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## Measuring Research Contributions of Prof. Anurag Kumar: A Scientometric Analysis

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# Measuring Research Contributions of Prof. Anurag Kumar: A Scientometric Analysis

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## Abstract

The present study aims to measure the contributions of Prof. Anurag Kumar, who served as the Director at the Indian Institute of Science (IISc) in Bengaluru between August 2014 to July 2020. He has contributed 181 publications during his 36 years of career. He has published his majority of publications 171 (94.48%) in collaboration; most active collaborators with Prof. Anurag Kumar are Altman E. with (17) publications, Kuri Joy (15), Anand (14), and Singh (12). His highest Collaboration Coefficient found is 0.73 in 2013, and the highest Modified Collaboration Coefficient is 1.33 in the year 2018. The highest degree of collaboration observed for Prof. Anurag Kumar was 1.00. The highest Collaborative Index of Prof. Anurag found is 4.75 in the year 2016. His publications received 2595 citations so far, with 14.3 citations for each publication and an average citation of 72.08 per year. He has produced most of his publications in the field of computer science (45.9%). He preferred conference papers as his communication channel, where he published 100 (55.24%) papers out of 181. Prof. Anurag Kumar has contributed the highest (62) publication between 2005-2010, and he has published his first publication at the age of 30.

**Keywords:** Anurag Kumar; Scientometric portrait; Scientometrics; Publication productivity; Authorship status; Authorship pattern; Research collaboration; Citation studies; Bibliometrics.

## **Introduction**

A scientometric portrait is a technique to document an eminent researcher (Vellaichamy and Amsan, 2016). A Scientometric portrait will deal with both qualitative (channels of communications) and quantitative (number of publications) productivity (Hazarika, Sarma, and Sen; 2010). Kalyane and Kalyane (1993) used the term 'Scientometric Portrait' for the first time in 1993 in their article entitled 'Scientometric Portrait of Vinodini Reddy', similarly Kalyane and Samanta (1994) also used the term Informetrics for measuring individuals research. Sen and Gan (1990) used the term 'Bio-bibliometrics, it is also deal with an individual publication, field of the research, and a subject. It will establish a functional relation between bio-data of an individual and his biblio-data (Kumar, Ruhela and Kumar; 2018). A scientometric portrait includes mathematical and statistical techniques to analyze a pattern of the publication's, preferences, collaboration and chronological distribution of publications (Qayyum and Naseer; 2013). The present study attempted to measure productivity, collaboration and authorship patterns of Prof. Anurag Kumar, the former Director of the Indian Institute of Science (IISc), Bengaluru.

For the present Scientometric analysis, Prof. Anurag Kumar has been taken as a case study. This study highlights Prof. Anurag Kumar's year wise publications and productivity; Biological & publishing career age; Authorship pattern; Collaborative research; Value of collaboration coefficient, collaboration index, degree of collaboration; Preferred channels of communication; Citations received and analysis; Publications country; Impact factor of top publications; FWCI of top-cited publications and top keywords. The study's primary purpose on individual researchers, especially on Prof. Anurag Kumar, is to encourage and be taken as a role model for the younger researchers, faculty members, and engineers in the field.

## **Bio sketch of Prof. Anurag Kumar**

Prof. Anurag Kumar is a well-known scientist in communication networks and the former Director of the Indian Institute of Science, Bengaluru. He has an outstanding academic record and secured the first place during his B.Tech Degree in Electrical Engineering from the Indian Institute of Technology Kanpur and awarded with the President of India's Gold Medal in 1977. Prof. Anurag Kumar has completed a PhD from Cornell University, under the guidance of Prof. T.L. Fine in 1981, and has been a member of the technical staff at AT&T Bell Labs, Holmdel, N.J. He focused on the performance analysis of computer systems, communication networks, and manufacturing systems during this time. In 1988, Prof. Anurag Kumar returned to India, since then as a faculty member of Department of Electrical Communication Engineering

(ECE), and has been with the Indian Institute of Science (IISc), Bangalore. In 1996, he became a professor. Prof. Anurag Kumar was Associate Chairman of the ECE Department from 2000 to 2004, Chairman of the ECE Department from 2004 to 2007, Chairman of the Electrical Sciences Division from 2007 to 2014, and Director of the IISc from August 2014 to July 2020. He is an Honorary Professor in the Department of ECE after superannuated from the director position at IISc.

During 1988 when the telecommunications revolution began in the country, and the internet was just an embryonic network. He was the coordinator of the National Education and Research Network (ERNET) at IISc, a joint national programme of the UNDP and the Government of India that developed India's first country-wide packet communication network.

He has several awards in his credit. He had received the S.V.C. Aiya Memorial Award from IETE Pune in 2001, IISc Alumni Award for Excellence in Engineering Research award in 2008, CDAC-ACCS Foundation Award (Advanced Computer & Communications Society) in 2009, VASVIK Award for Information Technology. From Systems Society of India award in 2015, Lifetime Achievement Award, in 2016. He has received 'Best Paper Award' for more than 08 papers.

Since 1992, he is elected Fellow of the Institute of Electronics and Telecommunication Engineers (IETE), India (FIETE); Since 1999, Fellow of the Indian National Academy of Engineering (FNAE); Since 2010, he is Fellow of the Indian Academy of Science (FASc); Since 2013, Fellow of The World Academy of Sciences (TWAS); Since 2005, Fellow of the Indian National Science Academy (FNA); Since 2005, he is the Fellow of the Institute of Electrical and Electronics Engineers. He is a recipient of the J.C. Bose National Fellowship, awarded by the Department of Science Technology, for the period from 2011-2021. During the period 2005-2009, he was an area editor for the IEEE/ACM Transactions on Networking and was then on its steering committee from 2010-2014.

He has published 181 peer-reviewed papers in journals and conferences in communications networking and distributed systems. Prof. Anurag Kumar has led the authorship of two primary textbooks on communication networking that have been used around the world. He guided 22 PhDs, 5 MSc. (Engineering) and over 50 ME projects.

During his tenure, he introduced initiatives to modernize IISc's administration and infrastructure, Division of Interdisciplinary Research, DIGITS, Office of Development and Alumni Affairs (ODAA, improve faculty recruitment, increase support from non-government sources, and enhance IISc's visibility abroad. In 2018, IISc was also recognized as an

Institution of Eminence (IoE) by the Government of India. His vision was to make IISc among the top 50 Institutions for higher education and research in the world.

## **Materials and Methods**

Scopus, an Elsevier's abstract and citation database, has been used to obtain the data for the present study. The data extracted by using the author name "Kumar, Anurag" and "Indian Institute of Science" as an affiliation with data freeze as of 10<sup>th</sup> July 2020 to avoid changes in the data due to daily updates in the database by Scopus. Authorship period (36 years) of Prof. Anurag Kumar, i.e., 1985-2020 was selected and obtained 181 records from Scopus. Besides, the present study also used SciVal database a web-based analytics solution by Elsevier to analyze FWCI for highly cited publications, Journal Citation Reports (JCR), an annual publication published by Clarivate Analytics available through Web of Science (WoS), and Google Scholar. VOSviewer has been used to visualizing bibliometric networks of search results.

