BIO-DATA

1. **Name:**   SANKAR KUMAR PAL, FNA, FASc, FNASc, FNAE, FTWAS, FIEEE, FIAPR, FIFSA, FIRSS, FAAIA

2. **Date of birth:**   13th of September 1950

3. **Present Designation:**   *National Science Chair,* SERB-DST, Govt. of India
    President, Indian Statistical Institute
    Emeritus Professor, Indian Statistical Institute
    Former Director and Distinguished Scientist
    Indian Statistical Institute

4. **Address:**

    a) Office:
    Machine Intelligence Unit
    Indian Statistical Institute
    203, B.T. Road,
    Kolkata 700 108, India

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    b) Residence:
    B-4 Lake View Park
    P.O. ISI
    Kolkata 700 108, India

    Tel: 91-33-2577-2030
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5. **Academic Qualifications:**

    i: B.Sc.(Hons)/ 1969/ Physics/ Calcutta University.
    ii: B.Tech./1972/ Radio Physics and Electronics/ Calcutta University.
    iii: M.Tech./1974/Radio Physics and Electronics/ Calcutta University.
    iv: Ph.D./ 1978-79/ Thesis: Studies on the Application of Fuzzy Set Theoretic Approach in Some Problems of Pattern Recognition and Man-Machine Communication by Voice/ Radio Physics and Electronics/ Indian Statistical Institute, Calcutta University. *(Work carried out at Indian Statistical Institute (ISI), Calcutta as its enrolled PhD student, but the thesis submitted to Calcutta University as ISI was not empowered to offer degree at that time in Computer Science/ Electrical Science).*
    v: Ph.D. and DIC/ 1982/ Thesis: Fuzzy Set Theory in Gray Tone Image Processing/ Electrical Engineering/ Imperial College of Science and Technology, London University.

    Post-Doctoral Research:

    vi: Imperial College of Science & Technology, Electrical Engineering Dept., London (1981-83)
    vii: University of California, Dept. of Computer Science, Berkeley, CA (1986-87)
    viii: University of Maryland, Center of Automation Research, College Park, MD (1986-87)
    ix: NASA Johnson Space Center, Information Technology Division, Houston, TX (1990-92 & 1994)

6. **Posts Held:**

    i: Senior CSIR Research Fellow, Electronics and Communication Sciences Unit (ECSU),

Indian Statistical Institute, Calcutta from March 1975 to December 1976.

ii: Computer Engineer, ECSU, Indian Statistical Institute, Calcutta from December 1976 to December 1981.

iii: Commonwealth Scholar, Electrical Engineering Department, Imperial College, London from October 1979 to October 1981 (on leave from ISI).

iv: MRC Post-doctorate Fellow, Electrical Engineering Dept., Imperial College, London from November 1981 to April 1983 (on leave from ISI).

v: Visiting Research Fellow (on invitation), School of Electrical and Electronics Engineering, Leicester Polytechnic, Leicester, England from 1st July 1981 to 31st July 1981 (on leave from Imperial College).

vi: Associate Professor, ECSU, Indian Statistical Institute, Calcutta from January 1982 to May 1987.

vii: Guest Teacher in Computer Science, Calcutta University from 1983 to 1986.

viii: Fulbright Visiting Scientist in the Computer Science Division, University of California, Berkeley and in the Center for Automation Research, University of Maryland, College Park from September 1986 to January 1987 (on leave from ISI).

ix: Professor, ECSU, Indian Statistical Institute, Calcutta from June 1987 to March 1993.

x: Professor-in-Charge of Physical & Earth Sciences Division, Indian Statistical Institute, Calcutta for the period 1988-90.

xi: **NRC Guest Investigator at NASA Johnson Space Center**, Houston, Texas from January 1990 to March 1992, and February 1994 to June 1994 (on leave from ISI).

xii: Professor and Head, Machine Intelligence Unit, Indian Statistical Institute, Calcutta from March 1993 to June 1998.

xiii: Jawaharlal Nehru Fellow, Machine Intelligence Unit, Indian Statistical Institute, Calcutta from September 1993 to August 1995.

xiv: **Distinguished Scientist** and Head, Machine Intelligence Unit, Indian Statistical Institute, Calcutta from July 1998 to July 2005.

xv: Visiting Professor, Department of Computing, Hong Kong Polytechnic University, Hong Kong from March 1999 to June 1999, from November 2000 to January 2001, and from December 2002 to January 2003 (on leave from ISI).

xvi: Visiting Scientist, Department of Computer Science and Computer Engineering, La Trobe University, Melbourne, Australia during June and July 2002 (on leave from ISI).

xvii: Visiting Scientist, Information Technology Division, US Naval Research Lab., Washington DC, USA, from June to August 2004 (on leave from ISI).

xviii: Principal Investigator, Center for Soft Computing Research, ISI, Kolkata from October 2005 to September 2015.

xix: **Director** and Distinguished Scientist, Indian Statistical Institute from August 2005 to July 2010.

xx: Sir J.C. Bose National Fellow, Indian Statistical Institute, Kolkata from April 2007 to September 2018 (with full fellowship grant till Sept 2015, and thereafter only with contingency grant).

xxi: Distinguished Scientist and Former Director, Indian Statistical Institute from August 2010 to September 2015.

xxii: INAE (Indian National Academy of Engineering) Chair Professor from April 2013 to March 2015.

xxiii: Raja Ramanna Fellow, Dept. of Atomic Energy, Govt. of India from October 2015 to September 2018.

xxiv: Emeritus Professor, Indian Statistical Institute, Kolkata from September 2018 to date.

xxv: **INSA (Indian National Science Academy) Distinguished Professor** from October 2018 to August 2020.

xxvi: Scholar-in-Residence, IIT Jodhpur from May 2019 to date (to mentor AI and Data Science research)

xxvii: **National Science Chair**, SERB-DST, Govt. of India from August 2020 to date.

xxviii: AICTE (All India Council for Technical Education) Distinguished Chair Professor from September 2021 to date.

xxix: **President**, Indian Statistical Institute from Sept 2022 to date

7.   Awards, Prizes and Honours:

A: **Shanti Swarup Bhatnagar Prize** for the year 1990 in Engineering Sciences. *(This is the most coveted award for a scientist in India)*

: Jawaharlal Nehru Fellowship for the year 1993

: Hari Om Ashram Prerit Vikram Sarabhai Research Award for the year 1993 in Electronics/Telecommunication/Informatics/Automation

: NASA Space Act Tech Brief Award from NASA Inventions and Contributions Board, USA., 1993

: IEEE Trans. Neural Networks Outstanding Paper Award from IEEE Neural Networks Council (USA), 1994

: NASA Patent Application Award from NASA Inventions and Contributions Board, USA, 1995

: Distinguished Speaker of IEEE Computer Society (USA) for Asia Pacific Region, 1998

: Ram Lal Wadhwa Gold Medal from IETE (The Institution of Electronics and Telecom. Engineers), India, 1997

: Om Prakash Bhasin Award in Electronics and Information Technology from Bhasin Foundation for Science and Technology, 1998 *(Award is given by the Prime Minister of India)*

: **Distinguished Scientist**, Indian Statistical Institute, July 1998 (*He is the first person outside Statistics & Mathematics to receive this honor from ISI*)

: **G. D. Birla Award** for Scientific Research from K. K. Birla Foundation, 1999 (*Award is given to only one considering all branches of science – basic, applied, medical etc.*)

: **Khwarizmi International Award (1st winner)** from the Iranian Research Organization for Science and Technology (IROST), Islamic Republic of Iran, 2001 (*Award is given by the President of Iran*)

: Syed Husain Zaheer Medal from Indian National Science Academy, 2001

: FICCI Award in Engineering and Technology from the Federation of Indian Chambers of Commerce & Industry, 2001-2002

: **Director**, Indian Statistical Institute for the term 2005-2010 (*He is the first Computer Scientist, as well as first person outside Statistics and Mathematics to become its Director after its inception in 1931*)

: P.C. Mahalanobis Birth Centenary Award (Gold Medal) for lifetime achievements and contributions in Science and Technology from the Indian Science Congress Association, 2006 (*Award is given by the Prime Minister of India at Indian Science Congress*),

: Distinguished Alumnus of the Institute of Radio Physics and Electronics, University of Calcutta, 2006

: J.C. Bose National Fellowship of the Government of India, 2007

: Vigyan Ratna Award from Science and Culture Organization, West Bengal, 2008

: P.C. Mahalanobis Memorial Medal from Indian Science News Association, 2010

: **Padma Shri** in 2013, conferred by the President of India, for distinguished service in Science and Engineering. *(This is one of the highest civilian awards of the Nation)*

: INAE (Indian National Academy of Engineering) Chair Professor, 2013

: IETE (The Institution of Electronics and Telecom. Engineers, India) Diamond Jubilee Medal, 2013

: IEEE (USA) Fellow Class Golden Jubilee Medal, 2014

: Prof. S.N. Mitra Memorial Award from Indian National Academy of Engineering, 2015.

: Raja Ramanna Distinguished Fellowship, Department of Atomic Energy, Govt. of India, 2015

: Jawaharlal Nehru Birth Centenary Lecture award from Indian National Science Academy,

2017
: IEEE Tencent Rhino-Bird International Expert 2017
: **Distinguished Professorial Chair**, Indian National Science Academy, 2018 *(One of the highest scientific honors that the Academy confers)*
: **National Science Chair**, SERB-DST, Government of India, 2020
: First Prof. C. Mohan Gold Medal Award for Excellence in Soft Computing from the Soft Computing Research Society, 2020.
: AICTE nominated Distinguished Chair Professor, AICTE (All India Council for Technical Education), 2021
: **President**, Indian Statistical Institute from Sept 2022 to date *(He is the first Ex-employee of ISI being elected to hold this honorable Chair after its inception in 1931)*

B**:** Fellow, TWAS (The World Academy of Sciences for the Advancement of Science in Developing Countries), Italy, 1998. ***(When he was elected in 1998, TWAS prize for Engineering Sciences did not exist. Later, when the prize was initiated in 2003, he was no eligible to contest for that which is allowed only before elected as a Fellow as per TWAS rule.)***

: Member, European Academy of Sciences and Arts, Austria, 2022.

: Life Fellow, Institute of Electrical and Electronics Engineers (L-FIEEE), USA, 2015.
: Fellow, Institute of Electrical and Electronics Engineers (FIEEE), USA, 1993.
: Fellow, International Association for Pattern Recognition (FIAPR), USA, 2002.
: Fellow, International Fuzzy Systems Association (FIFSA), USA, 2007.
: Fellow, International Rough Set Society (FIRSS), Poland, 2016.
: Fellow, Asia-Pacific Artificial Intelligence Association (AAIA), Hong Kong, 2021.

: Fellow, Indian National Science Academy (FNA), 1993.
: Fellow, Indian Academy of Sciences (FASc), 1996.
: Fellow, National Academy of Sciences, India (FNASc), 1993.
: Fellow, Indian National Academy of Engineering (FNAE), 1995.
: Fellow, West Bengal Academy of Science and Technology (FAScT), 2000.
: Fellow, Institution of Engineers (FIE), India.
: Life Fellow, Institution of Electronics and Telecommunication Engineers (FIETE), India, 1997.

