SNIP and Beyond[1]

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Abstract

This paper presents a journal indicator of citation impact of a scientific-scholarly journal. It builds further upon Eugene Garfield's groundbreaking ideas presented in many of his early and later publications, by combining his concept of a journal impact factor with his notion that "evaluation studies using citation data must be very sensitive to all divisions, both subtle and gross, between areas of research; and when they are found, the study must properly compensate for disparities in citation potential (Garfield, 1979, p 249)". The proposed indicator is based on a tailor made delimitation of a journal's subject field, and takes into account the frequency and immediacy of citation and database coverage in a subject field applying the concept of source or citing-side field normalization. The first part of the paper outlines the main features of SNIP. The second part discusses the base ideas of source normalization and proposes research lines aimed to further explore its potentialities in research assessment methodologies.

Introduction

Eugene Garfield's original and illuminative studies of the scientific communication system have generated an enormous impact not only upon library and information scientists, but also upon producers of scientific literature databases, journal publishers and editors, librarians, research managers and research performance assessors. His studies were based on the Science Citation Index (SCI), one of his key information products published by the Institute for Scientific Information, a company he founded in 1960. A good illustration of the use of the SCI and related indexes for studying the structure of the scholarly communication system is the following paragraph in which he relates citation counts in the SCI to a concept of 'quality' of a scientific journal.

"Since authors refer to previous material to support, illustrate, or elaborate on a particular point, the act of citing is an expression of the importance of the material. The total number of such expressions is about the most objective measure there is of the material's importance to current research. The number of times all the material in a given journal has been cited is an equally objective and enlightening measure of the quality of a journal as a medium for communicating research results (Garfield, 1979, pp. 23–24)".

Relationships among journals were analyzed in terms of citations from one journal to another, and core journals and more peripheral ones were identified. Equally important, his analyses provided the basis for a unique 'internal' monitor of the adequacy of coverage of the SCI itself.

The journal statistics Garfield explored were soon isolated from the study context and published by ISI in rankings of journals by impact factor, probably the bibliometric construct most widely used in the scholarly and publishing community. Nowadays journal publishers and editors use journal metrics to obtain answers to questions as to how a journal compares with its competitors. Librarians use it to determine which journals are likely to be the most useful for the researchers in their institution. Research managers apply journal citation measures when dealing with the question how they should devise an effective publication strategy for the papers written in their group, and many research performance assessors use

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such measures as tools for assessing the research performance of an individual researcher or research group.

The potentialities of journal citation measures in the contexts outlined above are intensively discussed among practitioners in the field of library and information science and quantitative science studies, but also in the broader scientific community and in the various user groups. Perhaps the following three statements represent a consensus among most if not all participants (e.g., Moed, 2005; Glanzel, 2009).

1. Journal performance is a complex, multi-dimensional concept that cannot be fully captured in a single metric.
2. In the construction and interpretation of journal citation measures It is crucial to take into account differences in communication and citation practices between research fields.
3. Although journal quality is an aspect of research performance in its own right, journal impact measures should not be used as surrogates of actual citation impact of a group's publications.

The extensive use of the journal impact factor (JIF) for purposes for which it was not designed, raised a series of criticisms, all aiming to adapt the measure to the new user environments and to propose new types of indicators. But the impact factor is still the norm, it is the metric 'to beat'. During the past years, numerous other approaches to the measurement and ranking of journal impact were explored. Without claiming completeness, important approaches are as follows.

