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The analysis of expert opinions' consensus quality

Adrianna Kozierkiewicz-Hetmańska

Wroclaw University of Technology, Wybrzeze Wyspianskiego 27, 50-370 Wroclaw, Poland

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ABSTRACT

In many situations we need to obtain one, common decision (which can be understood as a consistent state of knowledge) out of opinions collected from many experts or any other external sources. This entails a problem concerning the reliability of such decision. We would like to know that decisions based on experts' opinions are trustworthy. Unfortunately, in many cases the determination of such decision is difficult and expensive, especially when big sets of input data are involved in the process. This paper presents a framework which allows to assess the quality of the aforementioned final decision. Its output is based solely on the analysis of its input (e.g. an assumed representation of experts' opinions). Moreover, the paper contains an overview of several types of possible approaches to the considered topic.

1. Introduction

In recent years we can observe a rapid growth of information, its sources and methods of representation. It has caused the necessity of developing methods for their storing and processing. Modern companies are characterised by an increasing complexity of used systems and amount of data which is stored in not only one, central database, but frequently in several distributed collocations. Furthermore, sometimes the same data is replicated among multiple databases to ensure its safety. To properly manage a company that has to deal with such diversity, the effective methods of knowledge integration from all of the possible sources are required. Moreover, companies are constantly enforced to question a reliability of acquired results coming from an integration process due to its high complexity and significant size of its input.

In general, any source of knowledge can be treated as an expert's opinion. In the simplest case, they can be collected even from ordinary relational databases. For example, some company's branches posses different data referring to their local management. This diversity may imply different business decisions taken on regional and completely different on the global level. Obviously, mistakes made during the development of such strategy can cause losing a lot of money or even going bankrupt. Therefore, before trusting the aforementioned strategy (a result of an integration of experts' opinions coming from a tremendous amount of data concerning local company's branches), its quality assessment is indispensable. Unfortunately, such verification is not easy due to the computational complexity of calculating of some assumed quality metrics. Moreover, processing a large set of experts opinions is very expensive in terms of a time consumption when distributed knowledge sources are involved.

In our work we assume that to make a decision regarding some problem we ask many experts for their opinion or we process data from various sources. Thus, we have to deal with a knowledge of a collective, and based on it we have to make the final decision. It has been proved in [1] that the Consensus Theory can be useful in determining a consistent knowledge of a collective.

However, in a real situation the final solution is not simple to achieve. Before designating any conclusions from experts' opinions we would like to know if it is possible to get reliable and high quality consensus. The general idea of the considered problem is presented in Fig. 1.

In this paper we assume that experts' opinions share a unified representation. To simplify this process, we will use real numbers and binary vectors for such representation. Furthermore, we propose conditions which should be fulfilled, by a set of collected opinions, in order to achieve the highest quality of the final consensus. Therefore, we claim that the analysis of dependencies between the number of experts (knowledge bases) and elements of sets representing their opinions (without determination of the consensus) is enough to assess the quality of consensus.

The main contribution of this paper is a set of new theorems, which contain conditions for maximal quality of the consensus for assumed knowledge structures. Subsequently, we also investigate particular issues concerning consistency of profiles (knowledge bases) and their susceptibility to a consensus. All proposed

E-mail address: adrianna.kozierkiewicz@pwr.edu.pl

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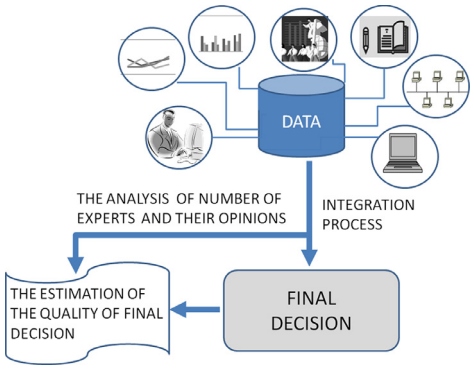

Fig. 1. General idea of the presented problem.

theorems are discussed and some ideas for improving the quality of a consensus are presented. The obtained results are novel, the quality of consensus has not been widely investigated in the literature.

The remaining part of this paper is organised as follows. In the next section a brief summary of related work is described. Section 3 contains the introduction to the Consensus Theory. In Section 4 some different representations of experts opinions are presents along with an analysis of the quality of consensus. Section 5 concludes the paper.