C**:** ONRIFO (Office of Naval Research International Field Office, Government of USA) Fellowship in 2004.
: INSA-JSPS (Government of Japan) Fellowship in 1996.
: National Academy of Science (National Research Council) - NASA (Government of U.S.A.) Senior Research Associate Award in 1989.
: Fulbright Post-Doctoral Visiting Award (Government of U.S.A) in 1986.
: Medical Research Council (Government of U.K.) Post-Doctoral Award in 1981.
: Commonwealth Scholarship (Government of U.K.) in 1979.

D: Best Production Award in the 7th World Book Fair, New Delhi, 1986 to his book - Fuzzy Mathematical Approach to Pattern Recognition, John Wiley and Sons (Halsted Press), N.Y., 1986. The book has also been **translated into Indonesian Bahasa and Chinese Languages.**
: His book - Fuzzy Models for Pattern Recognition: Methods that Search for Structures in Data, IEEE Press, N.Y., 1992 was in the list of *IEEE Best Seller* **books till 1995**.

8.   **Editorial and other Professional Activities:**

A: *Associate Editor*: IEEE Trans. on Pattern Analysis and Machine Intelligence (IEEE Press) (2002-2006), IEEE Trans. on Neural Networks (IEEE Press) (1994-1998; 2003-2006), IEEE Trans. on Fuzzy Systems (IEEE Press) (1993-1995), Pattern Recognition Letters (Elsevier) (1993-2011), Neurocomputing (Elsevier) (1995-2005), Int. J. Approximate Reasoning (Elsevier) (1992-1993), IET Image Processing (IEE Press) (2007-2019), Int. J. Pattern Recognition and Artificial Intelligence (World Scientific) (2003 to date), Information Sciences (Elsevier) (2000 to date), Fuzzy Sets and Systems (Elsevier) (2003 to date), LNCS Trans. on Rough Sets (Springer) (2003 to date), Journal of Data, Information and Management (Springer) (2018 to date), Engineering Applications of Artificial Intelligence (Elsevier) (2022 to date), Applied Intelligence (Kluwer) (2002-2012), Fundamenta Informaticae (IOS Press) (2003-2019), Int. J. Computational Intelligence and Applications (World Scientific), Journal of Intelligent Information Systems (Springer) (2008-2012), The Journal Ingeniería y Ciencia, (published by Escuela de Ciencias y Humanidades and the Escuela de Ingeniería of Universidad EAFIT in Colombia) (2014-2015), and Proc. INSA-A (Indian National Science Academy-A).

:   *Editor-in-Chief*: Int. J. Signal Processing, Image Processing and Pattern Recognition, SERSC, Korea (2008-2019).

:   *Book Series Editor:* Frontiers in Artificial Intelligence and Applications (FAIA), IOS Press; Netherlands (2007 to date); Statistical Science and Interdisciplinary Research, World Scientific, Singapore (2008 to date).

:   *Executive Advisory Editor:* IEEE Trans. on Fuzzy Systems (1996-2000), Int. J. Approximate Reasoning (Elsevier) (1993 to date), Int. J. Image and Graphics (World Scientific), Int. J. Computational Science and Engineering (Inderscience), Int. J. Business Intelligence and Data Mining (Inderscience), Int. J. Machine Intelligence and Sensory Signal Processing (Inderscience) (2016-2021), and Data-Centric Engineering (Cambridge Univ. Press).

:   *Guest Editor*: IEEE Computer, IEEE Systems, Man and Cyberns-A, Theoretical Computer Science: Theory of Natural Computing (Elsevier), Fundamenta Informaticae (IOS Press), Neurocomputing (Elsevier), Pattern Recognition Letters (Elsevier), Applied Intelligence, Information Sciences (Elsevier), Applied Soft Computing (Elsevier), IET Image processing (IEE Press), Natural Computing (Springer), Int. J. Engg. Intell. Syst., Proc. Indian National Science Academy, and J. Inst. Elect. Telecom. Engg. (India)

B: Founder and founding President, Indian National Academy of Engineering (INAE), Kolkata Chapter.
:   Founding President, Indian Society for Rough Sets (ISRS).
:   Founding Executive Member, Indian Unit for Pattern Recognition and Artificial Intelligence (IUPRAI).
:   Founding Executive Member and then Life Member, Indian Society for Fuzzy Mathematics and Information Processing (ISFUMIP).

9.   **Establishing a Center for Excellence in Soft Computing Research and Leading Projects for National Importance**

A: Center for Excellence in Soft Computing Research:

The Department of Science & Technology (DST), Government of India has established under its IRHPA (Intensification of Research in High Priority Areas) scheme the ***Center for Soft Computing Research: A National Facility*** at ISI, Kolkata under his leadership.

The center, having first of its kind in the country, plays a major role in the current and future IT perspective of the nation and provides a strong base for research and training, and collaborative work with Industry and other research organizations. It promotes soft computing research activity, through funding and monitoring, in institute like NITs and other less endowed institutes. It also provides a six-month postgraduate certificate course on soft computing. ***In 2010, the Governing Council of ISI has declared the Center as its Associate (Affiliated) Institute.*** (See *Annexure A*)

B: Principal Investigator of other Projects of National Importance: Some Examples

(a) *"Handling Uncertainties for Machine Interpretation of Ill-defined Structures Present in Gray Level Images"* in the Machine Intelligence Unit, ISI, Kolkata, Sponsored by DEAL, DRDO, Dehradun. (duration August 1993 to October 1995)
(b) *"A Neuro-fuzzy Image Recognition System: Methodology Development for Forensic Applications"* in the Machine Intelligence Unit, ISI, Kolkata, Sponsored by CSIR, New Delhi. (duration June 1993 to June 1997)
(c) *"Cancer Management in Soft Computing Paradigm"* in the Machine Intelligence Unit, ISI, Kolkata, Sponsored by CSIR, New Delhi. (duration October 1997 to March 2001)
(d) *"Knowledge-Based Connectionist Data Mining System: Design and Application"* in the Machine Intelligence Unit, ISI, Kolkata, Sponsored by CSIR, New Delhi. (June 2000 to March 2006)
(e) *"Statistical, Structural and Soft Computing based techniques for Pattern Recognition: Theory, Algorithms, and applications to Bioinformatics",* in Center for Soft Computing Research, ISI, Kolkata, Sponsored by INDO-BRAZIL Project, Coordinated by DST, New Delhi. (September 2010 to August 2013)

10.   International Collaborations:

Formal collaboration and research projects with the following foreign universities

a) Osaka Prefecture University, Osaka, coordinated by the Japan Society for the Promotion of Science (JSPS).
b) INSEAD (Dept. of IT Management), Fontainebleau, France, coordinated through INSEAD Research Grant.
c) Warsaw University, Poland, coordinated by the Polish State Committee for Scientific Research (KBN), Poland and Department of Science & Technology (DST), India.
d) University of Naples Parthenope, Italy coordinated through Naples University Research Grant under ISI-Naples University joint research program.
e) Hong Kong Polytechnic University, Hong Kong, coordinated by the Research Grants Council, Hong Kong.
f) Zhejiang University, China, coordinated by the Ministry of Science & Technology of the People's Republic of China and the Department of Science & Technology (DST), India.
g) NASA Johnson Space Center, Houston, through NRC-National Academy of Science Research Associateship Program (1990-94).
h) Computer Vision Lab, University of Maryland, College Park, MD, USA through Fulbright program.
i) US Naval Research Lab., Washington DC through ONRIFO program.
j) La Torbe University, Melbourne, Australia, coordinated by the Australian Research Council (ARC).
k) University of Sao Paulo, Brazil, coordinated through Indian National Sciences Academy and Brazilian Academy of Science.

(For other collaborating institutes, viz, 45 foreign and 16 Indian, leading to joint

publications, see Annexure D)

11.   Teaching and Research Experience

Forty-eight years' experience in research and teaching Pattern Recognition, Image Processing, Fuzzy Logic, Artificial Neural Networks, Soft Computing. Taught to M.Stat. and M.Tech.(CS) courses in ISI and Calcutta University, as well in Ph.D. programs abroad, e.g., Soft Computing and Data Mining in Trento University, Italy.

Research interests include Pattern Recognition and Machine Learning, Image Processing, Data Mining, Soft Computing, Fuzzy Sets and Uncertainty Analysis, Neural Nets, Genetic Algorithms, Rough Sets, Web Intelligence, Bioinformatics, Safety analytics, Computing with Words, and Big Data.
                    (See *Annexure B* for significant research contributions)

Ph.D. Theses Supervised and Post-doctorates mentored:

PhDs: 22 (10 awarded from ISI, 7 awarded from Jadavpur University, 2 awarded from Calcutta University 2 awarded from The Hong Kong Polytechnic University, Hong Kong, and 1 working at IIT Kharagpur).

Post-doctorates: 20

Note: *Among the 21 PhDs that he has graduated so far,* several are internationally known researchers and science leaders with awards & honors like, Padmashree, S.S. Bhatnagar Prize, Infosys Prize, P.C. Mahalanobis National Award of MOSPI, GoI, J.C. Bose National Fellow, Fellows of IEEE, TWAS, IAPR, IFSA, INSA and other National Academies. *Further, five of them and two of his post-docs, and he himself (eight together) are featured in the Stanford list of top 2% scientists worldwide in the domain of Artificial Intelligence and Image Processing.*

Publications and Citation Index:

21 Books (Authored: 8, Edited Monograph: 13), 17 Edited Conference Proceedings, 489 Research papers (286 in International Journals, 61 in Book Chapters and 142 in Conference Proceedings), and 3 Patents. (*List of publications is enclosed*).

Google Scholar h-index = **80**, i10-index = 280, i100-index = 67, g-index = 178, highest citations of a single paper = **5525** and total citations ≈ **35,000+** (as in Aug 2022)

- According to 2020 Stanford list of top 2% scientists world-wide, he has been featured within the **top 0.106920052%** with **C-score = 4.10705055** and **subject-wise rank of 230** in the domain of **Artificial Intelligence and Image Processing**. For world-wide full list of top 2% scientists covering all disciplines, see: http://shorturl.at/qHIJ4 (where he ranked #14374).

- He is ranked #14225 in World's top 2% Scientists **covering all disciplines** as per the standardized citation indicators, 2021, maintained by Elsevier. See https://elsevier.digitalcommonsdata.com/data.../btchxktzyw/3.

- He is ranked #418 within the Top 1,000 Scientists globally in the field of **Computer Science**, according to 2022 edition of World-wide Ranking of Top 1,000 Scientists released by Guide2Research (https://www.guide2research.com/scientists/) and Research.com (research.com/scientists-rankings/computer-science).

(See *Annexure C* for some examples of quality recognitions of his work by other researchers)

US/ Foreign Patents Granted:

D. Bhandari, C.A. Murthy and S.K. Pal, Optimization technique using evolutionary algorithms, US patent # 8,700,548; Issued on April 14, 2014.

S.K. Pal and S. Meher, Rough Wavelet Granular Space and Classification of Multispectral Remote Sensing Image, Korea Patent # IN-800853-05-KR-NAT, Issued Patent (21 Jan 2015); China Patent # IN-800853-04-CN-NAT, Application Granted (27 Jan 2016); US Patent # IN-800853-03-US-NAT, Application Granted (6 Oct 2015).

