Does Google Scholar contain all highly cited documents (1950-2013)?

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ABSTRACT

The study of highly cited documents on Google Scholar (GS) has never been addressed to date in a comprehensive manner. The objective of this work is to identify the set of highly cited documents in Google Scholar and define their core characteristics: their languages, their file format, or how many of them can be accessed free of charge. We will also try to answer some additional questions that hopefully shed some light about the use of GS as a tool for assessing scientific impact through citations.

The decalogue of research questions is shown below:
1. Which are the most cited documents in GS?
2. Which are the most cited document types in GS?
3. What languages are the most cited documents written in GS?
4. How many highly cited documents are freely accessible?
   a. What file types are the most commonly used to store these highly cited documents?
   b. Which are the main providers of these documents?
5. How many of the highly cited documents indexed by GS are also indexed by WoS?
6. Is there a correlation between the number of citations that these highly cited documents have received in GS and the number of citations they have received in WoS?
7. How many versions of these highly cited documents has GS detected?
8. Is there a correlation between the number of versions GS has detected for these documents, and the number citations they have received?
9. Is there a correlation between the number of versions GS has detected for these documents, and their position in the search engine result pages?
10. Is there some relation between the positions these documents occupy in the search engine result pages, and the number of citations they have received?

To answer these questions, a set of 64,000 documents indexed in Google Scholar has been collected, after performing 64 queries by year (from 1950 to 2013) using Google Scholar’s advanced search, and collecting the maximum number of records that GS displays for any given query, which as we know is always 1,000. These 64,000 documents receive 122,245,865 citations in Google Scholar and 35,182,077 in Web of Science Core Collection.

Full raw data available at: http://dx.doi.org/10.6084/m9.figshare.1224314

KEYWORDS

Google Scholar / Academic Search Engines / Top cited documents / Highly cited documents / Citation Analysis / Language / Open Access / Editions / Academic SEO / Search Engine Optimization / SERP / Search Engine Result Page / Web of Science

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1. INTRODUCTION

1.1 About this title

The reason behind the title of this work and its structure as questions is not simply a rhetorical device intended to attract the reader’s attention. It is a genuine statement of intentions, since there is no absolute empirical certainty that our sample contains all the highly cited documents present in Google Scholar (GS) at the moment we collected the data. If GS provided a feature that allowed us to sort documents according to number of citations, as traditional bibliometric databases do (Web of Science and Scopus), we wouldn’t harbor any doubts about this matter. Since this is not the case, we can not be completely sure that when we make a query by year of publication in GS, it will show us the 1,000 most cited documents published during that range of years (as we know, 1,000 is the maximum number of results GS will display for any given query). In short, we are not entirely sure that the data we collected comprises only highly cited documents in GS, and therefore it is likely that some of these documents don’t actually belong to the group of “upper crust” documents in GS for each of the years in the selected range (1950-2013).

Nevertheless, there is strong evidence suggesting that our sample contains a very large portion of the highly cited documents in GS:

Firstly, in its documentation, GS explicitly declares¹ that the number of citations received by a document is one of the factors involved in the calculation of the position this document will occupy on the results page, although they don’t specify the overall weight of this factor in the calculation. A high correlation between the position documents occupy in the search engine results page (SERP) when they are sorted by Google Scholar’s default relevance criteria, and the position they occupy when they are sorted simply by their number of citations (See question 10, Figure 24) would confirm that citation count is indeed the factor that is given the highest weight in Google Scholar’s ranking algorithm, and therefore it would be safe to presume that the first positions of a query will always be occupied by the most cited documents that satisfy said query.

Secondly, we can see other evidences that support the validity of our sample: in order to verify that the documents in our sample were in fact highly cited documents, we retrieved the top 1,000 most cited documents on the Web of Science Core Collection for each year in the range 1950-2013 (as of October the 30th 2014), and compared the two sets of documents for each year. The results showed that, on average, 81% of the documents in our sample from GS with a link to a WoS record² were also present in the ranking of the top 1,000 most cited documents in WoS. With the WoS dataset, we could also learn how many highly cited documents in WoS were missing from our GS dataset. In this respect, the results show that the number of highly cited documents in WoS that are not present in our GS sample is insignificant. There are only 396 (1.3%) documents in our WoS sample that have received enough citations to be included among the 30,000 most cited documents in our GS sample, but that according to their document ID are not present in this sample. Likewise, if we consider the 40,000 most cited documents in our sample, this figure raises to 1,645 (4.1%). As we lower the citation threshold, this figure obviously increases (See Question 1). This result seems logical for two reasons:

¹ About Google Scholar: How are documents ranked?  
http://scholar.google.com/intl/en/scholar/about.html [accessed on October 7th 2014]

² Collaboration between Google Scholar and Web of Science  
http://wokinfo.com/googlescholar/ [accessed on October 24th 2014]
a) factor ranking: citations are the main ranking factor but not the only one. Therefore, for documents with the highest number of citations, the position achieved clearly correlates with citations. In contrast, in the lower positions, where the number of citations is also lower, the effect of other ranking factors is more evident.

b) statistical noise: in the first positions, the differences between the documents in terms of citations are high, so the statistical error must be very large to obtain documents in wrong positions. However, as we approach the border cut (1,000 documents), the differences between the documents are smaller, and therefore small errors can result in significant changes in positions over the lower ranks (especially for positions in the margin 800-1,200).

Lastly, our own experience, gained through the daily observation of hundreds of searches. Usually, the relevance ranking used by GS is reduced to simply placing the highest cited documents in the first results pages, with very rare exceptions. This is something anyone can check just by doing a search in Google Scholar. We encourage researchers to experience this for themselves.

To sum up, in this work we analyse the 1,000 documents that GS retrieves for each one of 64 queries by year, from 1950 until 2013. Presumably, among them we should be able to find the most cited documents published in each of those years.

1.2 Citation Classics: Highly Cited Documents

The idea of identifying the most influential documents in science using the number of citations they generate in the scientific literature was introduced, like many other bibliometric tools, by Eugène Garfield. On January 3rd 1977, Garfield published an essay entitled “Introducing Citation Classics: the human side of scientific papers” (1977), which appeared in Current Contents. The candidates for Citation Classics were selected from a group of 500 most cited papers during the years 1961-1975. Many of these had been listed before in Current Contents. From 1977 to 1993, 400 Citation Classic Commentaries were published in Current Contents. The full texts of these mostly one-page articles are now available in an open access server at http://garfield.library.upenn.edu/classics.html.

From 2001, the Highly Cited Papers were integrated in a new product from Thomson Scientific: the Essential Science Indicators. Neither Scopus nor other databases have released alternatives to this product.

What we do have is an extensive scientific literature, published during the last few decades, on the matter of highly cited documents in different journals, subject areas, institutions or countries (Oppenheim & Renn 1978; Narin & Frame 1983; Plomp 1990; Glänzel & Czerwon 1992; Glänzel, & Schubert 1992a-b; Glänzel et al. 1995; Tijssen et al. 2002; Aksnes 2003; Aksnes & Sivertsen 2004; Kresge et al. 2005; Levitt & Thelwall 2009; Smith 2009; Persson 2010). Recently, the need of ranking any product of scientific activity according to its citation performance has caused the emergence of this kind of classifications (top 1%, 10%, 15%). The calculation of percentiles, previously proposed explicitly by Maltrás (2003), has recently been rediscovered by other authors (Bornmann 2010, Bornmann & Mutz 2011, Bornmann et al. 2011).

The appearance of Google Scholar opened up new possibilities in this field. Its birth at the end of 2004 signaled a revolution in the way scientific publications were searched, retrieved and accessed (Jacsó, 2005).

From the get-go, GS became not only a search engine for scientific and academic documents, but also for the citations these documents receive. Although it took five years to get over its “beta” stage, today we can say without a doubt that GS is not only the largest database of scientific, academic and technical information in the world (Orduña-Malea et al., 2014, Ortega 2014), but also the richest and
most varied, since Google’s crawlers systematically parse and process the whole academic web, not making distinctions based on subject areas, languages, or countries (Ortega 2014). Despite the limitations of its spiders and processing software, the lack of normalization processes and quality control filters, GS is an irreplaceable source of global scientific knowledge.

Studies about GS have been limited to: a) explain how it works, its features, limitations, errors, etc.; b) define its coverage and size; c) compare the number of citations received by documents of a given subject area in GS, to the citations they receive in other databases; and d) its growth and evolution over time. However, the study of highly cited documents regardless of their discipline or field has never been addressed in a comprehensive manner.

Therefore, the objective of this work is to identify the set of highly cited documents in GS and define their core characteristics: language, file format, and how many of them can be accessed to free of charge. We will also try to answer some additional questions that - hopefully - shed some light about the use of GS as a tool for assessing impact through citations.

In short, we intend to answer the following questions:

2. RESEARCH QUESTIONS

1. Which are the most cited documents in GS?
2. Which are the most cited document types in GS?
3. In what languages are the most cited documents in GS written?
4. How many highly cited documents are freely accessible?
   a. What file types are the most commonly used to store these highly cited documents?
   b. Which are the main providers of these documents?
5. How many of the highly cited documents indexed by GS are also indexed by WoS?
6. Is there a correlation between the number of citations that these highly cited documents have received in GS and the number of citations they have received in WoS?
7. How many versions of these highly cited documents has GS detected?
8. Is there a correlation between the number of versions GS has detected for these documents, and the number citations they have received?
9. Is there a correlation between the number of versions GS has detected for these documents, and their position in the search engine result pages?
10. Is there some relation between the positions these documents occupy in the search engine result pages, and the number of citations they have received?
3. MATERIALS AND METHODS

This longitudinal study describes a set of 64,000 documents indexed in Google Scholar, obtained after performing 64 queries by year (from 1950 to 2013) using Google Scholar’s advanced search, and collecting the maximum number of records that GS displays for any given query, which as we know is always 1,000.

This process was carried out twice, with a few days between the first and the second download processes. In one case, it was done from a computer connected to our university’s IP range (to obtain WoS data embedded in GS), and in the other case, from a computer with a normal Internet connection (to obtain data about open access links unadulterated by our university’s subscriptions). Besides, this also worked as a reliability check, because we confirmed that the two datasets contained the same records. These processes took place on the 28th of May and 2nd of June, 2014.

