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10 years of research impact: top cited papers in Scopus 2001-2011

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Section 1: Behind the data

10 years of research impact: top cited papers in Scopus 2001-2011

Dr. Gali Halevi and Dr. Henk F. Moed

Scopus is celebrating 10 years since its launch. As the largest abstract and citation database of peer-reviewed literature available today, [Scopus](#) boasts 53 million records, 21,915 titles from 5,000 publishers. In this paper we aimed to identify some of the top cited papers indexed in Scopus across various disciplines between 2001 and 2011. In addition, we contacted the authors of these papers to seek their insight about why they think their papers are as highly cited as they are.

In order to achieve this, we conducted a comprehensive search on all Scopus data, limiting the results to articles published between 2001 and 2011. Scopus is the largest abstract and citation database of peer-reviewed literature, and features smart tools to track, analyze and visualize research. The initial search results yielded more than 13 million records (as of June 11, 2014). This set was further refined, to include only full research articles while excluding reviews, editorials or book chapters. The search results were then limited to one of Scopus' 26 subject categories at a time (see [Table 1](#) for full list). Each set of articles under a subject category was sorted by "cited by" counts (i.e. citations), which enables the highly cited articles to be identified.

In the first stage, we selected the top 5 articles most cited in each category. These articles were manually examined to ensure that they are indeed associated with the correct subject area. In cases where one article was associated with more than one subject area, we made an informed decision as to which subject area to assign it, based on both the article content (mainly retrieved from its title and abstract) and whether the journal is best associated with one subject area. In cases where we found the same top cited article for more than one discipline, the most cited article unique to that subject area was used. The same was done, if, regardless of our initial limitation, the top cited article was a review or a type of methodological paper.

In this paper we review the following 8 subject areas and their top cited articles:

- Agricultural and Biological Sciences
- Arts and Humanities
- Computer Science
- Chemical Engineering
- Energy
- Engineering
- Environmental Science
- Medicine

Agricultural and Biological Sciences

The top cited article in Agricultural and Biological Sciences in 2001 - 2011 is: Tamura, K., Dudley, J., Nei, M., Kumar, S. [MEGA4: Molecular Evolutionary Genetics Analysis \(MEGA\) software version 4.0](#) (2007) *Molecular Biology and Evolution*, Vol. 24, No. 8, pp. 1596-1599. Cited 17,359 times (as of June, 2014)

Description: MEGA [[Molecular Evolutionary Genetics Analysis](#)] is a freely available software tool for conducting statistical analysis of molecular evolution and for constructing [phylogenetic trees](#). MEGA is used by biologists in a large number of laboratories for reconstructing the evolutionary histories of species and inferring the extent and nature of the selective forces shaping the evolution of genes and species (1). This software was first developed by Sudhir Kumar and Koichiro Tamura in the laboratory of [Dr. Masatoshi Nei](#) (2). The first version of this software was released in 1993. As expected, the main disciplines citing this article are Agricultural and Biological Sciences, Biochemistry, Genetics and Molecular Biology, Immunology, Medicine and Veterinary Sciences. However, there are several interesting disciplines citing this software including Social Sciences, Arts and Humanities and Business, which may not seem directly related to the core research field of this software. A closer look at these citing disciplines reveals that the software has been used to track Ancient DNA in Anthropology and Archeology and to sketch the markup of civilization (3, 4) as well as study the phenomenon of the emergence and extinction of languages (5).

Comments from Prof. Kumar:

This article described a useful software tool that enables comparative analysis of DNA and protein sequences from different individuals, strains, and species. Such analyses are becoming very important in this age of genomics, and increasingly larger numbers of scientists are using MEGA software to analyze their data.

Comments from Prof. Nei:

MEGA4 is the fourth version of the MEGA, and in this version a new Maximum Composite Likelihood method of estimating evolutionary distances and other evolutionary parameters have been introduced. It has also been made usable in Linux and Intel-based Macintosh computers. Because of these new features, the MEGA4 article has been cited a large number of times. This improvement of the software was done primarily by Koichiro Tamura and Sudhir Kumar. Further improvement of the software was published later in the [MEGA5 \(2011\)](#) and [MEGA6 \(2013\)](#) articles.

Arts & Humanities

The top cited article in Arts & Humanities in 2001 - 2011 is:

McCall, L.

[The complexity of intersectionality](#) (2005) Signs, Vol. 30, No. 3, pp. 1771-1800. This article was cited 640 times (as of July, 2014).

