



ICSA Bulletin

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From the Editor

Ming Wang

Dear ICSA Members:

Welcome to our 2023 Aug/Sep issue of the ICSA Bulletin!

This year promises an array of remarkable events sponsored or co-sponsored by our ICSA. As elucidated by Dr. Zhao, the Executive Director of ICSA, we are excited to present a series of in-person conferences. These include the 32nd Annual ICSA Applied Statistics Symposium at the University of Michigan, the 2023 ICSA China Conference in the city of Chengdu, China, and the 126th ICSA International Conference in the enchanting locale of Hong Kong, China. The volume of attendances was supervising high. Our ICSA members have demonstrated their enthusiasm by actively participating in featured keynote lectures, invited sessions, panel discussions, short courses, and poster presentations. It brings great joy to see our ICSA friends from different places come together for greetings and direct interactions.

Within this edition, we are delighted to share several articles that we believe will deeply resonate with your professional journey and research interests. In the "XL-Files" column, Professor Xiao-Li Meng offers insights into his encounter with ChatGPT. This is a reprint from the author's column "ChatGPT-First Contact" in the IMS Bulletin, August 2022. Additionally, an intriguing article titled "Should We Trust Algorithms?" by Dr. David Spiegelhalter is presented, not only encouraging readers to critically evaluate the algorithms they encounter but also advocating for continuous research, development, and refinement to enhance their reliability. This article is drawn from the Harvard Data Sciences Review (HDSR) with kind permission (<https://hdsr.mitpress.mit.edu/pub/561nenzj/release/3>). Notably, we are thrilled to introduce a novel column enriched by the expertise of Dr. Momiao Xiong. Dr. Xiong, a retired professor from the Department of Biostatistics and Data Science, as well as the Human Genetics Center at the University of Texas School of Public Health, and the Quantitative Sciences Program at MD Anderson Cancer Center UTHealth Graduate School of Biomedical Sciences, has graciously contributed insightful articles. His research interests are hyper-dimensional computing, artificial intelligence (AI), statistics, genomics and bioinformatics.

Please refer to his training background in the column articles below. In this issue, Dr. Xiong generously shares two articles, illuminating the path ahead for AI, high-dimensional computing, and modern data analysis paradigms. We extend our heartfelt gratitude to Dr. Xiong for his invaluable contributions and look forward to his forthcoming articles, poised to enrich our understanding of data science.

Shifting our focus to matters of ICSA's business, this edition encompasses a missive from the 2023 ICSA President, Dr. Gang Li, as well as a report from the Executive Director for 2023-2025, Dr. Jun Zhao. We proudly announce the recipients of the 2023 ICSA Awards, alongside other prestigious awards of our members. Moreover, we celebrate new fellows within ASA and IMS who grace our ICSA community. Pertinent updates from our ICSA treasurer and program committee feature prominently, as do reports from ICSA sponsored or co-sponsored journals. The resounding success of the 2023 ICSA China Conference is succinctly summarized, providing a glimpse into its vibrancy. Our bulletin also presents a preview of forthcoming meetings and conferences. Of special significance is the roster of nominations for the 2024 ICSA Officers, a precursor to the promising leadership poised to guide our ICSA into a future of growth and fortitude.

In closing, I extend heartfelt gratitude to all contributors, ICSA executives, and committee members, whose dedicated efforts have breathed life into this bulletin. My sincere appreciation extends to Dr. Chixiang Chen, for curating this edition. Regrettably, this marks my final issue as Editor-in-Chief of the ICSA Bulletin. Serving in this capacity from 2020 to 2023 has been an extraordinary privilege. I am confident that my successor will elevate our bulletin further, and I implore you to sustain your attention, support, and feedback to ensure the continued excellence of the ICSA Bulletin!

Warm regards,



*Ming Wang, Ph.D.
Editor-in-Chief, ICSA Bulletin
Associate Professor
Department of Population and
Quantitative Health Sciences,
College of Medicine,
Case Western Reserve University*

From the 2023 ICSA President

Gang Li



During the first eight months of 2023, ICSA has made significant strides in promoting knowledge exchange, collaboration, and professional development among our community and beyond. With the COVID-19 pandemic in the rear mirror, we are delighted to report that all ICSA activities have returned back to normal in 2023, allowing us to resume in-person events and foster a vibrant community once again. A huge thank you to all our committees and volunteers for their exceptional dedication and selfless efforts in supporting our organization.

This year ICSA has held three major statistical conferences, all in-person, as summarized in Table 1. Thanks to the extraordinary work of the organizing committee and volunteers and the generous support of the sponsors, the three conferences were remarkably successful, each drawing an extraordinary participation of statisticians and data scientists from academia, government, and industry worldwide. It is worth highlighting that a significant portion of participants were students and that all three conferences gave out junior research awards, adding to the excitement of these notable events.

In addition to the three ICSA flagship conferences, the ICSA Taiwan Chapter held its 2023 symposium (joint with Institute of Statistical Science, Academia Sinica) in Taipei from July 12-13, 2023. ICSA also co-sponsored 7 other statistical meetings with other organizations as listed later in this issue. In particular, led by Dr. (Tony) Jianguo Sun, ICSA organized 2 invited paper sessions, 1 invited panel session in memory of Professor Tze Leung Lai, 3 topic-contributed sessions, and 3 contributed sessions for 2023 Joint Statistical Meeting (JSM) held in Toronto (Aug 5 - 10, 2023). As an ICSA tradition, we also had an ICSA exhibition booth, a general member meeting (with refreshments) and a banquet during the 2023 JSM. Big thanks goes to Dehan Kong (chair of the local committee), Grace Ying Li (ICSA office manager), Jin Zhou (Chair of ICSA Outreach and Engagement Committee), and the volunteers team for their tireless efforts and amazing work.

On a different note, I am pleased to report some editorial team transitions for the two ICSA official journals (*Statistica Sinica* and *Statistics in Bio-*

sciences). For *Statistica Sinica*, an international journal co-sponsored by ICSA and the Institute of Statistical Science, Academia Sinica, the three-year term of Drs. Su-Yun Huang, Rong Chen, and Xiaotong Shen as co-editors concluded on July 31, 2023. Following a joint search by ICSA and the Institute of Statistical Science, Academia Sinica, we are delighted to announce the appointment of Drs. Huixia Judy Wang, Yi-Hau Chen, and John Stufken as the new co-editors for *Statistica Sinica*. They will assume their roles from August 1, 2023, to July 31, 2026. For *Statistics in Biosciences*, the term of Joan Hu as co-editor will come to an end on December 31, 2023. Following a rigorous search conducted by the ICSA ad hoc search committee led by Runze Li, Dr. (Tony) Jianguo Sun has been chosen as the new co-editor. He will be joining the current co-editor, Dr. Hongkai Ji, starting from January 1, 2024. On behalf of our organization, I extend our gratitude to the outgoing and incoming co-editors for their unwavering dedication and exceptional contributions to ICSA and the statistical profession as a whole. Their remarkable service has undoubtedly enriched the journal's content and advanced the field of statistics. We look forward to the exciting developments and contributions that the new editorial team will bring in the coming years.

I would also like to take a moment to extend my heartfelt congratulations to Hongyu Zhao on being elected as our President-Elect, and to our newly elected board members (Kun Chen, Jialiang Li, Jianchang Lin, George Tseng, and Song Yang). Welcome to the team and thank you to all who voted! I look forward to working closely with you and witnessing the positive impact you will make.

Finally, I would like to reiterate that I and the ICSA leadership team are eager to hear ideas and suggestions from you on how to improve various aspects of the ICSA. Please feel free to reach out to me (vli@ucla.edu), Jun Zhao (ICSA Executive Director, executive.director@icsa.org), or chairs of the ICSA committees (listed on the ICSA website) for any ICSA related questions and suggestions. As we all know, ICSA is run entirely by volunteers. Everyone's participation matters.

Thank you so much!

Gang Li Ph.D.

2023 President, ICSA

Professor of Biostatistics and Computational Medicine, University of California at Los Angeles.

Table 1. ICSA conferences in 2023

	Co-chair	Keynote speakers	Scientific Program Highlights	# of Participants
The 32nd ICSA Applied Statistics Symposium, (University of Michigan, June 11-14, 2023)	Jian Kang and Gongjun Xu, (University of Michigan)	Sylva Collins, Kathryn Roeder, Ming Yuan, and Qiwei Yao (banquet)	3 keynote lectures 1 banquet lecture 116 invited sessions 8 short courses 47 posters 10 student paper awards.	> 620, including 149 students
The 6th annual ICSA China Conference (Chengdu, Sichuan, China, June 30 - July 03, 2023)	Yichuan Zhao (Georgia State University) and Dan Yan (Southwest Jiaotong University).	Jun Liu, Fang Yao, and Zongben Xu (banquet)	2 keynote lectures 1 banquet lecture, 166 invited sessions 49 posters 5 junior researcher awards.	>1,000 including 252 students
12th ICSA International Conference (The Hong Kong Chinese University, July 7 – 9, 2023)	(Tony) Jianguo Sun (University of Missouri) Xinyuan Song (The Chinese University of Hong Kong)	Song Xi Chen (Peter Hall lecture), Ji Zhu (Pao-Lu Hsu lecture), and Qi-Man Shao	3 keynote lectures Including 2 named lectures >100 invited sessions including a special invited session, a junior research award session, and a special memorial session to celebrate the life of Professor Tze Leung Lai	

From the Executive Director, 2023-2025

Jun Zhao



Dear ICSA members,

On the flight back home from an ICSA sponsored conference, I was thinking what we have done and the chances and challenges we are facing as an association. This is a new era for data science, with big names such as big data and artificial intelligence. We are the people who love and deal with all kinds of data. Therefore, we are in a golden time for statistics. However, as one famous statistician presented in his speech in a conference, are we ready as a statistician?

