy marriage;
- social stability / social instability;
genre of the piece of writing.

Subjectively formed, the assessment degrees of the factors’ importance were presented in a certain scale and inserted into the table for each particular period. Having received the data on the importance of each factor for individual writers we faced a problem of determining aggregate ranks of the factors for all authors (or for the whole period). In some cases the table cells for some factors were left empty. Routine summation of the factors’ ranks is not satisfying, and does not meet our demands. Thus a problem arises — a mathematical tool is needed to work with incomplete data. So far a necessary degree of formalization of the factors’ influence has not been reached, therefore we inevitably resorted to qualitative and intuitive characteristics. Thus, viewing these as input data, however ill-formed, we find it possible to formalize processing of those with the help of a well-developed apparatus of assessment expertise, however subjective the original theoretical assumption may be.

3. The aggregate ranking algorithm

Our approach to solving the problem is as follows. We code this problem with the language of the group (social) choice theory (more precisely, with one of the varieties of this language, as different authors use different terms for the same objects).

Instead of the term “factor” we will use the term alternative, and the set of all alternatives will be denoted by $D$. Let there be another nonempty finite set $S$. In the group choice theory the elements of this set are called participants, individuals, members, subjects, experts. The set $S$ is called a society or a group. Let $n$ denote the cardinality of $D$ and $m$ is the cardinality of $S$. In our research the elements of the set $S$ are the writers in the studied chronological range. Assume that every element $i \in S$ is matched by a certain preference relation of $\succeq_i$ on the set $D$. Then one says that the profile of individual preferences $\{\succeq_i\}_{i \in S} = R_S$ is given on the set $D$. This assumption can be interpreted as follows. Each member (individual participant, expert) of a group (society), has its own values system, preferences, based on which, he (she) is able to compare any pair of elements in the set of alternatives. In other words, the profile of individual preferences is a model of a values systems set of individuals from a certain group. In our case the writers play the role of individual participants. Unfortunately, we do not have an opportunity to interview these members. Therefore one can estimate a role of every alternative only studying their works, biography, publications literary critics about them and their pieces of writing. The fact that this source of information is highly subjective, forces us to demand from the processing of the expert estimates procedure to be as simple as possible, since special accuracy of data processing methods is unnecessary if the data is inaccurate. For the formation of primary data, we chose a fairly traditional tabular method, which is, in fact, equivalent to setting of ranking chains for each author. In other words, each author is assigned to a chain (ranking).

$$R^{(k)} = \{x_{q_1} \succeq_k x_{q_2} \succeq_k \ldots \succeq_k x_{q_m}\}, k = 1, \ldots, m,$$

where “$x_i \succeq_k x_j$” means “$x_i \succ_k x_j$”, if an expert (author) Number $k$ ”prefers strongly alternative $x_i$ over alternative $x_j$“ (the factor $x_i$ more important than the factor $x_j$), or ”$x_i \sim_k x_j$”, if an expert (author) number $k$ does not distinguish between alternatives $x_i$ and $x_j$ (the effects of these factors are equivalent from the expert’s viewpoint). The set of such rankings is the profile of private preferences. Note that this representation of expert judgments would be convenient, in particular, in the case where an expert could not form his opinion on some of the alternatives. This means that a writer’s work is not clearly traced by reflection of influence of a certain factor (alternative). Then such alternatives are placed at the end of the chain, and the sign of equivalence $\sim_k$ is put between them.
Next, to each ranking $R^{(k)}$ we match a square matrix

$$R^{(k)} = \parallel R^{(k)}_{ij} \parallel, \quad i = 1, \ldots, n, \quad j = 1, \ldots, n,$$

denoted by the same symbol $R^{(k)}$, with elements defined by the rule

$$R^{(k)}_{ij} = \begin{cases} 
2, & \text{if } x_i \succ_k x_j, \\
1, & \text{if } x_i \sim_k x_j, \\
0, & \text{if } x_j \succ_k x_i \text{ or } i = j.
\end{cases}$$

Note that the elements of this matrix satisfy the following conditions

$$R^{(k)}_{ij} \in \{0, 1, 2\}, \quad R^{(k)}_{ij} + R^{(k)}_{ji} = 2, \quad i \neq j, \quad R^{(k)}_{ii} = 0.$$

The matrix $R^{(k)}$ we constructed determines ranking uniquely, and vice versa, is uniquely determined by ranking.