- In order to account for differences in citation practices between research fields – both the frequency and the immediacy of citation –, Pudovkin and Garfield (2004) developed a ranking procedure of scientific journals similar to percentile ranking, that generate rank-normalised impact factors of scientific journals based on citation analysis.
- One of the limitations of traditional citation analysis is that all citations are considered 'equal'. Following Pinski and Narin (1976), several authors applied algorithms based on Google PageRank to the journal-to-journal citation network whereby the subject field, quality and reputation of a journal have a direct effect on the value of the citations it gives to other journals (Bollen, Rodriguez and Van de Sompel, 2006; Bergstrom, 2007; West et al., 2008; González-Pereira, Guerrero-Bote and Moya-Anegón, 2009).
- The Hirsh Index, originally developed as a tool to evaluate individual scientists, has become a popular bibliometric indicator ever since its launch in 2005 (Hirsch, 2005). Braun, Glanzel and Schubert (2005) and others explored the use of Hirsch Indices calculated for for scientific journals.
- Citation distributions of scientific journals are known to be skewed. Stringer, Sales-Pardo and Amaral (2008) developed a model for the asymptotic number of citations collected by papers published in a journal and obtained evidence that the corresponding citation distribution for articles cited at least once is approximately normal, enabling one to quantify both the typical impact and the range of impacts of papers published in a journal.
- In view of the complex nature of journal citation distributions, the development and testing of models describing such distributions – which has a long tradition in library and information science – is ongoing. Glanzel (2009) modelled a journal citation distribution as a negative binomial distribution, and characterized a journal's impact by estimating the two parameters of this distribution.
- The approaches indicated above are all based on citation counts. But more and more studies explore the use of data on downloads of papers in full text format from electronic publication archives (e.g., Bollen and Van de Sompel, 2008). Journal 'usage' factors are constructed and calculated, and their correlation with citation-based measures is examined.

This paper presents a journal indicator that is a member of the family of journal citation indicators that use the concept of the ISI journal impact factor as a starting point, and aim at taking into account important factors that do affect a journal's citation rate, but that have little to do with its performance. It builds further upon Eugene Garfield's ideas presented in many of his early and later publications (e.g., Garfield, 1972; 1996; 2005). The new indicator was developed at the Centre for Science and Technology Studies (CWTS) at Leiden University (Moed, 2010).
The structure of this paper is as follows. The details of the SNIP indicator are presented in ***Section 2***. This section also explains the concept of source normalization, and shows how it can be used to construct an indicator of journal citation impact. ***Section 3*** highlights general features of the new indicator and presents typical examples. Finally, ***Section 4*** presents concluding comments. It makes suggestions for further research and development of the concept of source normalization. All empirical data presented in this paper are obtained from bibliometric versions of Scopus created at the Centre for Science and Technology Studies (CWTS) at Leiden University, the Netherlands, based on raw data extracted from Elsevier's Scopus in September 2008 and July 2009, used in this paper to calculate indicators for the (citing) years 2007 and 2008, respectively.

Source normalized impact per paper (SNIP)

Source normalization
Many authors have underlined that it is improper to make comparisons between citation counts generated in different research fields, because citation practices can vary significantly from one field to another. For instance, articles in biochemistry often contain over 50 cited references, while a typical mathematical paper has perhaps only 10. This difference explains why biochemical papers are cited so much more often than mathematical ones. Eugene Garfield's view on this is clear. "Evaluation studies using citation data must be very sensitive to all divisions, both subtle and gross, between areas of research; and when they are found, the study must properly compensate for disparities in citation potential (Garfield, 1979, p 249)".
One way to overcome differences in citation potential is calculating 'relative' indicators that calculate the ratio of a journal's citation impact per paper and the world citation average in the subject field covered by the journal (e.g., Sen, 1992; Marshakova-Shaikevich, 1996; van Leeuwen and Moed, 2002). This approach can be denoted as target normalization. A second approach is based on the idea of source normalization, labelled by Zitt and Small (2008) as "citing-side normalization". Its base idea is that the actual citation rate of a set of target papers in a subject field is 'normalized' or 'divided' by a measure of the frequency at which articles in that field cite other documents. The indicator presented in the current paper is based on this idea.
A journal's source normalized impact per paper, SNIP, is a ratio of two measures: it divides the number of times a journal's articles are cited – i.e., its raw impact per paper – to the frequency at which papers in the journal' subject field cite other materials – the subfield' s citation potential. In other words, it measures a journal's citation rate per cited reference in – or per citation given in – documents in the journal's subject field. Figure 1 summarizes the principal characteristics of this indicator:

- It aims at taking into account only peer reviewed articles published in a journal, both as cited and as citing documents.
- A journal's subject field is defined in a dedicated manner, taking into account a journal's scope.
- It accounts for differences in the frequency and immediacy of citation between research fields, by applying the idea of source normalization.

- It corrects for differences in the extent to which the publication database used in the calculations covers a subject field.