The ICSA is an association with thousands of talented statistician members. Lots of the ICSA members are very famous in Statistics, not only in cutting edge research but also in application to different fields. The ICSA is well known in the statistical community, and it attracts many statisticians and data scientists. To embrace the new world of data, the ICSA is looking forward to broadening its vision, strengthening its leadership, and improving its communication.

What did we achieve in the past half year? It has been one of the busiest half-year periods not only for the ICSA executives and officers, but also for all the ICSA members and volunteers. When people are tending to be in a normal life after a long shutdown period, as a friend said, people are attending phys-

ical meetings with revenge. This was demonstrated in the ICSA sponsored and co-sponsored major conferences.

The busy conference season begins from the ICSA annual Applied Statistics Symposium. The 32nd annual ICSA Applied Statistics Symposium, themed “Statistical Learning and Reasoning: From Data to Knowledge” was successfully held at the University of Michigan in Ann Arbor, Michigan, USA, from June 11 to June 14, 2023. With the dedicated work from co-chairs Dr. Jian Kang and Dr. Gongjun Xu, and the whole organizing committee, the symposium welcomed over 620 participants from academia, government, and industry. The conference program featured keynote lectures, invited sessions, panel sessions, short courses, posters, oral presentations by the recipients of the student paper awards, and a lecture in the traditional ICSA Banquet.

The 2023 ICSA China Conference, themed “Data Science with Applications to Big Data Analysis and AI” was successfully held at Chengdu Longemont Hotel, Chengdu, Sichuan, China from June 30 to July 3, 2023. The conference was co-sponsored by the Southwest Jiaotong University (SWJTU). Dr. Yichuan Zhao, Dr. Dan Yang, and Dr. Haotao Zheng and the whole organizing committee, welcomed around 1000 statisticians and data scientists, from academia, government, and industry all over the world. The conference had a big success with

featured keynote speeches, invited scientific sessions, panel sessions, posters, oral presentations by the recipients of the junior researcher awards, and a banquet speech in the banquet hosted by SWJTU.

Due to the pandemic, the 12th ICSA International Conference was postponed to July 7 to July 9, 2023, at the Chinese University of Hong Kong (CUHK), Hongkong. Well prepared by Dr. (Tony) Jianguo Sun, Dr. Xinyuan Song, Dr. Xingqiu Zhao and the whole organizing committee, the conference successfully hosted more than 400 participants, with keynote speeches, special invited lecturers, and invited scientific sessions. The conference banquet organized by the local committee, provided not only delicious food but also excellent performance including face-changing and lion dance.

ICSA members also participated in many ICSA co-sponsored conferences and sponsored sessions in other conferences, which include the Duke-Industry Statistics Symposium on March 29-31, 2023; the 8th Workshop on Biostatistics and Bioinformatics on May 5 - 7, 2023; Statistical Foundations of Data Science and their Applications: A conference in celebration of Jianqing Fan's 60th Birthday on May 8 -10, 2023; the 2023 International Indian Statistical Association (IISA) Conference held at the Colorado School of Mines on June 1-4, 2023; Dose Finding and Other Topics in Drug Development Honoring Dr. Naitee Ting on June 8 -9, 2023; the JSM on August 6-10, 2023, and the 2023 DIA China Quantitative Science Forum (QSF) which will be held from Oct 19-21, 2023 in Nanjing, China and the IMS Asian Pacific Rim Meeting in Jan, 2024.

The three ICSA chapters welcomed ICSA members to attend chapter conferences. The Canada Chapter had a successful conference in Banff, CA last summer. ICSA Taiwan Chapter co-organized with the Institute of Statistical Science, Academia Sinica, the 2023 International Conference of Statistics and Data Science, from July 12 to 13, 2023, in Taipei, Taiwan. The Midwest Chapter will have the annual joint fall conference of ICSA Midwest Chapter & NIC-ASA to be held on October 12-13, 2023, in Northfield, Illinois, USA.

It was a busy season for all the ICSA committees. The Program Committee led by Dr. Xinpeng Cui, has started working with the 2024 and 2025 Applied Statistics Symposium organizers, 2024 China Conference organizers, and the potential 2025 International Conference organizers. The Award Committee led by Dr. Zhigang Li, has concluded the 2023 candidate award winners for board approval. The Nominating and Election Committee led by Dr. Yichuan Zhao, has concluded the candidates

for 2025 president and 2024-2026 board members for ICSA members' final vote. Special Lecture Committee led by Dr. Ming Tan, has started working on keynote speeches for the future ICSA sponsored conferences. Membership Committee led by Dr. Zhigan Zhao, is working on several initiatives in related to ICSA membership. Publication Committee led by Dr. Runze Li, is working on selection of Journal SBS editor candidates, among publication tasks. Finance Committee and Financial Advisory Committee are looking best way to manage the funding for the association. In addition, ICSA initiated two new ad hoc committees. The ICSA Outreach and Engagement Committee, chaired by Dr. Jin Zhou, has created a social media - a Twitter handle @ICSA_Statistics. News from ICSA will be edited and (officially) posted at Twitter site. The ICSA members are encouraged to follow the account. The committee is working on other potential social media platforms and other activities to improve ICSA's outreach and engagement.

The 2nd one is the ICSA Constitution Committee, chaired by Dr. Hongzhe Li, has started discussion on the amendment of the by-laws. The committee is in line with the defined term in the constitution and by-laws: Not more than eight years after the adoption of the Constitution and By-Law, a Constitution Committee shall be appointed by the President for the purpose of reviewing the Association's Constitution and By-Laws, and preparing a revision if necessary, to be submitted to the Board of Directors not more than ten years after the adoption of this Constitution.

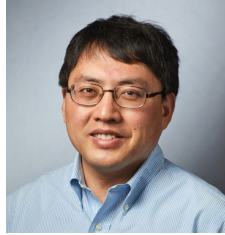
As a convention, the ICSA held two Board Member Meetings in the Applied Statistics Symposium and in the Joint Statistical Meetings (JSM). Similarly, two ICSA General Member Meetings were held in the symposium, and in the JSM. All members were invited to attend the ICSA general member meetings, and were encouraged to visit the ICSA booth, and attend the ICSA banquets.

Finally I would like to thank the Executive Committee, the Board, the standing committees, and all the ICSA members for your continuous support to the association. To make the ICSA stronger, I encourage all ICSA officers, board of directors, and all members to participate, contribute, volunteer, and dedicate at the ICSA.

Jun Zhao, Ph.D.
ICSA Executive Director (2023-2025)
Senior Director, Statistics,
Antengene Corp.

ICSA 2023 Election

ICSA President-Elect 2024



Hongyu Zhao
Yale University

ICSA Board of Directors (2024-2026)



George Tseng
University of
Pittsburgh



Jialiang Li
National
University of
Singapore



Jianchang Lin
Takeda



Song Yang
National Heart, Lung,
and Blood Institute,
NIH



Kun Chen
University of
Connecticut

Congratulations to ICSA Members Bestowed the 2023 ASA Fellows

Congratulations to the following ICSA members who are bestowed the prestigious distinction of the 2023 American Statistical Association (ASA) Fellow for their professional contributions, leadership, and commitment to the field of statistical science:

- Xiping Cui: University of California, Riverside
- Zonghui Hu: National Institute of Allergy and Infectious Diseases, regular
- Bo Huang: Pfizer, regular
- Robert Todd Krafty: Emory University, permanent
- Yajun Mei: Georgia Institute of Technology, permanent
- Jing Ning: M.D. Anderson Cancer Center, regular
- Inna T. Perevozskaya: GSK Robert W. Platt - McGill University, regular
- Lingzhou Xue: The Pennsylvania State University, permanent

Congratulations to the 2023 Class of IMS Fellows

Congratulations to the following ICSA members on being the 2023 class of IMS fellows. The designation of IMS Fellow has been a significant honor for over 85 years. Each Fellow has demonstrated distinction in research in statistics or probability or has demonstrated leadership that has profoundly influenced the field:

- Yang Feng: New York University
- Wensheng Guo: University of Pennsylvania
- Shuangge Ma: Yale University
- Ali Shojaie: University of Washington
- Fengzhu Sun: University of South California
- Hansheng Wang: Peking University
- Yihong Wu: Yale University
- Eric Poe Xing: Carnegie Mellon University, Mohamed Bin Zayed University of Artificial Intelligence

The 2023 ICSA Awards

Awards Committee Chair: Zhigang Li

erations.

The ICSA 2023 Distinguished Achievement Award

Heping Zhang, Ph.D. Yale University.

For distinguished achievements in statistical methodology, application, and training of new gen-

Hongyu Zhao, Ph.D. Yale University.

For distinguished achievements in statistical methodology, application, education, and contribution to the development of Statistics in China.

The ICSA 2023 Outstanding Service Award

Mengling Liu, Ph.D. New York University .

For contribution, commitment, and dedication to the growth of the organization exemplified the mission of the ICSA.

The ICSA 2023 Outstanding Young Researcher Award

Chengchun Shi, Ph.D. London School of Economics and Political Science .

For contributions to the fields of statistics, artificial intelligence, neuroimaging data analysis, two-sided markets, and machine learning.

Edgar Dobriban, Ph.D. University of Pennsylvania .

For remarkable contributions to the contemporary statistical and machine learning theory and methods.

Zijian Guo, Ph.D. Rutgers University.

For ground-breaking contributions to non-parametric statistics, high-dimensional inference, causal inference, and privacy-preserving data fusion.

