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Group decision making and soft consensus: Analyzing citation classics by means of H-Classics

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Abstract

Citation classics provide a view on the documents that could be considered the basis of a scientific area and that have therefore attracted historical and great interest by the researchers. Because of the potential relation that can be established between quality research and citation counts, the identification of citation classics also is a main way used to carry out a methodical assessment of research performance. In recent times, the H-Classics, a methodology that is founded on the popular h-index, has been introduced to determine the highly cited papers. This research aims to provide an insight into the development of soft consensus in group decision making via H-Classics. Particularly, we identify both the scientific actors (researchers, institutions, countries, and journals) making the biggest research contribution to the development of this scientific area and the topics covered.

Keywords: Citation classics; h-index; H-Classics; consensus; group decision making

1. Introduction

Group decision making (GDM), being a notable part of everyday life in current organizations, involves various decision makers (participants) interacting to make a common decision [1, 2]. Here, before making the decision, it is crucial to know the consensus among the participants and even improving it whether necessary [3].

In the first approaches developed in the setting of GDM, consensus was meant to be a unanimous and entire accord [4, 5]. However, a fuzzy majority was suggested as more suitable due to the fact that a unanimous and entire accord is unlikely reachable in practice [6]. Since then, the fuzzy majority concept has been essential for a new meaning of consensus (soft consensus) that is able to reflect the wide spectrum of possible partial accords among the decision makers and guide the discussion until general accord is reached [7].

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The decision made should be generally accepted by all the participants involved in the problem. Therefore, the consensus has been the principal aim of GDM. Concretely, the meaning of consensus based on the fuzzy majority concept has widely been assumed by most of the methodologies dealing with GDM problems [8, 9, 10].

After a productive research in this scientific area, it is necessary to comprehend its scientific structure by analyzing its past, present and future. Although the scientific area of soft consensus in GDM has already been analyzed via bibliometric techniques [11], it is not the case for the highly cited papers, which are usually considered important in the development of a scientific area as they have attracted the interest of the researchers. The highly cited papers are characterized by the "citation classics", also called "literary classics" or "classic articles", which is a bibliometric concept that Garfield introduced in 1977 [12]. Citation classics have been contemplated as "gold bullion of science" because they are used to find out essential information toward the progress of a scientific area and they also help comprehend the future, present and past of its scientific structure [13].

In this research, we analyze the highly cited papers published on soft consensus in GDM. They are identified by means of the H-Classics, an approach recently introduced by Martínez et al. [14] that overcomes the drawbacks related to the traditional approaches identifying highly cited papers. The analysis is intended to:

- Give an historical perspective on the scientific progress in the scientific area of soft consensus in GDM.
- Recognize the main intellectual makers, such as researchers, institutions, countries, and journals.
- Identify the major advances and the hot topics to inspire other works.

This research is structured into four sections. In Section 2, we describe in detail the approach applied to perform the analysis. Section 3 presents the different results obtained in this research, and Section 4 covers the principal conclusions.

2. Data and bibliometric analysis

2.1. Data source

Different bibliographic databases may be used to carry out bibliographic studies. The most important bibliographic databases are Web of Science from Clarivate Analytics, Scopus from Elsevier, and Google Scholar. On the one hand, Google Scholar has the drawback that it presents citation information that is not view as reliable and precise. On the other hand, even though Scopus covers a broader research literature than the Web of Science, the journals not listed by the Web of Science usually have a low citation impact as they are nationally focused. In fact, the Web of Science indexes the most notable contributions of the diverse scientific areas, including therefore a complete retrospective quality coverage of papers related to soft consensus in GDM. In addition, this bibliographic database is considered suitable for analyzing the highly cited papers because it contains the most reliable and accurate citation counts. Therefore, our bibliometric analysis relies upon the usage of the Web of Science to construct an adequate list of papers.

2.2. Sample of the study

The study sample is composed of papers indexed in the Web of Science during the timespan 1985-2018. Furthermore, this sample is limited to literature review papers and full length papers (documents such as letters, corrections, editorials, meetings, books reviews, and others, were not included in this study). In consequence, the following Web of Science advanced search query was executed to retrieve the documents subject to study:

TS = ("decision making" AND "fuzzy" AND "consensus")

This query returned a total of 815 papers. However, some of them was removed as they were not focused on the scope of this study (given that this manipulation of the papers was manually carried out, the result might contain a nonsignificant percentage of human errors). For each paper, the citation count, keywords, institutions, authors, journal, year of publication, and title, were obtained.