We downloaded the source HTML code for each of the result pages in our queries, parsed them to extract all the relevant information, and saved it in spreadsheet, which is a format more appropriate for the analysis of data. The fields extracted were the following (Figure 1):

- **Publication year**: It is the year that was used in the query, and not that contained in the bibliographical description of the record retrieved.
- **Rank**: The position that each document occupies in the search engine results page of GS.
- **Full Text**: Only marked when GS found a freely accessible version of the document. Then, some additional fields were obtained:
  - **Domain**: The domain where GS has found a full text version of the document.
  - **Link**: Link to the full text of the document.
  - **Format**: File type of the full text version of the document.
- **Brackets**: Some records display text in square brackets before the title of the document. The most common occurrences are: “[BOOK]” (the record is a book) and “[CITATION]” (the record has only been found in the reference list of another document), “[PDF]” and “[HTML]” (to indicate that the document has been found in those formats).
- **Title**: Title of the document.
- **Title Link**: The URL pointing to where the record has been found (it is not a link to a freely accessible version of the full text, since the document may be behind a paywall).
- **Authors – Publication Source – Year – Domain/Publisher**: This field contains information about the authors, publication source, year of publication, and publisher of each document. However, not all this information is always displayed for all records, and it is usually cropped to fit one line.
  - **Authors**: List of authors. When the author has a public Google Scholar Citations profile, his/her name includes a link to his/her profile. When there are many authors, only the first two or three are displayed.
  - **Publication source**: Name of the source where the document has been published, and, sometimes, publication details (volume, issue, pages). This information is not always displayed, and when it is, it’s not always complete.
  - **Year**: year when the document was published. This field has been proved to correspond with the field “Publication year”, previously described.
  - **URL domain / Publisher**: Domain where this document has been found, or, sometimes, the name of its publisher (only for big publishers).
- **Abstract**: First lines of the abstract (it is also cropped to fit a fixed space).
- **GS Citations**: Number of citations the document has received according to GS.
- **Link to GS Citations**: URL pointing to the list of citing documents in Google Scholar.
- **Link to Related documents**: URL pointing to the list of related documents.
- **Versions**: Number of versions GS has found of the documents.
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- **Link to Versions**: URL pointing to the list of versions GS has found of the same document.
- **Web of Science**: This data will only appear if the query is performed from a computer connected to an IP range with access to Thomson Reuters' Web of Science, and only for the documents that are indexed both in GS and WoS.
  - WoS Citations: Number of citations according to Web of Science.
  - WoS accession number (UT): identification number of the document in Web of Science. This code allows us to accurately match a GS record with a WoS record.
  - WoS Link: URL pointing to the list of citing documents in Web of Science.

**Figure 1. Fields extracted from Google Scholar's SERP**

In addition to these fields, we added a few more in order to answer our questions related to: **type of the source publication**, and **language** of the document.

Given the difficulty of ascertaining the typologies of the documents indexed in Google Scholar (this information is not systematically provided by the search engine), we have devised three different strategies that, combined, have allowed us to know the type of a large portion of documents in our data set:

a) All documents where the field **Brackets** = “[BOOK]” have been considered as books (codified as “B”).

b) For documents that were also indexed in WoS, GS data was merged with WoS data to obtain the document types. The correspondence is as follows:
   - Journal (“J”): “Article”, “Letter”, “Note”, “Reviews”.
   - Book (“B”): “Book”, “Book Chapter”.
   - Conference Proceedings (“C”): “Proceedings Papers”.
   - Others (“O”): “Book Review”, “Correction”, “Correction, Addition”, “Database Review”, “Discussion”, “Editorial Material”, “Excerpt”, “Meeting Abstract”, “News Item”, “Poetry”, “Reprint”, “Software Review”.

c) Lastly, we analysed the **publication source** (where possible), searching for keywords that could indicate the type of the source publication:
   - Journal (“J”): “Revista”, “Anuario”, “Cuadernos”, “Journal”, “Revue”, “Bulletin”, “Annuaire”, “Anales”, “Cahiers”, “Proceedings”\(^3\).

\(^3\) The word “Proceedings” is used both for journals (i.e. “Proceedings of the National Academy of Sciences”) and for conference proceedings (i.e., “Proceedings of the 4th Conference…”). Initially, records containing this word in the **Publication Source** field were all considered as conference proceedings, but a manual check was carried out to reassign those that were really journal articles.
Combining these three strategies, we identified the document type for 71% of the 64,000 documents in our sample. We couldn’t identify the document types for the remaining 29% because this would have required doing it manually for 18,590 documents, which would have taken an excessive amount of time. This information was saved in a new field called Source Type, and was codified as follows:

- B: Books or book chapters.
- J: Journal articles, reviews, letters and notes.
- C: Conference proceedings.
- O: Others (meeting abstracts, corrections, editorial material…).
- Unknown: we haven’t been able to assign a source type (29% of the sample).

As regards the language of the documents (GS doesn’t provide this information either), we used the language in which the title and abstract of the document were written, as well as WoS data (when available) as a basis for a new Language field.

In essence, we will show a sectional view (global results) as well as a longitudinal view (results by year, in order to detect potential changes) of this sample of documents.

The measures we have used to summarise the data are: absolute and relative frequencies of various aspects of the documents (questions 1-5), and the Pearson correlation (questions 6-10), with $p \leq 0.01$.

4. RESULTS

The structure we have followed to present the results of each research question is as follows: first we describe the results we have obtained, and after that, under a separate heading called “Discussion & limitations”, we lay out and discuss possible inquiries and uncertainties raised by these findings.
Question 1.
Which are the most cited documents in Google Scholar?

In Table 1 we present the top 25 most cited documents in Google Scholar. Additionally, Appendix A shows the top 1% most cited documents in our sample (a total of 640 documents).

These lists are a faithful reflection of the all-encompassing indexing policies of Google Scholar: the academic/scientific/technical world against the scientific world displayed in traditional citation-based databases. In this respect, we can state that GS offers an original and different vision as regards what the most influential documents in the academic/scientific world are, from the perspective of their citation count. This is caused by several reasons:

First, its coverage is not limited to seminal research works in the entire spectrum of scientific fields, but it also covers greatly influential works directed not only to researchers but also to people who are training to become researchers or practitioners in their respective fields. This is testified by the presence of statistical manuals (Handbook of Mathematical Functions with Formulas, Graphs, and Mathematical Tables; Biostatistical Analysis; Statistical Power Analysis for the Behavioral Science), laboratory manuals (Molecular cloning: a laboratory manual), manuals of research methodology (Case study research: Design and methods), and works that have become a de facto standard in professional practice (Diagnostic and statistical manual of mental disorders, Numerical recipes: the art of scientific computing; Genetic algorithms in search, optimization, and machine learning).

Second, a high proportion of the highly cited documents are books (a document type that is essential in the humanities and the social sciences as a vehicle for the communication of new results, and in the experimental sciences as a way to consolidate and disseminate knowledge). In fact, 62% of the top 1% most cited documents in our sample are books (see Appendix A). Moreover, books are the document type with a highest citation average: 2,700, against an average of 1,700 in journal articles, and 2,200 for conference proceedings. The importance of books and conference proceedings is therefore thoroughly proven.

Although the ranking is dominated by studies from the natural sciences, and within those, especially the life sciences, it also contains many works from the social sciences, especially from economics, psychology, sociology, education... and also from the Humanities (philosophy and history). For instance: The structure of scientific revolutions; Diffusion of innovations; and Imagined communities. Reflections on the origin and spread of nationalism).

Many of the works leading this ranking are clearly methodological in nature: they describe the steps of a certain procedure or how to handle basic tools to process and analyse all kinds of data. Precisely because they are essential to researchers, they reach such a high number of citations. This phenomenon is widely known in bibliometrics, where it has already been observed that works that deal with new data collecting and processing techniques or methodologies are more likely to receive a great number of citations.

Even though, as we comment before, GS presents a very different ranking of highly cited academic documents compared to the rankings offered by the traditional citation-based databases, in other aspects it presents a very similar portrait of the world of research to the one offered in traditional databases. This is so because the most cited scientific documents in GS match very closely with those that have been already identified as highly cited in the Web of Science (Garfield, 2005). This explains the high correlation found in the rankings of documents according to their number of citations in GS and WoS (See Question 6).
Therefore, it is not surprising that the most cited document according to GS is the already famous article written by Lowry, “Protein measurement with the Folin phenol reagent” published in 1951 in the Journal of Biological Chemistry, where he developed a new method to measure the concentration of a protein in a solution. The reasons for the success of this article were revealed by the author himself (Lowry, 1977), and in a short note published in the same journal on the occasion of its hundredth anniversary in 2005 (Kresge et al., 2005).⁴

We’ll use this article as an example in the next section to comment some uncertainties and discuss the possible limitations of these results.

⁴ See his profile on Google Scholar: http://scholar.google.com/citations?user=YCS0XAcAAAAJ&hl=es
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Table 1. Top 25 most cited documents in Google Scholar (1950-2013)

| Document type | Bibliographic reference | 1st ed. Pub. Year | GS Citations |
|---------------|-------------------------|-------------------|--------------|
| J             | LOWRY, O.H. et al., (1951). Protein measurement with the Folin phenol reagent. The Journal of biological chemistry, 193(1), 265-275. | 1951 | 253671 |
| J             | LAEMMLI, U.K. (1970). Cleavage of structural proteins during the assembly of the head of bacteriophage T4. Nature, 227(5259), 680-685. DOI: 10.1038/227680a0 | 1970 | 221680 |
| J             | BRADFORD, M.M. (1976). A rapid and sensitive method for the quantitation of microgram quantities of protein using the principle of protein dye binding. Analytical Biochemistry, 72, 248-254. DOI: 10.1006/abio.1976.9999 | 1976 | 185749 |
| B             | SAMBROOK, J., FRITSCH, E. F., & MANIATIS, T. (1982). Molecular cloning: a laboratory manual. New York, Cold Spring Harbor Laboratory Press. | 1982 | 171004 |
| B             | AMERICAN PSYCHIATRIC ASSOCIATION. (1952). Diagnostic and statistical manual: mental disorders. Washington, American Psychiatric Assn., Mental Hospital Service. | 1952 | 129473 |
| B             | PRESS, W. H. (1986). Numerical recipes: the art of scientific computing. Cambridge [Cambridgeshire], Cambridge University Press. | 1986 | 108956 |
| B             | YIN, R. K. (1984). Case study research: design and methods. Beverly Hills, Calif, Sage Publications. | 1984 | 82538 |
| B             | ABRAMOWITZ, M., & STEGUN, I. A. (1964). Handbook of mathematical functions: with formulas, graphs, and mathematical tables. Washington, Government printing office. | 1964 | 80482 |
| B             | KUHN, T. S. (1962). The structure of scientific revolutions. Chicago, University of Chicago Press. | 1962 | 70662 |
| B             | ZAR, J. H. (1974). Biostatistical analysis. Englewood Cliffs, Prentice Hall International. | 1974 | 68267 |
| J             | SHANNON, C.E. (1948). A mathematical theory of communication. The Bell System Technical Journal, 27, 379-423. | 1948 | 66851 |
| J             | CHOMCZYNSKI, & SACCHI, N. (1987). Single-step method of RNA isolation by acid guanidinium thiocyanate-phenol-chloroform extraction. Analytical Biochemistry, 162, 156-159. DOI: 10.1006/abio.1987.9999 | 1987 | 63871 |
| J             | SANGER F, NICKLEN S, & COULSON AR. (1977). DNA sequencing with chain-terminating inhibitors. Proceedings of the National Academy of Sciences of the United States of America. 74, 5463-7. DOI: 10.1073/pnas.74.12.5463 | 1977 | 63767 |
| B             | COHEN, J. (1969). Statistical power analysis for the behavioral sciences. New York, Academic Press. | 1969 | 63766 |
| B             | GLASER, B. G., & STRAUSS, A. L. (1967). The discovery of grounded theory: strategies for qualitative research. New York, Aldine de Gruyter. | 1967 | 61158 |
| B             | NUNNALLY, J. C. (1967). Psychometric Theory. New York, McGraw-Hill. | 1967 | 60725 |
| B             | GOLDBERG, D. E. (1989). Genetic algorithms in search, optimization, and machine learning. Reading, Mass, Addison-Wesley Pub. Co. | 1989 | 59764 |
| B | ROGERS, E. M. (1962). Diffusion of Innovations. Pxi. 367. Free Press of Glencoe, New York; Macmillan, New York; London. | 1962 | 55738 |
|---|---|---|---|
| J | BECKE, A.D. (1993). Density Functional Thermochemistry III The Role of Exact Exchange. J. Chem. Phys., 98, 5648-5652. DOI: 10.1063/1.464913 | 1993 | 54642 |
| J | LEE, C., YANG, W. & PARR, R.G., 1988. Development of the Colle-Salvetti correlation-energy formula into a functional of the electron density. Physical Review B, 37(2), 785-789. DOI: 10.1103/PhysRevB.37.785 | 1988 | 52316 |
| J | MURASHIGE, T. & SKOOG, F. (1962). A revised medium for rapid growth and bio assays with tobacco tissue cultures. Physiologia Plantarum, 15, 473–497. DOI: 10.1111/j.1399-3054.1962.tb08052.x | 1962 | 52011 |
| B | ANDERSON, B. R. O. (1983). Imagined communities: reflections on the origin and spread of nationalism. London, Verso. | 1983 | 51177 |
| J | FOLSTEIN, M.F., FOLSTEIN, S.E. & MCHUGH, R., (1975). “Mini-mental state.” Journal of Psychiatric Research, 12(3), 189-198. DOI: 10.1016/0022-3956(75)90026-6 | 1975 | 51150 |
| J | TOWBIN, H., STAEHELIN, T. & GORDON, J. (1979). Electrophoretic transfer of proteins from polyacrylamide gels to nitrocellulose sheets: procedure and some applications. Proceedings of the National Academy of Sciences of the United States of America, 76(9), 4350-4354. DOI: 10.1073/pnas.76.9.4350 | 1979 | 50608 |
| B | PAXINOS, G., & WATSON, C. (1982). The rat brain in stereotaxic coordinates. Sydney [etc.], Academic Press. | 1982 | 50471 |
Discussion & Limitations