This article discusses the complexity of studying the issue of intersectionality and offers different methods to do so. Intersectionality (or intersectionalism) is the study of intersections between forms or systems of oppression, domination or discrimination (6). The article was written by [Leslie McCall](#), a professor at Northwestern University whose main areas of research include social inequality, economic and political sociology, methods, and social theory. This article is highly cited by research papers in Arts & Humanities and Social Sciences in the context of gender-related psychology, ethnic identity and feminism. Yet, it is also cited by Business and Management research focusing on women's careers in business (7), workplace diversity (8) and women's leadership skills development (9). Another interesting discipline citing this paper is Environmental Sciences, which refers to it in the context of gender-related client change adaptation (10) and gender migration patterns (11), to name two examples.

Comments from Dr. McCall:

I believe [the high citation count] has to do with interdisciplinary interest in the issue of intersectionality across a wide range of fields. I try to extend the usefulness of the concept for quantitative as well as qualitative research. The latter tends to dominate the study of intersectionality, so this article has helped justify research in more quantitatively oriented fields.

Energy

The top cited article in Energy in 2001 - 2011 is:

Allison, J., et.al.

[Geant4 developments and applications](#) (2006) IEEE Transactions on Nuclear Science, Vol. 53, No. 1, pp. 270-278. This article was cited 1,450 times (as of July 2014)

[Geant4](#) is a software tool developed by scientists from all over the world. The article boasts 44 authors from various countries including UK, USA, Japan, Switzerland, Italy, Spain and Russia to name a few. Geant4 is a software toolkit for the simulation of the passage of particles through matter. It is used for a large number of experiments and projects in a variety of application domains, including high energy physics, astrophysics and space science, medical physics and radiation protection (22). The article was mostly cited by articles in the field of Physics and Astronomy and Engineering. In addition, a large number of citations were received from the field of Medicine where the toolkit is used to track the effect of materials on the human body (23).

Comments from Prof. Asai:

"Geant4 developments and applications" is our second general publication followed by "Geant4 - A Simulation Toolkit", J.S. Agostinelli et al., Nuclear Instruments and Methods A, Vol. 506 (2003) 250-303. Geant4 is a software toolkit for simulating elementary particle passing through and interacting with matter. Its areas of application include high energy, nuclear and accelerator physics, as well as studies in medical science, space science and material science, which are rapidly expanding.

Chemical Engineering

The top cited article in Chemical Engineering in 2001 - 2011 is:

Kreuer, K.D.

[On the development of proton conducting polymer membranes for hydrogen and methanol fuel cells](#). (2001) Journal of Membrane Science, Vol. 185, No. 1, pp. 29-39. This article was cited 1,689 times (as of July 2014).

Proton conducting polymer membranes are of general interest because such membranes can be used to conduct protons in fuel cells, which convert, for example hydrogen or methanol into electrical energy and show promise as low emission power sources. So far, the benchmark membrane material was Nafion, a sulfonated tetrafluoroethylene based fluoropolymer-copolymer discovered in the late 1960s by Walther Grot of DuPont which is not only used in fuel cells, but also in other electrochemical devices, chlor-alkali production, metal-ion recovery, water electrolysis, plating, surface treatment of metals, batteries, sensors, Donnan dialysis cells, drug release, gas drying or humidification, and superacid catalysis for the production of fine chemicals (17). The paper actually reveals structure/property relationships for Nafion and alternative hydrocarbon ionomers, and it presents improved proton conducting polymer membranes (a/k/a polymer electrolyte membranes), along with methods for the manufacture thereof (16). The article even provided visions about membranes conducting protons in the absence of any humidification. Due to the wide range of applications and the need for better membranes, this article was found to be highly cited by Chemistry, Materials Science, Chemical Engineering and Energy.

Comment from Prof. Kreuer:

I am aware of the impact this paper has generated in the community. This is a pioneering work, making, for the first time, a semi-quantitative connection between morphology (microstructure) and transport (proton conductivity, water transport) of fuel cell membranes (hydrocarbon versus PFSA). The disclosed differences provide rationales for explaining many other properties. The materials are highly relevant for fuel cell and other electrochemical applications, and the paper provides clear guidelines for optimizing such materials.

Computer Science

The top cited article in Computer Science in 2001 - 2011 is:
Lowe, D.G.
[Distinctive image features from scale-invariant keypoints](#) (2004) International Journal of Computer Vision, Vol. 60, No. 2, pp. 91-110. This article was cited 15,797 times (as of July 2014).

