



A Bibliographic Analysis of IEEE Intelligent Systems Publications

Zhuo Feng and Qingpeng Zhang, *University of Arizona*

Xin Li, *City University of Hong Kong*

Guanyan Ke, *National University of Defense Technology, China*

Gang Xiong, *Chinese Academy of Sciences*

It has been 25 years since *IEEE Intelligent Systems (IS)* published its first issue. Originally named *IEEE Expert*, the journal focused on the application of expert systems solving real problems in engineering, medicine, science, business, and so on.¹ At the end of 1997, its name changed to *IEEE Intelligent Systems and their Applications*, which was abbreviated to *IEEE Intelligent Systems* in 2001. After 25 years' development, *IS* has become the number one magazine in the AI field.²

In the past 25 years, *IS* experienced rapid progress. From 1986 to 1989, *IS* had four volumes per year. It then expended to six volumes per year. The impact factor of *IS* was 3.144 in 2009.² Its H index became 49 in 2010 (<http://apps.isiknowledge.com/CitationReport.do>).³ *IEEE* is becoming a high-impact venue where prestigious AI researchers publish their recent advances and explorations. To better understand the authors and studies in this magazine, we conducted a bibliographic study on its publications. Specifically we focus on the most productive and highly cited authors and institutions in *IS*, the authors and institutions

most cited in *IS*, and the journals and institutions that cited *IS* articles the most.

Data and Methodology

For this analysis, we collected *IS* publications from the Institute for Scientific Information (ISI) Web of Science, an online academic citation index provided by Thomson Reuters. Because ISI does not have *IS* articles published in 1986, we manually collected such information from the IEEE Xplore digital library. We also collected reference information and articles that cited *IS* articles from the ISI Web of Science. Our data set covers articles from 1986 (vol. 1, issue 1) to 2010 (vol. 25, issue 2).

IS does not just cover research articles. To investigate the academic collaborations between researchers, however, we focused on

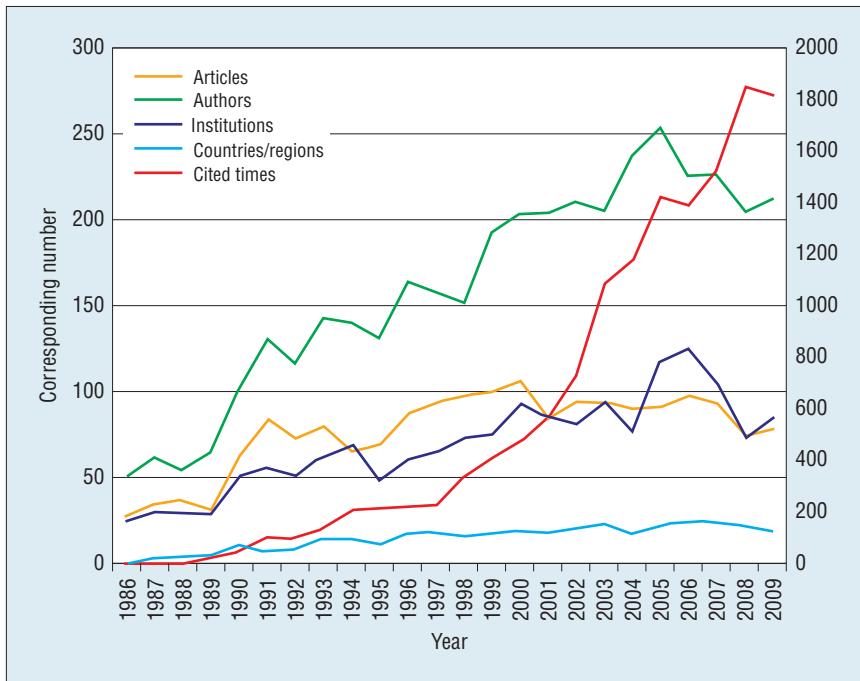


Figure 1. *IEEE Intelligent Systems* publication trends (1986–2009). The articles, authors, institutions, and countries and regions use the left axis, and the cited times uses the right axis.

research articles including academic articles, proceedings reprints, and special issue editorials. Other documents, such as news and EIC editorials, are opted out from our analyses. From 1986 to the middle of 2010, *IS* published 2,120 articles, which include 1,130 research articles, 779 editorials, 118 news items, and 37 letters. In our data set, we included 1,870 articles, made up of 1,130 research articles and 740 research-related editorials.