2.3. Methodology

The works analyzing highly cited papers have as a general characteristic the application of a selection criterion using a threshold value to make a distinction if a document is identified as a highly cited paper or not [12, 16]. To do so, one of the following two approaches have traditionally been applied:

- The number of highly cited papers to be retrieved determines the threshold value [12].
- The number of citations received determines the threshold value [17].

Even though these two approaches have widely been applied, they share these disadvantages: neither the citation patterns of the scientific areas nor their scientific evolution are considered [14]. To overcome these drawbacks, Martínez [14] introduced the H-Classic concept, which is founded on the robust bibliometric measure h-index [15]:

> "A researcher has index h if h of her or his N_p papers have at least h citations each, and the other $(N_p - h)$ papers have $\leq h$ citations each."

The h-index determines the most fruitful core of a researcher's output in relation to her or his most cited documents [18]. The term H-core (Hirsch core) was introduced by Rousseau to determine this core [19]. It consists of the first h papers, which are considered as the group of top quality papers concerning the researcher's career [20]. Founded on the H-core, the H-Classic concept was formulated as follows[14]:

> "H-Classics of a research area A could be defined as the H-core of A that is composed of the h highly cited papers with more than h citations received."

The H-Classic gives a fair and unbiased criterion to perform a systematic search procedure for citation classics in any scientific area, avoiding the potential biased of studies of highly cited papers carried out up until now. Since the concept of H-Classics was introduced, it has been used in different studies [21, 22, 23]. To determine the papers of a scientific area classed as H-Classics, the following four steps are carried out [14]:

1. Choice of the database used to get the sample of the study. As we have previously mentioned, the Web of Science[1] is used as bibliographic database for the present study because it indexes the most trustworthy research information. In addition, it provides many tools of analysis to treat that information.
2. Identification of the scientific area subject to analysis. The main research papers associated with the scientific area under study must be identified. Whether the scientific area matches one of the disciplines of the Web of Science, the collection of journals of interest can be retrieved easily and, in consequence, the sample of papers that must be studied. Otherwise, we must run an appropriate query to obtain the sample of papers to be studied. In this research, we run the query shown in Section 2.2 to retrieve the papers that are relevant in the scientific area of soft consensus in GDM.
3. Calculation of the h-index associated with the scientific area. We must rank the papers according to their citation counts to determine the h-index associated with the scientific area. To do so, we must order the papers by their citation counts in a decreasing way. We focus here on locating the first paper whose location in the ranking is below its citation count as the h-index correspond to paper located above in the ranking. This can manually be done, however, the Web of Science provides several tools facilitating the computation of the h-index for a particular collection of documents. After using these tools, we find that the h-index associated with the scientific area under study is 69.
4. Retrieving the papers located in the H-core of the scientific area. It includes the first h highly cited papers in the ranking obtained in the above step. Appendix A lists the 69 papers that are identified as H-Classics in the scientific area under study.

Finally, we import the raw data retrieved to SciMAT[2] [24]. This is done to create a knowledge base and carry out a step of pre-processing. Recall that SciMAT is an open source software for science mapping analysis that helps perform a de-duplication step over researchers, institutions, and keywords. By doing it, we combine those entities symbolizing the same researcher, institution, or keyword, into only one entity.

[1] https://apps.webofknowledge.com/
[2] https://sci2s.ugr.es/scimat/

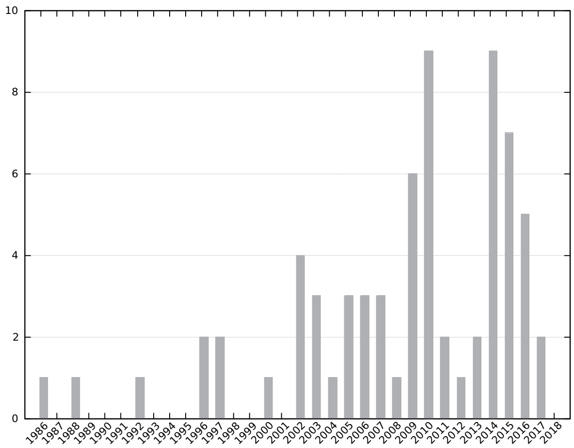

Fig. 1. H-Classic papers per year of publication.