Then let’s find the matrix

$$R = \sum_{k=1}^{m} R^{(k)}, \quad (1)$$

which is the sum of matrices $R^{(k)}$. It will be the basis for making a group decision. Next, we put $i$-th line of the matrix to be matched to $i$-th alternative, $i = 1, \ldots, n$, and calculate sum of the items in every line. Then we arrange alternatives in descending order of the amounts received. We will have

$$R = \{x_{q_1} \succeq x_{q_2} \succeq \ldots \succeq x_{q_n}\}, \quad (2)$$

where ”$x_i \succeq x_j$” means ”$x_i \succeq x_j$”, if $i$-th line items sum more then $j$-th line items sum or ”$x_i \sim x_j$”, if these sums are equal.

Further actions require clarification of the research purpose. If we aim at obtaining final streamlining (group decision), we can consider arranging (2) to be final and stop here. There are reasons for that. The ranking 2 and its matrix (1) can be considered as first iteration for the Kemeny median [14] as the the loss matrix

$$r = \parallel r_{ij} \parallel, \quad r_{ij} = 2 - R_{ij}, \quad i, j = 1, \ldots, n.$$

We can move further and construct the Kemeny median. But algorithms of its construction are quite cumbersome. This is not justified where a quick response is needed.

4. A place of the method and the need for its complication

Here a question arises concerned with the potential advantages of the described method over other known methods of group solution development. The first advantage is it is easy to implement as the algorithm is reduced to the construction of individual preferences matrices based on known individual rankings, summing of these matrices and a single inverse action which is construction of the resulting ranking by summing of the elements in the rows of the group ranking matrix. The second one is a way to take into account the lack of demand for a particular category of authors’ interests in a form of placing the corresponding alternatives at the end of the ranking chain with the postulation of their equivalence.

We do not discuss disadvantages of the method in detail. However we touch this issue upon. The starting point within the group choice theory is the Arrow theorem [15] on the impossibility of an ideal democratic group choice. It is worth mentioning what is implied. We assume that there is a rule $P$ that for any profile of individual preferences gives a new preference relation $\succeq_P = P(R_S)$ on the set $D$. Such a rule we will call a group (social) choice rule (social welfare function). We will call a group choice rule to be an Arrow’s rule (ideal rule) if it meets the following requirements (group choice axioms).
4.1. The condition of universality

4.1.1. The group choice rule $P = P(R_s)$ must be determined for any profile $R_s$.

4.1.2. The set $S$ contains more than one element.

4.1.3. The set $D$ contains more than two elements.

4.2. The condition of positive association of group and individual preferences

Let $R_s^{(1)} = \{≽_k \}_{k \in S}$, $R_s^{(2)} = \{≽_k \}_{k \in S}$ be two profiles of individual preferences, $≽_S = P(R_s^{(1)})$, $≽_S = P(R_s^{(2)})$ the corresponding group preference relation. Suppose that for each $k \in S$ the two individual preference relations are connected in the following ways: for $x'$ and $y'$ distinct from a given alternative $x$, $x' ≽_k y'$ if and only if $x ≥_k y'$; for all $y'$, $x ≥_k y'$ implies $x ≽_k y'$; for all $y'$, $x ≻_k y'$ implies $x ≽_k y'$. Then $x ≻_S y$ implies $x ≻_k y$.