In this research, we try to indentify three things: the *IS* core, which are the most active authors and institutions in *IS*; the *IS* reference core, which are authors and institutions that *IS* authors most frequently cite; and the *IS* citing core, which are the journals and institutions that often cite *IS* articles.

We identified the authors by their last name, first initial, and affiliations. We made our best effort to clean the data set and align authors with same names. Institution information was also subjected to a similar manual verification process.

To measure the productivity of institutions and countries and regions, we used two measures: article count and adjusted productivity score (APS).⁴ The *article count* measures counts for all articles an author participated in. The APS credits $1/n$ to each author if an article is coauthored by n authors. To measure the impact of authors and institutions, we also took two measures: the *citation count* measure credits the citations to all authors, while the *adjusted citation score* (ACS) credits $1/n$ of the citation for each author if the article is coauthored by n authors.^{5,6} We also applied the H index to identify key authors and institutions.³ The H index presents the maximum number H for an author if he or she has H papers being cited at least H time(s). In this article, we only counted the number of articles published in *IS* and calculated their citations in the scope of the ISI Web of Science database. We also extended the H-index measure to institutions.

Publication Trends

In our data set, there are 3,232 authors and 921 institutions from 47 countries. In each year, there were on average 75 research articles published. Each article had on average 2.64 authors and 1.40 institutions.

Figure 1 shows the number of research articles, authors, institutions, countries and regions, and citations received per year for the articles in our data set. The number of articles increased significantly in 1990 when the number of volumes increased from four to six per year. The number of authors and institutions per year experienced a rapid increase until 2005 and 2006, respectively, and then became stable. During this period, *IS* was obtaining international recognition. The increase in the number of citations shows an exponential curve.

Figure 2 shows the percentage of major countries' contributions to *IS*, according to the APS measure. The top 10 countries are the US, China, England, Italy, Spain, Germany, the Netherlands, Greece, Canada, and Scotland. Although US authors have always been the most active contributors since the magazine's launch, its proportion shows a clear decreasing trend. Before 2000, more than 50 percent of the articles were from the US. Today they make up 20 to 30 percent. Accordingly, other countries' contributions have gradually increased. In the 21st century, China, which is now the second-largest article contributor to *IS*, shows a rapidly increasing trend. Chinese authors even published 15 percent of the articles in 2008.

England and Germany also show a continuous contribution to *IS*. In the 21st century, they generally contributed approximately 4 to 10 percent of the publications. Other top countries'

authors also contributed significantly in certain time periods, such as Spain in 2006–2008, the Netherlands in 2000 and 2009, Greece in 2009, and Canada in 1990, 1995, 2001, 2005, and 2009.

Figure 3 shows the ratio of citations attracted by different country's publications according to the ACS measure. The top 10 countries are the US, England, China, Spain, Italy, Czech Republic, Germany, France, Portugal, and Canada. Similarly to Figure 2, the US has always received the most citations among all countries, but its proportion is decreasing. From 1989 to 1990, US authors received more than 80 percent of the citations. In the 1990s, that figure decreased to 60 percent. By the 2000s, the percentage was less than 50 percent. Periodically, some countries received a higher portion of citations, such as Germany in 2001–2006 and England in 2004–2009. And some countries had a particular year with higher citations, such as Canada in 1989 and Spain in 2008.

IS Core

In our data set, on average each article was cited 8.2 times. Table 1 shows the top 10 highly cited articles in *IS*. These highly influential articles contain both review and tutorial articles such as “Semantic Web Services” and “What Are Ontologies, and Why Do We Need Them?” and new approaches such as “Feature Subset Selection Using a Genetic Algorithm” and “An Architecture-Based Approach to Self-Adaptive Software.” B. Chandrasekaran’s 1986 article “Generic Tasks in Knowledge-Based Reasoning: High-Level Building Blocks For Expert System Design” is also a highly cited article according to Google Scholar (739 Web citations). However, because the ISI database does not carry articles published in 1986, it is not directly shown in our analysis.