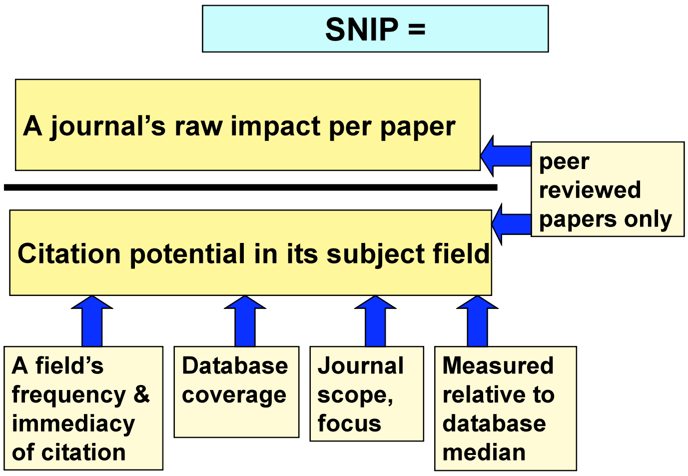

Figure 1. Main features of SNIP

Raw impact per paper

This measure is similar to the ISI (currently Thomson Reuters) journal impact factor. It is defined as the average citation rate in a particular year (the citing or impact factor year) of papers published in a journal during the *three* preceding years. By considering three cited preceding years rather than two – as is the case in the ISI impact factor –, results for journals in fields showing a slowly maturing impact that does not peak after one or two years can be expected to be more reliable. From the data on the age distributions of cited references in 27 disciplines published by Lancho-Barrantes, B.S., Guerrero-Bote, V.P. and Moya-Anegón, F. (2010) it can be concluded that a time window of three cited years is indeed a fair compromise. 'Papers' include articles, reviews and proceedings papers. Informal, non-peer reviewed communications such as editorials and letters to the editor are discarded both as cited and as citing sources.

A journal's subject field

A journal's subject field is defined as the collection of papers citing the journal. In this way a subfield is defined by the (formal) users of a journal, whose behaviour can be expected to properly reflect the journal's scope. One technical aspect should be clarified here. As outlined below, the time frame of three preceding cited years plays a key role not only in the calculation of the raw impact per paper, but also in that of a journal's citation potential. But in the SNIP methodology, the articles constituting a journal's subject field do not necessarily have to cite 1-3 year old papers published in the journal, because this would introduce a bias in favour of articles citing recent materials above older documents. Therefore, a ten-year time window is applied: a journal's subject field consists of the articles citing at least one 1-10 year old paper published in the journal.

Citation potential

Citation potential in a subject field captures how frequently authors in that field cite other documents in their reference lists. A first operationalization would simply be the average number of cited references in articles covering a field. But the SNIP methodology takes into account three additional factors.

- It counts only cited references that are *one to three years old.* In this way, raw impact per paper and citation potential relate to the same time window. This is appropriate, because the probability for a 1-3 year old article in a journal to be cited is proportional to the average number of 1-3 year old cited references contained in papers in the journal's subject field. If one would use the *total* number of cited references as the probability factor, journals in fields in which articles tend to have long reference lists and citations a low immediacy, such as taxonomy, would be disadvantaged.
- SNIP's measure of citation potential only takes into account cited references published in sources that are *indexed for the database (i.c., Scopus)*. For instance, citations to books are not included. To the extent that journal metrics is used to assess journals indexed for a database, it is appropriate to count only cited references actually published in indexed journals. In this way, one corrects for differences in database coverage across research fields. If not, the citation impact of indexed journals in fields in which database coverage is not as high as it is in (bio-)medical and physical sciences, such as mathematics, engineering, social sciences and humanities, would be systematically undervalued.
- Citation potential is itself normalized by calculating a *relative* database potential. In a first step citation potential is calculated for all journals in the database. Next, the *median* journal in terms of citation potential is identified, and the value of its citation potential is used as a normalization factor, by dividing the citation potential of each journal by that of the median journal. Hence, journals for which the subject field shows a citation potential above that for the median journal in the database have a relative citation potential above one.

General features

Comparing a journal's SNIP with its raw impact per paper, – which in its turn is to some extent similar to the Thomson impact factor – , the following features can be noted.