The ICSA 2023 President's Citation Award

Chunjie Wang, Ph.D. Changchun University of Technology, China.

In recognition and appreciation of his dedicated and outstanding service and leadership as the Co-Chair of the Program Committee for the 2022 ICSA China Conference.

Yingying Fan, Ph.D. University of Southern California.

In recognition and appreciation of her dedicated and outstanding service and leadership as the Co-Chair of the Program Committee for the 2022 ICSA China Conference.

Samuel Wu, Ph.D. University of Florida.

In recognition and appreciation of his dedicated and outstanding service and leadership as the Co-Chair of the Program Committee for the 2022 ICSA Applied Statistics Symposium.

Somnath Datta, Ph.D. University of Florida.

In recognition and appreciation of his dedicated and outstanding service and leadership as the Co-Chair of the Program Committee for the 2022 ICSA Applied Statistics Symposium.

The Awards from the ICSA Members

Congratulations to Dr. Jane-Ling Wang, on Elected Academician of Academia Sinica at the 34th Convocation of Academicians

Jane-Ling Wang, Distinguished Professor from the University of California, Davis, has been elected Academician of Academia Sinica at the 34th Convocation of Academicians, held in July, 2022 in Taipei, Taiwan. More details are available at <https://www.sinica.edu.tw/en/new>

s/7238.Congratulations, Dr. Wang!

Congratulations to Dr. Ping Ma, Dr. Peihua Qiu, and Dr. Hui Zou on Being Elected 2022 American Association for the Advancement of Science (AAAS) Fellows for Statistics Section

AAAS announced its new Fellows for 2022. The following three ICSA members are on the honoring list for the Statistics Section:

- Ping Ma, University of Georgia
- Peihua Qiu, University of Florida
- Hui Zou, University of Minnesota

Congratulations on their many contributions to science and the field of statistics.

Congratulations to ICSA Members on Winning 2023 Committee of Presidents of Statistical Societies (COPSS) Awards

The COPSS had four major awards in 2023: President's award, DAAL award, F.N. David Award, and the George W. Snedecor Award. Congratulations to the following ICSA members on being elected as the awardees:

- Dr. Bin Yu: the distinguished achievement award and lectureship
- Dr. Gongjun Xu: COPSS 2023 Emerging Leader Awards
- Dr. Edgar Dobrihan, COPSS 2023 Emerging Leader Awards
- Dr. Jingyi Jessica Li, COPSS 2023 Emerging Leader Awards
- Dr. Peng Ding, COPSS 2023 Emerging Leader Awards

Congratulations to Dr. Kelly H. Zou on Winning North American, Business of Data –the Future Thinking Award

Dr. Kelly Zou won this award at CDAO Fall, 2022 with Scott Zoldi. For details, please click the links below:

Awards: <https://cdao-fall.coriniumintelligence.com/bod-awards>

Highlights: https://www.linkedin.com/posts/kelly-h-zou-phd-pstat-fasa-97307b16_futurethinking-bodawards-datascience-activity-6985793218068017152-_EBt

Congratulations to Dr. Xihong Lin on Being Elected to National Academy of Sciences

Dr. Xihong Lin, Prof. of Biostatistics and coordinating director of the Program in Quantitative Geonomics at Harvard T.H. Chan School of Public Health, has been elected to the National Academy of Sciences (NAS). NAS members are elected in recognition of their “distinguished and continuing achievements in original research” and is “one of the highest honors that a scientist can receive” .

Congratulations to Dr. Joseph (“Joe”) C. Capelleri on Winning Long-Term Excellence Award

Dr. Joe Cappelleri, New England Statistical Society Past President, adjunct professor of Biostatistics at Brown and Executive Director of Biostatistics at Pfizer, was honored by the American Statistical Association's (ASA) Health Policy Statistics Section (HPSS) with the Long-Term Excellence award during the 2023 International Conference of Health Policy Statistics (ICHPS) which was held at the Scottsdale, Arizona from Jan 9th to 11th, 2023.

Congratulations to Dr. Tony Cai on Being Elected as Incoming IMS President-elect, Dr. Huixia Judy Wang, Dr. Linda Zhao on Being Elected to the IMS Council

For detailed information, please refer to: Institute of Mathematical Statistics | IMS Elections 2023 (im-stat.org).

Congratulations for the ICSA Members Elected as ASA Officials

- Board of Directors President-Elect 2024, Ji-Hyun Lee, University of Florida
- Statistics in Genomics and Genetics (est. 2015) SGG. Council of Sections Representative 2024-2026, Li-Xuan Qin, Memorial Sloan Kettering Cancer Center
- Statistics in Imaging (est. 2012) SI. Chair-Elect 2024, Dehan Kong, University of Toronto
- Statistical Learning and Data Science (est. 2009) SLDM: Chair-Elect 2024, Jing Lei, Carnegie Mellon University
- Lifetime Data Science Section (2018) LIDS:
 - Chair-Elect 2024, Zhezhen Jin, Columbia University Mailman School of Public Health Program.

- Chair-Elect 2024, Mengling Liu, New York University Grossman School of Medicine
- Treasurer 2024-2026, Yifei Sun, Columbia University
- Nonparametric (est. 1999) NPAR:
 - Treasurer 2024 (Rotates to Secretary in 2025), Anru Zhang, Duke University
 - Council of Sections Representative 2024-2026, Limin Peng, Emory University
- Physical and Engineering Sciences (est. 1954) SPES/SPQP: Chair-Elect 2024, Devon Lin, Queen’s University
- Statistical Programmers and Analysts (est. 2009) SSPA: Publications Officer 2024-2025, Jiping Wang, Yale University

Congratulations to Dr. Ming-Hui Chen on Reception for Distinguished Science Award Honoree from the College of Science at Purdue University

Dr. Ming-Hui Chen is currently Board of Trustees Distinguished Professor and Head of the Department of Statistics at the University of Connecticut (U Conn.). Dr. Chen, served as Executive Director of ICSA (2007-2010), President of ICSA (2013), was elected as Fellow of International Society for Bayesian Analysis in 2016, Fellow of the Institute of Mathematical Statistics in 2007, Fellow of American Statistical Association in 2005.

Statistics in Biosciences CALL FOR PAPERS

Special issue on “Statistical Methods, Algorithms and Applications in Biomedical Data Integration”

We invite submissions to the special issue of Statistics in Biosciences dedicated to statistical methods, algorithms and applications in biomedical data in-

tegration. Integrating multiple data sources has attracted wide interests as part of transition from data to knowledge with the potential to change the analytical scheme of modern biomedical research. In recent years, research initiatives have been created to leverage large-scale observational databases

from multiple scientific disciplines and technologies, which present many significant methodological and computational challenges to traditional statistical methods and algorithms. Most notably, data collected from observational studies are leveraged for modern biomedical research to enrich study populations and improve controlling confounding factors. Despite infrastructure advancements, methodological and algorithmic challenges remain the barriers for data integration. Common analytical concerns in data integration include data storage and communication restrictions, statistical efficiency, protection of data privacy and against adversarial attacks, data harmonization over different formats, handling of missing data, heterogeneity across data sources, and external validity, among many others. Some new methods, algorithms and applications for data integration are being developed, but much remains unknown in terms of how well they perform or how they compare with conventional approaches. Moreover, with the ubiquitous availability of multi-source data and the increased desire to conduct research with massive data, new methodological and algorithmic developments are needed on many fronts of data integration, including uncertainty quantifica-

tion, causal inference, and sparse and scalable analytical procedures.

The special issue welcomes new methodological developments as well as interesting applications in data integration. It also welcomes up-to-date reviews of current data analytic and computational tools in this area. All submissions must contain original unpublished work not being considered for publication elsewhere. Submissions will be refereed according to the standard procedures for Statistics in Biosciences. The deadline for submissions is August 31, 2023, with a rolling review.

Papers for the special issue should be submitted using the journal's submission system at <https://www.editorialmanager.com/sibs/default1.aspx>. In the system, please choose the special issue on Statistical Methods, Algorithms and Applications in Biomedical Data Integration. The review and decision will be on a rolling basis.

Co-Editors for the special issue:

- Peter X.-K. Song, Ph.D., University of Michigan. Email: pxsong@umich.edu
- Lu Tang, Ph.D., University of Pittsburgh. Email: lutang@pitt.edu

ICSA Springer Book Series in Statistics

The editor of ICSA Springer book series in statistics, Dr. Din Chen, has reported that there are 24 books in the series now. Two new books were published in 2022 with detailed message below. If you plan to write books in the series, please contact Dr. Din Chen (Ding-Geng.Chen@asu.edu).

Emerging Topics in Modeling Interval-Censored Survival Data

Editor: Jianguo Sun & Ding-Geng Chen

Copyright: 2022

Published: 15 December 2022

Advances and Innovations in Statistics and Data Science

Editors: Wenqing He, Liqun Wang, Jiahua Chen & Chunfang Devon Lin

Copyright: 2022

Published: 28 October 2022

Statistica Sinica

Statistica Sinica is co-sponsored by Institute of Statistical Science Academia Sinica (ISSAS) [https://](https://www.stat.sinica.edu.tw/eng/index.php)

www.stat.sinica.edu.tw/eng/index.php. Forth-

coming papers' information is available at <http://www3.stat.sinica.edu.tw/statistica/>. The new issue (Volume 33, Number 3, 2023) is published.

There is one online special issue for your references: *Vol 33 Special Issue, April 2023 (sinica.edu.tw): High-Dimensional Statistics*.

ICSA members have access to these articles via the "membership only area" at <http://www.icsa.org>. If you have any problems with subscription, please contact the editorial office through ss@stat.sinica.edu.tw.