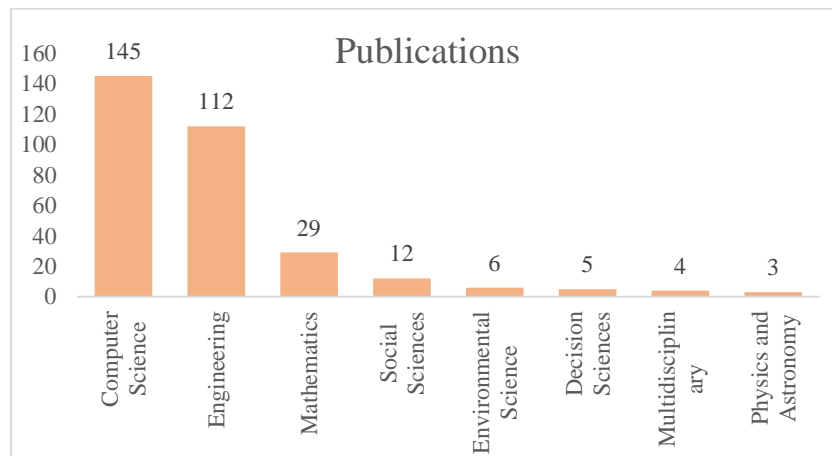
The present study of 'Single Author' measure the research output of Prof. Anurag Kumar and analysis the parameters such as year of publication, document types, the pattern of authorship and amount of research in collaboration with co-authors from different countries, productivity by actual and publishing age, channels of communication, journals and their country of publication and impact factor (IF), prolific authors, citation pattern and analysis. The statistical data retrieved from the database was put to the spreadsheet to analyze quantitative and inferential methods. The data calculated and represented in the format of the tables. Data analyzed using various Scinetometric indices, including the Collaboration Index (CI), Degree of Collaboration (DC), Collaboration Coefficient (CC), Modified Collaboration Coefficient, Multi Authorship Index (MAI), Relative Citation Impact (RCI), Relative Uncited Index (RUI).

## **Results**

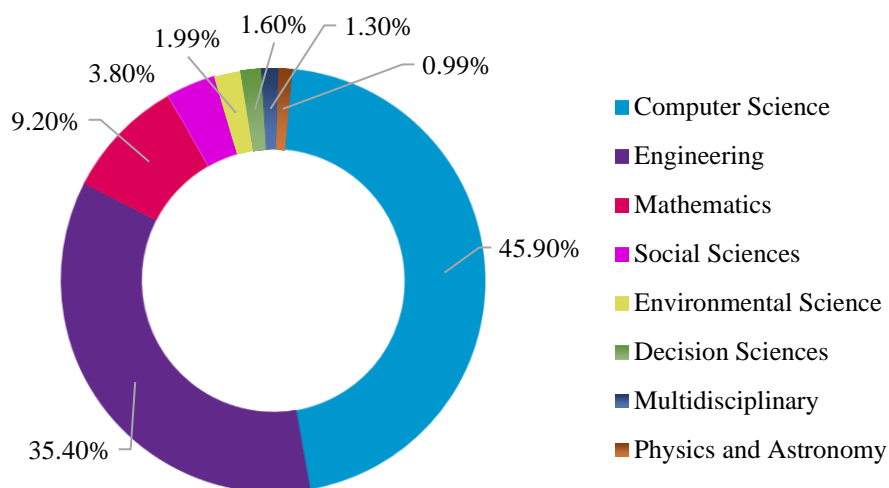
### **Domain-wise contributions**

Prof. Anurag Kumar has contributed his research publications in the following domains A = Computer Science, B = Engineering, C = Mathematics, D = Social Sciences, E = Environmental Science, F = Decision Sciences, G = Multidisciplinary, and H = Physics and Astronomy. He has contributed the highest publications (45.9%) in computer science, followed by engineering (35.4%), mathematics (9.2%), social sciences (3.8%). (Figure-1 and 2)

**Figure-1: Publications by Research Area**



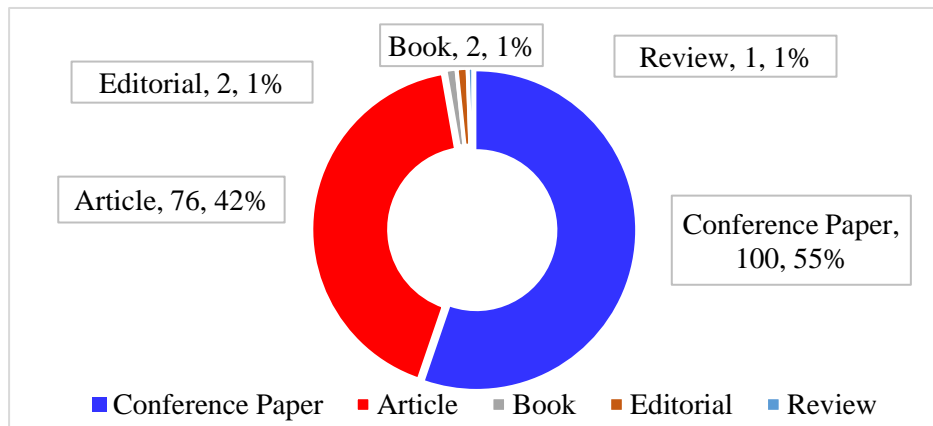
**Figure-02: Percentage-wise Publications by Research Area**



**Document Types**

Prof. Anurag Kumar has published 181 publications (Figure-3), including conference papers, articles, books, editorial, and reviews. He has contributed the highest conference papers 100 among his contribution, which alone shares 55.24% of the total publications, followed by articles 76 (42%), books 2 (1.11%), editorials 2 (1.11%), and review 1 (0.54%). Of the total publications, 6 (3.32%) papers published as open access, and 175 (96.68%) are closed access publications. The Figure-3 indicates that Prof. Anurag Kumar has contributed more through his conference papers.

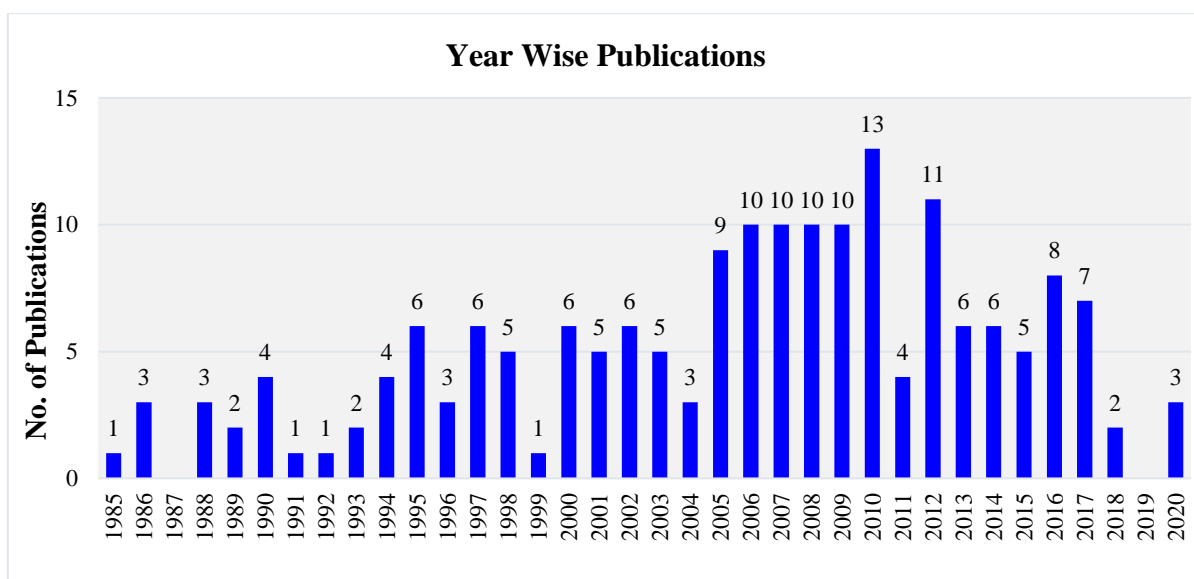
**Figure-03: Document types**



**The productivity of Prof. Anurag Kumar**

Figure-4 presents the year wise contributions by Prof. Anurag Kumar in the chronological period. During the year from 2005-2020, in 16 years, he has contributed 114 (62.98%) papers with an average of 7 papers per year. His highest productivity year was 2010, with 13 publications, followed by the second highest with 11 publications in 2012. He did not publish any paper in the years 1987 and 2019. Figure-04 implies that during the period of his directorship at IISc from August 2014 to July 2020 for seven years that also under tremendous administrative pressure, Prof. Anurag Kumar has produced 31 publications that shows his dedication and commitment towards his research.