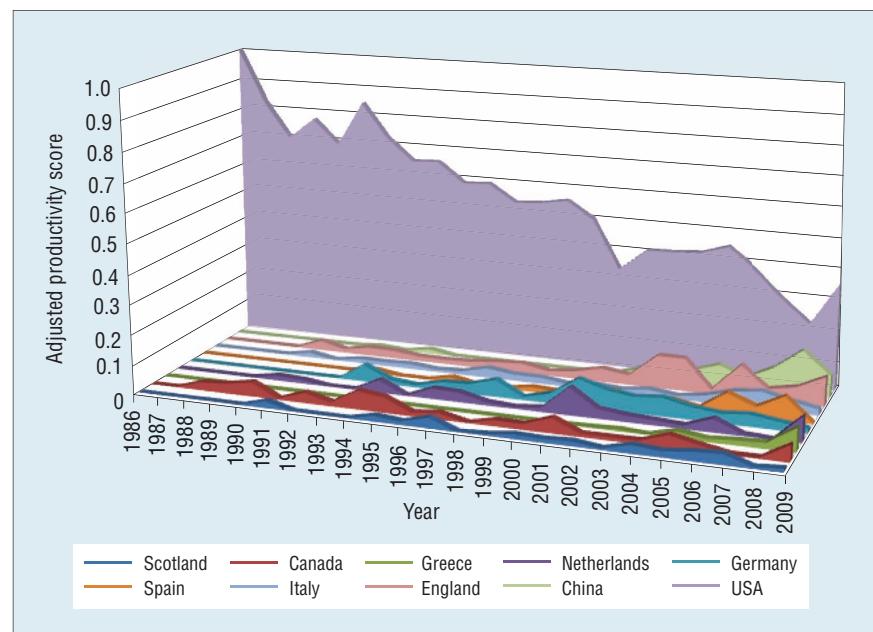


Figure 2. Publication ratio trends for top 10 countries by their adjusted productivity score (APS). While more than 50 percent of the articles were from the US before 2000, other countries such as China have more recently gained ground.

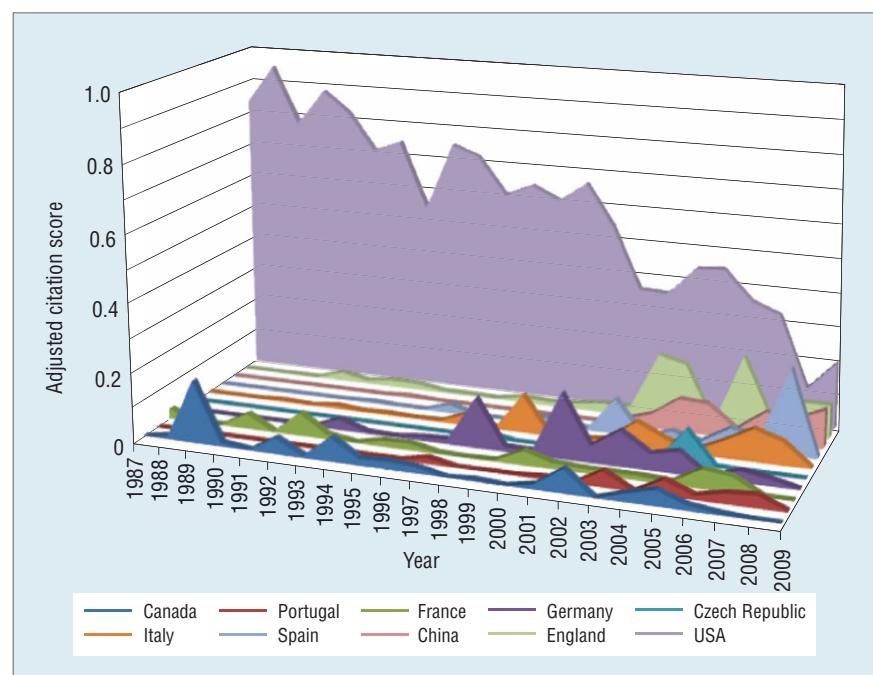


Figure 3. Citation ratio trends for the top 10 countries by adjusted citation score (ACS). Again, the US has traditionally received the most citations among all countries, but its proportion is decreasing.