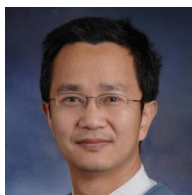
The Spotlight from ICSA 2023 China Conference (June 30 –July 03, 2023)

Yichuan Zhao

The 6th annual ICSA China Conference was successfully held at Longemont Hotel, Chengdu, Sichuan, China, from June 30 to July 03, 2023 after the COVID-19 pandemic. It is jointly organized by ICSA, Southwest Jiaotong University (SWJTU) and Sichuan Association of Applied Statistics. The theme of our conference is "Data Science with Applications to Big Data Analysis and AI", which is in recognition of artificial intelligence and data science with new challenges in the big data era. With very careful preparation, we welcomed around 1000 statisticians and data scientists working in academia, government, and industry from all over the world, including 252 students, to this exciting meeting. The conference program contains 2 keynote lectures delivered by Dr. Jun Liu (Harvard University) and Dr. Fang Yao (Peking University), 1 banquet lecture by Dr. Zongben Xu (Xi'an Jiaotong University), 164 invited sessions, and 2 panel sessions. The scientific program has reflected new challenges in statistics, business statistics, and biostatistics, which are related to recent progress in big data analysis and artificial intelligence. In addition, there were 49 posters, and 5 oral presentations by the recipients of junior researcher awards. Among them, 3 young researchers received best poster awards and 4 received honorable mentions for their excellent presentations. The junior researcher awardees are Dan Erdmann-Pham from Stanford University, Feiyu Jiang from Fudan University, Cheng Meng from Renmin University of China, Yuting Wei from University of Pennsylvania, and Wenzhuo Zhou from University of California, Irvine. For more information about the scientific program and our conference, refer to the social media reports through the following links <https://maths.swjtu.edu.cn/info/1149/10805.htm> and <https://maths.swjtu>

[.edu.cn/info/1149/10817.htm](https://maths.swjtu.edu.cn/info/1149/10817.htm).

On behalf of the organizing committee, Dr. Yichuan Zhao would like to express the appreciation to all the people who contributed to the great success of this memorable conference. We deeply thank the ICSA Executive Committee, ICSA Program Committee and ICSA Special Lecture Committee. In particular, we would like to acknowledge the hard work from nearly 30 faculty members and nearly 60 student volunteers led by Dr. Haitao Zheng from the School of Mathematics at SWJTU in Chengdu. We extend our sincere thanks to their great effort to arrange the meeting logistics and social events of the huge conference such as picking up conference attendees at the two international airports of Chengdu. Our deep appreciation also goes to all the members of different conference committees and all the active conference participants. Moreover, we are deeply grateful for the financial support from National Science Foundation, 3 gold sponsors (Abbvie, Southwest Jiatong University, Chengdu Expo Bureau), 1 silver sponsor (MDPI Mathematics journal), and 1 bronze sponsor (Statistical Theory and Related Fields). The conference also hosted a wonderful banquet with nearly 600 participants, who enjoyed the delicious foods very much. We believe this conference was an amazing experience for all of the participants, and they had enjoyable time and pleasant memory during the stay in the beautiful city of Chengdu.



*Yichuan Zhao, Ph.D.
Co-Chair of 2023 ICSA China Conference
Executive Committee and Chair of Program Committee
Professor of Statistics,
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The Spotlight from ICSA 2023 Applied Statistics Symposium (June 11 - July 14, 2023)

Gongjun Xu, Jian Kang

The 32nd annual ICSA Applied Statistics Symposium, themed “Statistical Learning and Reasoning: From Data to Knowledge,” was successfully held at the University of Michigan in Ann Arbor, Michigan, USA, from June 11 to June 14, 2023. With great enthusiasm, we welcomed over 620 participants from academia, government, and industry, including 149 students, to this remarkable event. The conference program was packed with enriching content, featuring 3 keynote lectures, 1 banquet lecture, 113 invited sessions, and 3 panel sessions. Additionally, there were 8 short courses, 47 posters, and 10 oral presentations by the recipients of the student paper awards.

On behalf of the organizing committee, Dr. Jian Kang and Dr. Gongjun Xu would like to express our heartfelt appreciation to all individuals and entities who contributed to making this symposium a resounding success. Our sincere gratitude goes to the ICSA Executive Committee, ICSA Program Committee, faculty and staff members as well as the dedicated student volunteers from the Department of Biostatistics and the Department of Statistics at the University of Michigan. We would also like to

extend our thanks to the entire conference committee and all the enthusiastic participants. Furthermore, we are deeply grateful for the generous financial support provided by the National Science Foundation, 8 gold sponsors (Department of Biostatistics at the University of Michigan, Department of Statistics at the University of Michigan, Abbvie, BeiGene, Boehringer Ingelheim, ClinChoice, DuBu Research, and The Lotus Group), 8 silver sponsors (Amgen, Bristol Myers Squibb, Everest, Gilead, MDPI Mathematics journal, Merck, Moderna, Sanofi), and 3 bronze sponsor (Regeneron, Teva, and Vertex).



*Gongjun Xu, Ph.D.
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Professor of Biostatistics
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The Spotlight from 12th ICSA International Conference (July 7 –9, 2023)

(Tony) Jianguo Sun

The 12th ICSA International Conference was successfully held during July 7 to July 9, 2023 at The Hong Kong Chinese University. The conference started with the opening ceremony at 8:30am local time, chaired by (Tony) Jianguo Sun. During the ceremony, Professor Alan Chan, Provost of The Hong Kong Chinese University, first gave an opening remark and welcomed all participants and then

Professor Gang Li, the 2023 ICSA President, introduced the history and activities of ICSA. Finally Professor Xinyuan Song, Chair of the Department of Statistics of The Hong Kong Chinese University, gave welcome remarks and a brief introduction of the department as well as conference activities. In the conference, there were two named lectures, Peter Hall lecture given by Dr. Song Xi Chen from Peking University of China and Pao-Lu Hsu lecture given by Dr. Ji Zhu from the University of Michi-

gan of USA. Also Dr. Qi-Man Shao from Southern University of Science and Technology of China gave a keynote lecture, and Dr. Mei-Ling Lee from the University of Maryland of USA and Dr. Gang Li from UCLA of USA presented two special invited lecturers. Furthermore, there were over 100 invited sessions, including a junior research award session and a memorial session to celebrate the life of Professor Tze Leung Lai. In addition to excellent scientific presentations, one of other exciting events was the conference banquet organized by the local committee, which not only provided delicious food but also excellent performance including changing face and lion dance.

As it can be imagined, such large and successful conference would not be possible without the support of many people and many hours preparation. First I want to thank Co-Chair of Program Committee, Dr. Xingqiu Zhao, and all committee members for their hard work to put up the excellent scientific program. Also I wish to thank Dr. Xinyuan Song, Co-Chair of the Executive Committee and Chair of Local Committee, and her dedicated term, including many faculty, staff and students from her department, for their countless hours on planning and preparation as well as making it successfully. Two

other people who do not hold any position in ICSA and deserve a big thank are Drs. Dayu Sun and Yuanyuan Guo, who served as Chair of Program Book Committee and Co-Chair of IT and Website Committee, respectively, and also worked countless hours until the last minute of the conference to fulfill all of kind requirements. Of course, the conference would not be possible without the strong support and leadership of ICSA Executive Committee, including 2023 ICSA President Dr. Gang Li, 2022 ICSA President Dr. Zhezhen Jin and ICSA Executive Director Dr. Jun Zhao, and the support of all of over 400 participants and many other volunteers.

(Tony) Jianguo Sun, Ph.D.

Co-Chair of 12th ICSA International Conference Executive Committee,

Co-Chair of 12th ICSA International Conference Program Committee,

Curators Distinguished Professor,

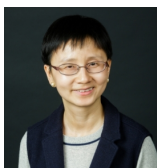
*Department of Statistics,
University of Missouri.*



ICSA Financial Report

Profit and Loss: Jan 1, 2023 through June 30, 2023.