**Figure-04: Year-wise Productivity by Prof. Anurag Kumar**



## Authorship Pattern of Prof. Anurag Kumar in Chronological Order

Table-1 depicts the authorship pattern of Prof. Anurag Kumar; he has started his authorship by publishing his first paper at the age of 30 (publishing career age 1) in the year 1985. Nearly all of his 181 publications have published on international communication channels and only one in the Indian journal, namely *Sadhana*. He has contributed 10 (5.52%) publications without any collaboration during his productivity career. The remaining 171 (94.48%) are the results of the collaboration. A 74 (40.88%) are collaborated with two authors, followed by 53 (29.28%) three, 27 (14.91%) four, 3 (1.65%) five, 7 (3.86%) six, 3 (1.65%) seven, 3 (1.65%) eight, and 1 (0.55%) are in collaboration with more than nine collaborators. He has the highest number of collaborative publications 13 (7.18%), in 2010. Year-wise Number of single-authored and multi-authored publications have been calculated for each year, and it found that there are no multi-authored publications published during 1989 and 1992. The citation trends can be seen between the years 2005-2010. In six years, 1325 citations marked, which alone share 51.05% of the total citations. He has received the highest citations 328 (12.63%) for his publications published in 2007 and followed by the second highest 312 (12.02%) citations to the publications published in the year 2008.

Multi Authorship Index (MAI) by Viswanathan V., Elango, B., Yugapriya, S. (2019) value ranges between 0.71 and 1.06 during 1985-2020. Data in Table-1 reveals that Prof. Anurag Kumar has many single-authored publications, but he has preferred collaborative authorship.

**Table-1: Authorship Pattern and Multi-Author Index of Prof. Anurag Kumar**

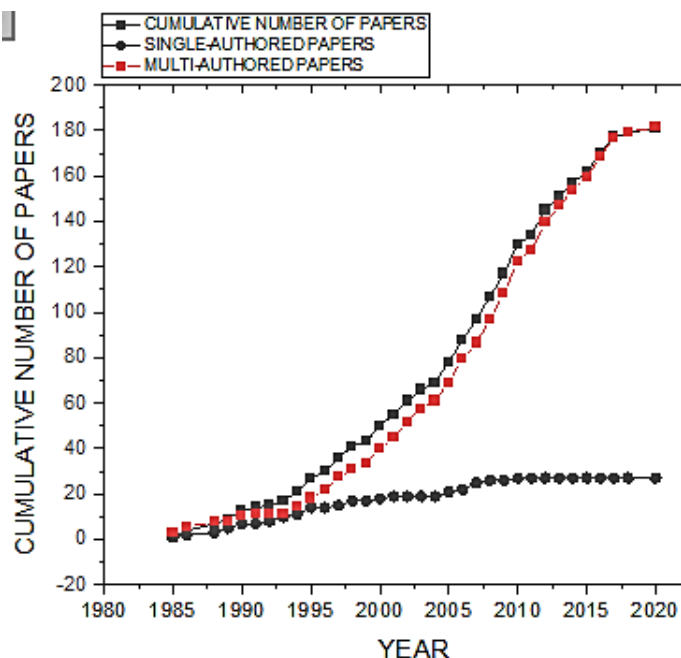
Biological Age of Prof. Anurag Kumar	Year	Number of papers under various authorships										TMA	TP	CP	Citations	CC	MAI	Publishing Career Age
		1	2	3	4	5	6	7	8	9	More than 9							
30	1985	0	1									1	1	1	9	9	1.06	1
31	1986	1	2									2	3	4	17	26	0.71	2
33	1988	1	2									2	3	7	22	48	0.71	4
34	1989	2										0	2	9	61	109	0.00	5
35	1990	1	1	1		1						3	4	13	94	203	0.79	6
36	1991	0	1									1	1	14	0	203	1.06	7
37	1992	1										0	1	15	5	208	0.00	8
38	1993	0	1	1								2	2	17	39	247	1.06	9
39	1994	0	4									4	4	21	8	255	1.06	10
40	1995	1	3	2								5	6	27	36	291	0.88	11
41	1996	0	1	2								3	3	30	16	307	1.06	12
42	1997	0	5	1								6	6	36	37	344	1.06	13
43	1998	1	4									4	5	41	234	578	0.85	14
44	1999	0	1									1	1	42	1	579	1.06	15



45	2000	0	3	2			1					6	6	48	94	673	1.06	16
46	2001	1	2	1	1							4	5	53	42	715	0.85	17
47	2002	0	1	4	1							6	6	59	68	783	1.06	18
48	2003	0	3	2								5	5	64	126	909	1.06	19
49	2004	0	3									3	3	67	21	930	1.06	20
50	2005	0	2	5	1				1			9	9	76	289	1219	1.06	21
51	2006	1	2	4	3							9	10	86	114	1333	0.95	22
52	2007	0	5	2	2	1						10	10	96	328	1661	1.06	23
53	2008	0	3	6	1							10	10	106	312	1973	1.06	24
54	2009	0	2	2	5		1					10	10	116	136	2109	1.06	25
55	2010	0	3	5	1	1	2	1				13	13	129	146	2255	1.06	26
56	2011	0	3		1							4	4	133	11	2266	1.06	27
57	2012	0	4	3	4							11	11	144	135	2401	1.06	28
58	2013	0	1	1	2			1	1			6	6	150	94	2495	1.06	29
59	2014	0	3		1		2					6	6	156	53	2548	1.06	30
60	2015	0	3	1				1				5	5	161	13	2561	1.06	31
61	2016	0	3	2	1		1				1	8	8	169	19	2580	1.06	32
62	2017	0	1	3	2				1			7	7	176	13	2593	1.06	33
63	2018	0		2								2	2	178	2	2595	1.06	34
65	2020	0	1	1	1							3	3	181	0	2595	1.06	36
	Total	10										171	181		2595			
	Percentage	5.52										94.48	100					

TMA: Total Multi Authored; TP: Total Publications; CP: Cumulative Publications; CC: Cumulative Citations; MAI: Multi-Authorship Index

**Figure-05: Development Trend of Single Authored and Multi-Authored Publications of Prof. Anurag Kumar**



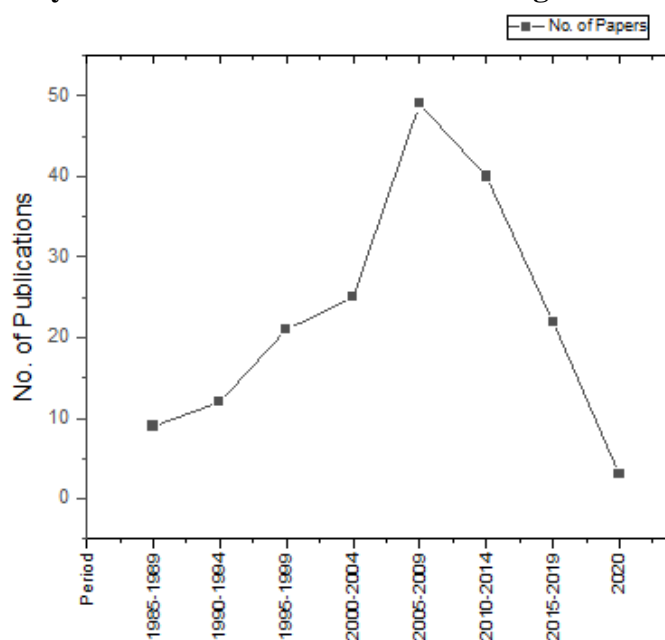
### Quinquennial publications

Prof. Anurag Kumar has published 181 publications over 36 years (1985-2020). Thus, the productivity of Prof. Anurag Kumar is 5.02 paper for a year. The first article by him published in 1985. He has published the highest 49 papers between 2005-2009, in which seven papers published as a single author, and 48 are with collaborations this shows the active collaboration research of Prof. Anurag Kumar at the age of 50-54. During his 36 years of publishing career from 1985-2020, he authored only 10 (5.52%) publications as a single author and 171 (94.48%) in collaboration (Table-2).