Books:

Authored Books:

   i. S. K. Pal and D. Dutta Majumder, Fuzzy Mathematical Approach to Pattern Recognition, John Wiley & Sons (Halsted), N.Y., 1986.

  ii. S. K. Pal and S. Mitra, Neuro-Fuzzy Pattern Recognition: Methods in Soft Computing, John Wiley, N.Y., 1999.

 iii. S. K. Pal and Simon C.K. Shiu, Foundation of Soft Case-Based Reasoning, John Wiley, N.Y., 2004.

  iv. S. K. Pal and P. Mitra, Pattern Recognition Algorithms for Data Mining, Chapman & Hall CRC Press, Boca Raton, FL, 2004.

   v. S. Bandyopadhyay and S. K. Pal, Classification and Learning with Genetic Algorithms: Applications in Bioinformatics and Web Intelligence, Springer Verlag, Heidelberg, 2007.

  vi. P. Maji and S.K. Pal, Rough-Fuzzy Pattern Recognition: Application in Bioinformatics and Medical Imaging, John Wiley, N.Y., 2012.

 vii. S.K. Pal, S.S. Ray and A. Ganivada, Granular Neural Networks, Pattern Recognition and Bioinformatics, Springer, Heidelberg, 2017.

viii. D.B. Chakraborty and S.K. Pal, Granular Video Computing: with Rough Sets, Deep Learning and in IoT, World Scientific, Singapore, 2021.

Edited Books:

  ix. J. C. Bezdek and S. K. Pal (Eds.), Fuzzy Models for Pattern Recognition: Methods that Search for Structures in Data, IEEE Press, N.Y., 1992.

   x. S. K. Pal and P. P. Wang (Eds.), Genetic Algorithms for Pattern Recognition, CRC Press, Boca Raton, Florida, 1996.

  xi. S. K. Pal and A. Skowron (Eds.), Rough Fuzzy Hybridization: A New Trend in Decision Making, Springer Verlag, Singapore, 1999.

xii. S. K. Pal, A. Ghosh and M. K. Kundu (Eds.), Soft Computing for Image Processing, Physica Verlag, Heidelberg, 2000.

xiii. S. K. Pal, T. S. Dillon and D. S. Yeung (Eds.), Soft Computing in Case Based Reasoning, Springer Verlag, London, 2001.

xiv. S. K. Pal and A. Pal, (Eds.) Pattern Recognition: From Classical to Modern Approaches, World Scientific, Singapore, 2001.

xv. D. Zhang and S. K. Pal (Eds.), Neural Networks and Systolic Array Design, World Scientific, Singapore, 2002.

xvi. A. Ghosh and S. K. Pal (Eds.), Soft Computing Approach to Pattern Recognition and Image Processing, World Scientific, Singapore, 2002.

xvii. S. K. Pal, L. Polkowski and A. Skowron (Eds.), Rough-Neural Computing: Techniques for Computing with Words, Springer Verlag, Heidelberg, 2003.

xviii. S. K. Pal and J. F. Peters (Eds.), Rough-fuzzy Image Analysis: Foundations and Methodologies, Chapman & Hall/CRC, Boca Raton, Florida, 2010.

xix. S. K. Pal, A. Petrosino and L. Maddalena (Eds.), Handbook in Soft Computing for Visual Surveillance, Chapman & Hall/ CRC Press, Boca Raton, Florida, 2012.

xx. S. Misra and S. K. Pal (Eds.), Soft Computing Applications in Sensor Networks, Chapman & Hall/ CRC Press, Boca Raton, Florida, 2017.

xxi. A. Pal and S. K. Pal, (Eds.) Pattern Recognition and Big Data, World Scientific, Singapore, 2017.

12. **Academic & Administrative Leadership and National/ International Contributions**

: He has made pioneering and seminal contributions in the development and evolution of the discipline Data Science and Analytics starting from pattern recognition and fuzzy sets since March 1975, to image processing since 1979, machine learning and neural networks since 1987, soft computing and machine intelligence since 1992, data mining since 2000, granular computing since 2007, and deep learning since 2017. These contributions are characterized by Google Scholar **h-index of 80 and total citations of 35,000+**, with citations of most-cited single paper equal to **5525** (as in Aug 2022).

: He has built an active research school since 1983 on Machine Intelligence and Learning which comprises the activity in the areas of Pattern Recognition, Image Processing, Soft Computing, Data Mining, Fuzzy Sets and Systems, Artificial Neural Networks, Genetic Algorithms etc. This school has been recognized as a **separate department, named Machine Intelligence Unit (MIU) of Indian Statistical Institute**, Kolkata in 1993. The school is now enjoying International and National recognition under his direction. As an independent evidence towards this, he together with his former six Ph.D. students, one post-doc student and two other members of MIU are featured in the recent Stanford list of top 2% scientists worldwide in the domain of Artificial Intelligence and Image Processing. **This demonstrates his visionary leadership**.

: The DST, New Delhi has established in Indian Statistical Institute (ISI) under his leadership the **Center for Soft Computing Research: A National Facility.** The center, which is first in the country, acts as a strong base for nationwide research and training in the said field with linkage to industries and premier institutes in India and abroad, with special provision for less endowed institutions. The Center has been declared in 2010 as an **Associate Institute of ISI** by its Governing Council.

: He was the **first Director in the 74-year history** of the Indian Statistical Institute, after its inception in 1931, who is a Computer Scientist, not a Mathematician or a Statistician like his nine predecessors. This is indeed a very significant achievement that reflects the impact of his interdisciplinary research contributions comprising Computer Science and Statistics, as well as his eminence in leadership particularly to an Institute which is internationally known primarily for Statistics and Mathematics.

: During his term as the Director of ISI (August 2005 - July 2010), he established the **third Centre of ISI at Chennai**, more than three decades after the second Centre was established at Bangalore, with focus on conducting more applied research. Establishing the **fourth Center of ISI in North-East region** of the country (founded in Tezpur Central University) was an outcome of his vision document, and the creation of the center was approved during his tenure.

In doing so, he was carrying out the **wish expressed by the honorable prime minister of India, Prof. Manmohan Singh,** in his speech on December 24, 2006, in the Inaugural Ceremony of the Platinum Jubilee of ISI, namely, that ISI should expand its activities to serve the nation in a better fashion in statistics, information technology (IT) and planning.

: During the said inaugural ceremony on December 24, 2006, the prime minister Prof. Manmohan Singh declared 29th June, the birthday of Prof. Prasanta Chandra Mahalanobis, founder of ISI, as the **National Statistics Day** to be observed every year**.** An **honorary D.Sc. degree** was conferred on Prof. Singh.

: He established a full-fledged **International Statistical Education Centre (ISEC)** in the ISI campus by enhancing the scope and presence of the existing programme, on the eve of its Diamond Jubilee, and providing it a distinct identity in a separate campus with infrastructural facilities on international standard.

: He was instrumental in **getting approval from the Cabinet (Government of India) of the IISc pay-scales** for ISI faculty. Before this, they had been getting the lower UGC pay-scales; thereby failing to attract good faculty.

: Under his leadership (during January 1990 to March 1992, and February 1994 to June 1994) an active research group on fuzzy logic and uncertainty analysis was formed in the Software Technology Branch, **NASA Johnson Space Center, Houston,** TX, U.S.A.

: He has delivered Keynote, Plenary or Invited talks and special courses in various National and International Conferences/Workshops and Institutes in India and abroad on an average of about 10 per year since 1994. The number **countries visited as an academic visitor is 44.** The number of **foreign collaborating institutes** that lead to joint publications/ books is **45**.

Besides, he **has many international activities** abroad contributing to the society. These include: guiding research work leading to PhD degree; serving in various academic bodies and committees for evaluating e.g., research projects for Government funding, annual

progress of research centers/ institutes, PhD theses, as well as in international committees for prestigious awardee selection, fellow-election, faculty selection/ promotion, and preparing new course curriculum, in Europe, Hong Kong, USA, Malayasia, Singapore, and Australia, among others.

: His book - Fuzzy Models for Pattern Recognition: Methods that Search for Structures in Data, IEEE Press, N.Y., 1992 was in the list of **IEEE Best Seller books** till 1995.

His book - Fuzzy Mathematical Approach to Pattern Recognition, John Wiley and Sons (Halsted Press), N.Y., 1986, which is unique in its kind, has been translated into **Indonesian Bahasa and Chinese Languages**. (https://www.tokopedia.com/maxisiahaan/fuzzy-pendekatan-matematik-untuk-pengenalan-pola-oleh-sankar-k-pal)

: He has **graduated 21 PhD students**, so far, in India and abroad. All are internationally well placed in academia and industry. Many of whom are **internationally known leading scientists** with recognitions like Padmashree, S.S. Bhatnagar Awardee, Infosys Awardee, TWAS Prize Awardee, INAE Chair Professor, Fellows of IEEE, TWAS, IFSA, INSA and other National Academies, Editor-in-Chief of IEEE Transactions, Director of Premier Institute, and are featured in Stanford list of top 2% scientists worldwide

: He is the scientist who **introduced the Soft Computing** concept and research in India.

: International Conference on Pattern Recognition and Machine Intelligence (**PReMI**), the Proceedings of which are being published by Springer Verlag, Heidelberg, under its prestigious LNAI (Lecture Notes in Artificial Intelligence) Series, is his **brainchild.** Its nine editions, so far, were held in ISI, Kolkata (2005, 2007, 2013, 2017 & 2021), IIT-Delhi (2009), Asam Central University, Tezpur (2019), Higher School of Economics, Moscow, Russia (2011), and Warsaw University of Technology, Poland (2015). This biennial event primarily helps Indian researchers and students in the said areas to interact among themselves as well as with experts from India and abroad for furtherance of their research.

: He is the **Third Padma Awardee** of ISI after Prof. P.C. Mahalanobis and Prof. C.R. Rao. His Padma Shri in 2013 came after 45 years since 1968 when Prof. P.C. Mahalanobis and Prof. C.R. Rao received Padma Bhibhusan and Padma Bhusan respectively.

: A one-day workshop on "**40 Years of Fuzzy Sets at Indian Statistical Institute**" was organized in honor of him at ISI, Kolkata on September 13, 2015, to celebrate his 65th birth anniversary.

: Played a key role in India in **educating and mentoring** several scientists/engineers/researchers in industries, universities & research organizations for applying pattern recognition, image processing, soft computing and machine intelligence theories

: Actively involved in conducting and participating in various **outreach programs** of the country for educating students/ scholars/ teachers in remote places in India, particularly in North-East regions of the country, since 2000. This includes the visit to several schools in rural areas for inspiring the young students for science education and opting for science career.

In this spirit, his Center for soft computing research also provided fellowships to faculty and scholars from **less endowed institutions** of the country to work at the center for quality improvement.

: Instituted **two Merit-cum-Means Scholarships** in 2013 for supporting two economically backward students of Classes IX and X every year in his alma-mater, Ariadaha Kalachand High School, Kolkata 700057. This facilitates them to complete their secondary school education for societal benefit.

: Instituted a **Gold Medal Award** at ISI in 2003 for the best M.Tech.(CS) dissertation. This encourages and promotes research excellence which, in turn, serves the society better.

: Acted as the Chairman of several National Scientific Committees including the Information technology Academic Council (IT-AC), Govt. of West Bengal, and the Syllabus Committee for classes VI to XII, CLTP (**Computer Literacy Training Program**), West Bengal Board of Secondary Education, Govt. of West Bengal.