The paper presents a method for extracting distinctive invariant features from images that can be used to perform reliable matching between different views of an object or scene by using object recognition algorithm. The algorithm was published by David Lowe in 1999. Applications of this algorithm include object recognition, robotic mapping and navigation, image stitching, 3D modeling, gesture recognition, video tracking, individual identification of wildlife and match moving. The algorithm is [patented in the US](#); the owner is the University of British Columbia (18). In addition to being highly cited in related disciplines such as Engineering and Mathematics, this article and the method described are also cited by Health, Decision and Social Sciences fields. In Health Sciences the method is used for organ imaging (19), while in Social Sciences it is used to track the processing and interpretation of visual images by humans, to give an example (20). Examining Decision Sciences in the context of this article, the method has been used to study decision processing based on visual recognition, such as street signs (21).

Comments from Prof. Lowe:

The reasons for the high citations include the fact that it describes a useful algorithm for other researchers in computer vision to match images in a way that wasn't available previously. In addition, the method is very efficient compared to previous approaches, so it is widely used in practice which leads to further citations.

Engineering

The top cited article in Engineering (focusing on Condensed Matter Physics) in 2001 - 2011 is:
Geim, A.K., Novoselov, K.S.
[The rise of graphene](#) (2007) Nature Materials, Vol. 6, No. 3, pp. 183-191. This article was cited 11,102 times (as of July 2014).

Graphene is pure carbon in the form of a very thin, nearly transparent sheet, one atom thick. It is remarkably strong for its very low weight (100 times stronger than steel) and it conducts heat and electricity with great efficiency. It was first produced in the lab in 2004 (24). This article discusses the nature and uses of Graphene and the emergence of a new paradigm of 'relativistic' condensed matter physics.

Citing articles are from a wide spectrum of sciences including Materials Sciences, Chemistry, Energy, Pharmacology, Computer Science and so forth, in all of which Graphene is used, studied and developed. Graphene is probably a good example of basic research leading to a technological innovation. Thus, examining citations to this article in Social Sciences, one notices that this article is cited by papers describing the global Graphene research front (25), patenting trends (26) and the use of Graphene in technological developments (27) to name a few.

Comment from Prof. Geim:

This paper should be viewed in combination with our paper "[Electric field in atomically thin carbon films](#)" (Science, 2004). Both are equally well cited as laying foundations for graphene research, a Nobel-prize winning subject.

Environmental Science

The top cited article in Environmental Science in 2001 - 2011 is:
Kolpin, D.W., Furlong, E.T., Meyer, M.T., Thurman, E.M., Zaugg, S.D., Barber, L.B., Buxton, H.T.
[Pharmaceuticals, hormones, and other organic wastewater contaminants in U.S. streams, 1999-2000: A national reconnaissance](#) (2002) Environmental Science and Technology, Vol. 36, No. 6, pp. 1202-121. This article was cited 3,279 times (as of July 2014).

The article was written by US Geological Survey researchers who utilized five newly developed analytical methods to measure concentrations of 95 OWCs (organic wastewater contaminants) in water samples from a network of 139 streams across 30 states during 1999 and 2000. This study represented the first national-scale investigation of pharmaceuticals and other OWCs in streams of the U.S. The results of the study demonstrate the prevalence of pharmaceuticals and other OWCs in U.S. streams and the importance of obtaining data on metabolites to fully understand not only the fate and transport of OWCs in the hydrologic system, but also their ultimate overall effect on human health and the environment. As it touches on a wide range of environmental issues, this article is cited by articles in Chemistry, Agriculture, Medicine, Earth Sciences and so forth. However, it is worth noting its citations in law and regulations articles which fall under Social Sciences (28) as well as Economy and Business related articles which look at policy issues related to OWCs (29).

Comments from Ms. Kolpin:

Yes, I was aware that our ES&T article from 2002 was being highly cited by the scientific community. In fact, this research was noted as the most frequently cited paper in the field of environmental science since 2010 and was prominently used in the article "Top-cited articles in environmental sciences: Merits and demerits of citation analysis" (Khan, M.A. and Ho, Y-S., *Sci. Total Environ.*, v. 431, p. 122-127).

There are probably multiple factors for the number of citations this paper has received, but I think the primary reason is that it has turned out to be a seminal paper on the occurrence of contaminants of emerging concern (CECs) in water resources and was the first national-scale study of such compounds conducted in the United States. If you look at the number of papers published annually on the topic of CECs you can see that since 2002 (the year our paper was published) there has been a continual and dramatic increase in the number of papers being published each year. This increasing trend in CEC papers published annually documents the ever increasing interest by the scientific community in the rapidly evolving topic of CECs. Thus, even though the percentage of papers citing our 2002 ES&T papers may be slowly decreasing with time, it is likely being offset by the total number of papers being published on the topic (keeping the number of citations for our 2002 paper at a healthy pace).