1. How confident are we that the 64,000 documents that make up our sample really contain the most cited documents in GS?

Although there are certain evidences that suggest that we have been able to collect the vast majority of the most cited documents in GS between 1950 and 2013 (as of the 28th of May 2014), as we already explained at the beginning of this study (see Introduction), there are still some questions that should be cleared up.

To this end, first we have tried to find out if any of the documents in our sample aren’t really highly cited documents, and second, if there are any highly cited documents that haven’t been included in our sample. To do this, we have compared the 1,000 most cited papers in GS against the 1,000 most cited papers in WoS between 1950 and 2013 (Figure 2).

Figure 2. Minimum number of citations received by top cited (1,000, 900, 890, 850) documents in Google Scholar and WoS (1950-2013)

On the one hand, we have detected that the results displayed by GS to our queries become extremely erratic in terms of their citation count from about the 900th result onwards. This means that it is highly probable that approximately the last 100 documents for each year in our sample (a total of 6,400 documents) aren’t actually highly cited documents, and therefore should be excluded from the sample.

In contrast, we also have checked that some documents in WoS with a number of citations that slightly exceed the threshold set by the 1,000 documents returned by GS, are not present in the first 1,000 results of the search engine.
Nonetheless, all these inconsistencies happen in the last 100 positions of each query for each year, whereas in the first 900 the consistency is high. To sum up, despite the various limitations described above, we can affirm that the majority of the documents in our sample are highly cited documents.

2. *In order to be able to trust the results that our search strategy yielded, we must ask ourselves if the documents in our sample were really published in the year GS says they were published.*

To answer this question we carried out two different tests. In the first place, we tested the internal consistency of the search engine. We checked if the results displayed by GS met the requirements of our query. We found that the year of publication of the documents according to GS matched the year we entered in our query in practically 100% of the cases. Only two records out of 64,000 displayed a different year to the one we typed in the search box.

Secondly, we tested the external consistency. For those documents that had been linked to a WoS record (32,680 out of 64,000), we compared the publication year according to GS to the one displayed in the WoS record. Since WoS is a controlled database with a minimum error rate as regards its bibliographic information, we have used it as a benchmark. The results showed that the publication years in GS and WoS matched in 96.7% of the cases (31,600 documents). Curiously enough, the years where we detected more mismatches were 2012 and 2013. Consequently, we must conclude that the error rate in the publication years is very low for this subset of the sample.

*Figure 3. Publication year mismatches between journal articles in Google Scholar and Web of Science*

However, we have observed that, in the case of books, Google lumps together all the different editions of a same book, and systematically selects the latest edition of the book as the primary version. As a result, GS takes the publication date of the last edition (and not the publication date of the first edition) as the publication date of the book. This decision, as understandable as it is from a search point of view (users will probably want to access the latest edition of a book), obviously affects our sample. In Figure 4, the frequency distributions for both the publication year of the top 600 most cited books in our sample according to Google Scholar, and the publication year of the 1st edition of these books are displayed.
In any case, it should be noted that this limitation doesn’t affect the status of these books as highly cited documents, only the year of publication assigned to them\(^5\). Moreover, this fact may be the reason behind the higher number of books in the last five year of the sample (see Question 2).

3. When some time after collecting our sample, we checked again the number of citations to Lowry’s article, we were taken by surprise by the result we found. As of the 21\(^{st}\) of October, 2014, this study had 192,841 citations according to GS (Figure 5 top). However, on the 28\(^{th}\) of May, 2014, when we collected our sample, this number was 253,671 (figure 5 middle). This means than within 5 months, Lowry’s article has lost nothing less than 60,000 citations. Therefore, right now, it is not the highest cited article in GS, giving way to Laemli’s work (Figure 5 bottom)

\(^5\) With the exception, of the book *Mathematical theory of communication*, a special case study expanded and commented in Appendix B
The debate is served...

How is it possible that the total number of citations of a document decreases over time? What are the reasons for these changes? Are the results offered by GS concerning citations stable and reliable, and consequently, the results concerning which the most cited documents are?

There is an explanation for this phenomenon, although it's difficult to justify that a document presents a lower number of citations in the present than the number it presented in the past. The behavior of this document in WoS is more logical, since in these months it has accumulated a few more citations: as of the end of May 2014, it had 303,832 citations, and on October the 21st, 2014, it had 305,202 according to GS (Figure 5 top), and 305,248 according to WoS (Figure 6 bottom). WoS data in GS is updated regularly but not in real time.

Why does this phenomenon occur in GS?

The answer is related to the dynamic nature of the Web: information is added and removed constantly, and therefore, GS always displays what is currently available on the Web. This is explained in Google Scholar’s help pages\(^6\), where they warn that “Google Scholar generally reflects the state of the web as it is currently visible to our search robots and to the majority of users”. Presumably, this drastic change in citations took place when GS made a major “re-crawling” of the documents in its database earlier this year (around the third week of June 2014 according to our data).

\(^6\) My citation counts have gone down. Help! [http://scholar.google.com/intl/en/scholar/help.html#corrections](http://scholar.google.com/intl/en/scholar/help.html#corrections) [accessed on 24th October 2014]
4. The consequences of this phenomenon in our study are self-evident: did we really collect the most cited documents?

To this end, we collected the entire sample again on the 4th of October, 2014, and compared the two samples to learn how many of the documents in our earlier sample are not present in the new sample (Table 2).

Table 2. Comparison of two samples of 64,000 highly cited documents (May and October, 2014)

| Position in rank | No of different documents | %  |
|------------------|---------------------------|----|
| 1-100            | 402                       | 0.6|
| 101-200          | 340                       | 0.5|
| 201-300          | 319                       | 0.5|
| 301-400          | 373                       | 0.6|
| 401-500          | 450                       | 0.7|
| 501-600          | 588                       | 0.9|
| 601-700          | 778                       | 1.2|
| 701-800          | 1176                      | 1.8|
| 801-900          | 1802                      | 2.8|
| 901-1000         | 3174                      | 5.0|
| TOTAL            | 9402                      | 14.7|

Only 14.7% of the 64,000 documents in the most recent sample were not also present in our earlier sample. Moreover, most of these new documents are placed in pretty low positions in Google Scholar’s ranking of results.

5. Are we sure that all versions of a same document (not only different editions or reprints, but also translations to other languages) have been successfully merged, and that all their respective citations have been added, removing any possible duplicates?

GS has declared that they do exactly this (Verstak & Acharya, 2013), but we don’t have empirical data to comment on the potential errors regarding this issue.

Nevertheless, it is not difficult to find obvious errors, like the case of the classic work in Molecular Biology “Molecular cloning: a laboratory manual” (Figure 7), where it is clear that there are still many different versions with a high number of citations that haven’t been merged. This, of course, is an exceptional case. Normally, documents will not present as many versions as this example (See Question 7; Table 7), nor as many citations.
Lastly, a few well-known issues in bibliometrics (Garfield, 2005) should be kept in mind before proceeding to observe the ranking of the top 1% most cited documents in Google Scholar (see Appendix A). First, the citation windows: a document published in 1950 has had 64 years to receive citations, whereas a document published in 2013 has had only one year. Secondly, the different paces at which obsolescence takes place in the different scientific fields: generally, documents stop being cited at some point after their publication date. Thirdly, the exponential growth of production: as production volumes increase, the number of citations also increases.
Question 2.
Which are the most cited document types in Google Scholar?

Document types and its evolution

The typologies of the documents in our sample are shown in Figure 8. As we stated in the methods section, we have been able to determine the typology of 45,410 documents in our sample (71%). The typologies of the remaining 29% are unknown.

Figure 8. Document types of the highly cited documents in Google Scholar

There is a clear predominance of journal articles, which make up a much higher fraction of the total than books and book chapters. The presence of conference proceedings is almost non-existent. Admittedly, this distribution might have been different if we could have defined the document type of the remaining 29% of our sample.

Figure 9 presents this distribution from a longitudinal perspective, where we find the following three phenomena:

- A steady decrease over time in the number of documents with an unknown document type.
- A constant increase in the number of books, which become the most frequent document type in the last five years (2009-2013). As an example, in the 1,000 results for the year 2013, we only find 27 journal articles. What's the reason for this obvious overrepresentation of the book format over the rest of the formats in the last years? We believe this phenomenon has very much to do with the decision of using the most recent edition of a book (and therefore, the most recent publication date), as the primary version of the document (See Question 1, Figures 3-4). This causes, for example, that a classic book originally published in 1965, and reprinted over the years with its latest edition published in 2012, will be considered as having been published in 2012. Since Google Scholar only presents 1,000 results for any given query, and we only collected information about the primary versions of the documents, these books are overshadowing other publications that have really been published in these years.
- Conference proceedings play an insignificant role in this sample, although they achieve greater presence during the last decade of the twentieth century.
Figure 9. Document types of the highly cited documents in Google Scholar, broken down by years

Citations and document types

Books is the document type with a higher average citations per document (Table 3), followed by conference proceedings. Journal articles rank third in this list.