**Table-2: Quinquennial publication productivity of Prof. Anurag Kumar during 1985-2020**

Sl. No.	Period	Single Authored Papers	Cumulative Single	% of Single Authored	Multi Authored Papers	Cumulative Multi-authored	% of Multi-authored	Total Papers	Cumulative Total	% of Total Papers
1	1985-1989	4	4	40.00	5	5	2.92	9	9	4.97
2	1990-1994	2	6	20.00	10	15	5.85	12	21	6.63
3	1995-1999	2	8	20.00	19	34	11.11	21	42	11.60
4	2000-2004	1	9	10.00	24	58	14.04	25	67	13.81
5	2005-2009	1	10	10.00	48	106	28.07	49	116	27.07
6	2010-2014	0	10	0.00	40	146	23.39	40	156	22.10
7	2015-2019	0	10	0.00	22	168	12.87	22	178	12.15
8	2020	0	10	0.00	3	171	1.75	3	181	1.66
	<b>Total</b>	<b>10</b>		<b>100</b>	<b>171</b>		<b>100</b>	<b>181</b>		<b>100</b>

**Figure-06: Periodicity and Collaboration of Prof. Anurag Kumar**



### Authorship Status in Collaborative Publications

Table - 3 presents the authorship status of Prof. Anurag Kumar in his publications. He has collaborated with 540 authors to produce his 181 publications. During the study period, the average number of Publication per Author is 0.33, and the average number of Authors per Publication is 3.01. He is the first or primary author in 27 (14.91%) publications and the remaining 154 publications as co-author. In the co-authored publications, he is the second author for 91 publications and the third author for 39 publications. In the rest of 11 publications, his author position ranges from five to ten. The table indicates that Prof. Anurag Kumar has authored prominently in the first or second position, which shares 65.19% of his total publications.

**Table-3: Authorship Status in Collaborative Publications of Prof. Anurag Kumar**

No. of Publications	Position of Author										Total	Total Authors
	1	2	3	4	5	6	7	8	9	10		
1	10	1									11	11
2	10	60									70	140
3	3	23	31		1						58	174
4	2	5	8	11							26	104
5				2	1						3	15
6	1	1			2	2					6	36
7		1				1	1				3	21
8	1							2			3	24
9											0	0
10											0	0
11											0	0
12											0	0
13											0	0
14											0	0
15										1	1	15
<b>Total</b>	<b>27</b>	<b>91</b>	<b>39</b>	<b>13</b>	<b>4</b>	<b>3</b>	<b>1</b>	<b>2</b>	<b>0</b>	<b>1</b>	<b>181</b>	<b>540</b>

### Collaboration

Collaboration is essential in the research, particularly science and technological research undertaken in collaboration with many researchers of the same and sub-fields. Table- 4 reveal that Altman, E. is a most active researcher and has collaborated the highest number of research papers (17) with Prof. Anurag Kumar, followed by Kuri, J. (15), Anand, S.V.R. (14). Singh,

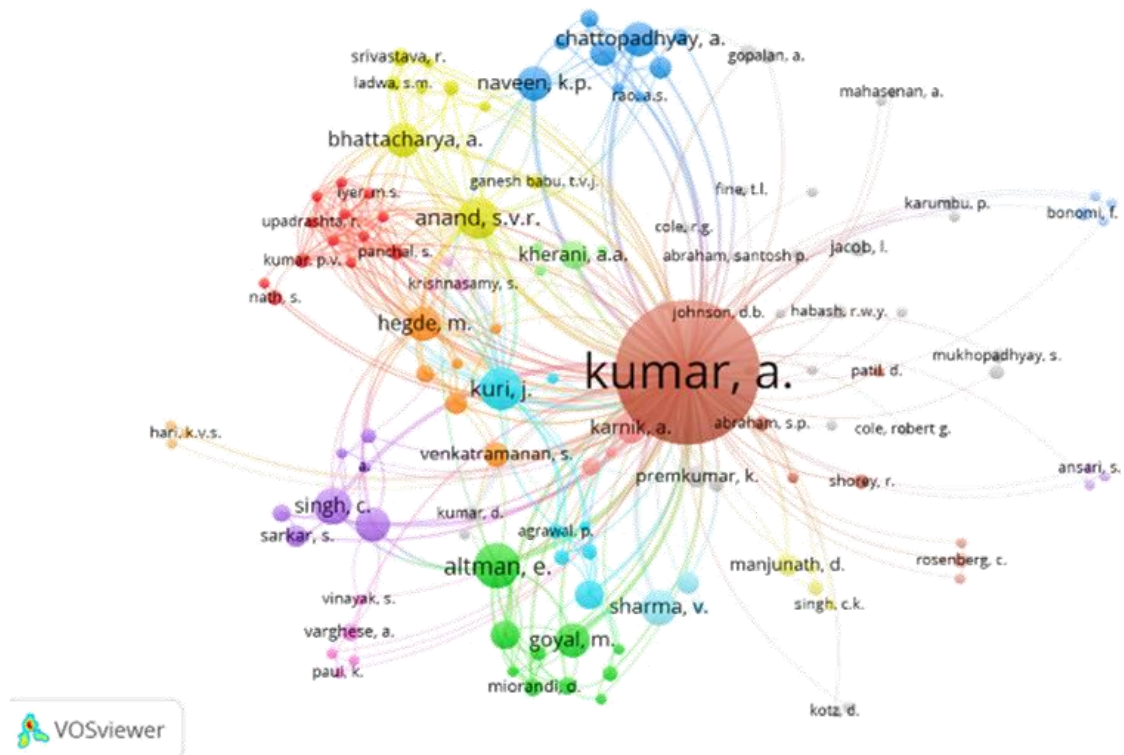
C., (12). While Bhattacharya, A., Chattopadhyay, A., Goyal, M., Hegde, M. Karnik, A., Naveen, K.P., and Sundaresan, R. are contributed (10) each with Prof. Anurag Kumar. Six researchers collaborated for four publications each, and twelve researchers co-authored three publications each. The 30 researchers have collaborated for two papers each, and 70 authors collaborated only one publication with him. In his research group, 212 authors have collaborated with Prof. Anurag Kumar, and the total number of authorships are 545.

**Table-4 Authorship credit of researchers collaborating with Prof. Anurag Kumar**

Author Name	Period of Collaboration FPY-LPY	TY	No. of Authorships	Citations	Norm. Citations
Kumar, Anurag	1985-20	36	181	2595	174.87
Altman, E.	2005-17	17	17	730	34.33
Kuri, J.	1994-17	24	15	200	19.12
Anand, S.V.R.	1993-17	25	14	94	11.09
Singh, C.	2008-16	9	12	186	18.23
Bhattacharya, A.	2010-17	8	10	74	9.83
Chattopadhyay, A.	2012-18	7	10	49	12.69
Goyal, M.	2002-08	7	10	55	18.39
Hegde, M.	2000-17	18	10	64	6.43
Karnik, A.	2000-08	9	10	160	8.21
Naveen, K.P.	2010-20	11	10	96	10.38
Sundaresan, R.	2009-20	12	10	100	13.38
Sharma, V.	2002-10	9	9	208	11.03
Kherani, A.A.	2000-05	6	7	95	7.5
Panda, M.K.	2005-12	8	7	58	4.38
Ramaiyan, V.	2005-12	8	7	126	6.57
Coupechoux, M.	2012-17	6	6	41	8.74
Venkatramanan, S.	2011-14	4	5	25	2.28
6 Authors with four pubs each	1988-08	21	24	375	NA
12 Authors with 3 Pubs each	1995-20	26	36	713	NA
30 Authors with 2 Pubs each	1986-20	35	60	448	NA
75 Authors with 1 Pub each	1985-20	36	75	638	NA

FPY: First publication year; LPY: Last publication year; TY: Total years

**Figure-07: Authorship Network of Prof. Anurag Kumar**



### Measure of Collaboration

Table-5 depicts four collaboration indices for 36 years (1985 to 2020) of the authorship career of Prof. Anurag Kumar. Collaborative Index (CI) given by Lawani (1980) ranges from the highest CI 4.75 in the year 2016, followed by 4.67 in 2013, and the lowest CI 1.00 can be seen in the year 1989. The mean value of the Collaborative Index is 2.68 during the years from 1985 to 2020.