4.3. The condition of the independence of irrelevant alternatives

Let $R_s^{(1)} = \{≽_k \}_{k \in S}$ and $R_s^{(2)} = \{≽_k \}_{k \in S}$ be two profiles of individual preferences, $≽_S = P(R_s^{(1)})$, $≽_S = P(R_s^{(2)})$ the corresponding group’s preference relation. Then

$$\forall \Delta \subseteq D \left( \exists \Lambda \subseteq S \left( \forall x, y \in \Delta \forall k \in \Lambda \ x ≥_k y, \ \forall k \in S \setminus \Lambda \ y ≽_k x \right) \land \right.$$  

$$\land \left( \forall x, y \in \Delta \forall k \in \Lambda \ x ≽_k y, \ \forall k \in S \setminus \Lambda \ y ≻_k x \right) \Rightarrow$$

$$\Rightarrow (x ≽_S y \Rightarrow x ≽_S y). \quad (3)$$

Let us formulate this requirement differently. Let $U$ be a subset of the alternatives in $D$. Let the preference profile be changed as follows: in individual pairwise comparisons of alternatives belonging to the set $U$, preferences remain unchanged. Then the group choices’ narrowing onto $U$ must be equal. If $U$ is just a two-element set, then the condition (3) is as follows. If there are two profiles such as in pairwise comparisons between two alternatives $x$ and $y$ preferences of each subject are the same in both profiles, the orders of preferences of society with respect to $x$ and $x u$ must be the same for both profiles. This means that if members compare two alternatives, the team should forget that there are all other alternatives. What is important to know is who prefers $x$, and who prefers $y$, which I. Ekeland characterized in an elegant manner [16]: When it comes to choosing between Pierre and Paul, Jean’s advantages should not be taken into account.
4.4. The condition of citizen’s sovereignty

Definition. A group choice rule will be considered as imposed if for at least one pair of distinct alternatives $x$ and $y$, $x \succeq_k y$ for all $i = 1, \ldots, n$, but $y \succ_S x$.

The group choice rule is not to be imposed.

4.5. The condition of nondictatorship

Definition. A group choice rule is considered to be dictatorial if there exists an individual $i$ such that for all $x$ and $y$ $x \succ_k y$ implies $x \succ_S y$ regardless of the preference relations of all the other members.

The group choice rule is not to be dictatorial.

Theorem (Arrow, 1951). If a group choice rule satisfies conditions of universality, of positive association of group and individual preferences and of the independence of irrelevant alternatives, then it is either imposed or dictatorial.

In some cases, a decision is made on the basis of formalized processing of expert assessments. There are a number of well-known processing procedures, as a means of presenting expert assessments. A significant part of these procedures includes those, assuming a ranking of the alternatives by experts (with the use of points, pairwise comparisons, etc.) and further ranking after a process of informing about the individual preferences. This means that all the procedures do not leave beyond the scope the above group choice problem. In turn, it means that any procedure for working out a group decision on alternatives ranking, based on individual rankings, is imperfect regarding group choice axioms. It is unlikely that all group choice axioms can be satisfied. Therefore, while analyzing the group decision procedures it is important to understand which axioms are implemented and which are not. Among the experts in the field of expert evaluation the Kemeny median method is known (see e.g., [14]). It gives a rule satisfying all the group choice axioms with the exception of the axiom of independence. Thus, the Kemeny median is the best group solution possible. However, the algorithms of the Kemeny median construction are very time-consuming, and their procedures’ interpretation in the language of the subject field may prove difficult. Other known group choice procedures do not satisfy the axiom of independence, and apart from that, some more ”desirable” requirements have to be sacrificed: transitivity of relations, at least in individual preferences, as in the method of pairwise comparisons, or the universality of the rule, that is, to assume the possibility of the existence of individual preference profiles for which the rule does not provide for an unambiguous group choice, etc. The weakening of the axiom system of group choice leads to a huge variety of group choice procedures. Each of those is neither better nor worse than others, because it is not the Arrow rule. Therefore, the question of the advantages and disadvantages of each particular procedure lies outside mathematics and sometimes outside the subject field. The latter fully applies to the procedure we have outlined.