: Served in various **National/ International high-power committees** for Awards, Honors, University Vice-Chancellor selection, selecting the Director of National Institute of Technology (NIT), selecting the Chief Statistician of India, MOSPI, GoI, Reviewing the overall performance of IIT and IISER, Project Evaluation, Planning and Program, and in Institutional Governing Councils, among others.

: Founder of the Kolkata Chapter of INAE (Indian National Academy of Engineering) in 2007, and its Founding President (July 2007 - Oct 2017).

: Founding President of Indian Society for Rough Sets (2010 – 2015)

: Founder and Founding Head of Machine Intelligence Unit, ISI (March 1993 – July 2005).

: Founder of the Center for Soft Computing Research: A National Facility, ISI, in 2004, and its Founding PI (2004 - Serving the society 2015).

: **Director** (Head of both Administrative and Academic affairs), **Indian Statistical Institute (ISI)** for the term August 2005 – July 2010. ISI is an Institute of National Importance which has ten centers/units all over India with headquarters at Kolkata.

13. Named Lectures Delivered

i: *Japanese Fuzzy Logic Companion Lectures* in 1988 and 1990 for the engineers and scientists of Japanese industries who want to apply fuzzy logic for commercial product.
ii: 1993 *Vikram Sarabhai Lecture* in Electronics/Telecommunications/Informatics/ Automation in the Physical Research Laboratory, Ahmedabad.
iii: *Jawaharlal Nehru Fellowship Lecture* of Jawaharlal Nehru Memorial Fund, delivered at Electronics Niketan, Department of Electronics, Govt. of India, and at Allahabad University, Allahabad in 1994.
iv: *Amal K. Roy Memorial Lecture* of the Institute of Electronics & Telecomm. Engineers (IETE), India, Kolkata Chapter, 1996.
v: *Platinum Jubilee Lecture in Information Technology* of the Institute of Engineers (India), 1996.
vi: 1997 *Ramlal Wadha Gold Medal Lecture* of the Institute of Electronics & Telecomm. Engineers (IETE), India.
vii: *Ananta K. Sengupta Memorial Lecture,* Dept. of Applied Physics, Calcutta University, Calcutta, 1998.
viii: *IEEE (USA) Distinguished Visitor Lectures* in 1998, 1999, 2003 and 2012 in fifteen IEEE Chapters of Australia, Singapore, China, Hong Kong, New Zealand, and Bangladesh.
ix: 67th *Annual General Meeting Special Lecture* of Indian Academy of Science, 2001.

x: 2001 *S.H. Zaheer Medal Lecture* of Indian National Science Academy (INSA), delivered at the Department of Mathematics, Punjab University, Chandigarh.

xi: 5th *Distinguished Information Technology (IT) Lecture*, Ministry of Communication and Information Technology, Govt. of India, New Delhi, 2003.

xii: *The Bengal Science Lecture in IT and Bio-IT* under the National Program *"Year of Scientific Awareness 2004"*, Calcutta, organized by the Science & Technology Council and Department, Govt. of West Bengal, India.

xiii: *Kolkata Kolon Talk* in S. N. Bose Center of Basic Science in 2004.

xiv: *Golden Jubilee Plenary Talk* at the CSIR-Central Mining Research Institute (CMRI), Dhanbad, India in 2006.

xv: *1st D. M. Bose Memorial Lecture* on his 121st Birth Anniversary, 26th November 2006, at the Bose Institute, Kolkata.

xvi: *Golden Jubilee Talk* at the ICAR-Central Inland Fisheries Research Institute, Barrackpore, Kolkata on 21st May 2007.

xvii: *Zdzislaw Memorial Plenary Talk* in Warsaw, Poland on 29th June 2007 under the Int. Conference on Rough Sets and Emerging Intelligent Systems Paradigms (RSEISP), 2007.

xviii: *Prof. A.K. Chowdhury Memorial Talk* in Jadavpur University, Kolkata on January 6, 2008, under the 9th Int. Conference on Distributed Computing and Networking (ICDCN), 2008.

xix: *Bose Colloquium Lecture* at the S.N. Bose National Center for Basic Sciences, January 8, 2010.

xx: *P. C. Mahalanobis Memorial Lecture* of Indian Science News Association, delivered at Visva-Bharati, Shantiniketan, July 17, 2010.

xxi: *Zdzislaw Pawlak Memorial Plenary Talk* in Warsaw, Poland on 28th June 2010 under the 7th Int. Conference on Rough Sets and Current Trends in Computing (RSCTC), 2010.

xxii: *Golden Jubilee Distinguished Lecture* at Hong Kong Baptist University, Hong Kong, March 3, 2011

xxiii: *Prof. P.P. Chatterjee Memorial Lecture*, Department of Applied Mathematics, University of Calcutta, India, September 5, 2011

xxiv: *IEEE Distinguished Visitor Lectures* at Bangladesh University of Engineering & Technology (BUET), Dhaka, BRAC, Dhaka, and Rajshahi University of Engineering & Technology (RUET), Rajshahi in November 2012.

xxv: *5th Srinivasa Ramanujan Memorial Lecture* at the Netaji Subhas Open University, Kolkata on 7th March 2013.

xxvi: *Faraday Memorial Lecture* at the IEEE Hyderabad Section, Hyderabad, September 22, 2013.

xxvii: *4th Convocation Speech* at the National Institute of Technology (NIT), Patna, September 28, 2014.

xxviii: *59th Convocation Speech* at Jadavpur University, Kolkata, December 24, 2014.

xxix: *11th Convocation Speech* at the Dhirubhai Ambani Institute of Information and Communication Technology (DA-IICT), Gandhinagar, January 17, 2015.

xxx: *National Science Day Lecture* at the CSIR-Centeral Glass and Ceremic Research Institute, Kolkata, February 25, 2015

xxxi: *2015 Prof. S.N. Mitra Award Lecture* of Indian National Academy of Engineering (INAE) at the Defence Institute of Advanced Technology (DIAT), Pune, December 10, 2015

xxxii: *64th Foundation Day Lecture*, CSIR-CEERI, Pilani, September 21, 2016

xxxiii: *Golden Jubilee Celebration Inaugural Lecture,* Electronics and Telecommunication Engineering Dept., Indian Institute of Engineering Science and Technology (IIEST), Shibpur, March 01, 2017

xxxiv: *2017 Jawaharlal Nehru Birth Centenary Lecture* of Indian National Science Academy (INSA) at Savitribai Phule Pune University, July 12, 2017

xxxv: *National Science Day Lecture* of Indian National Academy of Engineering - Kolkata Chapter at Calcutta University, Salt Lake Campus, Kolkata, February 28, 2018

xxxvi: National Technology Day Talk at DIT University, Dehradun on May 11, 2018.

xxxvii: *Foundation Day Lecture,* IIT Patna, August 6, 2018.

xxxviii: *Teachers' Day Lecture of the year 2018,* ICAR-Indian Agricultural Research Institute, New Delhi, September 5, 2018.

xxxix: 14th Convocation Address, National Institute of Technology (NIT), Calicut, Kozhikode, Kerala, September 29, 2018.

xl: *Prof. Meghnad Saha Memorial Lecture of the National Academy of Sciences, India,* Jharkhand Chapter, to commemorate the 125th Birth anniversary of its founder, CSIR-NML Auditorium, Jamshedpur, October 5, 2018

xli: *Prof. M. N. Saha Memorial Lecture of the National Academy of Sciences, India,* Varanasi Chapter, to commemorate the 125th Birth anniversary of its founder, Banaras Hindu University, Varanasi (BHU), March 29, 2019.

xlii: *CSIR Foundation Day Lecture*, CSIR Madras Complex and CSIR-Structural Engineering Research Center, Chennai, September 27, 2019.

xliii: *Special Public Lecture* (Webinars) as a part of Golden Jubilee Celebration of DST, GoI, organized by the NASI-Delhi Chapter and MHRD-Institution Innovation Council, Deen Dayal Upadhyaya College, University of Delhi, Sept 26, 2020

xliv: *Indian National Science Academy Anniversary Lecture,* 88th INSA Anniversary General Meeting, CSIR-National Institute of Oceanography, Visakhapatnam, December 14-16, 2022.

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Annexure A: Center for Soft Computing Research: A National Facility

Annexure B: Significant Research Contributions

Annexure C: Examples of Recognition by other Researchers in the Field

Annexure D: Collaborating Institutes Leading to Joint Publications (Papers, Books & Conf. Proceedings)

Annexure E: Visits Abroad (2007 onwards)

Annexure F: Examples of Committees Served in India and Abroad

Center for Soft Computing Research: A National Facility
(https://www.isical.ac.in/~scc)

IRHPA (Intensification of Research in High Priority Areas) is a complementary program to the SERC program of the DST, Government of India, with activities consisting of setting up of units/core groups around an eminent scientist and major National Research Facilities to nucleate research activities in these areas. The scheme has contributed to augment general R&D capabilities at academic institutions and national laboratories.

Under the said IRPHA scheme *a Center for Soft Computing Research: A National Facility* is set up at the Indian Statistical Institute (ISI), Kolkata, with Prof. Sankar K. Pal as the Principal Investigator (PI) and the Head, because of his outstanding contributions and achievements in the area of soft computing and machine intelligence.

The Center has been declared in 2010 as an **Associate Institute of ISI** by its Governing Council.

Objectives:

The center focuses mainly on basic research, as well as on manpower development and promoting soft computing research in other institutes in the country. The activities of the center include:

a) conducting basic research in pattern recognition, machine learning, image and video analysis, computational theory of perception, computing with words, granular computing, cognitive vision, data mining, web intelligence, bioinformatics, fuzzy sets, rough sets, neural networks, support vector machines, evolutionary algorithms, particle swarm optimization, hybrid techniques etc.,

b) demonstrating applications to some focused areas like social network analysis, video surveillance, biometrics, and remotely sensed image analysis apart from web mining, temporal data analysis, bioinformatics, and medical image analysis,

c) supervising the work for Ph.D. and Master's degree theses, and mentoring Post-docs.

d) developing manpower: providing a three-month value addition certificate course on machine intelligence and soft computing (entry through interview) for postgraduate degree holders in order to enable them to join CS/ IT related research or teaching institutes or industries,

e) providing fellowships to faculty and scholars from less endowed institutions in the country to work at the center for quality improvement,

f) imparting training to researchers/students from industry and academia including R&D labs; providing training to government officials; and offering regular short term advanced courses on upcoming research areas,

g) supporting collaborative work, with travel allowances and local hospitality, to scientists/ researchers of national institutes, laboratories and universities e.g., IIT, Delhi; IIT, KGP; CDAC, Kolkata and NIT, Rourkela,

h) nurturing and upgrading soft computing community and institutes like NITs & CDAC in the country by conducting collaborating projects, evaluating project proposals for funding

them by DST through the Center and monitoring the progress,

i) conducting a network project involving premier research institutes like IITs and IISc.

j) organizing seminars/conferences/workshops/schools by eminent faculty from India and abroad,

k) providing a forum of exchanging ideas or establishing a linkage among scientists of leading institutions and industry working in similar areas by inviting interested faculty/ research personnel.

Collaboration with foreign Institutes: International collaboration with organizations like CIMPA, France, University of Palermo, Italy; University of Trento, Italy; INSEAD, France, and Meiji University, Japan; University of Sao Paolo, Brazil; and other Soft Computing Centers like The Berkeley Initiative in Soft Computing, and European Center for Soft Computing.