In this study, the value of Degree of Collaboration (DC) introduced by Subramanayam (1983) ranges from the highest DC 1.0 in 10 different years of his career age, followed by 0.90 in 2006. Lowest DC is 0.67 in the year 1986 & 1988. The mean value of Degree of Collaboration is 0.89 during the period from 1985 to 2020, which indicates that Prof. Anurag prefers collaboration work in his research. DC 1.00 indicates that there is no single author publication and DC 0.00 indicates that there is no collaborated publication.

Collaborative Coefficient (CC) given by Ajiferuke (1988) indicates the differences between the levels of authorship pattern and a measure to collaborative research. The value of Collaborative Coefficient ranges highest CC 0.73 in 2013, followed by 0.70 in 2017, and lowest collaboration coefficient is CC 0.33 in 1986 & 1988. The mean value of the Collaboration Coefficient is 0.54 during the years from 1985 to 2020. CC 0.00 indicates no collaboration authorship in the years 1989 & 1992.

Modified Collaboration Coefficient (MCC) introduced by Savnur & Srikanth (2010) value ranges highest from 1.33 in 2018, followed by 1.17 in 1993 and 0.96 in 2020, and the lowest MCC counted 0.50 in 1998. The mean value of MCC is 0.64 during the years from 1985-2020. A decline in the number of publications can be seen between 2018 and 2020.

**Table-5: Measure of Collaboration of Prof. Anurag Kumar**

Year	Single Authors	Two Authors	Three Authors	Four Authors	Five Authors	> Five Authors	Total Publications	CI	DC	CC	MCC
1985	0	1					1	2.00	1.00	0.50	0.00
1986	1	2					3	1.67	0.67	0.33	0.50
1988	1	2					3	1.67	0.67	0.33	0.50
1989	2						2	1.00	0.00	0.00	0.00
1990	1	1	1		1		4	2.75	0.75	0.49	0.66
1991	0	1					1	2.00	1.00	0.50	0.00
1992	1						1	1.00	0.00	0.00	0.00
1993	0	1	1				2	2.50	1.00	0.58	1.17
1994	0	4					4	2.00	1.00	0.50	0.67
1995	1	3	2				6	2.17	0.83	0.47	0.57
1996	0	1	2				3	2.67	1.00	0.61	0.92
1997	0	5	1				6	2.17	1.00	0.53	0.63
1998	1	4					5	1.80	0.80	0.40	0.50
1999	0	1					1	2.00	1.00	0.50	0.00
2000	0	3	2			1	6	3.00	1.00	0.61	0.73
2001	1	2	1	1			5	2.40	0.80	0.48	0.60
2002	0	1	4	1			6	3.00	1.00	0.65	0.78
2003	0	3	2				5	2.40	1.00	0.57	0.71
2004	0	3					3	2.00	1.00	0.50	0.75
2005	0	2	5	1		1	9	3.44	1.00	0.66	0.74
2006	1	2	4	3			10	2.90	0.90	0.59	0.66
2007	0	5	2	2	1		10	2.90	1.00	0.61	0.68
2008	0	3	6	1			10	2.80	1.00	0.63	0.69
2009	0	2	2	5		1	10	3.60	1.00	0.69	0.77
2010	0	3	5	1	1	3	13	3.77	1.00	0.69	0.74
2011	0	3		1			4	2.50	1.00	0.56	0.75
2012	0	4	3	4			11	3.00	1.00	0.64	0.70
2013	0	1	1	2		2	6	4.67	1.00	0.73	0.88
2014	0	3		1		2	6	3.67	1.00	0.65	0.78
2015	0	3	1			1	5	3.20	1.00	0.60	0.76
2016	0	3	2	1		2	8	4.75	1.00	0.68	0.76
2017	0	1	3	2		1	7	3.86	1.00	0.70	0.81

2018	0		2			2	3.00	1.00	0.67	1.33
2020	0	1	1	1		3	3.00	1.00	0.64	0.96

CI: Collaborative Index (CI); DC: Degree of Collaboration; CC: Collaborative Coefficient; MCC: Modified Collaboration Coefficient (MCC)

### Channels of Communication

The Selection of channels for publication is an essential activity in the research to share their ideas through high impact factor journals to reach-out a wide range of audience. Channels of Communication used by Prof. Anurag Kumar have been examined by using different indicators such as the number of papers appeared, publishing country and, an Impact factor of the journals. Distribution of Prof. Anurag Kumar's 181 publications is spread over 80 resources. A channel-wise scattering of publications of Prof. Anurag Kumar is provided in Table-6. He has published 18 papers in *IEEE ACM Transactions on Networking* (1996-20), followed by 17 in a *Proceedings IEEE INFOCOM* (1990-18), 11 papers in *International Conference on COMMunication Systems and NETworks* (2009-14), 6 papers each in *IEEE Global Telecommunications Conference* (1995-2001), *IEEE International Conference on Personal Wireless Communications* (1997-2005), and *IEEE Transactions on Mobile Computing* (2008-18). He has published his articles in high and medium impact factor journals (Table-6).

**Table-6: Channels of communication used by Prof. Anurag Kumar**

Rank	Source Title	No of Publications	Cumul ative	FPY-LPY	TY	IF
1.	<i>IEEE ACM Transactions on Networking</i>	18	18	1996-20	25	3.315
2.	<i>Proceedings IEEE INFOCOM</i>	17	35	1990-18	29	NA
3.	<i>International Conference on COMMunication Systems and NETworks</i>	11	46	2009-14	06	NA
4.	<i>IEEE Global Telecommunications Conference</i>	6	52	1995-01	07	NA
5.	<i>IEEE International Conference on Personal Wireless Communications</i>	6	58	1997-05	09	NA
6.	<i>IEEE Transactions on Mobile Computing</i>	6	64	2008-18	11	5.112
7.	<i>IEEE International Conference on Communications</i>	5	69	2002-06	05	NA
8.	<i>International Conference on Signal Processing and Communications</i>	5	74	2004-16	13	NA
9.	<i>Wireless Networks</i>	5	79	2006-10	05	2.659
10.	<i>International Symposium on Modeling and Optimization in Mobile, Ad Hoc and Wireless Networks</i>	5	84	2009-15	06	NA
11.	<i>Ad Hoc Networks</i>	5	89	2014-16	03	3.643
12.	<i>Sadhana Academy Proceedings in Engineering Sciences</i>	4	93	1990-07	17	0.849