Table 3. Citations according to document types

| Document types         | Millions of citations | Average citations per document |
|------------------------|-----------------------|-------------------------------|
| Journal Articles       | 57.2                  | 1700                          |
| Books                  | 30                    | 2700                          |
| Conference proceedings | 1.6                   | 2200                          |
| Others                 | 1.2                   | 2050                          |

Journals containing highly cited documents (1950 y 2013)

The articles contained in our sample have been published in a total of 3,131 different journals. In Table 4 we show the list of journals where the majority of articles are concentrated. As it could not be otherwise, multidisciplinary journals (Science and Nature) are the ones with the higher number of highly cited journals, followed by the major journals in the natural sciences (Physics and Chemistry). As regards the social sciences, only economics and psychology journals (American Economic Review, and Econometrica) are capable of reaching prominent positions.
Table 4. Top 25 Most frequent journals in the highly cited documents in Google Scholar

| Journal                                           | No of articles | Area                      |
|---------------------------------------------------|----------------|---------------------------|
| NATURE                                           | 1518           | Multidisciplinary          |
| SCIENCE                                          | 1437           | Multidisciplinary          |
| NEW ENGLAND JOURNAL OF MEDICINE                  | 848            | Medicine                  |
| PHYSICAL REVIEW                                  | 671            | Physics                   |
| PROCEEDINGS OF THE NATIONAL ACADEMY OF SCIENCES OF THE UNITED STATES OF AMERICA | 574            | Multidisciplinary          |
| CELL                                             | 483            | Biology                   |
| JOURNAL OF BIOLOGICAL CHEMISTRY                  | 452            | Biochemistry               |
| PHYSICAL REVIEW LETTERS                          | 432            | Physics                   |
| LANCET                                           | 363            | Medicine                  |
| JOURNAL OF THE AMERICAN CHEMICAL SOCIETY         | 328            | Chemistry                 |
| JAMA-JOURNAL OF THE AMERICAN MEDICAL ASSOCIATION | 251            | Medicine                  |
| AMERICAN ECONOMIC REVIEW                         | 244            | Economics                 |
| ECONOMETRICA                                     | 217            | Economics                 |
| PSYCHOLOGICAL REVIEW                             | 210            | Psychology                |
| REVIEWS OF MODERN PHYSICS                        | 206            | Physics                   |
| CHEMICAL REVIEWS                                 | 203            | Chemistry                 |
| JOURNAL OF POLITICAL ECONOMY                     | 200            | Economics                 |
| JOURNAL OF PHYSIOLOGY-LONDON                     | 200            | Medicine                  |
| PSYCHOLOGICAL BULLETIN                           | 194            | Psychology                |
| JOURNAL OF CHEMICAL PHYSICS                      | 187            | Physics                   |
| ASTROPHYSICAL JOURNAL                            | 183            | Physics                   |
| BIOCHEMICAL JOURNAL                              | 180            | Biochemistry               |
| PROCEEDINGS OF THE ROYAL SOCIETY OF LONDON SERIES A-MATHEMATICAL AND PHYSICAL SCIENCES | 180            | Mathematics; Physics      |
| CIRCULATION                                      | 174            | Medicine                  |
| JOURNAL OF CLINICAL INVESTIGATION                | 164            | Medicine                  |

**Discussions & Limitations**

1. **Google Scholar does not provide document type information systematically for all its documents (only for books).**

Because of this, we could not determine the document types of the entire data set, since this would have required a manual inspection of the remaining 18,590 documents. If we did this, our guess is that the fraction of books and book chapters would increase, since this is the typology that GS has more trouble identifying.

2. **Would the weight of the book format be different over the years, had Google Scholar decided to take the first edition of books as their primary version?**

Without a doubt, yes (see Question 1; Figure 4).
Question 3.
In what languages are the most cited documents in Google Scholar written?

In Figure 10 we show the document distribution according to language. As we can see, English dominates over the rest of languages as the most widely used language for scientific communication, accounting for 92.5% of all the documents in our sample. The second and third places are occupied by Spanish and Portuguese respectively, but neither of them reach even 2% of the total.

![Figure 10. Distribution of languages used in the highly cited documents in GS](image)

In Figure 11 we can observe the same data broken down by years. The results for the language variable are much more stable through the years than the ones found for the document types. In this case, the English language predominates in every year, with an oscillation between its maximum and minimum value of less than 10% (87% in 2013, and 95% in 1991).

![Figure 11. Distribution of languages in the highly cited documents in GS by years of publication](image)

The “Others” category includes the following languages: Italian, Swedish, Indonesian, Finnish, Danish, Bulgarian, Polish, Norwegian, Turkish, Latin, Slovenian, Serbian, Dutch, Macedonian, Malayan, Japanese, Czech, Estonian, Slovak, Mongolian, Catalan, Croatian, Lithuanian, and Ukrainian.
Discussions & Limitations

1. **As with document types, Google Scholar does not provide information about the languages in which the documents it indexes are written.**

   Because of this, we developed a strategy to determine this information, using WoS data where possible (around 50% of the cases), and the title and abstract of the document in all the other cases. This approach, however, may have introduced an overrepresentation of the English language, since it is usual for a document written in a language other than English to provide its title and abstract in English as well, for the purpose of being indexed in international databases.

2. Additionally, our sample may contain records that are in fact translations of other documents (which may also be present in our sample).

   As we pointed out in previous studies (Martín et al. 2014), Google Scholar usually fails to group together different translations of a same document. This is the case of journals that are published both in English and in other language, or books that are translated into various languages (see Figure 12). This issue has an immediate effect for the works affected by this problem: their citations are scattered across different records, and this could affect their status as highly cited documents.

Figure 12. Example of language versions (Chinese, English, German, Spanish, French)

*The structure of scientific revolutions, by Kuhn*

| Citation | Title | Language | Cited by |
|----------|-------|----------|----------|
| 科學革命的結構 | 科學革命的結構 | Chinese | 15 |
| T S Kuhn, 程樹德 | 科學革命的結構 | Chinese | 5 |
| 程樹德, 孔恩 | 科學革命的結構 | Chinese | 3 |
| (Citation) 科學革命的結構 | 科學革命的結構 | Chinese | 1 |

Tip: Search for English results only. You can specify your search language in Scholar Settings.
Does Google Scholar contain all highly cited documents (1950-2013)?

allintitle: "la structure des révolutions scientifiques" author:Kuhn
Question 4.
How many highly cited documents are freely accessible?

The percentage of documents for which Google Scholar provides a freely accessible full text link can be observed in Figure 13. Over 40% of the documents in our sample provided a full text link, and these links are mostly concentrated in the last two decades. The lower rate of records with an open access link in the last four years might be explained by journal’s and publisher’s embargo policies. Additionally, the high percentage of books in the last 5 years of the sample may influence as well.

Figure 13. Percentage of freely accessible highly cited documents in Google Scholar. Global results for the 1950-2013 period (left), and broken down by decades (right)

These results are consistent with those published by Archambault et al. in 2013, (since they also found that over 40% of the articles from their sample were freely accessible from Google Scholar), and much higher than the results obtained by Khabsa and Giles (2014), and Björk et al. (2010), who found only a 24% and 20.4% of open access documents respectively.

What file types are the most commonly used to store these highly cited documents?

Full text links point to documents in a variety of formats. The most common one is the PDF format, followed by the HTML format. Figure 14 presents the distribution of these formats for all the documents that provide a Full Text Link. These results confirm the data previously identified, among others, by Aguillo, Ortega, Fernández & Utrilla (2010) and Orduña-Malea, Serrano-Cobos & Lloret-Romero, N. (2009).
Does Google Scholar contain all highly cited documents (1950-2013)?

Figure 14. File Formats of the highly cited documents in Google Scholar freely accessible (1950-2013)

![Pie chart showing file formats]

Figure 15 shows the same data broken down by years. We can see that the predominance of the PDF format is present throughout the entire range of years. However, it is also noteworthy that the HTML format has started gaining more presence for documents published in the last 25 years, with a peak of almost 20% of the share in 2010.

Figure 15. File Formats of the highly cited documents in Google Scholar that are freely accessible, broken down by years (1950-2013)

![Bar chart showing file formats by year]

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Which are the main providers of these documents?

We have found a total of 5,715 different providers of Full Text Links in our sample. However, a group of 35 providers account for more than a third of all the links. Table 5 shows these main providers.

| Provider                | N° of Full Text Links | Type of entity         |
|-------------------------|-----------------------|------------------------|
| nh.gov                  | 1405                  | Public administration  |
| researchgate.net        | 815                   | Social network         |
| harvard.edu             | 495                   | University             |
| pnas.org                | 478                   | Scientific society     |
| oxfordjournals.org      | 466                   | Publisher              |
| psu.edu                 | 424                   | University             |
| arxiv.org               | 423                   | Repository             |
| jbc.org                 | 414                   | Journal                |
| sciencedirect.com       | 394                   | Publisher              |
| wiley.com               | 324                   | Publisher              |
| jstor.org               | 322                   | Digital library        |
| rupress.org             | 304                   | University             |
| royal society publishing.org | 266                  | Scientific society     |
| ana journals.org        | 218                   | Scientific society     |
| dic mil                 | 208                   | Public administration  |
| stanford.edu            | 203                   | University             |
| google.com              | 188                   | Company                |
| mit.edu                 | 180                   | University             |
| tu-darmstadt.de         | 177                   | University             |
| nature.com              | 161                   | Publisher              |
| yale.edu                | 141                   | University             |
| caltech.edu             | 140                   | University             |
| physoc.org              | 140                   | Scientific society     |
| cmu.edu                 | 122                   | University             |
| umich.edu               | 120                   | University             |
| duke.edu                | 118                   | University             |
| princeton.edu           | 116                   | University             |
| wisc.edu                | 113                   | University             |
| ucsd.edu                | 112                   | University             |
| asm.org                 | 112                   | Scientific society     |
| berkeley.edu            | 107                   | University             |
| upenn.edu               | 104                   | University             |
| washington.edu          | 103                   | University             |
| columbia.edu            | 102                   | University             |
| ymg.com                 | 101                   | Company                |
| **TOTAL**               | **9616**              |                        |

If we analyse the top-level domains of these links, the most frequent are academic institutions (.edu) and organizations (.org). Moreover, the number of links provided by academic institutions is probably higher than 6,136, because there are many universities that use national top-level domains instead of .edu. Table 6 shows the 20 most frequent top-level domains.
Does Google Scholar contain all highly cited documents (1950-2013)?

This means that GS feeds highly cited documents mainly, at least as far as our sample is concerned, from universities (institutional repositories) and public organizations (working papers, grey literature), and not from commercial publishers. Of special note is the role of the scientific social network ResearchGate, where researchers often upload their publications.

Table 6. Main top-level domains contributing Full Text links in Google Scholar

| Domain | Nº of Full Text Links |
|--------|-----------------------|
| .edu   | 6136                  |
| .org   | 5528                  |
| .com   | 3466                  |
| .gov   | 1712                  |
| .net   | 1345                  |
| .de    | 678                   |
| .cn    | 489                   |
| .uk    | 485                   |
| .ca    | 404                   |
| .ru    | 374                   |
| .fr    | 357                   |
| .br    | 343                   |
| .it    | 275                   |
| .ch    | 214                   |
| .mil   | 210                   |
| .nl    | 186                   |
| .es    | 145                   |
| .tw    | 136                   |
| .au    | 131                   |
| .in    | 118                   |
| Others | 3117                  |
| TOTAL  | 25849                 |
Discussions & Limitations

1. Do these links really point to full text versions of the documents?

More rigorous analyses should be carried out in order to determine if there are false positives among these links. For example, a freely accessible PDF document containing a review of a book, or just the cover and the table of contents of a book could be mistaken for the book itself.

Moreover, the dynamic nature of the web means that a link that was accessible some time ago may no longer be available. How often does Google Scholar checks that these links are still functioning properly?

2. Our analysis deals only with the full text link provided for the version of the document GS considers as the primary version.