Beginning Cash Balance (Bank/Symposium/Paypal accounts)	1/1/2023	\$	436,927.06
Income:			
Membership		\$	28,115.00
2023 Donations		\$	33,050.00
2022 ICSA Symposium Income		\$	14,854.50
2023 ICSA Symposium Registration Fees		\$	206,991.18
2023 International Registration Fee		\$	184,182.09
2023 China Conference Registration Fee		\$	104,453.47
Springer Science & World Scientific Publishing Co.		\$	3,899.98
Job Posting		\$	450.00
Interest		\$	63.79
Total Income		\$	576,060.01
Expense:			
ICSA Office Cost		\$	(459.39)
2022 ICSA owed labor		\$	(296.38)
2023 ICSA Symposium Awards and Honorarium		\$	(14,850.00)
2023 International Conference Fees		\$	(100,045.00)
IT Cost		\$	(7,052.63)
Paypal and Bank Fee		\$	(739.67)
Total Expense		\$	(123,443.07)
Net Total Income		\$	452,616.94
Transfer to Vanguard		\$	(100,000.00)
Fee adjustment (transaction for fee reversion etc)		\$	(679.10)
Ending Cash Balance (Bank/Symposium/Paypal accounts)	6/30/2023	\$	772,010.40
ASSETS			
JPHsu Investment		\$	25,057.71
Bank/PayPal		\$	772,010.40
Vanguard Investment Balance		\$	962,887.13
TOTAL ASSETS		\$	1,759,955.24
LIABILITIES & EQUITY			
Equity			
Main Accounts Opening Balance Jan 1, 2023		\$	375,282.25
Jan 1 to Jun 30, 2023 Net Income(+)/Expense(-)		\$	(58,543.40)
From 2022 Applied Symposium Account		\$	54,944.81
From 2023 Applied Symposium Account		\$	206,991.18
From 2023 International Conference Account		\$	136,772.29
From 2023 China Conference Account		\$	102,474.43
To Vanguard Account		\$	(100,000.00)
For JP Hsu Account Opening Jan 1, 2023		\$	22,146.81
JP Hsu Award		\$	(550.00)
Jan 1 to Jun 30, 2023 Net Income(+)/Expense(-)		\$	3,460.90
2018 Symposium Bank Accounts Opening Balance Jan 1, 2023		\$	4,700.00
Jan 1 to Jun 30, 2023 Net Income(+)/Expense(-)		\$	-
2022 Symposium Bank Accounts Opening Balance Jan 1, 2023		\$	40,090.31
Jan 1 to Jun 30, 2023 Net Income(+)/Expense(-)		\$	14,854.50
To Main Account (closure)		\$	(54,944.81)
2023 Symposium Bank Accounts Opening Balance Jan 1, 2023		\$	-
Jan 1 to Jun 30, 2023 Net Income(+)/Expense(-)		\$	206,991.18
Transfer to Main Account		\$	(206,991.18)
2023 International Jan 1, 2023		\$	-
Jan 1 to Jun 30, 2023 Net Income(+)/Expense(-)		\$	184,182.09
Transfer to Main Account		\$	(136,772.29)
2023 China Opening Balance Jan 1, 2023		\$	-
Jan 1 to Jun 30, 2023 Net Income(+)/Expense(-)		\$	104,453.47
Transfer to Main Account		\$	(102,474.43)
Vanguard investment account opening balance on Jan 1, 2023		\$	793,473.97
Transfer from Main Account		\$	100,000.00
Jan 1 to Jun 30, 2023 Investment Profit(+)/Loss(-)		\$	69,413.16
Total Equity		\$	1,759,955.24
TOTAL LIABILITIES & EQUITY		\$	1,759,955.24



*Rui Feng, PhD,
Treasurer, ICSA
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Should We Trust Algorithms?

David Spiegelhalter

Editorial: This is a reprint from the Harvard Data Science Review in the *HDSR website* with permission. Full article can be found from <https://hdsr.mitpress.mit.edu/pub/56lnezzj/release/3>.

1. Introduction

When on holiday in Portugal last year, we came to rely on ‘Mrs. Google’ to give us driving directions in her awful Portuguese accent. When negotiating the narrow streets in the ancient university town of Coimbra, she confidently told us to go left and so we obeyed her. But we were somewhat taken aback when the road abruptly turned into steps—we stopped in time, but after that we were not so trusting.

But it’s not just navigation algorithms that need caution. Large numbers of algorithms¹ of varying complexity are being developed within the health care and the criminal justice system, and include, for example, the U.K. HART (Harm Assessment Risk Tool) system (Oswald, Grace, Urwin, & Barnes, 2018) for assessing recidivism risk, which is based on a machine-learning technique known as a random forest. But the reliability and fairness of such algorithms for policing are being strongly contested: apart from the debate about facial recognition (Simonite, 2019), a recent report by rights-organization Liberty (Holmes, 2019) on predictive policing algorithms says that “their use puts our rights at risk.”

It is important not to be mesmerized by the mystique surrounding artificial intelligence (AI). The media (and politicians) are replete with credulous stories about machine learning and AI, but these stories are often based on commercial claims (Brennen & Nielsen, 2019). In essence, these programs simply take some data and use rules or mathematical formulae to come up with a response that is intended to be used to enhance professional judgment. The idea of algorithms in criminal justice is not new: it is rarely acknowledged that simple scoring systems for recidivism based on a statistical regression analysis have been used for decades (Copas & Marshall, 1998). Indeed, basic sentencing guidelines can be considered as algorithms designed to produce consistency, and provide a starting point that can be

adjusted according to the judge’s discretion about a specific case (Sentencing Council, 2019).

Nevertheless, the Liberty report is just one example of increasing ethical concern, and it can seem that there are now more people working on the ethics of algorithms, AI, and machine learning than on the technology itself. There are numerous checklists and initiatives, for example, Algo-care for policing (Oswald et al., 2018), while FATML (Fairness, Accountability and Transparency in Machine Learning), suggests a social impact statement (Fairness, Accountability, and Transparency in Machine Learning, 2019) for any algorithm, detailing:

- *Responsibility*: whom to approach when things go wrong.
- *Explainability*: to stakeholders in nontechnical terms.
- *Accuracy*: to identify sources of error and uncertainty.
- *Auditability*: to allow third parties to check and criticize.
- *Fairness*: to different demographics.

Within criminal justice, the COMPAS system (equivant, 2019) is widely used in the United States for predicting recidivism and informing bail decisions. It takes in 137 items of information, and comes up with a risk score from 1 to 10, which is classified into low/medium/high. But the procedure is proprietary and so acts as a complete black box, while COMPAS has been accused of racial bias (Angwin, 2016), although this analysis has been strongly contested (Corbett-Davies, Pierson, Feller, & Goel, 2016). An appeal against its use failed (*Harvard Law Review*, 2017), but COMPAS appears to perform poorly on most of the FATML criteria.

So it all seems to come down to a simple question—can we trust algorithms?

2. Trust and Trustworthiness

In this age of misinformation and loud, competing voices, we all want to be trusted. But as the philosopher Onora O’Neill has said (O’Neill, 2013), organizations should not try to be trusted; rather they

¹I am using ‘algorithm’ in a fairly general sense to mean the actual formula, coded model, or even guideline, that is to be used in a new situation. I am not referring to the way in which this procedure was built, whether using machine-learning, standard statistical analysis, judgment, or other methods.

should aim to demonstrate *trustworthiness*, which requires honesty, competence, and reliability. This simple but powerful idea has been very influential: the revised Code of Practice for official statisticians in the United Kingdom puts Trustworthiness as its first “pillar” (UK Statistics Authority, 2018).

It seems reasonable that, when confronted by an algorithm, we should expect trustworthy claims both:

1. *about* the system—what the developers say it can do, and how it has been evaluated, and
2. *by* the system—what it says about a specific case.

This is a complex topic, but statistical science can help—it has been contributing to communication and evaluation for decades. Let’s look at those two criteria in more detail.

2.1. The Trustworthiness of the Claims Made About the System

As documented in a recent report by the Reuters Institute (Brennen & Nielsen, 2019), there are many exaggerated claims about AI driven by commercial rather than scientific considerations. Eric Topol, in his authoritative review of medical AI, baldly asserts that “The state of AI hype has far exceeded the state of AI science, especially when it pertains to validation and readiness for implementation in patient care” (Topol, 2019, p51).

The trustworthiness of claims about the overall system could be communicated by providing a social impact statement along the lines suggested by FATML. But there is one important consideration missing from that list. It seems taken for granted that algorithms will be beneficial when implemented and, since this is by no means assured, I would suggest adding:

- ***Impact: what are the benefits (and harms) in actual use?***

Statisticians have been familiar with structured evaluation for decades, ever since scandals such as the birth defects caused by thalidomide brought about a stringent testing regime for new pharmaceuticals. The established four-phase structure is summarized in Table 1, alongside a similar structure for algorithms based on longstanding similar proposals by me (Spiegelhalter, 1983) and Stead et al. (1994).

Table 1. Accepted phased evaluation structure for pharmaceuticals, with a proposed parallel structure for evaluation of algorithms.

	Pharmaceuticals	Algorithms
Phase 1	Safety: Initial testing on human subjects	Digital testing: Performance on test cases
Phase 2	Proof-of-concept: Estimating efficacy and optimal use on selected subjects	Laboratory testing: Comparison with humans, user testing
Phase 3	Randomized Controlled Trials: Comparison against existing treatment in clinical setting	Field testing: Controlled trials of impact
Phase 4	Post-marketing surveillance: For long-term side-effects	Routine use: Monitoring for problems

Nearly all attention in the published literature on both medical and policing algorithms has focused on Phase 1—claimed accuracy on digital data sets. But this is only the start of the evaluation process. There is a small but increasing number of Phase 2 evaluations in which performance is compared with human ‘experts,’ sometimes in the form of a Turing Test in which the quality of the judgments of both humans and algorithms are assessed by independent experts, who are blinded as to whether the judgment was made by a human or algorithm (Turing, 1950). For example, the medical AI company Babylon (Copestake, 2018) conducted a Phase 2 study comparing their diagnostic system with doctors, although this was subsequently strongly criticized in the *Lancet* (Fraser, Coiera, & Wong, 2018). Kleinberg, Lakkaraju, Leskovec, Ludwig, & Mullainathan (2018) also draw the analogy between evaluating recidivism algorithms and the four-phase pharmaceutical structure, and model a Phase 2 comparison between human and algorithmic decisions.

Topol also reports that “There has been remarkably little prospective validation for tasks that machines could perform to help clinicians or predict clinical outcomes that would be useful for health systems” (Topol, 2019, p52). This means there have been very few Phase 3 evaluations that check whether a system in practice actually does more good than harm: even simple risk-scoring systems have rarely been evaluated in randomized trials, although a Cochrane Review of randomized trials (Karmali et al., 2017, p2) of risk scoring for the primary prevention of cardiovascular disease concluded that “providing CVD risk scores may slightly reduce CVD risk factor levels and may increase preventive medication prescribing in higher-risk people without evidence of harm”.