5. The Kemeny median implementation

At the conference, after our research findings were shared with peers, the following questions (by prof. T. A. Azarnova and prof. I. L. Kashirina) were asked:

1. Is it possible to trace whether each writer is close to or far from the general trend of each period?

2. How objective are the input data and correspondingly the results obtained relating to each period description?

Referring to the first question, it can be noted that the distance between the group ranking and an individual ranking of each author can be measured by means of the Kemeny median apparatus implementation.
Definition. The number

\[ \rho(R, \tilde{R}) = \sum_{i<j} |R_{ij} - \tilde{R}_{ij}| \]

is a distance between two rankings \( R \) and \( \tilde{R} \) with their matrix denoted by the same symbols \( R = \|R_{ij}\|, \tilde{R} = \|\tilde{R}_{ij}\|, i, j = 1, \ldots, n \), respectively.

If we accept this, we consider the Kemeny median as the unique group choice because it gives the minimal sum of distances from each individual ranking to a group choice. Factually the following definition is accepted.

Definition. The Kemeny median is the ranking \( R^* \) that is satisfying the following

\[ \sum_{k=1}^{m} \rho(R^{(k)}, R^*) = \min_R \sum_{k=1}^{m} \rho(R^{(k)}, R), \]

where minimum is taken among all possible rankings of the alternatives \( x_1, \ldots, x_n \in D \).

When we find the group choice \( R^* \), we can compare each individual ranking \( R^{(k)} \) and \( R^* \) by counting the distance \( \rho(R^{(k)}, R^*) \).

This distance serves as a marker of how close each individual writer is to the general period’s trend (sharing common values and expressing views acute for the period) or, conversely, how far from the trend one is with one’s unique mindset. This distance is not explanatory, though. Further interdisciplinary analysis needs to be undertaken with a view to identifying possible reasons.

The second question appears to be unanswerable within the apparatus implemented. However the problem of the input data can be avoided by changing the procedure of the input data formation. This is discussed in the paragraph below.

6. About the input data objectivity

We stressed above that the forming of the input data used can be considered subjective. However, the input data forming process can be improved. Namely, one can choose a certain writer from the list and set a problem about his (her) individual alternatives ranking.

| Proposition | Expert N k. Primary data table. |
|-------------|----------------------------------|
| \( x_1 \succ x_2 \) | \( B^k_{1.1.2} \ldots B^k_{L.1.2} \) | \( B^k_{1.2} = \sum_{s=1}^{L} B^k_{s.1.2} \) | \( B^k_{2.1} = 2L - B^k_{1.2} \) |
| \( x_1 \succ x_3 \) | \( B^k_{1.1.3} \ldots B^k_{L.1.3} \) | \( B^k_{1.3} = \sum_{s=1}^{L} B^k_{s.1.3} \) | \( B^k_{3.1} = 2L - B^k_{1.3} \) |
| \( \ldots \) | | | |
| \( x_i \succ x_j \) | \( B^k_{1.i.j} \ldots B^k_{L.i.j} \) | \( B^k_{i,j} = \sum_{s=1}^{L} B^k_{s.i.j} \) | \( B^k_{j,i} = 2L - B^k_{i,j} \) |
| \( i < j \) | | | |
| \( \ldots \) | | | |
| \( x_{n-1} \succ x_n \) | \( B^k_{1.n-1.n} \ldots B^k_{L.n-1.n} \) | \( B^k_{n-1.n} = \sum_{s=1}^{L} B^k_{s.n-1.n} \) | \( B^k_{n.n-1} = 2L - B^k_{n-1.n} \) |