3. Results

In this section, we analyze the H-Classic papers in the scientific area of soft consensus in GDM. First, we show how the H-Classic papers are distributed per year of publication. Second, we identify the researchers, institutions, countries, and journals, generating the highest number of H-Classic papers. Third, we present the main topics that the H-Classic papers cover.

3.1. H-Classic papers per year of publication

The scientific area of soft consensus in GDM is composed of 69 papers classed as H-Classics. Fig. 1 depicts how these 69 H-Classics papers are distributed per year of publication. The first paper classed as H-Classics was published by Kacprzyk in 1986 [6]. In this work, and different from the conventional methodologies in which a crisp (threshold type) majority rule was used, the author proposed the use of a fuzzy majority rule defined via a linguistic quantifier to derive the result of a GDM problem. In fact, the first three H-Classic papers were published by Kacprzyk and his collaborators [6, 7], which are the precursors of this scientific area. Furthermore, even though it is in remotest years where highly cited papers are generally situated because of citations window, Fig. 1 shows that the research field of soft consensus in GDM is currently a hot topic and it is growing fast. Actually, the timespan 2009-2017 concentrates most of the papers classed as H-Classics.

3.2. Researchers, institutions, countries, and journals

The researchers who have published three or more H-Classic papers are shown in Table 1. E. Herrera-Viedma, affiliated to the University of Granada (Spain), has published the higher number of H-Classic papers. He nearly duplicates the researcher ranked in the second position. It should be remarked the presence of eight Spanish researchers (E. Herrera-Viedma, F. Chiclana, F. Herrera, F.J. Cabrerizo, L. Martínez. I.J. Pérez, and F. Mata) and four Chinese researchers (Z.S. Xu, Y.C. Dong, J. Wu, and Y.F. Xu).

Based on the information on researchers' address encountered in the H-Classic papers, the institutions whose researchers have published three or more H-Classics papers are shown in Table 2. The top most productive institutions are the University of Granada (Spain), the De Montfort University (England) and the Sichuan University (People's Republic of China). It is worth noting that the University of Granada duplicates the second ranked institution and nearly triplicates the third ranked institution.

The countries originating three or more H-Classics are shown in Table 3. The leading countries are Spain and People's Republic of China, which duplicate England, country ranked in third position. The predominance of Spain and People's Republic of China in generating H-Classic papers is evident.

Finally, the journals publishing three or more H-Classic papers are shown in Table 4. European Journal of Operational Research and Information Sciences are the most important journals. Along with these two journals, Fuzzy Sets and Systems has also contributed in an important way to the development of this scientific area.

Table 1. Most productive researchers of H-Classic papers.

Rank	Researcher	Institution	#H-Classic papers
1	E. Herrera-Viedma	University of Granada, Spain	25
2	F. Chiclana	De Montfort University, England	14
3	F. Herrera	University of Granada, Spain	12
4	F.J. Cabrerizo	University of Granada, Spain	8
4	Z.S. Xu	Sichuan University, People's Republic of China	8
6	Y.C. Dong	Sichuan University, People's Republic of China	7
6	L. Martínez	University of Jaén, Spain	7
8	S. Alonso	University of Granada, Spain	6
8	J. Kacprzyk	Polish Academy of Sciences, Poland	6
8	J. Wu	Shanghai Maritime University, People's Republic of China	6
11	I.J. Pérez	University of Cádiz, Spain	4
12	M. Fedrizzi	University of Trento, Italy	3
12	F. Mata	University of Jaén, Spain	3
12	W. Pedrycz	University of Alberta, Canada	3
12	Y.F. Xu	Sichuan University, People's Republic of China	3

Table 2. Most productive institutions of H-Classic papers.