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Significant Research Contributions

Pattern Recognition, Soft Granular Mining, Machine Intelligence and Data Science

Prof. Sankar K. Pal has made fundamental contributions to machine intelligence research by developing various modern approaches. He pioneered the development of fuzzy set theory, and neuro-fuzzy and rough-fuzzy computing, in general, and their applications in pattern recognition, image processing, machine learning, granular computing, data mining, machine-mind development, and knowledge-based systems, in particular. The theories and methodologies formulated allow human like (soft) decision by reducing the uncertainty and enhancing the performance, computational intelligence, speed, and flexible information processing capability of the system. The work is prominently significant when the pattern indeterminacy is due to inherent vagueness rather than randomness, and the data is heterogeneous and large. It is shown, both theoretically and experimentally, how the merits of fuzzy logic, artificial neural networks, genetic algorithms and rough sets along with psychological facts can be integrated synergistically to achieve these characteristics. In the process, he has introduced various new concepts, tools and measures towards uncertainty management and computing with words, and pioneered generic families of hybrid models for enhanced learning and knowledge mining with understandability and explain ability in natural language. This has led to significant technological development in data science. The contribution is significant both from theoretical and applied points of view, and has immense societal impact.

The Concept and Models Developed

Notable systems/ methodologies with theoretical analysis, developed by him, include: multi-valued recognition system (IEEE T-SMC, 7, 625-629, 1977; IEEE T-SMC, 22, 607-620, 1992); correlation between fuzzy sets (Fuzzy Sets and Systems, 17, 23-38, 1985); generalized set operators (IEEE T-SMC, 17, 840-847, 1987); bounds for membership functions (Inform. Sci., 65, 43-171, 1992); new entropy measures (IEEE T-PAMI, 4, 204-208, 1982; IEEE T-SMC, 21, 1260-1270, 1991); proving convergence under mislabeled training samples (IEEE T-SMC, 17, 1072-1077, 1987); generalized guard zone for unsupervised learning with proof of convergence (Pattern Recognition, 23, 325-335, 1990); probabilistic algorithm for active support vector learning (IEEE T-PAMI, 26, 413-418, 2004); fuzzy-MAT (Patt. Recog. Letts., 12, 585-590, 1991); fuzzy multilayer perceptron (IEEE T-NN, 3, 683-697, 1992); fuzzy self-organizing map (IEEE T-SMC, 26, 608-620, 1996); unsupervised feature selection using feature similarity (IEEE T-PAMI, 24, 301-312, 2002); granular network for unsupervised feature selection (Neural Networks, 48, 91-108, 2013); fuzzy-rough granular self-organizing map (Theoretical Computer Science, 466, 37-63, 2012; IEEE T-NNLS, 29, 1890-1906, 2016); granular flow graph (IEEE T-Cyberns., 47, 4096-4107, 2017); neighborhood rough filter and intuitionistic entropy (IEEE T-FS, 26, 2188-2200, 2018); video conceptualization and motion entropy (Inform. Sci., 543, 488-503, 2021); mixed category perception networks (IEEE T-NN, 6, 1091-1108, 1995; IEEE T-NN, 6, 1337-1354, 1995); unsupervised feature evaluation network (IEEE T-NN, 11, 366-376, 2000); Hough transform network (Electron. Letts., 35, 577-578, 1999); optimal stopping time for genetic algorithms (Fundamenta Informaticae, 35, 91-111, 1998); proving that GA-classifier approaches Bayes classifier under limiting conditions (J. Franklin Institute, 336, 387-422, 1999); variable-length chromosome genetic classifier (IEEE T-SMC-B, 30, 890-895, 2000); evolutionary-modular-rough-fuzzy knowledge based network (IEEE T-NN, 9, 1203-1216, 1998; IEEE T-KDE, 15, 14-25, 2003); granular case miner (IEEE T-KDE, 16, 292-300, 2004); rough case-based-reasoned granular mining (IEEE T-KDE, 18, 415-429, 2006); density based multi-scale data condensation (IEEE T-PAMI, 24, 1-14, 2002); generalized rough-fuzzy c-

means/medoids algorithm (IEEE T-SMC-B, 37, 1529-1540, 2007); generalized rough-fuzzy image entropy (IEEE T-SMC-B, 39, 117-128, 2009); nearest fragment operator for gene ordering (App. Intell., 26, 183-195, 2007); indices for web page ranking (IEEE T-KDE, 21, 21-34, 2009); stemmer via distribution based word segregation (IEEE T-SMC-B, 37, 350-360, 2007); fuzzy web surfer model (Proc. Int. Conf. Web Intelligence, 120-123, 2005); rough set theoretic spatio-temporal outlier detection (IEEE T-KDE, 26, 194-207, 2014); fuzzy granular social network model (Inform. Sci., 314, 100 -117, 2015; IEEE T-CSS, 5, 841-853, 2018); granular deep learning models (Neural Comp. and Appl., 32, 16533-16548, 2020; IEEE T-ETCI, 6, 171-181, 2022); and Z-number approach and computing with words (Theoretical Comp. Sci., 448, 2-14, 2013; Inform. Sci., 323, 143-178, 2015; Inform. Sci., 405, 227-258, 2017; IEEE T-CDS, 10, 726-737, 2018; IEEE T-ETCI, 4, 686-695, 2020; 2021, IEEE T-FS, DOI: 10.1109/TFUZZ.2021.3094657, 2021)

Applications

Their applications are demonstrated in **Speech recognition** (IEEE T-SMC, 7, 625-629, 1977; IEEE T-SMC, 8, 302-308, 1978); **Medical imaging** (IEEE T-PAMI, 5, 69-77, 1983; IEEE T-SMC, 16, 657-667, 1986; IEEE T-BME, 47, 934-940, 2000; IEEE T-KDE, 19, 859-872, 2007); **Space mission** (Inform. Sci., 72, 1-63, 1993; IEEE T-AP, 51, 862-871, 2003); **Remote sensing** (IEEE T-SMC-A, 26, 241-247, 1996; IEEE T-GRS, 39, 303-308, 2001; IEEE T-GRS, 40, 2495-2501, 2002; Patt. Recog., 45, 2690-2707, 2012); **Video tracking and surveillance** (IEEE T-Cyberns., 47, 4096-4107, 2017; IEEE T-FS, 26, 2188-2200, 2018; Inform. Sci., 543, 488-503, 2021; IEEE T-ETCI, 6, 171-181, 2022), **Bioinformatics** (IEEE T-KDE, 19, 859-872, 2007; IEEE T-SMC-B, 37, 742-749, 2007; IEEE T-BME, 56, 229-236, 2009; IEEE T-SMC-B, 40, 741-752, 2010; IEEE T-BME, 59, 1162-1168, 2012; Medical & Biological Engg. & Computing, 54, 701-710, 2016; IEEE T-NNLS, 29, 1890-1906, 2016; IEEE/ACM T-CBB, 15, 659-672, 2018; IEEE/ACM T-CBB, 18, 973—984, 2021); **Web intelligence** (IEEE T-KDE, 21, 21-34, 2009; Web Intell. and Agent Systs., 8, 181-202, 2010); **Context-granularization and machine-mind development** (Fundamenta Informaticae, 124, 197-229, 2013; Theoretical Comp. Sci., 448, 2-14, 2013; Natural Computing, 14, 603-635, 2015; Inform. Sci., 405, 227-258, 2017; IEEE T-CDS, 10, 726-737, 2018; IEEE T-ETCI, 4, 86-695, 2020); **Social network analysis** (Fundamenta Informaticae, 130, 317-342, 2014; Theoretical Comp. Sci., 551, 22-28, 2014; Inform. Sci., 316, 107-122, 2015; Patt. Recog. Lett., 67, 145-152, 2015; IEEE T-CSS, 5, 841-853, 2018); **Smart grid** (IEEE Syst, J., 12, 2353-2360, 2018; IEEE Syst, J., 12, 2645-2653, 2018; IEEE T-SC, 7, 211-220, 2022); and **Safety analytics** (IEEE T-FS, 28, 131-2142, 2020; IEEE T-FS, 30, 297-309, 2022).

- The aforesaid research in pattern recognition and machine intelligence has

    o **augmented the definition of soft computing** by introducing rough sets as another constituent; thereby enhancing significantly its basic computational intelligence characteristics, and hence the foundation for the conception and design of high Machine -IQ systems,

    o led to the emergence of several modern disciplines such as *Rough-fuzzy CTP (Computational Theory of Perception)* involving fuzzy sets with other computational paradigms/ tasks,

    o added a new dimension to ***Natural Computation* paradigm**, and

    o provided numerous powerful tools and theories for the **development of today's data science and analytics**, among others.

- Because of outstanding contributions, the Department of Science & Technology, Govt. of

India has established under his leadership the nation's first Soft Computing Research Center in ISI, Kolkata in 2004.

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Examples of Recognition by other Researchers in the Field

- Various authors have explained in their books the significance of the contribution of his work. Some of them devoted an entire section in their books whereas some others described his algorithms as examples. These include:

  Section 5.2 (pp. 177-182) of the book Fuzzy Tech. In Patt. Recog., Wiley, N.Y., 1982 by A. Kandel, (ii) **Example 3.8** (pp. 71-72) of the book Adaptive Patt. Recog. and Neural Nets., Addison-Wesley, N.Y., 1989 by Y.H. Pao, (iii) **Section 3.8.3** (pp. 147-150) of the book Adaptive Fuzzy Systems, Academic Press, N.Y., 1994 by T. Terano et. al., (iv) **Section 7.2** (pp. 180-190) of the book Using Fuzzy Logic: Towards Intelligent Systems, Prentice Hall, N.Y., 1994 by J. Yan et. al., (v) **Examples 13.5** (pp. 371-374) & **13.6** (pp. 375-377) of the book Fuzzy Sets and Fuzzy Logic : Theory and Applications, Prentice Hall, N. J., 1995 by G.J. Klir and B. Yuan, (vi) **Equation 7.3** (pp. 270, Chapter 7) of the book Computational Intelligence P.C. Tools, Academic Press, Boston, 1996 by R. Eberhart et al., (vii) **Section** on Image Processing (pp. 430-437) and Syntactic Recognition (pp. 437-444) with **Examples 12.9, 12.10 & 12.11** of the book Fuzzy Logic with Engineering Applications, McGraw Hill, N.Y., 1997 by Timothy J. Ross, (viii) **Sections 5.5A** (p. 581) and **5.7A** (pp. 627-628) of the book Fuzzy Models and Algorithms for Pattern Recognition and Image Processing, Kluwer Academic, Boston, 1999 by J.C. Bezdek et al., (ix) **Sections 10.5, 10.6 & 10.6.1** (pp. 213-217) of the book Image Processing: Principles and Applications, Wiley, N.J., 2005 by T. Acharya and A.K. Ray, and (x) **Sections 15.5** (p. 662), **15.5.2** (p. 666 & p. 669), and **15.6.1** (p. 673) of the book Neural Networks: A Classroom Approach, Tata McGraw-Hill, New Delhi, 2006 by S. Kumar.

  which have been **devoted entirely** to describing some of his algorithms/ definitions and their significance.