2. Related works

In many practical tasks we encounter a decision problem that needs to be solved based on a collective knowledge. However, this problem is difficult and not deeply investigated by researchers. Nguyen [1] proposed a formal mathematical model of the collective knowledge and applied Consensus Theory methods for generating it. The consensus methodology has been proved to be useful in solving conflicts and should also be effective for problems of a knowledge inconsistency resolution and the knowledge integration. The problem of determination of the collective knowledge is related to the knowledge integration problem. These issues were solved and thoroughly investigated for a logical and a relational structures as well as for ontologies. Refer to [1,2] where the author proposed the formal model for the knowledge integration and its algorithms. Additionally, a set of postulates for a knowledge function and their analysis, depending on a selected representation of knowledge states, were proposed.

In [3] authors introduced an algorithm aggregating the preference relations provided by experts in multi-expert decision making problems. In order to aggregate the individual preferences for each of the elements, from the set of aggregation functions, the most suitable one was selected by means of a consensus done through penalty. Authors assumed that the information provided by the experts was homogeneous and represented by means of a fuzzy preference relations that were fused into a single relation, called the collective preference relation. This fusion was done by using the aggregation function which was selected by the consensus.

Rosello and others [4] proposed a mathematical framework and a methodology for the group decision-making using distances and consensus within a linguistic information. Distances were defined from the geodesic distance in the graph theory and the Minkowski distance. The degree of the consensus is based on the concept of an entropy of the generalised qualitative assessments.

In [5] the decision support system was proposed. Experts provided their testimonies as fuzzy preference relations. The consensus process was supervised by a moderator called “super-expert”. Szmidt and Kacprzyk [6] presented the fuzzy analysis of the consensus based on an idea of a distance from the final consensus.

Mata [7] proposed a model of an adaptive consensus support system for decision-making problem with multi-granular linguistic information. The consensus process was improved by adapting search for preferences in disagreement to the current level of the consensus at each round. Additionally, authors defined three different methods of identifying the preferences that each expert should modify, in order to increase the agreement in the next consensus round.

The interesting problem was considered in [8] where authors assumed that decision makers provided their opinions using a linguistic expression instead of a single linguistic term. Furthermore, the paper considered a consensus reaching process in case of the hesitant linguistic group decisions making. From the assumed problem the novel distance based consensus measure was proposed.

In [9] an overview and a categorisation of some existing models for decision making problem was proposed. These models were applied in a prototype of a simulation-based analysis framework called AFRYCA for the resolution of decisions making problems under the consensus.

In [10] authors proposed the consensus model suitable to manage a large scale of decision makers, which was also raised by researchers in [11–15].

The decision problem is closely related to the issue of assessing the quality of determined decisions. Formal definition for the quality of knowledge was proposed in [1]. The author defined measures which allows to evaluate these consensuses referring to the profiles. They included the measure of a quality and a consistency. For selected cases, the author pointed out that the larger the consistency value of a profile the higher the quality of its consensus.

The problem of assessing the collective knowledge was also raised in [16]. The quality of the collective knowledge states were evaluated by comparing them with the real knowledge states. The author analytically proved that the collective knowledge state is always better than the worst element of the collective (the collective member).

Dong and others [17,18] used the social choice theory and the prospect theory for decision making problem and evaluate the consensus process. Authors considered different representations like the preference orderings, the utility functions, the multiplicative and fuzzy preference relations, and based on them, the individual preferences vector of alternatives were created. The standardized individual preferences vectors are aggregated into a collective preference vector. Authors calculated the consensus degree as a distance between the individual preference values and the collective preference values. The consensus degree evaluated the consensus process and it was used to adjust the opinions of the decision makers. The proposed framework avoided the internal inconsistency and satisfied the Pareto principle.

In [19] the author evaluated one-level and the two-level consensuses with the reference to the optimal solution. The prepared quality measure allowed to demonstrate that in comparison to the optimal solution the two-level algorithm and one-level method were good approximations and gives results worse for less than 5%.

In [20] authors showed interesting experimental results. They engaged four volunteer experts and they gave them definitions of the seventy-six variables and asked them to write, in a limited amount of time, rules describing the printer domain to the best of their ability. These rules were assessed and the analysis demonstrated that the collective knowledge achieves higher accuracy than a simple combination of the individual volunteers.

In [21] the quality was measured by the difference between the collective knowledge and the real world knowledge. Authors proposed a method for improving the quality of the collective knowledge. They have conducted an experimental research with a dif-