Rank	Institution	Country	#H-Classic papers
1	University of Granada	Spain	29
2	De Montfort University	England	13
3	Sichuan University	People's Republic of China	10
4	University of Jaén	Spain	7
4	National Distance Education University (UNED)	Spain	7
6	Polish Academy of Sciences	Poland	6
6	Southeast University	People's Republic of China	6
8	Zhejiang Normal University	People's Republic of China	5
9	Chinese University of Hong Kong	People's Republic of China	3
9	Istanbul Technical University	Turkey	3
9	University of Alberta	Canada	3
9	University of Trento	Italy	3
9	Xi'an Jiaotong University	People's Republic of China	3

Table 3. Most productive countries of H-Classic papers.

Rank	Country	#H-Classic papers
1	Spain	29
2	People's Republic of China	26
3	England	13
4	Poland	6
4	Taiwan	6
6	Italy	4
6	Turkey	4
6	United States of America	4
9	Canada	3

Table 4. Most productive journals of H-Classic papers.

Rank	Journal	#H-Classic papers
1	European Journal of Operational Research	8
1	Information Sciences	8
3	Fuzzy Sets and Systems	7
4	Information Fusion	6
4	Knowledge-Based Systems	6
6	IEEE Transactions on Fuzzy Systems	5
7	Applied Soft Computing	4
7	IEEE Transactions on Systems, Man, and Cybernetics - Part A: Systems and Humans	4
9	Decision Support Systems	3
9	International Journal of Information Technology & Decision Making	3

Fig. 2. Main topics covered by the H-Classic papers.

3.3. Topics

The analysis of keywords is a natural approach to find out the leading trends in a given scientific area. As a consequence, to recognize the topics investigated by the H-Classics papers, we create a tag cloud using the keywords contained in the H-Classic papers (see Fig. 2). We can observe that, of course, the most important keywords are "consensus" and "group decision making". However, it is noticeable how other associated terms also are important. Some of them are associated with the representation format used by the participants to verbalize their evaluations ("linguistic preference relations", "fuzzy preference relations", "preference relations") and other terms are associated with the aggregation preferences ("aggregation", "aggregation operators", "OWA operators"). In addition, other concepts as "majority" and "consistency" also are important in this scientific area.

4. Concluding remarks

In this research, utilizing the concept of H-Classics [14], we have analyzed the highly cited papers in the scientific area of soft consensus in GDM. In particular, the researchers, institutions, countries, journals, and topics covered, have been analyzed. An amount of 69 H-Classic papers have been identified in the timespan 1985-2018, with citation counts ranging from 71 to 725. The years in which more H-Classic papers have been published are 2010 and 2014, with nine H-Classic papers each. Spain, the University of Granada, and E. Herrera-Viedma, are the country, the institution, and the researcher, respectively, contributing more to the evolution of the scientific area of soft consensus in GDM. In addition, European Journal of Operational Research and Information Sciences are the journals where more H-Classic papers have been published.

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Appendix A. H-Classic papers in the scientific area of soft consensus in GDM