13.	<i>Lecture Notes in Computer Science Including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics</i>	4	97	2001-10	10	NA
14.	<i>International Conference on Signal Processing and Communications</i>	4	101	2010-16	07	NA
15.	<i>ACM Transactions on Sensor Networks</i>	4	105	2012-17	06	2.469
16.	<i>IEEE Journal on Selected Areas in Communications</i>	3	108	1986-17	32	11.42
17.	<i>Computer Networks</i>	2	110	2009-14	06	3.111
18.	<i>Allerton Conference on Communication, Control, and Computing</i>	2	112	2009-10	02	NA
19.	<i>IEEE Communications Magazine</i>	2	114	2000-07	08	11.052
20.	<i>IEEE International Symposium on Information Theory Proceedings</i>	2	116	2002-05	04	NA
21.	<i>IEEE Transactions on Computers</i>	2	118	1989-90	02	2.711
22.	<i>Operations Research Letters</i>	2	120	1992-94	03	0.757
23.	<i>Proceedings of The IEEE Conference on Decision and Control</i>	2	122	1986-88	03	NA
24.	<i>Performance Evaluation</i>	2	124	2005-12	08	1.567
25.	<i>Queueing Systems</i>	2	126	1990-97	08	1.114
26.	<i>ACM Transactions on Modeling and Computer Simulation</i>	1	127	1997-97	01	1.38
27.	<i>AT&amp;T Technical Journal</i>	1	128	1988-88	01	NA
28.	<i>IEEE Communications Letters</i>	1	129	2003-03	01	3.419
29.	<i>IEEE Transactions on Automatic Control</i>	1	130	1995-95	01	5.625
30.	<i>IEEE Transactions on Communications</i>	1	131	1995-95	01	5.646
31.	<i>IEEE Transactions on Information Theory</i>	1	132	2008-08	01	3.036
32.	<i>IEEE Transactions on Intelligent Transportation Systems</i>	1	133	2017-17	01	6.319
33.	<i>IEEE Transactions on Parallel and Distributed Systems</i>	1	134	1993-93	01	2.6
34.	<i>IEEE Transactions on Vehicular Technology</i>	1	135	2000-00	01	5.379
35.	<i>IETE Journal of Research</i>	1	136	2000-00	01	1.125
36.	<i>IETE Technical Review (Institution of Electronics and Telecommunication Engineers, India)</i>	1	137	2007-07	01	1.845
37.	<i>IIE Transactions (Institute of Industrial Engineers)</i>	1	138	1989-89	01	2.884
38.	<i>International Journal of Communication Systems</i>	1	139	1995-95	01	1.319
39.	<i>International Journal of Network Management</i>	1	140	2007-07	01	1.338
40.	<i>Journal of Network and Computer Applications</i>	1	141	2017-07	01	5.57
41.	<i>Mobile Networks and Applications</i>	1	142	2010-10	01	2.602
42.	<i>Networks</i>	1	143	1986-86	01	2.602



43.	<i>Telecommunication Systems</i>	1	144	1997-97	01	1.734
44.	<i>Others with one publication in Books, Conf. etc.</i>	37	181	1995-20		

FPY: First publication year; LPY: Last publication year TY: Total years; IF: Impact Factor

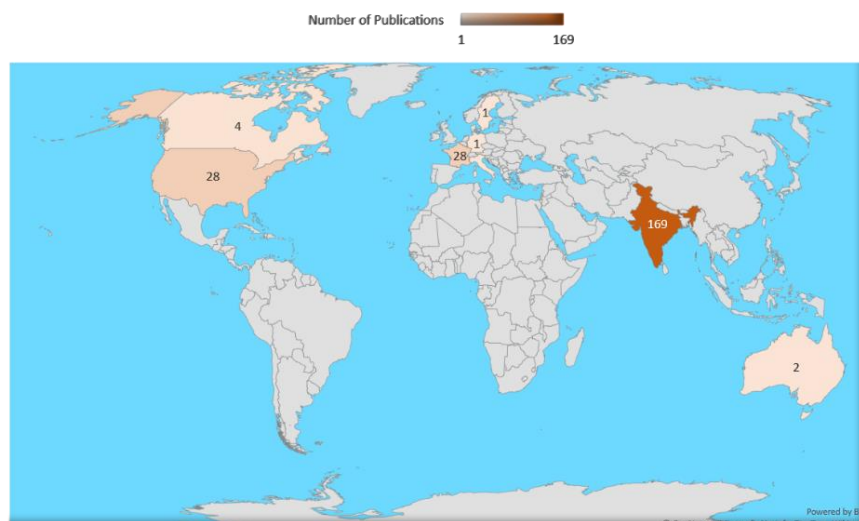
### Country-wise distribution

Prof. Anurag Kumar has published many publications in collaboration with foreign scholars, and these scattered in 181 publications published from India and abroad. Table-7 indicates that he has the highest number of 56 (30.93%) collaborations with France and the USA, followed by Canada (4). His productivity includes 169 (93.37%) publications with Indian collaboration and 74 (40.88%) with international collaboration.

**Table-7: Country-wise distribution of papers**

Country/Territory	Number of Publications	Percentage
India	169	93.37
France	28	15.46
United States	28	15.46
Canada	4	2.20
Australia	2	1.10
Germany	1	0.55
Israel	1	0.55
Italy	1	0.55
Singapore	1	0.55
Sweden	1	0.55
Undefined	7	3.86

**Figure-08: Country-wise Publications**



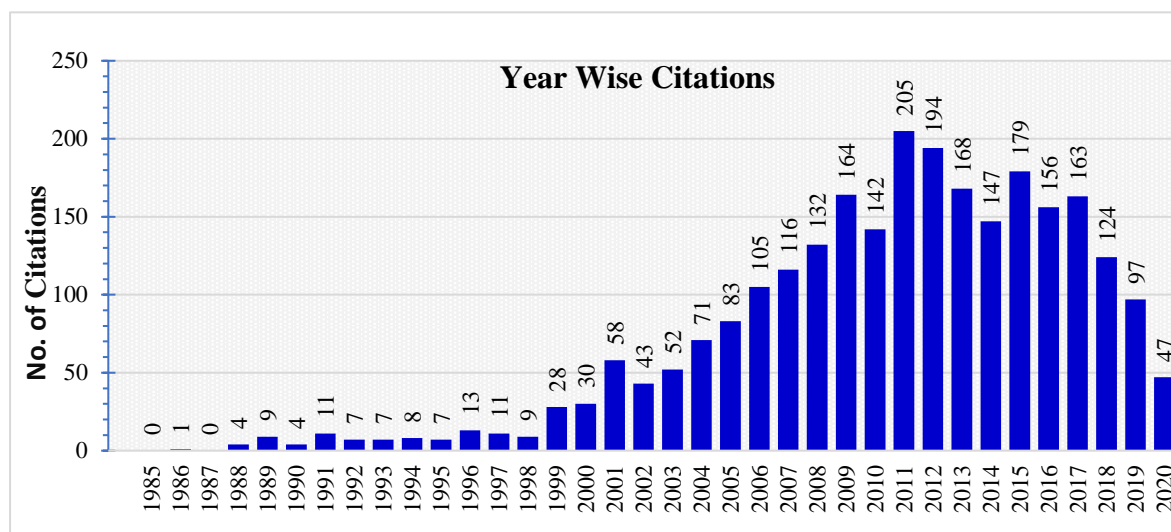
## Citation Pattern

Prof. Anurag Kumar has published 181 publications, and his publications have received 2595 citations so far. Thus, the citation rate for each publication is 14.3, and the average is 72.08 per year. A 27 (14.9%) papers have not received any citations yet, while one-third of his papers, i.e. 65 (35.91%) cited between 1-5 times, and 30 (16.57%) papers have cited between 1-6 times. The remaining 59 (32.59%) papers cited more than ten times. Majority of citations 1995 (76.87%) for his publications received between 2006-2018. He has received the highest citations 205 (7.89%) in the year 2011, followed by 194 (7.47%) in 2012, which is the second-highest of the total citations (Table-8).