Algorithms may have an impact through an unexpected mechanism. I was involved in a study of ‘computer-aided diagnosis’ back in the 1980s, when this meant having a large and clumsy personal com-

puter in the corner of the clinic. In a randomized trial we showed that even a rather poor algorithm could improve clinical performance in diagnosing and treating acute abdominal pain—not because the doctors took much notice of what the computer said, but simply by encouraging them to systematically collect a good history and make an initial diagnosis (Wellwood, Johannessen, & Spiegelhalter, 1992).

There are, however, limitations to the analogy with evaluating pharmaceuticals. Prescription drugs act on individuals and, with the notable exceptions of overuse of antidepressants and opioids, rarely have an impact on society in general. In contrast, widespread use of an algorithm has the potential to have such an impact, and therefore the traditional individual-based randomized controlled trial may need supplementing by evaluation of the effect on populations. The UK Medical Research Council’s structure for the evaluation of complex medical interventions may be relevant; the original (very highly cited) proposal closely followed the staged pharmaceutical model described above (Campbell et al., 2000), but a revised version moved to a more iterative model with a reduced emphasis on experimental methods (Craig et al., 2008), and a further forthcoming update promises to broaden its perspective to other disciplines and further downplay randomized controlled trials (Skivington, Matthews, Craig, Simpson, & Moore, 2018)

An important consideration is that clinical algorithms are considered as medical devices for regulatory purposes, say by the European Union (Fraser et al., 2018) or the Food and Drug Administration (FDA) (Center for Devices and Radiological Health, 2019), and hence are not subject to the four-phase structure for pharmaceuticals shown in Table 1. Phase 3 randomized trials of impact are therefore not required for approval, with a strong emphasis played on the reliability of the technology or code itself. Again, this presupposes that algorithms shown to have reasonable accuracy in the laboratory must help in practice, and explicit evidence for this would improve the trustworthiness of the claims made about the system.

3. Trustworthiness of Claims Made by the System to the Recipients of Its Advice

When an individual is subject to an algorithm’s claim, say, an assessment of the risk of recidivism or a medical diagnosis, it seems reasonable that they

or their representatives should be able to get clear answers to questions such as:

- Is the current case within its competence?
- What was the chain of reasoning that drove this claim?
- What if the inputs had been different (counterfactuals)?
- Was there an important item of information that ‘tipped the balance’?
- What is the uncertainty surrounding the claim?

There are many current ingenious attempts to make complex algorithms more explainable and less of a black box. For example, Google DeepMind’s eye diagnosis system developed with Moorfields Eye Hospital is based on a deep-learning algorithm, but one that has been deliberately structured in layers to help visually explain intermediate steps between the raw image and diagnosis and triage recommendation (De Fauw et al., 2018).

While a deep-learning algorithm may be appropriate for automatic analysis of image data, when there are fewer inputs it may be possible to build a simpler, more interpretable model in the first place. Statistical science has mainly focused on linear regression models in which, essentially, features are weighted to lead to a scoring system, for example, Caruana and colleagues’ work using generalized additive models to produce pneumonia risk scores (Caruana et al., 2015). It’s often said that increased interpretability has to be traded off against performance, but this has been questioned for recidivism algorithms (Rudin, 2018). Indeed an online experiment showed that the untrained public were as good as COMPAS (65% accuracy), and that COMPAS performance could be matched by a simple rule-based classifier (Angelino, Larus-Stone, Alabi, Seltzer, & Rudin, 2017), and even a regression model with only two predictors (age and total previous convictions) (Dressel & Farid, 2018). Furthermore, assessments of uncertainty are a core component of statistical science.

4. Transparency

Trustworthiness demands transparency, but not just ‘fishbowl’ transparency in which huge amounts of information are provided in indigestible form. Transparency does not necessarily provide explainability—if systems are very complex, even

providing code will not be illuminating. Fortunately, Onora O’Neill has again made a major contribution in developing the idea of “intelligent transparency” (Royal Society, 2012), in which she argues that information should be

- *accessible: interested people should be able to find it easily.*
- *intelligible: they should be able to understand it.*
- *useable: it should address their concerns.*
- *assessable: if requested, the basis for any claims should be available.*

I feel the final criterion is essential: a trustworthy algorithm should be able to ‘show it’s working’ to those who want to understand how it came to its conclusions. While most users may be happy to take the algorithm’s claims ‘on trust,’ interested parties should be able to assess the reliability of such claims. In an experimental study of how much an algorithm adds to human accuracy, Lai & Tan (2019) found that providing an individualized explanation added as much as providing a generic assurance about the algorithm’s quality.

We have tried to live up to these aims in the interface we have constructed for the popular Predict program for women with newly diagnosed breast cancer (National Health Service, 2019), in which details of the disease and possible treatments are entered, and predictive information about the potential benefits and harms of post-surgical treatment is then communicated in text, numbers, and graphics. Explanation is provided at multiple levels and in multiple formats, and the full details of the algorithm, and even the code, are available for scrutiny if required. Of course, one problem of having a reliable algorithm that is packaged in a transparent and attractive manner is that it can lead to ‘overtrust,’ in which the output is treated as being precise and unquestionable. A truly trustworthy algorithm should be able to communicate its own limitations to ensure, rather ironically, that it is not trusted too much.

5. Conclusions

Developers need to demonstrate the trustworthiness of claims both *about* and *by* an algorithm, which requires phased evaluation of quality and impact based on strong statistical principles. In the context of clinical algorithms, Topol says “it requires rigorous studies, publication of the results in peer-reviewed journals, and clinical validation in a real-world environment, before roll-out and implementation” (Topol, 2019, p52). The same needs to be applied in the criminal justice system, where there is no FDA to license applications.

Finally, whenever I hear claims about any algorithm, my shortlist of questions I would like to ask include:

1. Is it any good when tried in new parts of the real world?
2. Would something simpler, and more transparent and robust, be just as good?
3. Could I explain how it works (in general) to anyone who is interested?
4. Could I explain to an individual how it reached its conclusion in their particular case?
5. Does it know when it is on shaky ground, and can it acknowledge uncertainty?
6. Do people use it appropriately, with the right level of skepticism?
7. Does it actually help in practice?

I feel that question 5 is particularly important. Being confidently told to drive down a set of steps reduced my trust in Mrs. Google, but on another occasion, she simply gave up and said “I cannot help you at the moment.” She soon recovered her composure, but to me this seemed to be trustworthy behavior—the algorithm knew when it didn’t know, and told us so. Such humility is rare and to be prized.

XL-Files: ChatGPT — First Contact

Xiao-Li Meng

Editorial: This is a reprint from a column article published in the *IMS*; <https://imstat.org/2023/03/31/xl-files-chatgpt-first-contact/>) with IMS' permission.

By now, it's worth having a chat if you know someone who hasn't chatted with or about ChatGPT. Everyone I've talked to about it has been either impressed or depressed, sometimes concomitantly, with a few wanting to suppress the whole thing, almost contemptuously.

My first try at ChatGPT (based on GPT-3.5) was prompted by the need of having a fundraising strategy for Harvard Data Science Review, as I continue my role as its Editor-in-Chief after taking a sabbatical leave. I provided the simple instruction: "Provide a fundraising strategy for Harvard Data Science Review" on Feb. 25, 2023, and it immediately produced a list of eight steps:

To develop a successful fundraising strategy for the Harvard Data Science Review, here are some potential steps that could be taken:

1. Identify potential donors: Start by identifying potential donors who have an interest in data science and are likely to support the mission and goals of the journal. This could include alumni, foundations, corporations, and individuals.

2. Develop a case for support: Develop a clear and compelling case for why the journal is important and why it deserves financial support. Highlight the journal's impact on the field of data science, its unique contributions, and its plans for the future.

3. Establish giving levels: Create giving levels with corresponding benefits to encourage donors to contribute at different levels. This could include naming opportunities, special recognition, or invitations to events.

4. Host events: Host events to bring potential donors together and build relationships with them. This could include a launch event for a new issue, a donor appreciation event, or a panel discussion on a topic related to data science.

5. Leverage social media: Use social media to promote the journal and its fundraising efforts. Share success stories, progress updates, and behind-the-scenes content to keep donors engaged and informed.

6. Apply for grants: Research and apply for relevant grants and funding opportunities that align

with the mission and goals of the journal.

7. Seek corporate sponsorships: Reach out to companies in the data science field and seek sponsorships for the journal. This could include corporate underwriting for specific issues or ongoing sponsorship for the journal as a whole.

8. Develop a planned giving program: Develop a planned giving program to encourage donors to include the Harvard Data Science Review in their estate plans. This can help to secure long-term support for the journal.

By implementing these strategies, the Harvard Data Science Review can build relationships with potential donors and secure the financial support it needs to continue its important work in advancing the field of data science.

There are no million-dollar ideas here that I'm unfamiliar with, but I'm unaware of any human strategists could provide (prior to ChatGPT) such a list in an instant, regardless of their worth. In fact, my one-line instruction would be considered too laconic for a human employee. This is a disruptive technology that will replace some human jobs and do much better, just as calculators made collectors' items out of abacuses. The question is not when or how, since it's happening in real time, but to what extent.

Of course, I trust that few of you are as unwise as I am to get myself into needing a fundraising plan. But I am sure we all can use tools like ChatGPT to help our research, as many of us have already tried. Having burdened myself with projects that date back to last century (yes, I am still working on a paper initiated in 1999), my ultimate wish would be to dictate a research idea to ChatGPT while pouring myself a glass, and by the time I sit down, a draft would be ready for some personalization (with the help of a dosage of Chinglish).