- If a journal covers a subject field in which the citation potential is higher than that for the median journal in the database (in other words, the relative citation potential is above one), its SNIP value is lower than that of its raw impact per paper. For instance, for journals in the field of molecular biology SNIP tends to be lower than the raw impact per paper.
- On the other hand, for journals in subject fields in which citation potentials are lower than that for the median journal, the SNIP value exceeds that of the raw impact per paper. For example, for journals in the field of mathematics SNIP tends to be higher than the raw impact per paper.
- SNIP is constructed in such a way that by definition for 50 per cent of journals SNIP is higher than the raw impact per paper, while for another 50 per cent it is lower. In other words, taking the raw impact per paper as the norm, and characterizing SNIP, 50 per cent of journals goes up, and another 50 per cent goes down.

Selected outcomes

Examples of individual journals

Table 1 presents outcomes for selected journals. Data relate to the citing year 2007. The first journal, *Journal of Electronic Materials*, is the *median* journal in the database in terms of database potential. Therefore, the relative database potential of the subject field covered by this journal is 1.0. Outcomes of the next two journals, *Inventiones Mathematicae* and *Molecular Cell* illustrate the SNIP methodology quite clearly. The raw impact per paper of the latter journal is almost nine times that of the former (13.0 against 1.5), but the SNIP values are statistically similar (4.0 versus 3.8), as the citation potential of the molecular biological journal is 8 times that of the mathematical periodical (3.2 versus 0.4).

Table 1. SNIP values for specific journals

Journal	***Raw Impact per Paper***	***Relative Citation Potential***	***SNIP***
Journal of Electronic Materials	1.5	1.0	1.5
Inventiones Mathematicae	1.5	0.4	3.8
Molecular Cell	13.0	3.2	4.0
Journal of Gerontology A – Biological and Medical Sciences	3.7	2.0	1.8
Journal of Gerontology B – Psychology and Social Sciences	2.7	1.2	2.3
Journal of Molecular Spectroscopy	1.1	1.0	1.1
Nanoparticle Research	2.3	1.9	1.2

The second case relates to the sections of the *Journal of Gerontology*. The raw impact per paper of the section on biological and medical sciences is higher than that of the psychology and social sciences section, but for the SNIP values it is the other way around. Finally, the case of two journals in the field of atomic and molecular physics shows that the more topical journal *Nanoparticles Research* has a raw impact per paper that is about twice that of the more general *Journal of Molecular Spectroscopy*, but if one corrects for differences in citation potential between the subject fields covered by these two journals, SNIP values are almost identical.

Comparisons between SNIP and two other journal metrics

All Scopus journals were categorized into 5 main fields: engineering & computer science, health sciences, life sciences, physical sciences and social sciences (including humanities). Within each main field, journals were distributed among quartiles on the bases of their SNIP and RIP values, respectively. RIP is the abbreviation of the raw impact per paper, a metric that is statistically similar to the Thompson-ISI journal impact factor. Figure 2 compares the two distributions one with another. This figure shows for instance that about 6 per cent of journals is positioned in the SNIP top quartile – i.e., is among the 25 per cent of journals with the highest SNIP value within their main field -, but *not* in RIP top quartile. It follows that about 25 per cent of journals in the top SNIP quartile are *not* in the RIP top quartile. Summing up the percentages for each non-diagonal cell in Figure 2, a general conclusion is that 31 per cent of journals are in different quartiles. Comparing in the same way SNIP with SJR, a journal metric calculated by SCImago Journal Rank (SCImago, 2010), it was found that 45 per cent of journals are in different quartiles.