Key Authors

We identified key *IS* authors by considering the impact of their publications.

Table 2 presents the most-cited authors in *IS*. There are two types of influential authors in *IS*. The first type—including

ANALYSIS

Table 1. Most cited articles in *IEEE Intelligent Systems*.

Title	Cites	Year published
“Semantic Web Services”	349	2001
“What Are Ontologies, and Why Do We Need Them?”	302	1999
“Feature Subset Selection Using a Genetic Algorithm”	193	1998
“An Architecture-Based Approach to Self-Adaptive Software”	155	1999
“Distributed Intelligent Agents”	153	1996
“Validating Expert System Performance”	144	1987
“Automatic Ontology-Based Knowledge Extraction from Web Documents”	86	2003
“Toward a Technology for Organizational Memories”	71	1998
“Using AI in Knowledge Management: Knowledge Bases and Ontologies”	70	1998
“Ontology Learning and its Automated Terminology Translation”	68	2003

Table 2. Most-cited authors in *IEEE Intelligent Systems*.

Rank	Author	Institution	Article counts	Cites	ACS*
1	J. Hendler	University of Maryland	21	489	353.7
2	S. Staab	University of Karlsruhe	12	405	230.2
3	M.A. Hearst	University of California, Berkeley	9	161	158.7
4	B. Chandrasekaran	Ohio State University	10	377	157.8
5	S.A. McIlraith	Stanford University	2	387	135.3
6	D.E. O’Leary	University of Southern California	15	151	134.3
7	T.C. Son	New Mexico State University	1	349	116.3
8	H.L. Zeng	Stanford University	1	349	116.3
9	J.R. Josephson	Ohio State University	4	335	111.1
10	V.R. Benjamins	University of Amsterdam	4	309	107.7

*Adjusted citation score

Table 3. Rank for H index of authors in *IEEE Intelligent Systems*.

Author	Institution	H index
F.-Y. Wang	Chinese Academy of Sciences, University of Arizona	9
J. Hendler	University of Maryland	8
S. Staab	University of Karlsruhe	7
R.R. Hoffman	Institute for Human and Machine Cognition	7
H.C. Chen	University of Arizona	6
G. Klein	ARA	6
D. Fensel	Free University of Amsterdam	5
M. A. Musen	Stanford University	5
D.L. McGuinness	Stanford University	5
B. Chandrasekaran	Ohio State University	5
W. Swartout	University of Southern California	5
D. Zeng	Chinese Academy of Sciences, University of Arizona	5
S.M. Tang	Chinese Academy of Sciences	5

J. Hendler, S. Staab, M.A. Hearst, B. Chandrasekaran, and D.E. O’Leary—are both productive and highly influential. The second type—including S.A. McIlraith, T.C. Son, H.L. Zeng, J.R. Josephson, and V.R. Benjamins—has relatively smaller article counts. S.A. McIlraith, T.C. Son, and H.L. Zeng coauthored the most-cited article “Semantic Web Services,” and B. Chandrasekaran, J.R. Josephson, and V.R. Benjamins published the second-most-cited article in *IS*: “What Are Ontologies, and Why Do We Need Them?” Eight of the highly cited authors are in the US, and the others are in Germany and the Netherlands.

Table 3 shows the H index for *IS* authors, which considers both numbers

Table 4. Most productive institutions in IEEE Intelligent Systems.

Rank	Institution	Counts	APS*
1	Carnegie Mellon University	85	55.2
2	Massachusetts Institute of Technology	59	44.4
3	University of Southern California	60	43.7
4	Stanford University	49	33.5
5	University of Maryland	47	32.3
6	University of Arizona	58	25.5
7	Ohio State University	25	19.4
8	IBM	23	18.6
9	University of Karlsruhe	22	18.0
10	NASA	30	17.6

*Adjusted productivity score

of publications in *IS* and the number of citations for those articles. Compared to Table 2, the authors who have only a small number of highly cited articles are excluded.