**Table-8: Citation Pattern**

Number of times Cited	Number of publications	% of publications	Total Citations
0	27	14.92	0
1-5	65	35.91	169
6-10	30	16.57	221
11-15	14	7.73	179
16-20	8	4.42	138
21-25	9	4.97	202
26-30	9	4.97	255
31-35	5	2.76	166
36-40	3	1.66	112
41-50	3	1.66	132
51-100	4	2.21	298
100-300	4	2.21	723
Total	181	100.00	2595
Citations Per Paper			14.3

**Figure-09: Year-wise Citations Received**



## Citation Analysis

Relative Citation Impact (RCI) given by Kumari (2009) value ranges from the highest 3.26 in 1998 and 0.03 in 1999. Variation in the receiving pattern and Citation Index can be seen in Table-9.

He has received 2595 citations from 154 publications out of 181, with an average of 16.85 citations per paper. Out of 154 cited publications, the 9 publications published in 2007 got the highest number, i.e. 328 (12.64%) citations with an average of 36.4 citations for each paper. While his 05 publications published in the year 1998 have an average of 46.8 citations per paper, which is the highest during his publications career. *h*-index of Prof. Anurag Kumar is 26, *m*-index is 0.76, and *g*-index is 45.

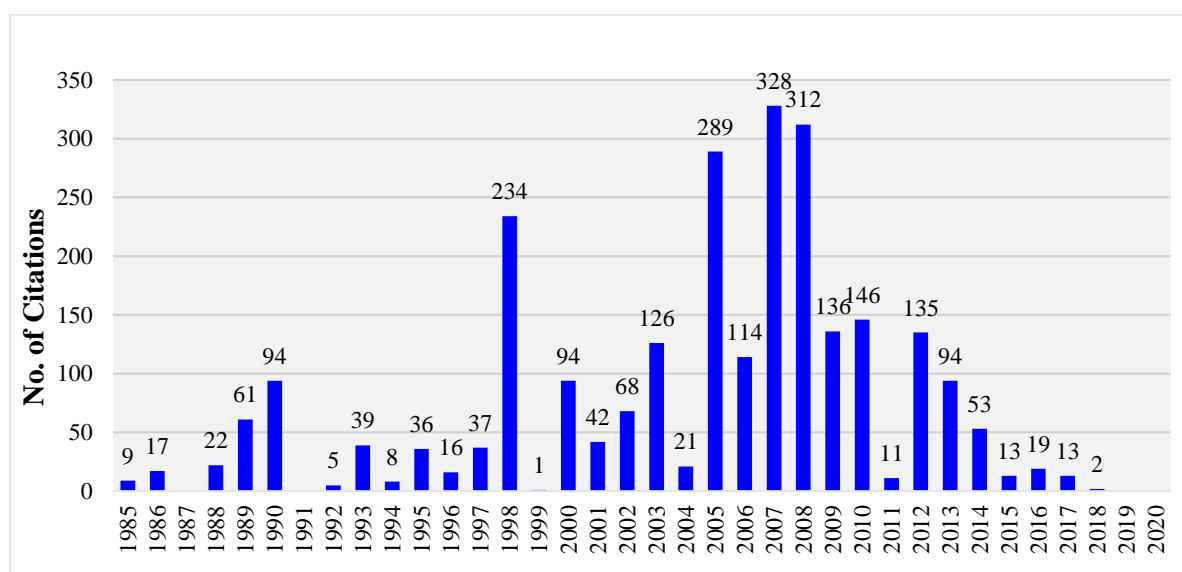
**Table-9: Citation Analysis of Prof. Anurag Kumar**

Year	TP	TP (%)	CP	TC	TC (%)	CPP	RCI
1985	1	0.55	1	9	0.35	9.0	0.63
1986	3	1.66	3	17	0.66	5.7	0.40
1988	3	1.66	3	22	0.85	7.3	0.51
1989	2	1.10	2	61	2.35	30.5	2.13
1990	4	2.21	3	94	3.62	23.5	1.64
1991	1	0.55	0	0	0.00	0.0	0.00
1992	1	0.55	1	5	0.19	5.0	0.35
1993	2	1.10	2	39	1.50	19.5	1.36
1994	4	2.21	3	8	0.31	2.0	0.14
1995	6	3.31	2	36	1.39	6.0	0.42
1996	3	1.66	3	16	0.62	5.3	0.37
1997	6	3.31	6	37	1.43	6.2	0.43
1998	5	2.76	4	234	9.02	46.8	3.26
1999	1	0.55	1	1	0.04	1.0	0.07
2000	6	3.31	6	94	3.62	15.7	1.09
2001	5	2.76	3	42	1.62	8.4	0.59
2002	6	3.31	5	68	2.62	11.3	0.79
2003	5	2.76	5	126	4.86	25.2	1.76
2004	3	1.66	3	21	0.81	7.0	0.49
2005	9	4.97	9	289	11.14	32.1	2.24
2006	10	5.52	9	114	4.39	11.4	0.80
2007	10	5.52	9	328	12.64	32.8	2.29
2008	10	5.52	10	312	12.02	31.2	2.18
2009	10	5.52	9	136	5.24	13.6	0.95
2010	13	7.18	10	146	5.63	11.2	0.78
2011	4	2.21	3	11	0.42	2.8	0.19

2012	11	6.08	11	135	5.20	12.3	0.86
2013	6	3.31	6	94	3.62	15.7	1.09
2014	6	3.31	5	53	2.04	8.8	0.62
2015	5	2.76	5	13	0.50	2.6	0.18
2016	8	4.42	4	19	0.73	2.4	0.17
2017	7	3.87	7	13	0.50	1.9	0.13
2018	2	1.10	1	2	0.08	1.0	0.07
2020	3	1.66	0	0	0.00	0.0	0.00
<b>Total</b>	<b>181</b>	<b>100.00</b>	<b>154</b>	<b>2595</b>	<b>100.00</b>	<b>415.1</b>	<b>1</b>

TP: Total Publications; CP: Cited Publications; TC: Total Citations; CPP: Citations per paper; RCI: Relative Citation Impact

**Figure-10: Publications-Wise Citations**



### Highly cited publications

Highly cited publications are presented in **Table-10**. Of the 10 highly cited publications, the 9 papers are published with US-based publishers, and 1 in the Netherlands. Among highly cited publications, he has published in journals with having more than two Impact factor. Field Weighted Citation Impact (FWCI) of his publications is also high. The highest FWCI of highly cited publication is a maximum 32.4, and the lowest is 5.88. He has published journal articles, which has the highest 216 citations published in the year 2007 in the journal with 3.315 impact factor and article has FWCI 8 score. His publication with the highest FWCI is 32.4 scores published in the year 2005. He has published a journal article with the highest 11.42 impact factor in the year 2007.