However, when the primary version of a document is not freely accessible, GS points the user to any other free version if available. Figure 16 is an example of a case where the primary version is the publisher’s edition of a journal article, but the Full Text link is a preprint from arXiv).

Figure 16. Primary version, Publisher and Full Text provider

3. For documents with more than one version, there may be more than one full text version of the document.

These versions may be hosted in other domains. Again, we want to stress that we only study the Full Text Links displayed for the primary versions of the documents.
Question 5.
How many of the highly cited documents indexed by GS are also indexed by WoS?

Almost half of the highly cited documents according to Google Scholar are not indexed on the Web of Science (Figure 17).

Figure 17. Percentage of highly cited documents in Google Scholar that are also indexed in the Web of Science (1950-2013)

This is extremely relevant, although the following issues should be taken into consideration:

- The different natures of GS and WoS as databases: GS covers academic documents (scientific, technical, educational...) published by all kinds of different sources and in all sorts of communication channels (books, theses, reports...), whereas the coverage in Web of Science Core Collection is oriented towards a more limited range of academic publications, i.e. journal articles and conference communications. This would confirm our hypothesis that GS measures a different kind of impact than the one measured by scientific databases: the academic impact.
- If we want to identify the most influential documents in the academic-scientific sphere, we must use GS.
- GS also identifies the most relevant scientific documents with a fair amount of reliability.

Furthermore, no significant differences are appreciated between 1950 and 2003 (Figure 18). However, the last decade suffers the consequences of the phenomenon we encountered in question 2: the overrepresentation of books in the last years caused by Google Scholar’s policy of taking the latest edition of books as their primary version.

Since Web of Science’s coverage of books is still very limited, it is not surprising that the reduction in the percentage of documents indexed in WoS in the last years closely matches the reduction in the number journal articles during the same years (Figure 9).
Discussions & Limitations

1. Is the GS-WoS connection correctly implemented?

A more in-depth study should be carried out to determine potential flaws in the matching of documents and the frequency with which they occur:

- False positives: a document in GS matched to a document in WoS even if they’re not really the same documents. For example, a book in GS might be matched to a review of that book indexed in WoS. This is the case of the book “The discovery of grounded theory: Strategies for qualitative research”, which was previously presented in Table 1.
- False negatives: documents indexed both in GS and WoS for which a connection hasn’t been established.

As a first approximation, we have selected the 398 most cited WoS documents between 1950 and 2013 that, according to their WoS ID (accession number), weren’t present in our GS sample. We have searched the titles of these documents on Google Scholar and found that 382 (96%) were in fact indexed in Google Scholar, and 300 of them were also connected to a different WoS record.

Therefore, these mistakes arise from incorrect connections between Google Scholar and Web of Science records, caused by the existence of various records with the same name in WoS. For example, a case where a document in Google Scholar has been connected to the Correction of an article in WoS, and not to the article itself is shown in Figure 19.
2. Is it possible that some highly cited articles according to the Web of Science are not indexed on Google Scholar?

As noted earlier in question 1, this may have happened in a very few cases, but not among the very highly cited (30,000 most cited documents in our sample).

3. The overrepresentation of books in the last decade

Again, this is one of the flaws in our sample, since it has caused that many journal articles published in those last years of the sample (2003-2013) and that have received many citations, are being left out in favor of books that were first published many years ago.
Question 6.
Is there a correlation between the number of citations that these highly cited documents have received in GS and the number of citations they have received in WoS?

We have calculated Pearson’s correlation coefficient for the number of citations that documents have received according to Google Scholar and the Web of Science, by year. The average correlation is 0.8 (calculated only for documents that are in both sources, which are 32,680). Figure 20 shows the Pearson correlation coefficient for each of the years in our sample.

Figure 20. Pearson correlation coefficient between Google Scholar and Web of Science citations (1950-2013)

This finding is consistent with the results found in many previous studies (Sanderson 2008; Kousha, & Thelwall 2008; Meho & Rogers 2008; Franceschet, 2010; Delgado López-Cózar & Cabezas 2013; Delgado López-Cózar & Repiso 2013), who also found a high correlation among the journal indicators published by Google Scholar/Google Scholar Metrics and the Web of Science/Journal Citation Reports. However, none of these studies had analysed a sample as large as this one (32,680 documents).

It is common among the studies that compare Google Scholar and the Web of Science to quantify the number of citations they have been able to find for the documents they index. In our sample, 91.6% of the documents have received more citations in GS than in WoS. Only 3,079 documents (9.4%) have more citations according to WoS than in GS. Furthermore, the average number of citations per document in GS is 1,790, and 1,080 in WoS, which means that on average, GS has 70% more citations per document than WoS.
**Discussions & Limitations**

1. As in question 5, the quality of the matching between GS and WoS plays an important part.

2. The instability of Google Scholar’s indicators is also an important factor and should be further analysed.

As an example, Lowry’s classic article had 253,671 citations at the end of May, 2014, when we collected the data (see Table 1), but on August the 5th the count had went down to 191,669 (Figure 21). WoS data seems to be much more stable, but it also went down from 304,893 citations in May, to 304,667 in August (See also Question 1, Figure 5).

**Figure 21.** The most cited scientific article in history, according to Google Scholar (top), and WoS (bottom). Screen capture from 7th of August, 2014
Question 7.
How many versions of these highly cited documents has GS detected?

One of the most interesting features of Google Scholar as an academic search engine is its ability to identify and connect all the different instances of the same document that have been deposited across the Web. We should bear in mind that a document can be stored in various locations: the journal publisher’s webpage (Cell), databases (PubMed), aggregators (Ingenta), library catalogues (Dialnet), subject or institutional repositories, and authors’ personal or institutional web pages. Moreover, documents might go through various versions and revisions, and they can be cited in different forms. Google acknowledges this reality and tries to find a solution.

Excerpt from Verstak, AA and Acharya, A (2013). *Identifying multiple versions of documents*. U.S. Patent No. 8,589,784. Washington, DC: U.S. Patent and Trademark Office:

“[…] it is typical that a particular document or portion thereof, appears in a number of different versions or forms in various online repositories. This generally results in multiple versions of a document being included in the search results for any given query. Because the inclusion of different versions of the same document does not provide additional useful information, this increase in the number of the search results does not benefit users. Also, search results including different versions of the same document may crowd out diverse contents that should be included. These problems have seriously affected the quality of a search result provided by a search engine.

Another problem arises in systems in which there are multiple versions of documents present. Documents in a document collection will have a number of citations to it by other documents. This is particularly the case for academic documents, legal documents, and the like. The number of citations (citation count) to a document is often reflective of the importance, significance, or quality of the document. Where there are different versions of a document present in a repository, each with its own citation count, a user does not have an accurate assessment of the actual significance, importance or quality of the document based on the individual citation counts.

For these reasons, it would be desirable to identify documents that are different versions of the same document in a document collection. It would also be desirable to manage these documents in an efficient manner such that the search engine can furnish the most appropriate and reliable search result.”

83% of the documents in our sample have more than one version, whereas 40% have 6 or more versions, 19% have 10 or more versions, and 200 documents have more than 100 versions (0.1%). The distribution of documents according their number of versions can be observed in Table 7:
Table 7. Distribution of documents according to their number of versions

| Nº of versions | Nº of doc. | Accumulated | Acc. % |
|----------------|-----------|-------------|--------|
| 1              | 10771     | 10771       | 16,83  |
| 2              | 6075      | 16846       | 26,32  |
| 3              | 6903      | 23749       | 37,11  |
| 4              | 6814      | 30563       | 47,75  |
| 5              | 5539      | 36102       | 56,41  |
| 6              | 4781      | 40883       | 63,88  |
| 7              | 3746      | 44629       | 69,73  |
| 8              | 2940      | 47569       | 74,33  |
| 9              | 2429      | 49998       | 78,12  |
| 10             | 1929      | 51927       | 81,14  |
| 11-15          | 5243      | 57170       | 89,33  |
| 16-25          | 3585      | 60755       | 94,93  |
| 26-50          | 2202      | 62957       | 98,37  |
| 51-100         | 762       | 63719       | 99,56  |
| 101-200        | 202       | 63921       | 99,88  |
| 201-300        | 40        | 63961       | 99,94  |
| 301-400        | 16        | 63977       | 99,96  |
| 401-500        | 9         | 63986       | 99,98  |
| More than 501  | 14        | 64000       | 100,00 |

**Discussions & Limitations:**

1. Does GS correctly identify all versions of a same document? Does it make mistakes, like linking a document with a different document (i.e., a review of that document, or a citation found in the list of references of another document), or failing to connect two records that refer to the same document? How frequently does it make these mistakes?

In order to successfully answer these questions, we would need to analyse a sample of documents and study all their versions individually. While we carry out this study, we present, by way of an example, an illustrative example in Appendix B.
Question 8.
Is there a correlation between the number of versions GS has detected for these documents, and the number citations they have received?

Using Pearson’s correlation coefficient, we have been able to determine that there is no correlation whatsoever between the number of citations of a document in Google Scholar and its number of versions \((r = 0.2^{**})\). Calculating it by year of publication yields similar results (Figure 22).

**Figure 22. Pearson's correlation between the nº of citations and nº of versions in Google Scholar documents (64,000 most cited documents in Google Scholar; 1950-2013)**
Question 9.
Is there a correlation between the number of versions Google Scholar has detected for these documents, and their position in the result pages?

Using Pearson's correlation coefficient, we also have determined that there is no correlation whatsoever between the number of versions of a document in Google Scholar and the position it occupies in the search engine results page (Figure 23). The average correlation for the results we collected from 64 queries is $r = -0.2**$.

Figure 23. Pearson's correlation between the number of versions of the documents in Google Scholar and their rank in the SERP
Question 10.
Is there some relation between the positions these documents occupy in the search engine result pages, and the number of citations they have received?

After calculating the Pearson correlation for each of the years in our queries, we obtained an average $r = 0.9^{**}$ (Figure 24). These results confirm that the most important factor in the calculation of the position a document will occupy in Google Scholar's SERP is its citation count, confirming the statement of Google Scholar in this regard.

**Figure 24. Pearson correlation between the number of citations of documents in Google Scholar and the position they occupy in the Search Engine Result Page**

Moreover, according to the scatterplot in Figure 25, the correlation is almost perfect until we reach the last 100 results of the queries, but then the correlation becomes much more tenuous. If we calculate the Pearson correlation for the first 900 and the last 100 results of each query separately, the average correlation for all years is $0.97^{**}$ and $0.61^{**}$ respectively. Clearly, the problem is restricted to the tail of the distribution.
Figure 25. Relationship between the number of citations of documents in Google Scholar and the position they occupy in the Search Engine Result Page.
5. CONCLUSIONS

As we’ve seen, the analysis of GS provides a very different vision to the question of which are the most influential academic, scientific and technical documents for the scientific, professional and educational community. This fact can be explained by Google Scholar’s own nature:

- Google Scholar’s crawlers sweep the entire academic web: the most well-known scholarly publishers (such as Elsevier, Springer, Sage, Willey, Taylor & Francis, IEEE, ACS, ACM, Macmillan, Willey, Oxford University Press); their digital hosts/facilitators (such as HighWire Press, MetaPress, Ingenta); societies and other scholarly organizations (such as the American Physical Society, American Chemical Society, ACM), government agencies (National Institute of Health, National Oceanic and Atmospheric Administration, U.S. Geological Survey), databases (Pubmed, ERIC), disciplinary repositories (such as arXiv.org, Astrophysics Data System, RePEc, SSRN, CiteBase), institutional repositories from universities or research centers, library catalogs (Dialnet), as well as personal web pages from researchers, professors, research groups, departments, faculties... hosted inside the servers of the university or research center they belong to.
- While traditional citation-based databases deal with the strictly scientific world (mainly journal articles, conference communications, and some books), Google Scholar’s aim is to index all kinds of scientific documents (scientific and professional journals, conferences, books, working papers, reports...), as well as educational documents (master’s and doctoral theses, teaching materials...), and technical and professional documents (reports, patents, american case laws, annuals...) circulating in the Web.
- It covers documents written in all languages and from all countries.