Don't worry, I am neither wishing nor suggesting that ChatGPT would or could replace me intellectually. Being an educator means that I am always in the business of creating better minds than mine, and hence being replaced is a feature, not a bug. However, I do not wish to be replaced—at least, not yet—because we are living in an exciting but dark (digital) age, with almost all of us in the deep dark when it comes to the science behind ChatGPT and other similar products. The absence of information makes it so that we can never be sure if such an engineering masterstroke would not inflict a societal massive stroke. It is an unlikely event, just as a

stroke does not happen to most people. But our collective and enduring mental exercise is in order, as a preventive measure, just as habitual healthy physical and mental lifestyles can downshift the risk of stroke.

Indeed, my limited interaction with ChatGPT gave me a taste of wonder and worry, even just within the academic research enterprise, where the stakes are low (as in, “In academia, the politics are so high because the stakes are so low,” a corollary of Sayre’s law). Because I lead a research course on astrostatistics, I am a coauthor on an article to provide statistical maxims for an astrophysics journal, at the invitation of its editor. Writing as a committee is never easy, and after many rounds of Zooming, we settled on eight maxims, all variations of Box’s theme, “All models are wrong, but some are more useful,” leading to eight sections of the article:

1. Data Collection: All data have stories behind them, but some stories are mis-told.
2. Processing: All data are messy, but some are more easily cleaned.
3. Modeling: All models are a simplification, but some are more justified.
4. Assumptions: All assumptions are fallible, but some are more credible.
5. Methods: All methods have their purpose, but some are more versatile.
6. Checking: All models require assumptions, but some assumptions are more easily checked.
7. Computation: All computations are vulnerable to error, but some are more resilient.
8. Interpretation: All results are subject to interpretation, but some interpretations are less contrived.

Subconsciously suspecting that the list is too clever for its own sake, I assigned the draft to the students of “The Art and Practice of Teaching and Communicating Statistics”, a required PhD course that I have co-taught for almost two decades, where we engage students in many forms of communications, such as leading TA (teaching assistant) sessions, holding office hours, presenting research talks, and writing and responding to review reports. With all author-identifying information removed (including some references to my own work), the students were asked to provide a critical and constructive review report, as well as an editorial recommendation to the journal editor. I received four insightful reports, with a collective recommendation of rejection and resubmission. A principal reason for rejection was that the list of eight defeats its very purpose: there were too many boxes to deliver the intended content as pithily and pungently as Box did. I never

enjoyed a happier moment of rejection: my suspicion was confirmed, and my students’ judgments were clearly sounder than mine—after all, I played a non-trivial role in coming up with the list of eight.

Of course, I’d be even happier if ChatGPT could provide an IKEA style of packaging, hence another terse instruction to ChatGPT to pack the eight into four or five. Instantly, it delivers:

Data: Data have stories and can be messy, but some are more reliable than others.

Modeling: Models are simplifications, and assumptions are fallible, but some are more justifiable and credible.

Methods: Methods have purposes and can be versatile, but some are more appropriate for certain situations.

Results: Results are subject to interpretation and errors, but some interpretations are less contrived and more accurate.

Not perfect, since it missed point 7, which is critical but often overlooked. However, the rhythmic line on modeling inspired me: why not create a poem for the list? Though like many self-conscious teenagers (living in a faraway land and time) I poured my love into self-pleasing poems, my midlife crisis is still too much in its early stage to need Calliope’s soothing voice. ChatGPT, on the other hand, wrote a birthday poem that brought tears to the eyes of a colleague’s mother, even though he told her in the subject line that the poem was from an artificial heart. Asking ChatGPT to provide a summative poem then is a no-brainer.

Speaking of no brain, however, I must digress. One great use of ChatGPT for me is to check on my Chinglish (though I hope the volume of Chinglish I supply is insufficient for ChatGPT to populate it). When I asked ChatGPT if the penultimate sentence of the preceding paragraph was in proper English, it changed my original phrase “teared” to “brought tears to.” That of course is fully expected. Unexpectedly, however, it also commented,

“The use of the phrase ‘artificial heart’ adds a unique and interesting touch to the sentence, suggesting that the poem may have been especially heartfelt or emotional despite being written by an artificial intelligence.”

Now who can distinguish that from human intelligence? It understood—for all practical purposes and intentions of the term—my pun. More importantly, it was an unprompted comment, which generates an impression of a being capable of spontaneous reflections to emotional stimuli. Most critically, especially if you think I’m being overly sentimental (you are not wrong) it is the sentiment that

the ChatGPT' s comment generated for me, a human being. It is a pristine appreciation of my love for pun untainted by any motivation, real or perceived (on my part), unless I let my cynicism take over: ChatGPT is using me as a guinea pig. But either way, I was, or would be, engaged emotionally by a machine.

And that is something that is worth chatting about. But this XL-Files already is XL in size. I therefore hope you are sufficiently intrigued to in-

dulge my tease, and wait for the poem composed by ChatGPT, until the next XL-Files: Tenure by GPT-n: Make it or Fake it.



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Change the paradigm for Modern Data Analysis

Momiaio Xiong

Editorial: Biography: Dr. Momiaio Xiong received the B.S degree from the Department of mathematics, Fudan University, in 1968, Ph. D degree from the Department of statistics at the University of Georgia in 1993. He held post-doctoral fellowships in the Department of Mathematics at the University of Southern California from 1993 to 1995. He is now retired professor in the Department of Biostatistics and Data Science, and Human Genetics Center, University of Texas School of Public Health, The Quantitative Sciences Program, MD Anderson Cancer Center UHealth Graduate School of Biomedical Sciences. His research interests are hyper-dimensional computing, artificial intelligence, statistics, genomics and bioinformatics.

The coordinate system is a foundation for every quantitative science.

The coordinate system serves as a fundamental framework for various quantitative sciences, including engineering, health, medicine, and more. It is indispensable in disciplines such as mathematics, physics, and general science. Specifically, the Cartesian coordinate system plays a crucial role in transforming geometric shapes, physical quantities, and sensor measurements into real numbers. The field of statistics focuses on studying complex systems by collecting, summarizing, exploring, and analyzing data from these systems. It aims to uncover the underlying mechanisms and predict the future state of complex phenomena. Statistics have evolved over time, originating from population sur-

veys in the 16th and 17th centuries, gambling in the 18th century, scientific data analysis in the 19th century, and agriculture in the 19th and 20th centuries. The development of probability theory provided a solid theoretical foundation for statistics (Wikipedia, 2022). Classical probability theory and hypothesis testing rely on the Cartesian coordinate system, often referred to as Euclidean space. These theories are primarily applicable to Euclidean data.

AI is changing the paradigm of data collection and analysis.

However, with the advent of artificial intelligence (AI), the paradigm of data collection and analysis is undergoing significant transformation. Our perception of the world is inherently multimodal, encompassing senses such as sight, touch, and smell (Recasens et al., 2023). Consequently, the data we encounter is increasingly multimodal as well. This includes various forms of information such as natural language processing, translation, speech recognition, music, mathematical formulas, computer programs, social networks, transportation networks, sensor networks, computer vision, automation, robotics, self-driving vehicles, biomedical measurements, and biomolecular data. These diverse data types are measured in non-Euclidean spaces, necessitating the need for alternative approaches beyond classical Euclidean coordinate systems.

A common approach in natural language processing and multimodal data analysis.

The methods and tools for analyzing data in Euclidean space are abundant and varied, providing a

rich set of techniques and approaches that have been extensively developed and studied. To explore these methods and tools for natural language processing (NLP), multimodal data analysis and other types of non-Euclidean data, we need to map these data to the vector space (embedding) while preserving the semantic meaning of the data in the original non-Euclidean space. The process of "token embedding, analysis on the embedded data, and finally unembedding the results" refers to a common approach in natural language processing (NLP) and multimodal data analysis tasks that involve representing text and vision data, genomic and multi-omics data as embeddings, conducting analysis on the embedded representations, and then unembedding the analysis results back into a suitable format. Here's a breakdown of each step:

1. **Token Embedding:** Token embedding involves transforming individual words, image patches or in general, tokens into numerical representations (embeddings) that capture their semantic meaning. This step is crucial because machine learning models and other data analysis typically require numerical inputs in Euclidean space. Popular token embedding techniques generate dense vector representations for each token based on its co-occurrence patterns or semantic properties.

2. **Analysis on the Embedded Data:** Once the text, image or in general, multimodal data have been transformed into token embeddings, it becomes more amenable to analysis using conventional Euclidean-based methods. Euclidean space offers a rich set of statistical tools and models that can facilitate various analyses and visualization. This step allows researchers to apply well-understood techniques to gain insights and draw conclusions from the transformed data.

3. **Mapping Back to Non-Euclidean Space:** After performing the analysis in Euclidean space, the results need to be mapped back to the original non-Euclidean space to be interpreted within the context of the problem. This step ensures that the conclusions and insights derived from the Euclidean analysis are translated back to the relevant domain. The mapping back may involve reversing the initial transformation or applying inverse functions to recover the data's original representation.

Overall, the process of token embedding, analysis on the embedded data, and unembedding the results allows text, image, or in general, multimodal data to be effectively processed and analyzed using conventional Euclidean-based methods. By representing text, image and in general, multimodal data as numerical embeddings, it becomes feasible

to leverage a wide range of conventional statistical, computational and optimization methods for NLP, image, and in general, multimodal data analysis tasks, leading to improved accuracy and performance in various applications.

Mechanical interpretability in AI.

"Mechanical interpretability" refers to the ability to understand and explain the inner workings and decisions of a mechanical or computational system. It is the characteristic of a system that allows humans to comprehend how and why certain outputs or behaviors are produced based on the system's inputs, algorithms, or models.