- His **two papers** [IEEE Trans. Syst., Man and Cyberns., SMC-7, pp. 625-629, 1977; In Fuzzy Sets: Theory and Applications to Policy Analysis and Information Systems (eds. P.P. Wang and S.K. Chang), pp. 223-230, 1980] appeared in the then list of key 65 references in fuzzy pattern recognition (Kandel, Fuzzy Tech. in Patt. Recog., Wiley, 1982, p. 211), and **seven papers** [J. Inst. Electron. and Telecom. Engrs., 23, pp. 113-120, 1977; IEEE Trans. Syst., Man and Cyberns., SMC-7, pp. 625-629, 1977; IEEE Trans. Syst., Man and Cyberns., SMC-8, pp. 302-308, 1978; Int. J. of Syst. Sci. 9, pp. 873-886, 1978; Int. J. of Syst. Sci. 9, pp. 887-897, 1978; IEEE Trans. Pattern Anal. Machine Intell., PAMI-5, pp. 69-77, 1983; IEEE Trans. Syst., Man and Cyberns., SMC-13, pp. 94-100, 1983] appeared in the then list of 1000 important references on fuzzy set theory and applications (Kandel, Fuzzy Math. Tech. with Applications, Addison Wesley, 1986, pp. 248, 253, 254).

- Bezdek et al. have made the following **two comments** in pages 550 and 668 of their book Fuzzy Models and Algorithms for Pattern Recognition and Image Processing, Kluwer, Boston, 1999, that

  o ``The **earliest paper** on image enhancement with fuzzy sets is due to Pal and King [IEEE Trans. Syst. Man and Cyberns., vol. 11, no. 7, pp. 494-501, 1981]'', and
  o ``The **first work** on fuzzy edge detection was apparently Pal and King [IEEE Trans. Pattern Anal. Machine Intell., vol. 5, no. 1, pp. 69-77, 1983]''.

- His paper IEEE Trans. Neural Nets, NN-3, pp. 683-697, 1992 has received the **1994 Outstanding Paper Award** from the IEEE Neural Networks Council, U.S.A.

- His three papers Journal of Biosciences, vol. 32, no. 5, 1019-1025, 2007; IEEE Trans. Biomedical Engineering, vol. 56, no. 2, pp. 229-236, 2009; and IEEE Trans. Biomedical Engineering, vol. 59, no. 4, pp. 1162-1168, 2012 are included as **Curated Papers in Saccharomyces Genome Database.** (**Saccharomyces Genome Database**, **Saccharomyces Genome Database**, **Saccharomyces Genome Database**)

- A detailed review of his book (1986) is provided by M. Roubens in ACM Computing Reviews, June 1987, pp. 308-309. This book received **Best Production Award** in the 7th World Book Fair, New Delhi, 1986, and has been translated into Indonesian Bahasa and Chinese Language. (https://www.tokopedia.com/maxisiahaan/fuzzy-pendekatan-matematik-untuk-pengenalan-pola-oleh-sankar-k-pal)

- The format of his book (1992) has **set the standards** (according to four IEEE reviewers) for future reprint books. The book had been in the list of **IEEE best sellers** for consecutive four years. In the Foreword of this book Prof. L. A. Zadeh, founder of fuzzy set theory, mentioned that **S. K. Pal first applied** fuzzy sets to the speech recognition problem in 1977. Subsequently, Bezdek and Pal have been major contributors to both the theory and applications of fuzzy models in image processing and pattern recognition. The following comments are made on the book by different reviewers:

  - `….. one of the best written concise discussions of fuzzy set theory and its applications to pattern recognition that I have ever seen.'- Frederick E. Petry, Tulane University
  - `The whole book is excellent and timely.'-George J. Klir, State University of New York at Binghamton

- In the Forewords of his book Pattern Recognition Algorithms for Data Mining (2004), following comments are made by three founders:

  - `The importance of the book is hard to exaggerate. It is a treatise that is an exemplar of authority, deep insights, encyclopedic coverage and high expository skill. ... Its authors, Professors S.K. Pal and P. Mitra are foremost authorities in pattern recognition, data mining and related fields.' - Lotfi A. Zadeh (founder of Fuzzy Set theory), University of California, Berkeley.
  - `The book presents an unbeatable combination of theory and practice and gives a comprehensive view on methods and tools in modern KDD.' - Zdzislaw Pawlak (founder of Rough Set theory), Polish Academy of Sciences, Warsaw.
  - `This volume provides a very useful, thorough exposition of the many facets of this application from several perspectives. ... I am pleased to recommend it as a valuable addition to the books in this field.' - Laveen N. Kanal (K.S. Fu Awardee in Pattern Recognition), University of Maryland, College Park.

- According to Science Citation Index (SCI), USA, his **three papers** (Patt. Recog., 26, pp. 1277-1294, 1993; IEEE Trans. Neural Networks, 3, pp. 683-697, 1992; and IEEE Trans. Neural Networks, 6, pp. 51-63, 1995) **ranked 2nd, 3rd, and 15th** respectively in the list of top-cited papers in Engineering Sciences from India during 1992-2001.

- Table below shows **largest citation** of his paper (Pal and Pal, Patt. Recog., 26, pp. 1277-1294, 1993) among the other most referenced OBIA (Object Based Image Analysis) papers. (vide, ISPRS J. Photogrammetry and Remote Sensing, vol. 65, pp. 2-16, 2010).

Citations of the most referenced OBIA relevant papers in ISI and Google Scholar. Per year calculation excludes the year of publication to avoid a bias in the publication order within the year of publication, and ends in 2008.

	ISI	Per year	Google scholar	Per year
OBIA specific				
Benz et al. (2004)	150	**37.5**	220	55.0
Burnett and Blaschke (2003)	63	**12.6**	101	20.1
Pesaresi and Benediktsson (2001)	86	**12.3**	92	13.1
Câmara et al. (1996)	49	**4.1**	331	27.3
Baatz and Schäpe (2000)	–	–	294	36.3
Blaschke and Strobl (2001)	–	–	72	10.2
For comparison				
Haralick and Shapiro (1985)	720	**30.6**	1104	48.0
Pal and Pal (1993)	777	**51.8**	1187	79.1

- According to *ISI Web of Science* (vide, Jose M. Merogo and Anna M. Gil-Lafuente, An Overview of Fuzzy Research in the ISI Web of Knowledge Proc. of the World Congress on Engineering 2009, vol. 1, WCE 2009, July 1-3, 2009, London, UK), : https://www.researchgate.net/publication/44259957

  o his paper (Pal and Pal, Patt. Recog., 26, pp. 1277-1294, 1993) is the **16th most cited** article in the world that uses the word 'fuzzy', and
  o he is the **10th topmost world leading expert** publishing largest no. of articles with the word 'fuzzy'.

- According to *Thomson Reuters's Web of Science* (vide, J.T. Yao, V. Vasilakos and W. Pedrycz, Granular Computing: Perspectives and Challenges, IEEE Trans, Cybernetics, 43, pp. 1977-1989, 2013), DOI: 10.1109/TSMCC.2012.2236648

  o his three papers (Pal and Mitra, IEEE Trans. TKDE, 16, pp. 292-300, 2004; Pal et al, Pattern Recog. Lett., 26, pp. 2509-2517, 2005; and Pal and Mitra, IEEE Trans. GSRS, 40, pp.2495-2501, 2002) ranked **17th, 23rd and 27th** in the list of top 31 papers which contributed to the h-index of 30 of "Granular Computing".

- According to Exaly (https://exaly.com/author/8761149/sankar-k-pal/rankings), he is the **3rd most cited author** of "*Pattern Recognition Letters*" in 2004.

- **Google Scholar Citation Indices** of his publications**:** *h-index = 80, i10-index = 280, i100-index = 67, g-index = 178, citation of the mostly cited paper **= 5525**, and total citations of **35,000+** (as in Aug 2022)

- Impact of the contribution is recognized in India/abroad not only by the Academies, Scientific/Professional bodies, Foundations but also by the **Industrial forum, like FICCI** (Federation of Indian Chambers of Commerce & Industry).

- He has graduated 21 PhD students, so far, in India and abroad; several of whom are **internationally known researchers and science leaders** with recognitions like Padmashree, S.S. Bhatnagar Awardee, Infosys Awardee, PCM National Awardee of MOSPI, GoI, INAE Chair Professor, Fellows of IEEE, TWAS, IFSA, INSA and other National Academies, Editor-in-Chief of IEEE Transactions, and Director of Premier Institute.

- He has been featured within the **top 0.106920052%** with **C-score = 4.10705055** and **subject-wise world-wide rank of 230** in the domain of **Artificial Intelligence and Image Processing** in the recent (2020) list of top 2% scientists world-wide based on an independent study done by **Stanford University** scientists. For methodology and data visit: https://journals.plos.org/plosbiology/article?id=10.1371/journal.pbio.3000918. For

world-wide full list of top 2% scientists, see: http://shorturl.at/qHIJ4 (Serial no.14374). For the list of Indian scientists see: https://docs.google.com/.../1mMonq947bS3KcMhsDpf.../edit... Further, his six graduated-PhDs and one post-doc are also included in that list.

- He is ranked #14225 in World's top 2% Scientists **covering all disciplines** as per the standardized citation indicators, 2021, maintained by Elsevier. See https://elsevier.digitalcommonsdata.com/data.../btchxktzyw/3.

- He is ranked #418 within the Top 1,000 Scientists globally in the field of **Computer Science**, according to 2022 edition of World-wide Ranking of Top 1,000 Scientists released by Guide2Research (https://www.guide2research.com/scientists/) and Research.com (research.com/scientists-rankings/computer-science). **All these demonstrate his visionary and the impact of his contributions.**

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Collaborating Institutes Leading to Joint Publications (Papers, Books, Journal Special Issues & Conf. Proceedings) (List is not exhaustive)

India:

IIT Kharagpur
IIT Delhi
IIT Jodhpur
IISc Bangalore
IIT Guwahati
Academy of Scientific and Industrial Research, CSIR-CSIO, Chandigarh
Central University, Hyderabad
Indian Statistical Institute, Bangalore Center, Bangalore
University College of Science and Technology, Calcutta University, Kolkata
Jadavpur University, Kolkata
CDAC-Kolkata
RCC Institute of Information Technology, Kolkata
Netaji Subhas Institute of Technology, New Delhi
National Institute of Technology Karnataka Surathkal, Mangalore
Indian Institute of Information Technology and Management-Kerala, Trivandrum
Tezpur Central University, Tezpur

Abroad:

NASA Johnson Space Center, Houston, TX, USA
US Naval Research Lab, Washington, DC, USA
University of Maryland, College Park, USA
University of Pensacola, Florida, USA
Duke University, Durham, North Carolina, USA
Colorado State University, Fort Collins, Colorado, USA
University of California, Santa Barbara, USA
Cyber Technologies Laboratory of Son Corporation, San Jose, USA
Fordham University, New York, USA
Florida Institute for Human and Machine Cognition, Florida
Washington University in St Louis, St. Louis, USA
Pennsylvania State University, Pennsylvania, USA
University of Michigan, Dearborn, USA
Florida International University, Miami, USA
Machine Intelligence Research Lab, Auburn, Washington, USA
University of Manitoba, Winnipeg, Canada
University of Alberta, Alberta, Canada