In conclusion, thanks to the wide and varied sources from which GS feeds, we are able to measure not only scientific impact, but also educational and professional impact in the broadest sense of the term (Kousha and Thelwall, 2008).

At the same time, as regards strict scientific impact, the analysis of GS data provides very similar results to the results obtained from traditional citation-based databases, with the advantage of being able to retrieve a larger and more varied number of citations, since they come from a wider range of document types, different geographical environments, and languages different to English.

The profile of the average highly cited document is: a book or journal article written in English and available online in PDF format.

The rest of the findings of this study can be summarised as follows:

- 40% of the highly cited documents in GS are freely accessible, mostly from educational institutions (mainly universities), and other non-profit organizations. The availability of these documents is essential for GS as a search engine.
- Almost half of these highly cited documents are not indexed in Web of Science, which for many years has has been considered the most prestigious scientific information database.
- There is a high correlation ($r = 0.8$) between the number of citations of these documents in GS and their citations in WoS.
- GS has detected more than one version for the 83.17% of the documents in our sample.
- There is no correlation between the number of versions GS has detected, and the number citations they have received.
- There is no correlation between the number of versions GS has detected for these documents, and their position in the result pages (SERPs).
There is a high correlation ($r = 0.9$) between the positions these documents occupy in the result pages and the number of citations they have received, at least in queries that only use the filtering option to select the documents published in a given year.