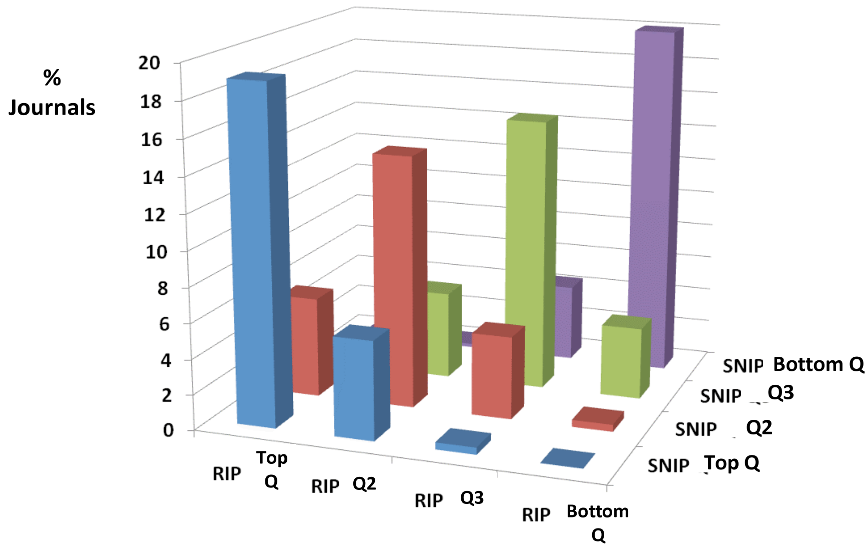

Figure 2. SNIP compared to RIP

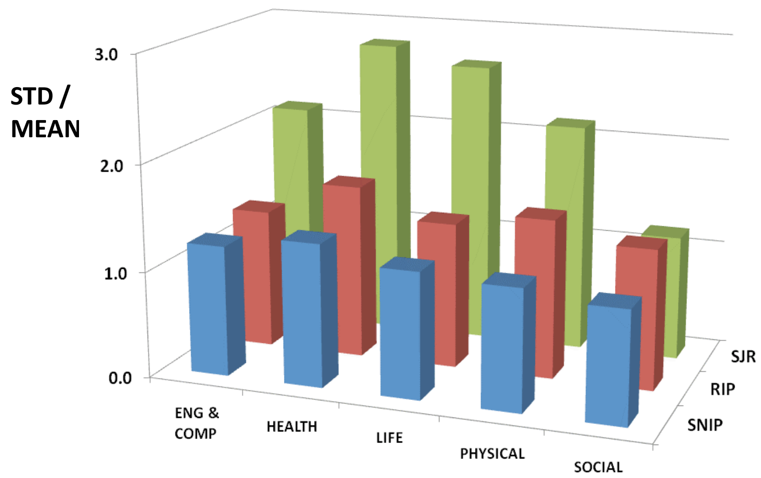

Figure 3. Variability in SNIP, RIP and SJR

Figure 3 directly compares SNIP, RIP and SJR. It plots for each of the five main fields listed above the ratio of the standard deviation and the mean value calculated for each of the three journal metrics. This figure shows that, compared to RIP, SJR enlarges and SNIP reduces the variability among journals. In other words, *within* each main field, SJR makes the differences among journal journals *larger*, whereas SNIP makes them *smaller*. It was found that this conclusion also holds for differences *between* main fields.

Beyond SNIP

As from January 2010 SNIP is included in Scopus, jointly with the SJR Indicator developed by the Scimago Research Group (González-Pereira, Guerrero-Bote and Moya-Anegón, 2009). SNIP and a series of related indicators are for all Scopus journals and for the past ten years freely available a website created and hosted by CWTS (CWTS, 2010a). Although it must be underlined that there is no such thing as a single 'perfect' indicator of journal performance, responses from the user communities and more research on the SNIP methodology will further assess and enhance SNIP's validity and usefulness. In this way, a next step is made along a trajectory that started with Eugene Garfield's invention and creation of the Science Citation Index, and the publication of his groundbreaking studies of the system of scientific-scholarly communication.

The article introducing the SNIP indicator (Moed, 2010) gives a list of what the author believes to be strong points of SNIP, a list of issues that should be taken into account when interpreting SNIP values, and problems that have to be further analyzed. These points are not repeated here in detail. Summarizing, strong points of the SNIP methodology are as follows. The delimitation of a journal's subject field does not depend upon some pre-defined categorization of journals into subject categories; it allows a sensible calculation of journal impact of multi-disciplinary or general journals; it corrects for differences in citation frequency and immediacy and in database coverage, between journals not only from different disciplines, but also within a discipline; and it aims at taking into account only peer reviewed articles.

In the light of these strong points of SNIP, this indicator is especially useful in social sciences and humanities, fields of which the large journal-based citation indexes cover only a relatively small part of the publication output, and in which the number of cited references to journal articles is low as well (see Moed, 2005, p. 126 a.f. for more information). SNIP explicitly takes these two factors into account. However, the effect of the inclusion of books – and their cited references – as sources in the database upon the SNIP values of indexed journals, awaits further research. Important points to keep in mind are that SNIP values tend to be higher for journals publishing review articles or showing a high journal self citation rate. Moreover, the source normalization applied in SNIP takes into account the growth of the literature in a field, or the extent to which papers in a field are cited from other fields, only to the extent that these factors are reflected in the citation potential in journals' subject fields.