Imperial College, London, UK
Leicester Polytechnique, Leicester, UK
University of Bradford, UK
Cambridge University, UK
INSEAD, Boulevard de Constance, Fontainebleau, Cedex, France
Institut De Mathematiques De Marseille, France
University of Naples Parthenope, Naples, Italy
National Research Council, Institute for High Performance Computing and
   Networking, CNR, Naples, Italy
University of Siena, Siena, Italy
University of Palermo, Sicily, Italy
University of Calabria, Italy
Institute of Mathematics, Warsaw University, Warsaw, Banacha, Poland
Warsaw University of Technology, Warsaw, Poland
HSE University, Moscow

Hong Kong Polytechnic University, Kowloon, Hong Kong
Hong Kong University of Science and Technology, Hong Kong
Baptist University of Hong Kong, Hong Kong
University of Macau, Macau
Tsinghua University, Beijing, China
Beijing Normal University, Zhuhai, China

Damietta University, New Damietta City, Egypt
Yonsei University, Seoul, South Korea
Sungshin University, South Korea
Maebashi Institute of Technology, Japan
University of Nagasaki, Nagasaki, Japan
National Central University, Taiwan
University of Tasmania, Australia
La Trobe University, Melbourne, Australia

Visits Abroad (2007 onwards)

- **Thailand:** Delivered a Keynote talk at the Asia Modelling Symposium (AMS 2007) held at Prince of Songkla University, Phuket, Thailand, March 27-30, 2007.
- **Italy:** Delivered a) a Keynote talk at the 6th Int. Workshop on Data Analysis in Astronomy, Erice, Italy, and b) a series of talks at the University of Naples, Italy during April 15-22, 2007.
- **Korea:** Delivered a Keynote talk at the Int. Conf on Multimedia and Ubiquitous Computing, 2007 at Korean Bible University, Seoul, Korea, April 25-28, 2007.
- **Mexico:** Attended the IFSA World Congress, Cancun, Mexico during June 18-21, 2007 for receiving the IFSA Fellowship Award and Chairing a session.
- **Poland:** Delivered Z. Pawlak Memorial Plenary Talk at the Int. Conf. on Rough Sets and Emerging Intelligent Systems Paradigms (RSEISP'07) at Warsaw University of Technology, Warsaw, Poland, June 27-30, 2007.
- **China:** Delivered a Plenary talk at the 3rd WSEAS International Conference on Data Mining and Intelligent Information (DMIP'07), Beijing Jiaotong University, Beijing, September 15-17, 2007.
- **Thailand:** Invited talk and discussion with the faculty of Computer Science, Statistics and Mathematics, Mahidol University, Bangkok, Thailand, Oct 31, 2007.
- **Italy:** a) Attended the TWAS Meeting, Trieste, Italy, and b) Visited the University of Naples, Italy for delivering a Guest Lecture, during November 12-18, 2007.
- **China:** Keynote talk at the 3rd International conference on rough Sets and Knowledge Technology (RSKT-2008), Southwest Jiaotong University, Chengdu, China, May 17-19, 2008.
- **Canada:** For the following purposes:
  a) Attended the 7th International Symposium on Methodologies for Intelligent Systems, York University, Canada, May 20-23, 2008 as a speaker,
  b) Invited talk at Brock University, Canada, May 22, 2008, and
  c) Visited the University of Manitoba, Canada, May 23-27, 2008.
- **Brazil:** Attended the INSA-Brazil Academy of Science Collaborative Workshop as a member of the Indian delegation team, Rio de Janeiro, Brazil, June 23-26, 2008, and also visited the Federal University of Rio de Janeiro for an Invited talk.
- **France:** Invited talk at INSEAD, Fontainebleau, France, June 28-29, 2008.
- **China:** Plenary talk at the 2008 IEEE conference on Granular Computing, Hangzhou, China, August 25-28, 2008.
- **Mexico:** Attended the TWAS meeting at the Mexico City, Mexico, November 8-13, 2008.
- **China:** Keynote talk at the 2008 International Symposium on Signal Processing, Image Processing and Pattern Recognition (SIP 2008), Hainan Island, China, December 13-15, 2008.
- **Italy:** Attended the ISI - EU project meeting at Trento, Italy, and delivered a series of talks at the University of Trento, Italy, February 4-10, 2009.

- **Netherlands:** Visited Virje University and IOS Press, Amsterdam, Netherlands for meetings, June 2-6, 2009.
- **Italy:** a) Delivered the Keynote talk at the International Workshop on Fuzzy Logic and Applications (WILF'09) at the University of Palermo, Italy, and   b) Visited the University of Naples & University of Milano, Italy for delivering a series of lectures under ISI-Naples collaborative programme, during June 7-23, 2009.
- **USA:** Visited the Computer Vision Lab, University of Maryland, College Park, USA for research collaboration, and delivered talks, August 18-31, 2009.
- **Italy:** Delivered an Invited talk at the International Conference for Digital Libraries and the Semantic Web (ICSD 2009) at the University of Trento, Italy, September 8-12, 2009.
- **South Africa:** Attended the TWAS General Meeting, Durban, South Africa, October 20 - 23, 2009.
- **China:** Delivered a Keynote talk at the 3rd Chinese Conference on Pattern Recognition (CCPR 2009) at Nanjing University of Science, Nanjing, China, November 3 - 6, 2009.
- **Italy:** Collaborative research under the formal agreement between ISI & University of Naples, Italy during April 22 - May 18, 2010. Besides delivered
  a) a series of talks at Naples University, Italy, and
  b) an Invited talk at the University of Salerno, Italy.
- **Poland:** Delivered
  a) a Keynote talk at 4th International KES Symposium on Agents and Multi-Agent systems - Technologies & Applications, Gdynia, Poland, June 23-26, 2010,
  b) a Keynote talk at 7th International Conference on Rough Sets & Current Trends in Computing, RSCTC 2010, Warsaw, June 28-30, 2010, and
  c) Performed collaborative research work with the Institute of Mathematics, University of Warsaw, Poland.
- **China:** Delivered a Keynote talk in the 'Cognitive Science and Information Science' section at the 7th International Conference on Cognitive Science (ICCS 2010) at China National Convention Center (CNCC) in Beijing, China, August 18 - 20, 2010.
- **China:** Delivered
  a) a Keynote talk at 5th International Conference on Rough Sets and Knowledge Technology (RSKT 2010), Beijing, China, and
  b) a Keynote talk at 10th China Conference on Rough Set and Soft Computing (CRSSC2010) at Chong Qing University of Posts and Telecommunications, Chong Qing, China, during October 11 - 15, 2010
- **Taiwan:** Delivered a Keynote talk at the 2nd International Symposium on Aware Computing (ISAC 2010) at Tainan, Taiwan, October 30 - November 3, 2010.
- **Brazil**: Delivered
  a) an Invited talk at 15th Iberoamerican Congress on Pattern Recognition (CIARP-10), Univ. of Sao Paulo, Sao Paulo,
  b) an Invited talk at Federal University-ABC, Sao Paulo, Brazil, and
  c) Performed collaborative work at the University of Sao Paulo under Indo-Brazil project, during November 8 - 14, 2010.
- **Hong Kong:** Delivered the Golden Jubilee Distinguished Lecture at Hong Kong Baptist University, Dept. of Computer Science and other collaborative work, February 28-March 9, 2011.
- **Indonesia:** Delivered the Keynote talk at the International Conference on Data Engineering and Internet Technology (DEIT 2011), Bali, Indonesia, March 14 - 17, 2011.
- **Italy:** Delivered a Keynote talk at 7th International Workshop on Data Analysis in Astronomy (DAA2011), Erice, Italy, and visit to University of Naples, Italy in connection

with the collaborative research under the formal agreement with ISI, during April 11-19, 2011.

- **USA:** Invited talk at the World Conference on Soft Computing, San Francisco State University, San Francisco, USA. Also visited the University of Maryland, College Park, USA for a talk, during May 23 - June 3, 2011.
- **Iran:** Keynote talk at 2011 Symposium on Artificial Intelligence and Signal Processing (AISP2011), Sharif University, Tehran, Iran, June 14 - 17, 2011.
- **Russia:** Attending the conference PReMI-11, Moscow as its General Chair, June 25-30. 2011.
- **Italy:** For the following purposes:
  a) Collaborative research at the University of Naples, Italy under the formal agreement with ISI,
  b) Attending the TWAS General Meeting, Trieste, Italy, and
  c) Delivering an invited talk at the University of Padova, Italy, during September 13-27, 2011.
- **Indonesia:** Keynote talk at the 3rd International Conference on Soft Computing, Intelligent System and Information Technology (ICSIIT), Bali, Indonesia, May 23-27, 2012.
- **Saudi Arabia:** Invited talk at the International Workshop on Three Approaches to Data Mining: Test Theory, Rough Sets and Logical Analysis of Data, King Abdullah University of Science and Technology (KAUST), Jeddah, Saudi Arabia, June 8-12, 2012.
- **Korea:** Keynote talk at the 4th International Conference on Advanced Communication and Networking (ACN 2012), Jeju, Korea, August 29-31, 2012.
- **USA:** a) Collaborative work with the Radiology Dept., University of Pennsylvania, Philadelphia, USA, and b) Invited talk at the ECE Dept., University of IOWA, USA, Oct 2-12, 2012.
- **China:** Attending the TWAS General Meeting at Tianjin, China, September 17-21, 2012.
- **Bangladesh:** IEEE Distinguished Visitor Talks during November 5 - 8, 2012 at
  a) Bangladesh University of Engineering & Technology, Dhaka,
  b) BRAC University, Dhaka, and
  c) Rajshahi University of Engineering & Technology, Rajshahi.
- **Macau:** Invited talk at the International Conference on Active Media Technology 2012 (AMT-12), Macau, December 3 - 7, 2012.
- **USA:** Collaborative work at the a) University of Pennsylvania, Philadelphia, USA, and b) University of Maryland, College Park, USA, during May 9 - 21, 2013.
- **Italy:** Keynote talk at the 23rd Italian Workshop on Neural Networks, Vietri, Salerno, Italy, and Collaborative research at the University of Naples, Italy under the formal agreement with ISI, during May 22-28, 2013.
- **Italy:** Invited talk at the International Conf. on Image Analysis and Processing (ICIAP), Naples, Italy, Sept 10-13, 2013.
- **Argentina**: Attending the TWAS General Meeting at Buenos Aires, Argentina, Sept. 30 - Oct. 5, 2013.
- **Bangladesh:** IEEE Distinguished Visitor Talk, American International University, Dhaka, Bangladesh, May 26, 2014.
- **Hong Kong:** Invited talk at the Computer Science Department, Hong Kong Baptist University, Hong Kong, June 12, 2014.
- **China:** Invited talk at the United International College of Hong Kong Baptist University, Zhuhai, China, June 16, 2014.
- **Bangladesh**: Keynote talk at the a) 3rd International Conference on Informatics, Electronics & Vision (ICIEV), 2014, Dhaka, Bangladesh, and b) 9th International Forum on

Strategic Technology (IFOST 2014), Cox's Bazar, Chittagong, Chittagong University of Science & Technology, Bangladesh, during May 22-26, 2014.