In short, J. Hendler, S. Staab, and B. Chandrasekaran are the highly cited authors with a top H index. They are considered the key authors for *IS* in this research.

Key Institutions

Table 4 shows the 10 most-productive institutions in *IS*. Carnegie Mellon University has the largest number of articles followed by the Massachusetts Institute of Technology (MIT), USC, and Stanford University. Nine of the 10 institutions are in the US. The other is in Germany (University of Karlsruhe). Most of these institutions have a high APS and counts ratio, which means most of the cooperation happened inside the institution.

Table 5 shows the most-cited institutions in *IS*, including nine universities and one research institution. Seven of the 10 institutions are in the US, and the other three are in Germany, England, and the Netherlands. There's a large overlap (eight) between the most-cited and most-productive universities and institutions.

Table 6 shows the H-index rank for institutions; we show the top 13 since the last five have the same index. Six of the top eight institutions are in the US and the other two are in England and China. Seven universities and institutions—Carnegie Mellon University, USC, MIT, Stanford University, University Maryland, University of Karlsruhe, and Ohio State University—are the leading institutions in this area and they appear in the lists of most-productive, most-cited, and high H-index institutions. There are only slight differences between the institutions' productivity, cites, and

Table 5. Most cited institutions.

Rank	Institution	Cites	ACS*
1	Stanford University	1,300	963.8
2	Carnegie Mellon University	1,240	555.5
3	University of Maryland	668	468.7
4	University of Southern California	717	400.5
5	University of Karlsruhe	455	390.7
6	University of Southampton	554	315.3
7	University of Amsterdam	525	308.3
8	Ohio State University	461	280.0
9	Massachusetts Institute of Technology	472	268.5
10	IBM	324	219.7

*Adjusted citation score

Table 6. Rank for H-index of Institutions in IEEE Intelligent Systems.

Institution	H index
Carnegie Mellon University	13
Stanford University	13
University of Southern California	12
Massachusetts Institute of Technology	12
University of Arizona	12
University of Maryland	10
University of Southampton	10
Chinese Academy of Sciences	9
University of Amsterdam	8
Free University of Amsterdam	8
University of Karlsruhe	8
University of Massachusetts	8
Ohio State University	8

Table 7. Most frequently cited articles by *IEEE Intelligent Systems* publications.

Title	Journal	Published year	Cited in IS
"The Semantic Web: A New Form of Web Content that Is Meaningful to Computers Will Unleash a Revolution of New Possibilities"	<i>Scientific American</i>	2001	23
"Generic Tasks in Knowledge-Based Reasoning: High-Level Building Blocks for Expert System Design"	<i>IEEE Expert</i>	1986	18
"Heuristic Classification* 1"	<i>Artificial Intelligence</i>	1985	14
"Induction of Decision Trees"	<i>Machine Learning</i>	1986	13
<i>Classification and Regression Trees</i>	Book	1984	13
"Qualitative Simulation"	<i>Artificial Intelligence</i>	1986	12
<i>Adaptation in Natural and Artificial Systems</i>	Book	1975	11
<i>Computer-Based Medical Consultations</i>	Book	1976	10
"A Robust Layered Control-System for a Mobile Robot"	<i>IEEE Journal of Robotics and Automation</i>	1986	10
"Truth Maintenance System"	<i>Artificial Intelligence</i>	1979	10

Table 8. Most-cited authors by *IEEE Intelligent Systems*.

Author	Institution	Cited article counts	Cited in IS
R.R. Hoffman	Institute for Human and Machine Cognition	47	87
B. Chandrasekaran	Ohio State University	35	72
F.-Y. Wang	Chinese Academy of Sciences, University of Arizona	34	58
J.R. Quinlan	Carnegie Mellon University	26	49
T. Berners-Lee	Massachusetts Institute of Technology	20	49
W.J. Clancey	Stanford University	21	46
G. Klein	ARA	32	46
J. De Kleer	Massachusetts Institute of Technology	23	42
A. Newell	University of Arizona	19	40
D.D. Woods	Ohio State University	21	33
R. Davis	Stanford University	22	33

H-index lists, which means productivity is closely correlated with influence at the institution level.