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## APPENDIX A

| Document type | Bibliographic reference | 1st ed. Pub. Year | GS Citations |
|---------------|-------------------------|------------------|--------------|
| J             | LOWRY, O.H. et al., (1951). Protein measurement with the Folin phenol reagent. The Journal of biological chemistry, 193(1), 265-275. | 1951 | 253671 |
| J             | LAEMMLI, U.K. (1970). Cleavage of structural proteins during the assembly of the head of bacteriophage T4. Nature, 227(5259), 680-685. DOI: 10.1038/227680a0 | 1970 | 221680 |
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| B             | SAMBROOK, J., FRITSCH, E. F., & MANIATIS, T. (1982). Molecular cloning: a laboratory manual. New York, Cold Spring Harbor Laboratory Press. | 1982 | 171004 |
| B             | AMERICAN PSYCHIATRIC ASSOCIATION. (1952). Diagnostic and statistical manual: mental disorders. Washington, American Psychiatric Assn., Mental Hospital Service. | 1952 | 129473 |
| B             | PRESS, W. H. (1986). Numerical recipes: the art of scientific computing. Cambridge [Cambridgeshire], Cambridge University Press. | 1986 | 108956 |
| B             | YIN, R. K. (1984). Case study research: design and methods. Beverly Hills, Calif, Sage Publications. | 1984 | 82538 |
| B             | ABRAMOWITZ, M., & STEGUN, I. A. (1964). Handbook of mathematical functions: with formulas, graphs, and mathematical tables. Washington, Government printing office. | 1964 | 80482 |
| B             | KUHN, T. S. (1962). The structure of scientific revolutions. Chicago, University of Chicago Press. | 1962 | 70662 |
| B             | ZAR, J. H. (1974). Biostatistical analysis. Englewood Cliffs, Prentice Hall international. | 1974 | 68267 |
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| Document type | Bibliographic reference | 1st ed. Pub. Year | GS Citations |
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| B             | NORTH, D. C. (1990). Institutions, institutional change, and economic performance. New York, Cambridge University | 1990 | 31019 |
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| J             | DUBOIS, M. et al. (1956). Colorimetric method for determination of sugars and related substances. Analytical Chemistry, 28(3), 350-356. DOI: 10.1021/ac60111a017 | 1956 | 30045 |
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| B            | ARENDT, H. (1958). The Human Condition. Chicago, The University of Chicago Press. | 1958 | 13482 |
| J            | JEMAL, A. et al. (2009). Cancer statistics, 2009. CA: a Cancer Journal for Clinicians, 59(4), 225. DOI:10.3322/caac.20006 | 2009 | 13454 |
| J            | BERENDSEN, H. J. C. et al. (1984). Molecular dynamics with coupling to an external bath. The Journal of Chemical Physics. 81, 3684. DOI:10.1063/1.448118 | 1984 | 13447 |
| J            | CHARLSON, M.E. et al. (1987). A new method of classifying prognostic comorbidity in longitudinal studies: development and validation. Journal of chronic diseases, 40(5), 373-383. DOI: 10.1016/0021-9681(87)90171-8 | 1987 | 13440 |
| J            | BELL, D. (1976 ). The coming of the post-industrial society. In The Educational Forum (Vol. 40, No. 4, p 574-579). Taylor & Francis Grou | 1976 | 13430 |
| J            | MORGAN, R.M. & HUNT, S.D. (1994). The Commitment-Trust Theory of Relationship Marketing. Journal of Marketing, 58, 20-38. DOI: 10.2307/1252308 | 1994 | 13408 |
| B            | MENEZES, A. J., VAN OORSCHOT, C., & VANSTONE, S. A. (1996). Handbook of applied cryptography. Boca Raton, Fla, CRC. | 1996 | 13393 |
| B            | MACINTYRE, R. J. (1985). Molecular evolutionary genetics. New York, Plenum. | 1985 | 13375 |
| B            | NIE, N. H., BENT, D. H., & HULL, C. H. (1970). SPSS: Statistical Package for the Social Sciences. New York [etc.], McGraw-Hill Book Company. | 1970 | 13369 |
| B            | KRUEGER, R. A. (1988). Focus groups a practical guide for applied research. Newbury Park, Calif, Sage Publications. | 1988 | 13369 |
| J            | VANDERBILT, D. (1990). Soft self-consistent pseudopotentials in a generalized eigenvalue formalism. Physical Review B. 41(11), 7892-7895. DOI: 10.1103/PhysRevB.41.7892 | 1990 | 13361 |
| B            | RECHTSCHAFFEN, A., & KALES, A. (1968). A manual of standardized terminology, techniques and scoring system | 1968 | 13338 |
| Document type | Bibilographic reference | 1st ed. Pub. Year | GS Citations |
|---------------|-------------------------|------------------|--------------|
| J             | GEIM, A.K. & NOVOSELOV, K.S., (2007). The rise of graphene. Nature materials, 6(3), 183-191. DOI: 10.1038/nmat1849 | 2007 | 13278 |
| B             | DERRIDA, J. (1976). Of grammatology. Baltimore, Johns Hopkins University Press. | 1976 | 13262 |
| J             | PERDEW, J. & ZUNGER, A. (1981). Self-interaction correction to density-functional approximations for many-electron systems. Physical Review B, 23(10), 5048-5079. DOI: 10.1103/PhysRevB.23.5048 | 1981 | 13261 |
| B             | BARNARD, C. J. (1938). The functions of the executive. Cambridge, Mass, Harvard University Press. | 1938 | 13257 |
| J             | QUINLAN, J. R. (1986). Induction of decision trees. Machine learning, 1(1), 81-106. | 1986 | 13252 |
| B             | HULST, H.C.V.D. (1957). Light scattering by small particles. New York, J. Wiley. | 1957 | 13248 |
| J             | SHARPE, W. F. (1964). Capital asset prices: a theory of market equilibrium under conditions of risk*. The Journal of Finance. 19, 425-442. DOI: 10.2307/2977928 | 1964 | 13242 |
| J             | HSU SM, RAINER L, & FANGER H. (1981). Use of avidin-biotin-peroxidase complex (ABC) in immunoperoxidase techniques: a comparison between ABC and unlabeled antibody (PAP) procedures. The Journal of Histochemistry and Cytochemistry : Official Journal of the Histochemistry Society. 29, 577-80. | 1981 | 13214 |
| B             | GELMAN, A. et al. (1995). Bayesian data analysis. London [etc.], Chapman & Hall. | 1995 | 13208 |
| J             | DEWAR, M. J. S. et al. (1985). Development and use of quantum mechanical molecular models. 76. AM1: a new general purpose quantum mechanical molecular model. Journal of the American Chemical Society, 107, 3902-3909. DOI: 10.1021/ja00299a024 | 1985 | 13178 |
| J             | BROWN, J. S., COLLINS, A., & DUGUID, (1989). Situated Cognition and the Culture of Learning. Educational Researcher. 18, 32-42. | 1989 | 13178 |
| B             | TRIBE, L. H. (1978). American constitutional law. Mineola, NY, The Foundation Press. | 1978 | 13169 |
| J             | TAMURA, K. et al. (2011). MEGA5: Molecular Evolutionary Genetics Analysis Using Maximum Likelihood, Evolutionary Distance, and Maximum Parsimony Methods. Molecular Biology and Evolution. 28, 2731-2739. DOI: 10.1093/molbev/msr121 | 2011 | 13145 |
| J             | DIJKSTRA, E.W. (1959). A note on two problems in connexion with graphs. Numerische Mathematik, 1(1), 269-271. | 1959 | 13125 |
| J             | MODIGLIANI, F., MILLER, M.H. & MODIGLIANI, F. (1958). The cost of capital, corporation finance and the theory of investment. The American economic, 48(3), 261-297. | 1958 | 13123 |
| J             | HUELSHENBECK, J., & RONQUIST, F. (2001). MRBAYES: Bayesian inference of phylogenetic trees. Bioinformatics. 17, 754-755. DOI: 10.1093/bioinformatics/17.8.754 | 2001 | 13120 |
| Document type | Bibliographic reference | 1st ed. Pub. Year | GS Citations |
|---------------|-------------------------|-------------------|--------------|
| J             | BINNIG, G. & QUATE, C.F. (1986). Atomic Force Microscope. Physical Review Letters, 56(9), 930-933. DOI: 10.1103/PhysRevLett.56.930 | 1986 | 13115 |
| J             | BURGES, C.C.J.C. (1998). A Tutorial on Support Vector Machines for Pattern Recognition. U. Fayyad, ed. Data Mining and Knowledge Discovery, 2(2), 121-167. | 1998 | 13088 |
| B             | REED, M., & SIMON, B. (1975). Fourier analysis, self-adjointness. New York, Academic Press. | 1975 | 13086 |
| J             | TAKAGI, T., & SUGENO, M. (1985). Fuzzy identification of systems and its applications to modeling and control. IEEE Transactions on Systems, Man, and Cybernetics. SMC-15, 116-132. | 1995 | 13081 |
| B             | BECKER, G. S. (1981). A treatise on the family. Cambridge, Mass, Harvard University Press. | 1981 | 13073 |
| B             | FUKUYAMA, F. (1995). Trust: the social virtues and the creation of prosperity. New York, The Free Press. | 1995 | 13069 |
| B             | NOZICK, R. (1974). Anarchy, state and utopia. New York, Basic Books. | 1974 | 13060 |
| J             | BARTLETT, G.R. (1959). Phosphorus assay in column chromatography. The Journal of Biological Chemistry. 234, 466-8. | 1959 | 13053 |
| B             | RAO, C. R. (1965). Linear statistical inference and its applications. New York, J. Wiley & Sons. | 1965 | 13052 |
| J             | YABLOMOVITCH, E. (1987). Inhibited Spontaneous Emission in Solid-State Physics and Electronics. Physical Review Letters. 58(20), 2059-2062. DOI: 10.1103/PhysRevLett.58.2059 | 1987 | 13051 |
| B             | SPERBER, D. et al. (2001). Relevance: communication and cognition = Guan lian xing : jiao ji yu ren zhi. Beijing, Bu lai ke wei er chu ban she. | 2001 | 13048 |
| B             | WILSON, W. J. (1987). The truly disadvantaged: the inner city, the underclass, and public policy. Chicago, University of Chicago Press. | 1987 | 13040 |
| B             | ARMAREGO, W. L. F., CHAI, C. & PERRIN, D. R. (1966). Purification of laboratory chemicals. Oxford, Butterworth-Heinemann. | 1966 | 13036 |
| J             | BEDNORZ, J. G., & MULLER, K. A. (1986). Possible highTc superconductivity in the Ba?La?Cu?O system. Zeitschrift Fur Physik B Condensed Matter. 64(2), 189-193. | 1986 | 13025 |
| J             | PERDEW, J. et al. (1992). Atoms, molecules, solids, and surfaces: Applications of the generalized gradient approximation for exchange and correlation. Physical Review B. 46 (11), 6671-6687. | 1992 | 13021 |
| J             | DERSIMONIAN, R. & LAIRD, N. (1986). Meta-analysis in clinical trials. Controlled clinical trials, 7(3), 177-188. DOI: 10.1016/0197-2456(86)90046-2 | 1986 | 13016 |
| J             | BROWNE, M. W., & CUDECK, R. (1993). Alternative Ways of Assessing Model Fit. SAGE FOCUS EDITIONS. 154, 136. | 1993 | 13007 |
| J             | BOYS, S., & BERNARDI, F. (2002). The calculation of small molecular interactions by the differences of separate total energies. Some procedures with reduced errors. Molecular Physics. 100, 65-73. DOI: 10.1080/00268977000101561 | 2002 | 13005 |
| Document type | Bibliographic reference | 1st ed. Pub. Year | GS Citations |
|---------------|-------------------------|-------------------|--------------|
| B             | ZIEGLER, J. F., BIERSC, J. J. & LITTMARK, U. (1985). The stopping and range of ions in solids. New York, Pergamon Press. | 1985 | 12978 |
| J             | PORTA, R.L. et al. (1998). Law and Finance. Journal of Political Economy, 106(6), 1113. | 1998 | 12974 |
| B             | BALANIS, C. A. (1982). Antenna theory: analysis and design. New York, Harper & Row publisher. | 1982 | 12966 |
| B             | BEAR, J. (1972). Dynamics of fluids in porous media. New York, Dover Publications. | 1972 | 12962 |
| J             | BÖYUM A. (1968). Isolation of mononuclear cells and granulocytes from human blood. Isolation of mononuclear cells by one centrifugation, and of granulocytes by combining centrifugation and sedimentation at 1 g. Scandinavian Journal of Clinical and Laboratory Investigation. Supplementum, 97, 77-89. | 1968 | 12946 |
| J             | HAMMER, M., & CHAMPI, J. (1993). Reengineering the corporation: A manifesto for business revolution. Business Horizons. 36(5), 90-91. | 1993 | 12943 |
| J             | REAVEN, G. M. (1988). Role of Insulin Resistance in Human Disease. Diabetes. 37(12), 1595-1607. | 1988 | 12922 |
| B             | BEZDEK, J. C. (1981). Pattern recognition with fuzzy objective function algorithms. New York, N.Y., Plenum Press. | 1981 | 12917 |
| B             | GUYTON, A. C., & HALL, J. E. (1998). Pocket companion to Textbook of medical physiology. Philadelphia, Pa, Saunders. | 1998 | 12898 |
| B             | BECK, U. (1986). Risikogesellschaft: auf dem Weg in eine andere Moderne. Frankfurt am Main, Suhrkam | 1986 | 12895 |
| B             | CRISTIANINI, N., & SHAVE-TAYLOR, J. (2000). An introduction to support vector machines: and other kernel-based learning methods. New York, Cambridge University Press. | 2000 | 12877 |
| B             | DILLMAN, D. A. (2000). Mail and internet surveys the tailored design method. New York, Wiley. | 2000 | 12872 |
| B             | PATTERSON, D. A., GOLDBERG, D., & HENNESSY, J. L. (1990). Computer architecture: a quantitative approach. San Mateo, Calif, Morgan Kaufman. | 1990 | 12865 |
| B             | VROOM, V. H. (1964). Work and motivation. New York, Wiley. | 1964 | 12840 |
| C             | AKAIKE, H. (1973). Information theory and an extension of the maximum likelihood principle. In B. N. PETRAN & F. CSANI, eds. International Symposium on Information Theory. Akademisist Kiadi, p 267-281 | 1973 | 12828 |
| B             | NOCEDAL, J., & WRIGHT, S. J. (1999). Conjugate gradient methods. In: Numerical optimization. New York, Springer. | 1999 | 12815 |
| J             | ALCHIAN, A.A. & DEMSETZ, H. (1972). Production, information and economic organization. American Economic Review, 62(5), 777-795. | 1972 | 12813 |
| C             | MACQUEEN, J. (1967). Some methods for classification and analysis of multivariate observations. Proceedings of the Fifth Berkeley Symposium on Mathematical Statistics and Probability. 1. Statistics : Held at the Statistical Laboratory University of California June 21-July 18, 1965 and December 27, 1965-January 7, 1966 with the Support of University of California, National Science Foundation, National Institutes of Health... <Et Al.> / Edited by Lucien M. Le Cam and Jerzy | 1967 | 12808 |
| Document type | Bibliographic reference | 1st ed. Pub. Year | GS Citations |
|----------------|-------------------------|-------------------|--------------|
| J              | ASHBURNER M, et al. (2000). Gene ontology: tool for the unification of biology. The Gene Ontology Consortium. Nature Genetics. 25, 25-9. | 2000 | 12802 |
| B              | TAFLOVE, A., & HAGNESS, S. C. (1995). Computational electrodynamics: the finite-difference time-domain method. Boston, Artech House. | 1995 | 12799 |
| J              | HUMPHREY, W., DALKE, A. & SCHULTEN, K. (1996). VMD: Visual molecular dynamics. Journal of Molecular Graphics, 14(1), 33-38. DOI: 10.1016/0261-2079(96)00098-0 | 1996 | 12788 |
| J              | CAMPBELL, D.T., & FISKE, D.W. (1959). Convergent and discriminant validation by the multitrait-multimethod matrix. Psychological Bulletin. 56(2), 81-105. DOI:10.1037/h0046016 | 1959 | 12780 |
| J              | PFAFFL, M.W. & PFAFFL, M.W. (2001). A new mathematical model for relative quantification in real-time RT-PCR. Nucleic acids research, 29(9), e45.DOI: 10.1093/nar/29.9.e45 | 2001 | 12778 |
| B              | SHAFER, G. (1976). A mathematical theory of evidence. Princeton, Princeton University Press. | 1976 | 12765 |
| J              | HOFFMANN, M. R. et al. (1995). Environmental Applications of Semiconductor Photocatalysis. Chemical Reviews. 95, 69. | 1995 | 12743 |
| J              | BONDI, A. (1964). van der Waals Volumes and Radii. The Journal of Physical Chemistry. 68(3), 441-451. DOI: 10.1021/j100785a001 | 1964 | 12731 |
| B              | BISHOP, C. M. (2006). Pattern recognition and machine learning. New York, Springer. | 2006 | 12724 |
| J              | FUJISHIMA, A., & HONDA, K. (1972). Electrochemical Photolysis of Water at a Semiconductor Electrode. Nature. 238 (5358), 37-38. DOI: 10.1038/238037a0 | 1972 | 12719 |
| J              | EMSLEY, , & COWTAN, K. (2004). Coot: model-building tools for molecular graphics.Acta Crystallographica. Section D, Biological Crystallography,60 (12), 2126. DOI: 10.1107/S0907444904019158 | 2004 | 12715 |
| B              | BARTLETT, F. C. (1932). Remembering: a study in experimental and social psychology. London, Cambridge University Press. | 1932 | 12710 |
| B              | KVALE, S., & TORHELL, S.-E. (1997). Den kvalitativa forskningsintervjun. Lund, Studentlitteratur. | 1997 | 12708 |
| B              | OSGOOD, C. E., SUCI, G. J., & TANNENBAUM, H. (1957). The measurement of meaning. Urbana, University of Illinois Press. | 1957 | 12706 |
| B              | KOHONEN, T. (1984). Self-organization and associative memory. Berlin, Springer-Verlag. | 1984 | 12705 |
| B              | LEBEBVRE, H. (1991). The production of space. Oxford, Blackwell. | 1991 | 12688 |
| J              | OLIVER, W., & PHARR, G. (1992). An improved technique for determining hardness and elastic modulus using load and displacement sensing indentation experiments.Journal of Materials Research,7(6), 1564-1583. DOI: 10.1557/JMR.1992.1564 | 1992 | 12687 |
| B              | FUKUNAGA, K. (1972). Introduction to statistical pattern recognition. New York, Academic Press. | 1972 | 12671 |
| Document type | Bibliographic reference | 1st ed. Pub. Year | GS Citations |
|---------------|--------------------------|-------------------|--------------|
| B | BRANDRUP, J., IMMERGUT, E. H., & ELIAS, H.-G. (1966). Polymer handbook. New York, Interscience Publishers a Division of John Wiley & Sons. | 1966 | 12661 |
| B | ACHENBACH, T. M., & EDELBROCK, C. S. (1983). Manual for the child behavior checklist: and revised child behavior profile. Burlington, VT, University of Vermont, Department of Psychiatry. | 1983 | 12653 |
| B | HUNTINGTON, S. (1997). The clash of civilizations and the remaking of world order. New York, NY, Simon & Schuster. | 1997 | 12633 |
| J | MALKIEL, B. G., & FAMA, E. F. (1970). EFFICIENT CAPITAL MARKETS: A REVIEW OF THEORY AND EMPIRICAL WORK*. The Journal of Finance, 25(2), 383-417. DOI: 10.2307/2325486 | 1970 | 12623 |
| J | ALAMOUTI, S.M. (1998). A simple transmit diversity technique for wireless communications. IEEE Journal on Selected Areas in Communications, 16(8). DOI: 10.1109/730453 | 1998 | 12604 |
| B | BATCHELOR, G. K. (1967). An introduction to fluid dynamics. Cambridge, University Press. | 1967 | 12591 |
| B | LITTELL, R. C. et al. (1996). SAS system for mixed models. Cary, N.C., SAS Institute, Inc. | 1996 | 12569 |
| B | BRESLOW, N. E., & DAY, N. E. (1980). Statistical methods in cancer research. Lyon, International Agency for Research on Cancer. | 1980 | 12562 |
APPENDIX B

A Case study: The Mathematical Theory of Communication in Google Scholar

This work, because of its bibliographic and bibliometric complexity, collects and illustrates the problems posed by this working paper on the treatment of highly cited documents. Therefore, it has been taken as a special case study, to develop it further.