Medicine

The top cited article in Medicine in 2001 - 2011 is:

Rossouw, J.E., et.al.

[Risks and benefits of estrogen plus progestin in healthy postmenopausal women: Principal results from the women's health initiative randomized controlled trial](#)

(2002) *Journal of the American Medical Association*, Vol. 288, No. 3, pp. 321-333. This article was cited 9,723 times (as of July 2014).

The paper assesses the major health benefits and risks of the most commonly used combined hormone preparation estrogen plus progestin in the United States and found that the overall health risks exceeded benefits from use of combined hormone preparation. The study was conducted by a group of scientists from the Division of Women's Health Initiative at the National Heart, Lung/Blood Institute in the USA.

This article is seen to be cited in disciplines other than medicine-related ones, including Social Sciences and Arts & Humanities. Although the article reports on a specific experiment related to drug prescription and its effect on women's health, it evoked a wider discussion which is seen in studies relating to health policy, women psychology and narratives relating to menopause (30, 31).

Comments from Prof. Rossouw:

We are aware that this article was and continues to be highly cited. The findings overturned many decades of conventional wisdom, in particular that hormone therapy would prevent cardiovascular disease and that the benefits would outweigh the risks. As a result of this perception of benefit, menopausal hormone therapy was being prescribed to millions of women for chronic disease prevention in addition to its established role in treatment of vasomotor symptoms. After the contrary findings were published, prescriptions for estrogen plus progestin hormone therapy declined by 75% in the first 18 months and have continued to decline. Nationally, breast cancer rates have declined in parallel with hormone prescriptions. In short, the article had a substantial impact on medical practice and on public health.

Observations

It is noticeable that 4 out of the 10 articles featured here describe the development of computer software. The practice of citing computer software when used in a study is a part of this phenomenon. Regardless of the subject field, the computational tools developed and written about are highly cited. Out of the 10 selected articles, 6 are the result of a scientific collaboration between two or more researchers. Collaboration is seen across institutions and countries which could be a result of a common global concern to damaging phenomena related to the environment.

The analysis of citing disciplines shows that research, regardless of its disciplinary origin, crosses subject-specific domains and has impact on a wide range of areas, some of which are quite surprising. It is plausible that the growing ability of researchers to be exposed to and read a wider range of literature encourages the transfer of knowledge from one discipline to another.

Subject	Article	Link
Agricultural and Biological Sciences	MEGA4: Molecular Evolutionary Genetics Analysis (MEGA) software version 4.0	http://www.scopus.com/inward/record.url?eid=2-s2.0-54049133744&partnerID=40&md5=1d3cc2d08a900cac9195fc5449e6ff36
Arts and Humanities	The complexity of intersectionality	http://www.scopus.com/record/display.url?eid=2-s2.0-23944514914&origin=resultslist&sort=plf-f&cite=2-s2.0-23944514914&src=s&nlo=&nlr=&nls=&imp=f&sid=0F0EEB08EB8678DE6DA47EF4EB047038.10QkqbljGqgQLQ4Nw7dqZ4A%3a240&sof=cite&sdt=cl&cluster=scopubyr%2c%222014%22%2ct&sl=0
Biochemistry, Genetics and Molecular Biology	Analysis of relative gene expression data using real-time quantitative PCR and the 2- $\Delta\Delta$ CT method	http://www.scopus.com/inward/record.url?eid=2-s2.0-0035710746&partnerID=40&md5=1989d15012db1b7616667232e06bbf50
Business, Management and Accounting	User acceptance of information technology: Toward a unified view	http://www.scopus.com/inward/record.url?eid=2-s2.0-1542382496&partnerID=40&md5=c635d7fd45a06a546da8e8aed290c639
Chemical Engineering	Processable aqueous dispersions of graphene nanosheets	http://www.scopus.com/inward/record.url?eid=2-s2.0-38949108623&partnerID=40&md5=1f43c215908152f166755a05363f233c
Chemistry	UCSF Chimera - A visualization system for exploratory research and analysis	http://www.scopus.com/inward/record.url?eid=2-s2.0-4444221565&partnerID=40&md5=c9a4f4d426be1828e82f0f8e84537387
Computer Science	Distinctive image features from scale-invariant keypoints	http://www.scopus.com/inward/record.url?eid=2-s2.0-3042535216&partnerID=40&md5=28d20d21e532843d1243c5120505043a
Decision Sciences	To parcel or not to parcel: Exploring the question, weighing the merits	http://www.scopus.com/inward/record.url?eid=2-s2.0-0001378820&partnerID=40&md5=50b37bfa7ca10235aa008539bee136fb
Earth and Planetary Sciences	First-year Wilkinson Microwave Anisotropy Probe (WMAP) observations: Determination of cosmological parameters	http://www.scopus.com/inward/record.url?eid=2-s2.0-17044381941&partnerID=40&md5=36cf9cb4ba795948e7331117aa3096f2
Economics, Econometrics and Finance	Evolving to a New Dominant Logic for Marketing	http://www.scopus.com/inward/record.url?eid=2-s2.0-1642587247&partnerID=40&md5=12f7d97c9f3f71c84369a18c44c2220e
Energy	Geant4 developments and applications	http://www.scopus.com/inward/record.url?eid=2-s2.0-33645696556&partnerID=40&md5=a5da91aed48b47270d579a3170e32b4c
Engineering	The rise of graphene	http://www.scopus.com/inward/record.url?eid=2-s2.0-33847690144&partnerID=40&md5=e7a10d1aae647a18ece362fa0c639319