IS Reference Core

This section looks at the articles cited by *IS* articles. We want to identify the major prior studies, researchers, and institutions that benefited *IS* research.

Table 7 shows the most-frequently cited articles by *IS* publications. These articles are mainly methodological papers and books that presented new concepts or approaches. They are foundational contributions to expert systems and intelligent systems. For these 10 highly cited articles, three are book chapters and six

are from *Artificial Intelligence*, *IS*, *Machine Learning*, and the *IEEE Journal of Robotics and Automation*, which are the high-impact journals or magazines of the AI field.

Table 8 presents the most-cited authors by *IS* together with the number of articles that were cited. Given that R.R. Hoffman, B. Chandrasekaran, and F.-Y. Wang are productive *IS* authors, they also contributed significantly to the foundation of *IS*. Other authors are mainly cited because of their publications in other journals, such as J.R. Quinlan, T. Berners-Lee, and W.J. Clancey.

Table 9 presents the most-cited journals and magazines by *IS*. We

can identify six publications specialized on AI and machine learning, including *Artificial intelligence*, *IS*, *AI Magazine*, *Machine Learning*, *IEEE Transactions on Systems, Man, and Cybernetics* and the Lecture Notes on Artificial Intelligence. The others, including the Lecture Notes on Computer Science, *Communications of the ACM*, *Computer*, and *Science*, have a general coverage on computer science related topics.

IS Citing Core

Lastly, we inspect the citing core, which is research that follows or benefited from *IS*' studies. Table 11 shows the journals that frequently cite *IS* articles.

Table 9. Most-cited journals and magazines by IEEE Intelligent Systems.

Publication name	Cited article counts	Cited in IS
<i>Artificial Intelligence</i>	270	474
<i>IEEE Intelligent Systems</i>	257	375
<i>Lecture Notes on Computer Science</i>	212	234
<i>Communications of the ACM</i>	143	186
<i>AI Magazine</i>	100	147
<i>Machine Learning</i>	54	98
<i>Computer</i>	77	89
<i>Lecture Notes on Artificial Intelligence</i>	76	81
<i>Science</i>	56	67
<i>IEEE Transactions on Systems, Man, and Cybernetics</i>	50	59

There are three IEEE journals in Table 10, including *IS* itself. Five of the 10 journals and magazines are specialized on AI, including *Expert Systems with Applications*, *IS*, *AI Edam-Artificial Intelligence for Engineering Design Analysis and Manufacturing*, *Artificial Intelligence*, and *Applied Artificial Intelligence*. *Expert Systems with Applications* benefits from *IS* publications significantly; it has larger numbers than *IS* self-citations.

Table 11 shows institutions that frequently cited *IS* articles. The Chinese Academy of Sciences has 125 articles that cited *IS* articles 209 times, followed by Carnegie Mellon University and Nanyang Technology University. In Table 11, there are five institutions in the US, two in England, one in China, one in Singapore, and one in Germany. Carnegie Mellon University, USC, Stanford University, and University of Karlsruhe are also appeared in *IS*' list of core institutions.

This article analyzes the contributions of authors, institutions, and countries based on *IS*' article, reference and citation data. We identified that J. Hendler, S. Staab and B. Chandrasekaran as the core authors for *IS* who are both productive and influential. Carnegie Mellon University, USC, MIT, Stanford University, University Maryland, University of Karlsruhe, and Ohio State University are the magazine's core institutions. US authors have always been the most-active and most-cited contributors since *IS*' launch. *Artificial intelligence* is the most referred journal in *IS*, while *Expert Systems with Applications* cites *IS* most.

In future work, we will conduct social network analysis on *IS*' coauthorship network to study their collaboration patterns. □

Table 10. IEEE Intelligent Systems article citations in other journals.