This issue can be addressed to an expert group, with each expert asked to rank the writer’s preferences. After that this problem can be considered as the one of the group choice problem.
and can be solved as is shown above. However, a problem still remains. If a factors list is long, it can prove difficult for a philologist to obey the transitiveness requirement. In this case the pairwise comparisons method can be applicable as it does not require an expert to obey transitiveness. On this stage each \( s \)-th expert is asked to fill in the primary data table identical to table 1, which is easier than ranking. In table 1 \( L = L_k \) is a total number of experts involved into the evaluation of factors for a \( k \)-th writer, and \( B_{s,i,j} (i = 1, \ldots, n - 1, \ j = i + 1, \ldots, n) \) is a point which should be given by the \( s \)-th expert in accordance with the rule

\[
B_{s,i,j}^k = \begin{cases} 
2, & \text{if expert number } s \text{ agrees that for a writer number } k \ x_i \succ_k x_j, \\
1, & \text{if expert number } s \text{ agrees that for a writer number } k \ x_i \sim_k x_j, \\
0, & \text{if an expert number } s \text{ agrees that for a writer number } k \ x_j \succ_k x_i \text{ or } i = j.
\end{cases}
\]

Table 1 is the basis for the next matrix called the matrix of pairwise comparisons (table 2).

**Table 2.** Writer N \( k \). Matrix of pairwise comparisons.

| Alternatives | \( x_1 \) | \( x_2 \) | \ldots | \( x_j \) | \ldots | \( x_n \) | Sum |
|--------------|-----------|-----------|--------|-----------|--------|-----------|-----|
| \( x_1 \)   | \( B_{1,1}^k = 0 \) | \( B_{1,2}^k \) | \ldots | \( B_{1,j}^k \) | \ldots | \( B_{1,n}^k \) | \( F_1^k = \sum_{j=1}^{n} B_{1,j}^k \) |
| \( x_2 \)   | \( B_{2,1}^k \) | \( B_{2,2}^k = 0 \) | \ldots | \( B_{2,j}^k \) | \ldots | \( B_{2,n}^k \) | \( F_2^k = \sum_{j=1}^{n} B_{2,j}^k \) |
| \( \ldots \) | \( \ldots \) | \( \ldots \) | \ldots | \( \ldots \) | \ldots | \( \ldots \) | \( \ldots \) |
| \( x_i \)   | \( B_{i,1}^k \) | \( B_{i,2}^k \) | \ldots | \( B_{i,j}^k \) | \ldots | \( B_{i,n}^k \) | \( F_i^k = \sum_{j=1}^{n} B_{i,j}^k \) |
| \( \ldots \) | \( \ldots \) | \( \ldots \) | \ldots | \( \ldots \) | \ldots | \( \ldots \) | \( \ldots \) |
| \( x_n \)   | \( B_{n,1}^k \) | \( B_{n,2}^k \) | \ldots | \( B_{n,j}^k \) | \ldots | \( B_{n,n}^k = 0 \) | \( F_n^k = \sum_{j=1}^{n} B_{n,j}^k \) |

This matrix is the basis for the input individual ranking \( R^{(k)} \) of \( k \)-th writer

\[
R^{(k)} = \{ x_{q_1} \succeq_k x_{q_2} \succeq_k \ldots \succeq_k x_{q_m}, \ k = 1, \ldots, m, \}
\]

where

\[
F_{q_1}^k \geq F_{q_2}^k \geq \ldots \geq F_{q_m}^k,
\]

and

\[
x_i \succeq_k x_j \text{ means } \begin{cases} 
  x_i \succeq_k x_j, & \text{if } F_{i}^k > F_{j}^k, \\
  x_i \sim_k x_j, & \text{if } F_{i}^k = F_{j}^k.
\end{cases}
\]

The set of these rankings is input data for the algorithm used.

7. Conclusion

Automatization of the process is in demand in philology. The study has shown that an opportunity exists for the philological data processing automatization. A mathematical apparatus was found. The group choice theory and the expert evaluation theory appear to be applicable for the goal stated. Within these one can reveal out-of-trend authors and disclose how far they are from the general trend. Yet, the reasons for this cannot be found within these theories’ apparatus. However, new issues have come to the fore, having potential for further interdisciplinary analysis.
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