Complexity

"A mathematical theory of communication" constitutes an article by Claude Shannon in 1948 in the Bell System Technical Journal and that was divided in two parts published separately.

Later, in 1949, this work is expanded and reedited in book form, published by the University of Illinois Press. On this occasion, is published co-authored by Claude Shannon and Warren Weaver, and the title varies imperceptibly: "The mathematical theory of communication".

Problematic

Despite being two articles published in 1948 and a book published in 1949, this work appears in the results of our analysis, which we remind that is limited to the period 1950-2013. So this raises a key question: Why this document appears in our sample?

Additionally, the fact that it is composed of two distinct works (article and book), both before 1950, generating different editions and different citations, raises a number of additional issues, which affect the functioning of the versions in Google Scholar as well as a number of additional issues raised in this working paper, for example:

Has GS identified all editions of the same document? Were successfully linked all editions of the same document? Were all citations received by each edition successfully merged? Was each citation successfully linked to each of the different editions?

Bibliographic search

In Figure B1 we show the query search for the work in Google Scholar by identifying the result with a higher number of versions.

Figure B1. Principal version of The mathematical theory of communication in Google Scholar

![Google Scholar search result](image)
Even before trying to study the number of versions gathered, this point raises a fundamental issue: has Google Scholar merged all versions of this work?

To do this, we proceeded to refine this query (adding the search command author:Shannon), obtaining a total of 230 results, which have been analyzed to see which of them should not constitute a version (the raw data of this analysis is available in the complementary material).

Of the 230 results, 71.7% (165) are records that correspond to versions of the work, while the rest are not true versions, and they appear in the results of this query because they comment or review Shannon’s work.

Of the 165 records, the first one includes a larger number of versions (shown in Figure B1). However, in the remaining 164 records, there are 3,714 potential citations (without eliminating possible duplicates).

*Number of versions for the main record*

On the one hand, we can observe the large amount of retrieved versions (830) and, on the other, that among these versions we can find both versions of the article, and versions of the book, although the latter are a minority.

Otherwise, a manual analysis gives us only 763, not the 830 displayed in Figure B1. That is, the figure shown is an approximation of the number of recovered versions. This effect has already been seen in the Hit Count Estimates to general queries (Orduna-Malea et al, 2014).

*Edition*

However, the biggest problem we found was the year of publication (2001). This is taken from the primary version, which corresponds with the last identified reprint of the book, although the dates for the rest of the versions themselves are properly identified (Figure B2).

*Figure B2. Versions grouped in Google Scholar about The mathematical theory of communication*
Therefore, as the primary version gives the publication year, this causes it to appear in the results of our sample, which should have been limited to the period 1950-2013.

Given the magnitude and global impact of the Shannon and Weaver work, the number of reprints and editions (in different languages) are very high, and we should also add some book reviews (as sometimes are taken as versions).

These other inquiries are answered in the remaining questions raised in the working paper, in a more detailed and comprehensive way, but especially detectable in this case study.

The decision of taking the publication date from the last available release is understandable from the point of view of the search engine service, although it limits its potential as an object of bibliometric analysis, and therefore should be considered. Nonetheless, it is likely that the number of highly cited works that are affected by this issue relatively low.

As a counterpoint to the model taken by Google Scholar to group different versions (Figure B2), an example from the library world (Figure B3) is offered, using a catalog where authority control is used (Worldcat).

As can be seen, the system recovers, after querying for the title "mathematical theory of communication" and author ("Shannon"), different versions of the book (in different languages), as well as the original article.

**Figure B3. The mathematical theory of communication in Worldcat**
Analysis

To further analyze this case, we have proceeded to download the 830 versions of the book “The Mathematical Theory of Communication”, belonging to the primary version in Google Scholar, in order to understand and describe it.

The raw data for this analysis is available in the supplementary material, in a spreadsheet file. For each version, we have considered the same parameters that we have used for the 64,000 highly cited documents, fully described in the Introduction of the Working Paper.

Additionally, for each version, we manually checked if it was done correctly or not. And in those cases where the connection is unsuccessful, we have classified the different errors into categories, further detailing the reason for the error where needed.

Of the total 830 versions, Google Scholar has really returned only 763, of which 602 (78.9%) are working properly. In the remaining versions (161), the following problems occur:

- False positive: when a document has been identified as a version of another document, but actually it is not.
- Citation: false positive specific case, when the identified version is a citation rather than a document.
- Broken Link: If the link is not working properly.
- Unknown: when we have not been able to verify if the version was correct. This has occurred mainly in cases in which the files were available in PS (PostScript) file format.

In Table B1 we summarize all data about errors in the 830 different versions grouped.

| Error Typology     | Frequency |
|--------------------|-----------|
| Citation           | 23        |
| Broken link        | 86        |
| False positive     | 14        |
| Unknown            | 38        |
| **TOTAL**          | **161**   |
## APPENDIX C

| Journal                                                        | Nº top cited articles |
|----------------------------------------------------------------|-----------------------|
| NATURE                                                         | 1518                  |
| SCIENCE                                                        | 1437                  |
| NEW ENGLAND JOURNAL OF MEDICINE                               | 848                   |
| PHYSICAL REVIEW                                               | 671                   |
| PROCEEDINGS OF THE NATIONAL ACADEMY OF SCIENCES OF THE UNITED | 574                   |
| STATES OF AMERICA                                             |                       |
| CELL                                                           | 483                   |
| JOURNAL OF BIOLOGICAL CHEMISTRY                               | 452                   |
| PHYSICAL REVIEW LETTERS                                       | 432                   |
| LANCET                                                        | 363                   |
| JOURNAL OF THE AMERICAN CHEMICAL SOCIETY                      | 328                   |
| JAMA-JOURNAL OF THE AMERICAN MEDICAL ASSOCIATION              | 251                   |
| AMERICAN ECONOMIC REVIEW                                      | 244                   |
| ECONOMETRIC A.                                                | 217                   |
| PSYCHOLOGICAL REVIEW                                         | 210                   |
| REVIEWS OF MODERN PHYSICS                                     | 206                   |
| CHEMICAL REVIEWS                                              | 203                   |
| JOURNAL OF POLITICAL ECONOMY                                  | 200                   |
| JOURNAL OF PHYSIOLOGY-LONDON                                  | 200                   |
| PSYCHOLOGICAL BULLETIN                                        | 194                   |
| JOURNAL OF CHEMICAL PHYSICS                                   | 187                   |
| ASTROPHYSICAL JOURNAL                                         | 183                   |
| BIOCHEMICAL JOURNAL                                           | 180                   |
| PROCEEDINGS OF THE ROYAL SOCIETY OF LONDON SERIES A-MATHEMATICAL AND PHYSICAL SCIENCES | 180 |
| CIRCULATION                                                   | 174                   |
| JOURNAL OF CLINICAL INVESTIGATION                             | 164                   |
| JOURNAL OF PERSONALITY AND SOCIAL PSYCHOLOGY                 | 162                   |
| PHYSICAL REVIEW D                                             | 160                   |
| JOURNAL OF EXPERIMENTAL MEDICINE                              | 153                   |
| PHYSICAL REVIEW B                                             | 149                   |
| NUCLEIC ACIDS RESEARCH                                        | 143                   |
| JOURNAL OF MOLECULAR BIOLOGY                                  | 141                   |
| QUARTERLY JOURNAL OF ECONOMICS                                | 136                   |
| PHYSIOLOGICAL REVIEWS                                         | 131                   |
| BIOCHIMICA ET BIOPHYSICA ACTA                                 | 128                   |
| COMMUNICATIONS OF THE ACM                                     | 124                   |
| Journal                                         | Nº top cited articles |
|------------------------------------------------|-----------------------|
| ANNUAL REVIEW OF BIOCHEMISTRY                 | 123                   |
| ADMINISTRATIVE SCIENCE QUARTERLY              | 116                   |
| HARVARD BUSINESS REVIEW                       | 113                   |
| ANALYTICAL BIOCHEMISTRY                       | 112                   |
| JOURNAL OF FINANCE                            | 111                   |
| JOURNAL OF THE AMERICAN STATISTICAL ASSOCIATION | 110                 |
| AMERICAN SOCIOLOGICAL REVIEW                  | 109                   |
| AMERICAN PSYCHOLOGIST                          | 106                   |
| ANALYTICAL CHEMISTRY                          | 103                   |
| JOURNAL OF CELL BIOLOGY                       | 102                   |
| JOURNAL OF FLUID MECHANICS                    | 102                   |
| NUCLEAR PHYSICS B                             | 100                   |
| BRITISH MEDICAL JOURNAL                       | 97                    |
| JOURNAL OF FINANCIAL ECONOMICS                | 94                    |
| JOURNAL OF MARKETING                          | 94                    |
| IEEE TRANSACTIONS ON PATTERN ANALYSIS AND MACHINE INTELLIGENCE | 93           |
| ANNALS OF MATHEMATICAL STATISTICS             | 93                    |
| JOURNAL OF PHYSICAL CHEMISTRY                | 90                    |
| PHYSICS LETTERS B                             | 87                    |
| HARVARD LAW REVIEW                            | 87                    |
| ACADEMY OF MANAGEMENT REVIEW                  | 86                    |
| CANCER RESEARCH                               | 84                    |
| JOURNAL OF GEOPHYSICAL RESEARCH               | 83                    |
| AMERICAN JOURNAL OF SOCIOLOGY                 | 82                    |
| BIOMETRIKA                                    | 81                    |
| ANNALS OF INTERNAL MEDICINE                   | 80                    |
| ARCHIVES OF GENERAL PSYCHIATRY                | 79                    |
| JOURNAL OF BONE AND JOINT SURGERY-AMERICAN VOLUME | 79              |
| AMERICAN JOURNAL OF MEDICINE                  | 75                    |
| STRATEGIC MANAGEMENT JOURNAL                  | 74                    |
| ANNALS OF MATHEMATICS                         | 74                    |
| NATURE GENETICS                               | 74                    |
| BIOCHEMISTRY                                  | 73                    |
| MANAGEMENT SCIENCE                            | 73                    |
| PHARMACOLOGICAL REVIEWS                       | 71                    |
| IEEE TRANSACTIONS ON INFORMATION THEORY       | 71                    |
| JOURNAL OF NEUROPHYSIOLOGY                    | 69                    |
| ACTA CRYSTALLOGRAPHICA                        | 66                    |
Does Google Scholar contain all highly cited documents (1950-2013)?

| Journal                                                                 | Nº top cited articles |
|------------------------------------------------------------------------|-----------------------|
| REVIEW OF ECONOMIC STUDIES                                             | 65                    |
| ANGEWANDTE CHEMIE-INTERNATIONAL EDITION                                | 65                    |
| JOURNAL OF APPLIED PHYSICS                                             | 64                    |
| PROCEEDINGS OF THE NATIONAL ACADEMY OF SCIENCES OF THE UNITED STATES OF AMERICA-BIOLOGICAL SCIENCES | 63        |
| CANCER                                                                 | 63                    |
| ECOLOGY                                                                | 63                    |
| ANNALS OF PHYSICS                                                      | 63                    |
| BIOMETRICS                                                             | 62                    |
| JOURNAL OF APPLIED PHYSIOLOGY                                          | 62                    |
| PROCEEDINGS OF THE IEEE                                                | 61                    |
| AMERICAN JOURNAL OF PHYSIOLOGY                                         | 61                    |
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