Rank	Paper	#Citations
1	Herrera F, Herrera-Viedma E, Verdegay JL. A model of consensus in group decision making under linguistic assessments. Fuzzy Sets Syst 1996;78:73–87	725
2	Kacprzyk. Group decision-making with a fuzzy linguistic majority. Fuzzy Sets Syst 1986;18:105–118	483
3	Herrera-Viedma E, Herrera F, Chiclana F. A consensus model for multiperson decision making with different preference structures. IEEE Trans Syst Man Cybern Part A-Syst Hum 2002;32:394–402	418
4	Bordogna G, Fedrizzi M, Pasi G. A linguistic modeling of consensus in group decision making based on OWA operators. IEEE Trans Syst Man Cybern Part A-Syst Hum 1997;27:126–132	395
5	Herrera-Viedma E, Martínez L, Mata F, Chiclana F. A consensus support system model for group decision-making problems with multi-granular linguistic preference relations. IEEE Trans Fuzzy Syst 2005;13:644–658	389
6	Herrera-Viedma E, Alonso S, Chiclana F, Herrera F. A consensus model for group decision making with incomplete fuzzy preference relations. IEEE Trans Fuzzy Syst 2007;15:863–877	350
7	Kacprzyk J, Fedrizzi M, Nurmi H. Group decision-making and consensus under fuzzy preferences and fuzzy majority. Fuzzy Sets Syst 1992;49:21–31	315
8	Kahraman C, Ruan D, Dogan I. Fuzzy group decision-making for facility location selection. Inf Sci 2003;157:135–153	314
9	Hsu HM, Chen CT. Aggregation of fuzzy opinions under group decision making. Fuzzy Sets Syst 1996;79:279–285	263
10	Cheng CH, Lin Y. Evaluating the best main battle tank using fuzzy theory with linguistic criteria evaluation. Eur J Oper Res 2002;142:174–186	248
11	Mata F, Martínez, Herrera-Viedma E. An adaptive consensus support model for group decision-making problems in a multigranular fuzzy linguistic context. IEEE Trans Fuzzy Syst 2009;17:279–290	245
12	Herrera-Viedma E, Cabrerizo FJ, Kacprzyk J, Pedrycz W. A review of soft consensus models in a fuzzy environment. Inf Fusion 2014;17:4–13	243
13	Atanassov K, Pasi G, Yager RR. Intuitionistic fuzzy interpretations of multi-criteria multi-person and multi-measurement tool decision making. Int J Syst Sci 2005;36:859–868	231
14	Dong YC, Zhang G, Hong WC, Xu Y. Consensus models for AHP group decision making under row geometric mean prioritization method. Decis Support Syst 2010;49:281–289	228
14	Cabrerizo FJ, Pérez IJ, Herrera-Viedma E. Managing the consensus in group decision making in an unbalanced fuzzy linguistic context with incomplete information. Knowledge-Based Syst 2010;23:169–181	228
16	Xu ZS, Yager RR. Intuitionistic and interval-valued intuitionistic fuzzy preference relations and their measures of similarity for the evaluation of agreement within a group. Fuzzy Optim Decis Mak 2009;8:123–139	219
17	Herrera F, Herrera-Viedma E. Choice functions and mechanisms for linguistic preference relations. Eur J Oper Res 2000;120:144–161	211
18	Alonso S, Herrera-Viedma E, Chiclana F, Herrera F. A web based consensus support system for group decision making problems and incomplete preferences. Inf Sci 2010;180:4477–4495	210
19	Cabrerizo FJ, Moreno JM, Pérez IJ, Herrera-Viedma E. Analyzing consensus approaches in fuzzy group decision making: Advantages and drawbacks. Soft Comput 2010;14:451–463	196
20	Olcer AI, Odabasi AY. A new fuzzy multiple attribute group decision making methodology and its application to propulsion/manoeuvring system selection problem. Eur J Oper Res 2005;166:93–114	191
21	Szmidt E, Kacprzyk J. Using intuitionistic fuzzy sets in group decision making. Control Cybern 2002;31:1037–1053	177
22	Xu ZS. A survey of preference relations. Int J Gen Syst 2007;36:179–203	175
23	Pérez IJ, Cabrerizo FJ, Herrera-Viedma E. A mobile decision support system for dynamic group decision-making problems. IEEE Trans Syst Man Cybern Part A-Syst Hum 2010;40:1244–1256	174
24	Cabrerizo FJ, Alonso S, Herrera-Viedma E. A consensus model for group decision making problems with unbalanced fuzzy linguistic information. Int J Inf Technol Decis Mak 2009;8:109–131	173
25	Szmidt E, Kacprzyk J. A consensus-reaching process under intuitionistic fuzzy preference relations. Int J Intell Syst 2003;18:837–852	169
26	Chiclana F, Tapia-García JM, del Moral MJ, Herrera-Viedma E. A statistical comparative study of different similarity measures of consensus in group decision making. Inf Sci 2013;221:110–123	168
26	Ben-Arieh D, Chen Z. Linguistic-labels aggregation and consensus measure for autocratic decision making using group recommendations. IEEE Trans Syst Man Cybern Part A-Syst Hum 2006;36:558–568	168
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Rank	Paper	#Citations
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30	Dong YC, Li Y, Feng B. The OWA-based consensus operator under linguistic representation models using position indexes. Eur J Oper Res 2010;203:455–463	150
32	Chiclana F, Mata F, Martínez, Herrera-Viedma E, Alonso S. Integration of a consistency control module within a consensus model. Int J. Uncertainty Fuzziness Knowl-Based Syst 2008;16:35–53	136
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