It must be noted that, although SNIP corrects for differences in citation and database characteristics between subject fields, and in this way makes metrics of journals from different fields more comparable one with another, it does *not* follow that *journals from different fields with the same SNIP value* have equal performance or quality. From a viewpoint that reaches beyond that of an individual subject field, but rather evaluates an entire discipline or even science as a whole, differences may exist among subject fields with respect to their importance or quality; some fields may be more mature than others; some may be emerging or rising, and others declining. Such differences have to be taken into account when assessing the performance of journals from different subject fields, even though in the assessment of journal performance of periodicals across a range of fields, as a first approximation, SNIP is much more appropriate than un-weighted metrics are.

An issue deserving special interest is that more sophisticated *methods to define subject fields* using citation analysis could be explored. In the SNIP methodology a journal's subject field is straightforwardly defined as the total collection of papers citing that journal. This set can be labelled as a 'first order' set. Still using citation analysis, one could explore ways to *expand* a subject field, for instance, with all papers citing with a frequency above a certain threshold the articles in the first order set, or, alternatively, with all papers citing the same papers as those cited by the articles published in the journal (but discarding those that are already in the first order set). By expanding the set in an iterative process, one could develop an index of proximity in terms of citation links between an article in the journal's subfield and the papers published in the journal itself, and examine how the numerical values of the indicator vary as a function of citation proximity.

In order to examine possible *biases due to the definition of a subfield using citation links*, one could define a journal's subfield also on the basis of an analysis of cognitive/semantic terms (specifically, noun phrases) in the title, abstract or even full text of papers. A journal's subfield could then be defined as the set of articles showing a certain degree of similarity in used terms (noun phrases) with those included in the papers published in that journal. A first analysis could focus on paper titles and abstracts only. How do the sets generated with the two methodologies compare one with another in terms of overlap; how sensitive are the outcomes to changes in the methodology; and can differences be explained in terms of citation biases? The outcomes of this research would also be useful for the further development and validation of journal subject classification systems in large databases such as Scopus.

This paper explored the potentialities of source normalization in the construction of indicators of *journal performance*. An important next step would be to examine the use of this concept in the development of bibliometric indicators of *institutional research performance* at the level of individual scientists, research groups, departments and entire institutions. It needs emphasizing that in a classical, target or cited-side normalization approach, correcting for differences in citation practices among research fields was only possible by using the *citation-per-publication ratio* as a primary indicator, and comparing a group's ratio with that calculated for all papers published worldwide in the subfields in which that group was active.

But the use of citation-per-publication ratios – field normalised or not – has its limitations, regardless of whether one calculates "averages of ratios" or "ratios of averages" (Leydesdorff & Opthof, 2010; Waltman et al., 2011). Apart from relating citation impact to the size of a unit of assessment's publication oeuvre, and calculating an *average impact per paper*, users in the research and policy domain have expressed the need to obtain an indicator properly measuring the citation impact of a *publication oeuvre as a whole*. (e.g., Moed et al., 1985, p.142; Moed, 2005, p. 304). The total, 'raw' number of citations to a publication oeuvre is not an appropriate indicator as it is affected by differences in citation practices among fields. But source normalization provides the possibility to calculate an indicator of 'total' oeuvre impact that properly takes into account such differences, without calculating citation-per-publication ratios. It could even be used to construct a field-(source-) normalized variant of the Hirsch Index (Hirsch, 2005).

One final, technical comment should be made at this point. As outlined above, the SNIP methodology applies a type of *database normalization* in such a way that, in terms of SNIP values compared to the raw impact per paper (RIP), 50 per cent of journals goes up, and another 50 per cent goes down. This is intentional, and reflects the close link the SNIP concept has with the original journal impact factor developed by Eugene Garfield – still the norm in the world of journal metrics. It is not necessarily so that a source normalized oeuvre impact (***SNOI***) should apply the same type of normalization across the database. After all, in institutional research assessment there does not seem to be a norm as influential as there is in journal performance measurement.

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