Publication Name	Citing articles counts	Cites to IS
<i>Expert Systems with Applications</i>	277	405
<i>IEEE Intelligent Systems</i>	249	375
<i>IEEE Transactions on Knowledge and Data Engineering</i>	93	122
<i>AI Edam-Artificial Intelligence for Engineering Design Analysis and Manufacturing</i>	91	144
<i>Decision Support Systems</i>	76	104
<i>International Journal of Human-Computer Studies</i>	73	100
<i>Knowledge-Based Systems</i>	61	91
<i>Artificial Intelligence</i>	59	65
<i>IEEE Transactions on Systems Man and Cybernetics Part A-Systems and Humans</i>	58	74
<i>Applied Artificial Intelligence</i>	57	91

Table 11. Institutions that cited IEEE Intelligent Systems articles the most.

Institution	Citing articles counts	Cites to IS
Chinese Academy of Sciences	125	209
Carnegie Mellon University	99	124
Nanyang Technology University	91	111
University of Arizona	89	128
University of Southern California	81	118
University of Southampton	81	88
Stanford University	79	100
University of Texas	65	70
University of Manchester	63	82
Massachusetts Institute of Technology	62	91

Acknowledgments

We thank Fei-Yue Wang and Daniel Zeng for their advice and guidance in this research. This work is supported in part by

the National Natural Science Foundation of China through grants 70890084, 60921061, and 90924302 and by CityU StUp 7200170 and SRG 7002518.

THE AUTHORS

Zhuo Feng is a PhD student in the Department of Systems and Industrial Engineering at the University of Arizona. Contact him at feng@email.arizona.edu.

Qingpeng Zhang is a PhD student in the Department of Systems and Industrial Engineering at the University of Arizona. Contact him at qpzhang@email.arizona.edu.

Xin Li is an assistant professor in the Department of Information Systems at the City University of Hong Kong. Contact him at Xin.Li@cityu.edu.hk.

Guanyan Ke is a project manager in the College of Mechatronic Engineering and Automation at the National University of Defense Technology, China. Contact her at keguanyan@gmail.com.

Gang Xiong is a research scientist in the Institute of Automation at the Chinese Academy of Sciences. Contact him at xiong.gang@ia.ac.cn.

Authorship," *Social Studies of Science*, vol. 10, no. 2, 1980, pp. 145–162.

5. E. Garfield and R. Merton, *Citation Indexing: Its Theory and Application in Science, Technology, and Humanities*, Wiley, 1979.

6. R. Rubin, *Foundations of Library and Information Science*, Neal-Schuman Publishers, 1998.

References

1. D. Pessel, "From the Editor-in-Chief," *IEEE Expert*, vol. 1, no. 1, 1986, pp. 4–5.
2. F.Y. Wang, "IS: The #1 AI Publication," *IEEE Intelligent Systems*, vol. 25, no. 4, 2010, pp. 2–3.
3. P. Ball, "Index Aims for Fair Ranking of Scientists," *Nature*, vol. 436, no. 7053, 2005, p. 900.
4. D. Lindsey, "Production and Citation Measures in the Sociology of Science: The Problem of Multiple

CN Selected CS articles and columns are also available for free at <http://ComputingNow.computer.org>.

ADVERTISER INFORMATION • NOVEMBER/DECEMBER 2010

Advertising Personnel

Marian Anderson: Sr. Advertising Coordinator
Email: manderson@computer.org
Phone: +1 714 821 8380 | Fax: +1 714 821 4010

Sandy Brown: Sr. Business Development Mgr.
Email sbrown@computer.org
Phone: +1 714 821 8380 | Fax: +1 714 821 4010

IEEE Computer Society
10662 Los Vaqueros Circle
Los Alamitos, CA 90720
Phone: +714 821 8380
Fax: +714 821 4010
www.computer.org

Advertising Sales Representatives (display)

Western US/Pacific/Far East:
Eric Kincaid
Email: e.kincaid@computer.org
Phone: +1 214 673 3742
Fax: +1 888 886 8599

Eastern US/Europe/Middle East:
Ann & David Schissler
Email: a.schissler@computer.org, d.schissler@computer.org
Phone: +1 508 394 4026
Fax: +1 508 394 4926

Advertising Sales Representatives (classified line ad)

Greg Barbash
Email: g.barbash@computer.org
Phone: +1 914 944 0940

Advertising Sales Representatives (jobs board posting)

Greg Barbash
Email: g.barbash@computer.org
Phone: +1 914 944 0940