**Table-10: Highly cited publications**

Sl. No.	Highly Cited Publications	Type of Publication	Country	Citations	FWCI	IF of Source Title
1	A. Kumar, E. Altman, D. Miorandi and M. Goyal, "New Insights From a Fixed-Point Analysis of Single Cell IEEE 802.11 WLANs," in <i>IEEE/ACM Transactions on Networking</i> , vol. 15, no. 3, June 2007, pp. 588-601. DOI: 10.1109/TNET.2007.893091.	Journal Article	USA	216	8	3.315
2	Anurag Kumar. 1998. Comparative performance analysis of versions of TCP in a local network with a lossy link. <i>IEEE/ACM Transactions on Networking</i> , 6, 4 (Aug. 1998), 485–498. DOI:10.1109/90.720921	Journal Article	USA	205	14.97	3.315
3	A. Kumar, E. Altman, D. Miorandi and M. Goyal, "New Insights From a Fixed-Point Analysis of Single Cell IEEE 802.11 WLANs," <i>IEEE INFOCOM 2005; Miami, FL; United States; 13 March 2005 through 17 March 2005</i> , pp. 1550-1561. DOI: 10.1109/TNET.2007.893091.	Conference Paper	USA	192	32.4	NA
4	Munish Goyal, Anurag Kumar and Vinod Sharma, "Power constrained and delay optimal policies for scheduling transmission over a fading channel," <i>IEEE INFOCOM 2003. Twenty-second Annual Joint Conference of the IEEE Computer and Communications Societies</i> , vol.1, San Francisco, CA, pp. 311-320, 2003. DOI: 10.1109/INFCOM.2003.1208683.	Conference Paper	USA	110	6.73	NA
5	F. Bonomi and A. Kumar, "Adaptive optimal load balancing in a nonhomogeneous multiserver system with a central job scheduler," in <i>IEEE Transactions on Computers</i> , vol. 39, no. 10, Oct. 1990, pp. 1232-1250. DOI: 10.1109/12.59854.	Journal Article	USA	90	NA	2.711
6	A. Kumar, D. Manjunath, and J. Kuri, <i>Wireless Networking</i> , ELSEVIER Inc., Burlington, MA, USA, 2008	Book	Netherlands	74	1.99	NA
7	Singh, C.K., Kumar, A. & Ameer, P.M. Performance evaluation of an IEEE 802.15.4 sensor network with a star topology. <i>Wireless Network</i> 14, 543–568, 2008. DOI: 10.1007/s11276-007-0043-8	Journal Article	USA	70	4.19	2.659
8	S. Shakkottai, E. Altman and A. Kumar, "Multihoming of Users to Access Points in WLANs: A Population Game Perspective," in <i>IEEE Journal on Selected Areas in Communications</i> , vol. 25, no. 6, pp. 1207-1215, August 2007. DOI: 10.1109/JSAC.2007.070814.	Journal Article	USA	64	3.72	11.42
9	S. Shakkottai, E. Altman and A. Kumar, "The Case for Non-Cooperative Multihoming of Users to Access Points in IEEE 802.11 WLANs," <i>Proceedings IEEE INFOCOM 2006. 25TH IEEE International Conference on Computer Communications, Barcelona, 2006</i> , pp. 1-12, DOI: 10.1109/INFCOM.2006.314.	Conference Paper	USA	48	10.54	NA

A. A. Kherani and A. Kumar, "Stochastic models for throughput analysis of randomly arriving elastic flows in the Internet," *Proceedings Twenty-First Annual Joint Conference of the IEEE Computer and Communications Societies*, vol.2, New York, NY, USA, 2002, pp. 1014-1023.  
 DOI: 10.1109/INFCOM.2002.1019349.

Conference Paper	USA	43	5.88	NA
Total		1112	88.42	

FWCI: Field Weighted Citation Impact; IF: Impact Factor

**Uncitedness and Relative Uncitedness Index**

Relative Uncitedness Index (RUI) given by Garg K. C. & Kumar S. (2014) indicates the Uncitedness of publications, higher the RUI number, less citation impact and zero number indicate that there are no uncited publications. Table-11 shows 27 (14.91) uncited publications out of a total of 181 publications published during the years 1985 to 2020. The Relative Uncitedness Index (RUI) value ranges from 0.18 to 1.81 during the study period (Table-11).

**Table-11: Relative Uncitedness Index**

Year	TP	TP (%)	UCP	UCP (%)	RUI
1985	1	0.55	0	0.00	0.00
1986	3	1.66	0	0.00	0.00
1988	3	1.66	0	0.00	0.00
1989	2	1.10	0	0.00	0.00
1990	4	2.21	1	3.70	0.45
1991	1	0.55	1	3.70	1.81
1992	1	0.55	0	0.00	0.00
1993	2	1.10	0	0.00	0.00
1994	4	2.21	1	3.70	0.45
1995	6	3.31	4	14.81	1.21
1996	3	1.66	0	0.00	0.00
1997	6	3.31	0	0.00	0.00
1998	5	2.76	1	3.70	0.36
1999	1	1.10	0	0.00	0.00
2000	6	3.87	0	0.00	0.00
2001	5	2.76	2	7.41	0.72
2002	6	3.31	1	3.70	0.30
2003	5	2.76	0	0.00	0.00
2004	3	1.66	0	0.00	0.00
2005	9	4.97	0	0.00	0.00
2006	10	5.52	1	3.70	0.18
2007	10	4.97	1	3.70	0.20
2008	10	5.52	0	0.00	0.00
2009	10	5.52	1	3.70	0.18

2010	13	7.18	3	11.11	0.42
2011	4	2.21	1	3.70	0.45
2012	11	6.08	0	0.00	0.00
2013	6	3.31	0	0.00	0.00
2014	6	3.31	1	3.70	0.30
2015	5	2.76	0	0.00	0.00
2016	8	4.42	4	14.81	0.91
2017	7	3.87	0	0.00	0.00
2018	2	1.10	1	3.70	0.91
2020	3	1.10	3	11.11	2.72
<b>Total</b>	<b>181</b>	<b>100.00</b>	<b>27</b>	<b>100.00</b>	<b>0.27</b>

TP: Total Publications; UCP: Uncited Publications, RUI: Relative Uncitedness Index

### Keyword Tomography

Keywords are crucial in the publications to index a paper appropriately. Table-12 provides frequencies of the keywords given in the publications. The high-frequency keywords are Computer Simulation (37), Markov Processes (34), Optimization (33), Standards (29), Telecommunication Traffic (26) Wireless Networks (24) Wireless Sensor Networks (24) are among the highly used keywords. These given keywords indicate the area of interests and research of the scholar.

**Table:12- High-frequency keywords in the titles of the publications used by Prof. Anurag Kumar**

<b>Keywords</b>	<b>Frequency</b>	<b>Keywords</b>	<b>Frequency</b>
Computer Simulation	37	Markov Decision Processes	13
Markov Processes	34	Ad Hoc Networks	12
Optimization	33	Bandwidth	12
Standards	29	Probability	12
Telecommunication Traffic	26	Telecommunication Networks	12
Wireless Networks	24	Communication Channels (information Theory)	11
Wireless Sensor Networks	24	Sensor Networks	11
Algorithms	23	Sensors	11
Mathematical Models	22	Telecommunication Links	11
Wireless Local Area Networks (WLAN)	22	Throughput	11
Queueing Theory	20	Asynchronous Transfer Mode	10
Wireless Telecommunication Systems	20	Base Stations	10
Scheduling	18	Carrier Sense Multiple Access	10
Sensor Nodes	18	Computer Networks	10

Quality of Service	17	Medium Access Control	10
Network Protocols	16	Stochastic Systems	10
Transmission Control Protocol	15	Communication Systems	9
Congestion Control (communication)	14	Game Theory	9
Local Area Networks	14	Internet	9
Random Processes	14	Packet Networks	9

## Conclusion

Prof. Anurag Kumar has published 181 publications between 1985-2020. He has published his first publication at the age of 30; during the 36 years of his research career, he had published 5.02 papers per year by serving various administrative capabilities including, the Director at the Indian Institute of Science (IISc) in Bengaluru.

He has contributed 10 (5.52%) publications as a single author, and the rest 171 (94.48%) published in collaboration with 638 co-authors, and Altman, E. is the highly collaborative author with 17 research papers. In contrast, his 56 (30.93%) papers are in collaboration with researchers from France and the USA.

He has published the highest (18) papers in *IEEE ACM Transactions on Networking* (1996-20). Prof. Anurag Kumar has received 2595 citations so far for 181 publications, while 27 (14.9%) of his publications have not cited so far, while New Insights From a Fixed-Point Analysis of Single Cell IEEE 802.11 WLANs paper published in *IEEE/ACM Transactions on Networking* received the highest (216) citations. A strong correlation can be seen between quantity, quality and the honours, fellowships, and awards. A scientometric portrait will be the source of inspiration and productivity for young professionals. The present study of Prof. Anurag Kumar as a researcher, his career achievements would inspire many and would be a role model for budding scientists and researchers of the field.

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## Conflicts of Interest

The authors declare that they have no conflict of interests.



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