- **Poland and France:** a) Plenary Talk at the 6th International Conference on Pattern Recognition and Machine Intelligence (PReMI'15), Warsaw University of Technology, Warsaw, Poland, and b) Visit at the Telecom Paris Tech, Paris, France, during June 24 – Jul 7, 2015.
- **Hungary:** Invited talk at the Szechenyi Istvan University, Gyor, Hungary, November 13-16, 2015.
- **Austria:** Attended the 13th General Conference and 26th TWAS General Meeting at Austrian Academy of Science, Vienna, Austria, November 17 – 21, 2015.
- **Germany:** Invited Talks at the
  a) Universitat Paderborn, November 22-25, 2015, and
  b) German Workshop on Computational Intelligence, Dortmund, Nov 26-27, 2015.
- **China:** Keynote Talk at the 2015 Annual International WICI Workshop at Beijing University of Technology, China and for collaborative research work, December 25 - 28, 2015.
- **Spain:** Series of Invited Talks at the 2nd International Winter School on Big Data (BigDat 2016) at University of Deusto, Bilbao, Spain, February 7 – 11, 2016.
- **Bangladesh:** Keynote talk at the 5th International Conference on Informatics, Electronics & Vision (ICIEV'16), University of Dhaka, Dhaka, Bangladesh, May 11-15, 2016.
- **UK:** Visit during June 7-18, 2016 for the following purposes:
  a) Visiting some departments of Imperial College, London, June 7 -10, 2016,
  b) Meetings at Data Mining Services, Ltd., Windsor, June 13 - 15, 2016, and
  c) Invited talk at Santander Bank, London, June 17, 2016.
- **Chile:** IRSS Fellow Lecture, International Joint Conference on Rough Sets (IJCRS 2016) at Universidad de Chile, Santiago, Chile, October 05-13, 2016.
- **Rwanda:** Attended the 27th TWAS General meeting at Kigali, Rwanda, November, 12 -17, 2016
- **Algeria:** Keynote talk at the 1st Mediterranean Conference on Pattern Recognition and Artificial Intelligence (MedPRAI 2016), Tebessi University, Tebessa, Algeria, November 20-24, 2016.
- **Bangladesh:** Keynote talks at the a) International Conference on Imaging, Vision and Pattern Recognition (icIVPR2017), University of Dhaka, Dhaka, February 13-14, 2017, and b) International Conference on Electrical, Computer and Communication Engineering (ECCE-2017) at Chittagong University of Engineering & Technology (CUET), Cox Bazar Bangladesh, February 16-18, 2017.
- **Australia:**
  a) Plenary address at the Workshop on Big Data Analysis, La Trobe University, Melbourne, March 13-15, 2017, and
  b) Invited talk in the Computer Science and Information Technology Dept., La Trobe University, Melbourne, Australia, March 16, 2017.
- **Hong Kong:** Distinguished Lecture and academic discussion with researchers at Hong Kong Baptist University, Hong Kong, May 15, 2017.
- **China:** Distinguished Lecture at Guangdong University of Technology, Guangzhou, China, May 17, 2017.
- **Poland:** Keynote talk at the International Joint Conference on Rough Sets, IJCRS 2017, University of Warmia and Mazury, Olsztyn, Poland and Collaborative Research work, June 30 – July 07, 2017.

- **Italy:** a) Invited Talks and Collaborative Research work at the Dept. of Science and Technology, University of Naples, Parthenope, Naples, Nov 19-23, 2017, and b) Invited talk at the University of Genoa, Italy, November 24, 2017.
- **China:** Collaborative discussion meetings at the Qingdao Forum on Science & Technology, and 2nd Qingdao International Academician Conference, Qingdao, China, August 16-18, 2018.
- **UK:** Series of invited talk(s) at 5th International School on Big Data (BigDat 2019), University of Cambridge, U.K., January 7-11, 2019.
- **Thailand:** Keynote talk at the International Conference on Information, System and Convergence Applications (ICISCA), Bangkok, Thailand, January 23-25, 2019.
- **China:** Keynote speech at the Int. Conf. on Smart Grid Technology and Data Processing: Smart Urban Resource and its Breakthrough in Technology and Management, Suzhou, China, 28 Feb – 1 Mar. 2019.
- **USA:** a) Collaborative research work at the Center for Automation Research, Dept. of Electrical and Computer Engineering, University of Maryland, College Park, MD during April 28 to May 03, 2019, and b) Invited talk in the Department of Electrical and Computer Engineering, University of Illinois, Urbana-Champaign (UIUC), IL, USA on May 7, 2019.
- **China:** Invited talk at the 3rd Qingdao International Academicians Conference, Qingdao, China, May 28 to 31, 2019.

Examples of Committees Served in India and Abroad (list is not exhaustive)

India:

— Chairman, Recruitment and Assessment of Scientists, Defence Research and Development Organization (DRDO), Govt. of India.
— Chairman, Project Review and Steering Group (PRSG) for the project ``Development of Isolating Tools for Steganographic Images", CDAC, MIT, Govt. of India.
— Chairman, Project Review and Steering Group (PRSG) for the project ``Setting up of National Resource Center on steganography", CDAC, MIT, Govt. of India.
— Chairman, Information Technology (IT) Academic Council, Govt. of West Bengal.
— Chairman, Syllabus Committee for classes VI to XII, CLTP (Computer Literacy Training Program), West Bengal Board of Secondary Education (WBBSE), Govt. of West Bengal.

— Member, Search Committee for selecting the Chairman, Chief Statistician of India, and four members of the Statistical Commission, Ministry of Statistics and Program Implementation (MOSPI), Govt. of India.
— Member, Selection Committee for Vice-Chancellor, Central South Bihar University, Bihar.
— Member, Selection Committee for Director, National Institute of Technology (NIT), Calicut, Kerala.
— Member, Selection Committee for Deputy Director, IIT Kharagpur
— Member, Search cum Selection Committee for selecting the First Vice-Chancellor of Presidency University, Kolkata.

— Member, Governing Council, Indian Association for Cultivation of Science (IACS), Kolkata.
— Member, Board of Governing Body, Indian Institute of Science Education and Research (IISER) Kolkata.
— Member, Board of Governors, DM-IIIT, Jabalpur.
— Member, First Governing Council, Presidency University, Kolkata.
— Member, Governing Board, Birla Industrial and Technological Museum (BITM), Kolkata.
— Member, Research Advisory Council, Central Scientific Instrument Organization, CSIR-CSIO, Chandigarh.
— Member, Governing Council, National Academy of Sciences, India (NASI).
— Member, Governing Council, Indian National Academy of Engineering (INAE).
— Member, Govt. Appointed Review Committee for overall performance of IIT Kharagpur.
— Member, Govt. Appointed Review Committee for subject-wise performance of ISER Kolkata.
— Member, Technical Advisory Group (TAG), Biotechnology Industry Research Assistance Council (BIRAC), DBT, Govt. of India

— Member, Technical Advisory Group, Immunization Data: Innovating for Action (IDIA), Grand Challenge India, Biotechnology Industry Research Assistance Council (BIRAC), DBT, Govt. of India, and Bill & Melinda Gates Foundation (BMGF)
— Member, Covid-19 India National Supermodel Committee, SERB-DST, Govt. of India.

— Member, Advisory Committee, Shanti Swarup Bhatnagar Prize (Engineering Sciences), CSIR, New Delhi, Govt. of India. (11 times since 1993)
— Member, Advisory Committee, CSIR Young Scientist Award, CSIR, New Delhi (5 times).
— Member, Advisory Committee, Swarnajayanthi Fellowship, Dept. of Science and Technology (DST), New Delhi, Govt. of India.
— Member, Empowered Committee for implementation of Awards and Fellowships for outstanding and meritorious research work in Statistics, Ministry of Statistics and Program Implementation, Govt. of India.
— Chairman, Sectional Committee, Indian National Academy of Engineering (INAE), New Delhi.
— Member, Sectional Committee (Engineering Sciences), Indian National Science Academy (INSA), New Delhi.
— Member, Sectional Committee (Engineering and Technology), Indian Academy of Sciences (IASc.), Bangalore.
— Sectional President, Physical Sciences, National Academy of Sciences, India (NASI), Prayagraj.
— Member, Fellowship Scrutiny Committee, National Academy of Sciences (NASI), Prayagraj.

— Member, INSA-INSPIRE Faculty selection committee, Govt. of India.
— Member, Advisory Committee, Fund for Improvement of Science & Technology Infrastructure in Universities, and other Higher Educational Institutions (FIST), DST, New Delhi, Govt. of India.
— Member, Project Advisory Committee (PAC), Electrical, Electronics and Computer Engineering, DST, New Delhi, Govt. of India.
— Member, Engineering Sciences Research Committee (ESRC), CSIR, New Delhi.
— Member, Steering Committee, Research Projects, DOE, New Delhi, Govt. of India.
— Member, Project Review Committee (PRC), Bharat Heavy Electricals Ltd. (BHEL), Hyderabad.
— Member, Governing Council of Delhi University, New Delhi.
— Member, Expert Committee of Post Graduate Courses, Indira Gandhi National Open University (IGNOU), New Delhi.
— Member, Academic Committee, Indian Institute of Information Technology (IIIT), Allahabad.
— Member, Promotional Assessment Committee (PAC), Indian Institute of Science, IISc, Bangalore. (12 consecutive years)
— Member, ITBT Task Force, Govt. of West Bengal.
— Member, Science and Technology Council, Govt. of West Bengal.
— Member, IT Cell, Maulana Abul Kalam Azad University of Technology (erstwhile West Bengal University of Technology), West Bengal
— Member, Faculty Recruitment/Promotional Committee in different Institutes such as IIT Delhi, IIT Kharagpur, IIT Roorkee, Visva-Bharati University, Santiniketan, Benaras Hindu University, Veer Surendra Sai University of Technology, Sambalpur, Jadavpur University, Calcutta University, Tezpur Central University, Manipur Central University, SRM University, Chennai, and SRM University, Amaravati.

— Chairman of all important committees of ISI nationwide as its Director during 2005-2010, and as Prof-In-Charge of the then Physical and Earth Sciences Division of ISI during 1988-1990.

— Charman, Ph.D./D.Sc. Committee, Indian Statistical Institute, Kolkata.
— Chairman, M.Tech. Syllabus Committee, Indian Statistical Institute, Kolkata.
— Chairman, Intellectual Property Rights (IPR) Committee, Indian Statistical Institute, Kolkata.
— Convener, Policy Planning and Evaluation Committee (PPEC), Indian Statistical Institute, Kolkata.
— Member, 4th Pay Scale Review Committee implementation for Faculty, Indian Statistical Institute, Kolkata.
— Member, Review Committee for the Protection of Research Risk to Human, Indian Statistical Institute, Kolkata.

Abroad:

— Director, Web Intelligence Consortium (WIC) India Center.
— Member, Project Evaluation Committee, NASA, USA.
— Member, IEEE Fellow Selection Committee, Neural Networks Council, USA.
— Member, Advisory Board, IEEE (USA) Distinguished Visitor Program for Asia Pacific Region.
— Member, Project Evaluation Committee, Hong Kong Research Council, Hong Kong.
— Member, PhD Thesis Evaluation Committee, Hong Kong Polytechnique University, Hong Kong.
— Member, Advisory Board, International Rough Set Society, 2011
— Member, External Expert Panel for Post Graduate IT Management Course, Hong Kong Baptist University, Hong Kong.
— PhD Thesis Foreign Examiner, University of Naples, Italy.
— Member, Expert Committee to evaluate the "Centre for New Methods in Computational Diagnostics and Personalized Therapy (SANO)" as a part of The International Research Agenda Program PLUS, Poland, 2022