Table 1: Full List of Top Cited Articles in [Scopus](#) (Data Collected July 2014)

Subject	Article	Link
Environmental Science	Pharmaceuticals, hormones, and other organic wastewater contaminants in U.S. streams, 1999-2000: A national reconnaissance	http://www.scopus.com/inward/record.url?eid=2-s2.0-0037085574&partnerID=40&md5=f0076a6d031995fc6468f66c7f172916
Immunology and Microbiology	Improved prediction of signal peptides: SignalP 3.0	http://www.scopus.com/inward/record.url?eid=2-s2.0-3042521098&partnerID=40&md5=3e66f800ebc7630ff24f0b95467be33c
Materials Science	The SIESTA method for ab initio order-N materials simulation	http://www.scopus.com/inward/record.url?eid=2-s2.0-0037171091&partnerID=40&md5=521af3b42a3e8b8fc508c10c473d609b
Mathematics	A fast and elitist multiobjective genetic algorithm: NSGA-II	http://www.scopus.com/inward/record.url?eid=2-s2.0-0036530772&partnerID=40&md5=174c7328a283b2aaa5c3f7c2b7b900ae
Medicine	Risks and benefits of estrogen plus progestin in healthy postmenopausal women: Principal results from the women's health initiative randomized controlled trial	http://www.scopus.com/inward/record.url?eid=2-s2.0-0037125379&partnerID=40&md5=b20cf8258a09c26d78c48fc72cee6097
Neuroscience	Automated anatomical labeling of activations in SPM using a macroscopic anatomical parcellation of the MNI MRI single-subject brain	http://www.scopus.com/inward/record.url?eid=2-s2.0-0036322886&partnerID=40&md5=e0c279770e722b228efd25fbcd86edbf
Pharmacology, Toxicology and Pharmaceutics	Minimal criteria for defining multipotent mesenchymal stromal cells. The International Society for Cellular Therapy position statement	http://www.scopus.com/inward/record.url?eid=2-s2.0-33747713246&partnerID=40&md5=931d063ca5e127676440830aedb7c972
Physics and Astronomy	Statistical mechanics of complex networks	http://www.scopus.com/inward/record.url?eid=2-s2.0-0036013593&partnerID=40&md5=19a1f060a576b614317e1f93740253d5
Psychology	Using thematic analysis in psychology	http://www.scopus.com/inward/record.url?eid=2-s2.0-33750505977&partnerID=40&md5=949c9a8170016855a4e4f5179927fd43
Social Sciences	User acceptance of information technology: Toward a unified view	http://www.scopus.com/inward/record.url?eid=2-s2.0-1542382496&partnerID=40&md5=c635d7fd45a06a546dda8aead290c639
Veterinary	Reproductive Loss in high-producing dairy cattle: Where will it end (ADSA foundation scholar award)	http://www.scopus.com/inward/record.url?eid=2-s2.0-0035379705&partnerID=40&md5=a312e535e8e24cd87f608f5606ba4230
Dentistry	Stem cell properties of human dental pulp stem cells	http://www.scopus.com/inward/record.url?eid=2-s2.0-0036704390&partnerID=40&md5=06d9d6cefdf5303e46583a04134c30e0

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