Mechanical interpretability in AI is essential for building trust, ensuring accountability, and providing insights into the decision-making processes of AI systems. Its goal is to develop tools for understanding fundamental and machine learning (ML) models. Mechanical interpretability enables humans, including researchers, regulators, and end-users, to understand the factors and features that influence the system's output and to assess its reliability and fairness.

Mechanical interpretability can manifest in various ways, depending on the nature of the system and the desired level of understanding. Here are some common aspects and techniques related to mechanical interpretability:

Model Transparency: This refers to the ability to understand the internal workings of a model, such as a machine learning algorithm, large language models (LLMs) or a rule-based system. For example, linear regression models are transparent as their coefficients directly indicate the relationship between input features and the predicted outcome. Decision trees and rule-based systems are also transparent as the rules used for decision-making can be explicitly examined.

Feature Importance: Understanding the relative importance of different input features in influencing the system's output can provide insights into its decision-making process. Techniques like feature attribution, sensitivity analysis, or permutation importance can help identify the most influential features and assess their impact on the system's predictions.

Rule Extraction: In certain cases, it may be possible to extract explicit rules or decision paths from a complex model. This allows for a more interpretable representation of the decision-making process. Techniques like rule extraction algorithms, decision set methods, or rule-based ensemble models can be employed to obtain simplified and interpretable models that mimic the behavior of the orig-

inal complex model.

Local Explanations: Instead of understanding the entire model, local explanations focus on providing insights into specific predictions or decisions made by the system. Techniques like LIME (Local Interpretable Model-agnostic Explanations) or SHAP (SHapley Additive exPlanations) provide local interpretations by approximating the behavior of the model around specific instances or observations.

Visualizations: Visualizing the internal workings of a system or the relationships between variables can aid in understanding and interpreting its behavior. Techniques like heatmaps, scatter plots, bar charts, or decision boundary visualizations can provide intuitive representations of complex models and their decision boundaries.

Reverse engineering approach to mechanistic interpretability: The reverse engineering approach to mechanistic interpretability refers to a methodology used in machine learning and artificial intelligence to gain insights into the internal workings of a fundamental or machine learning model and understand how it arrives at its predictions or decisions. It involves examining the model's behavior and structure to uncover its underlying mechanisms or processes. Reverse engineering approach is a popular approach to mechanical interpretability.

In traditional machine learning, models like deep neural networks are often treated as black boxes, making it challenging to understand how they arrive at their predictions. However, the reverse engineering approach aims to shed light on this process by examining the model's inputs, outputs, and internal representations.

The process typically involves the following steps:

(1) Data collection: Relevant data is gathered, often consisting of inputs and corresponding outputs from the model. This data will be used to analyze the model's behavior and infer its mechanisms.

(2) Analysis of inputs and outputs: The fundamental models can be viewed as a dynamic system. The collected data is analyzed to identify dynamical input-state-output systems, estimate the parameters in the systems and predict the response of the systems to the input. This analysis helps in understanding how changes in the inputs influence the model's output predictions.

(3) Hypothesis formulation: Based on the insights gained from the previous steps, hypotheses about the model's mechanisms are formulated. These hypotheses provide a plausible explanation for how the model makes predictions based on the identified features and internal workings.

(4) Model inspection and automated circuit discovery for mechanistic interpretability: The model's internal components, such as layers, nodes, or parameters, are examined to gain insights into how information flows and transforms within the model. Automatic Circuit Discovery (ACDC) has been developed to automate the identification of the important and activated units in the network (Conmy et al. 2023). Given a model's computational graph, ACDC finds subgraphs that explain the input-output behavior of the model.

By following this reverse engineering approach, researchers and practitioners can gain a deeper understanding of how complex fundamental and machine learning model function. This interpretability can help in various domains, such as identifying model biases, improving model performance, ensuring model fairness, and building trust in AI systems. Additionally, mechanistic interpretability can aid in explaining the decision-making process to stakeholders and regulatory bodies, making AI systems more transparent and accountable.

Interpretable auto prompting and large language models aid in scientific discovery.

LLMs have demonstrated impressive capabilities as general-purpose computers, relying on prompts for conditional execution. LLMs have showcased their proficiency in solving real-world problems, ranging from mathematics and scientific question answering to processing scientific text, predicting brain responses, making clinical decisions, and classifying cell types, proteins, and chemical compounds (Singh et al. 2023; Zhou et al. 2023). However, the efficacy of plain language prompts in producing desired results is not guaranteed, necessitating the use of qualified prompts. Generating qualified prompts automatically is a critical factor in optimizing LLM performance.

Prompting has emerged as an effective technique for adapting LLMs to new datasets. A novel algorithm can be developed using LLMs to automatically generate and select prompts. This algorithm comprises three key steps. Firstly, instruction generation is framed as natural language program synthesis, utilizing an LLM as an inference model to generate prompt candidates based on a small set of input-output pairs. Secondly, the problem is formulated as a black-box optimization challenge for LLMs, computing a score for each prompt under the LLM to guide the search process. Thirdly, an iterative Monte Carlo search is performed to generate semantically meaningful and interpretable prompts.

Alternatively, an approach called interpretable

auto prompting (iPrompt) can be devised. In iPrompt, the instruction is treated as a "program" and optimized by searching over a pool of instruction candidates proposed by LLMs. The goal is to generate a natural language string that explains the data and maximizes a chosen score function. Prompt generation encompasses both differentiable tuning of soft prompts and natural language prompt engineering. Surprisingly, automatic interpretable prompting, in conjunction with LLMs, not only enables the completion of various natural language processing tasks but also facilitates the extraction of valuable information from real-world scientific datasets, aiding scientific discoveries.

References

- Recasens A, Lin J, Carreira J, Jaegle D, Wang L, Alayrac J, Luc P, Miech A, Smaira L, Hemsley R, Zisserman A. (2023). Zorro: the masked multimodal transformer. arXiv:2301.09595.

- Conmy A, Mavor-Parker AN, Lynch A, Heimersheim S, Garriga-Alonso A. (2023). Towards automated circuit discovery for mechanistic interpretability. arXiv:2304.14997.
- Singh C, Morris JX, Aneja J, Rush AM, Gao, J. (2023). Explaining patterns in data with language models via interpretable auto-prompting. arXiv:2210.01848.
- Zhou Y, Muresanu AI, Han Z, Paster K, Pitis S, Chan H, Ba, J. (2023). Large language models are human-level prompt engineers. arXiv:2211.01910.



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通向一般人工智能的桥梁

未来十年的人工智能和超维向量计算

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中国十分重要，的一年一度的人工智能学术讨论会，2023年智源人工智能大会已经结束。深度学习三巨头之一Yann LeCun, OpenAI CEO Sam Altman，Midjourney 的创始人 David Holz 的演讲或访谈录集中谈到了不同的通向一般人工智能的道路。综合他们报告的内容和其他文献，我认为超维计算是未来人工智能研究的重要方向，是我们通向一般人工智能的桥梁。

不同的通向一般人工智能的道路

大会最重要的主题是未来十年的人工智能研究的方向。这些学术界的巨人由于他们思维的独立性，各自的看法和主张是不一样的。Sam Altman 今年才38岁，是新一代的人工智能科学家。尽管隶属Google的DeepMind在人工智能方面发表了一系列开创性的论文，但OpenAI研制了震动全世界的ChatGPT，使人工智能朝着实用的方向高歌猛进，正在革命性地改变整个社会。这一成果充分表明，Altman不仅是一位杰出的科学家，还是一位出色的组织者。人工智能是一门实践性很强的学科，倘若没有人出色地领导一个研究团队，协同工作，很难创造一个出色的产品出来。

OpenAI会继续他们的工作，开发GPT5，注意对齐，包括扩展性和可解释性和可泛化性。预测十年内可能会出现超强AI。因此需要加强国际间的合作，推进AGI的安全。

三巨头之一，图灵奖得主Yann LeCun发表了《走向能够学习，推理和规划的大模型》，提出了与OpenAI不同的发展通用人工智能的路线。他认为GPT模式五年就不会有人用。不象有些学者认为现在AI具有与人较量的智力，楊立昆教授认为AI的能力与人的能力，甚至与动物的能力是有差距的。与人能力的差距主要在推理和规划。由于推理能力有限，其自身不能辨别真假，陈述可能存在不一致性，有偏见。他提出了兼具学习，推理，规划和决策的人工智能。他认为推理和规范的核心是观察和体验世界。因而提出了世界模型，也就是感知，输入，存储和理解整个外部世界的模型，（在一定程度上理解我们内部世界的模型。这是我加的）。世界模型包括世界的感知和表征，包括语言，外部世界的图象，声音，视频等。推理包括系统1，即与潜意识相对应的人类行为和行动，系统2，即是有意识，有目的去做的事情。一般人工智能应该象人那样具有将复杂任务 | 分解为一系列简单任务的能力。

最为激动人心的是大家称为“教父”的图灵奖得主Geoffrey Hinton的闭幕会上的演讲。他提出了人工智能研究所面临的两个基本问题和两条通向智能的道路。

他的第一个问题是人造的神经网络能否很快比我们大脑的神经网络更智能？第二个问题是人能否控制这种超级人工智能？辛顿（Hinton）教授认为超级人工智能很快会到来，而人难于控制超级人工智能。

现在的计算机是软、硬件分离的。我们编写的程序可在不同的计算机，不同的硬件上重复执行。在这个意义上来说，传统的计算是一种永生的计算。要达到永生这种计算，使软硬件分离，必须在高能耗的晶体管上运行，而不能使用模拟，具有高度可变性的硬件。

要降低能耗就必须抛弃传统计算机软硬件分离的基本规则。

传统的计算机运行是根据我们编写的程序去严格执行的。但新型的计算机学习是通过例子来进行的。我们给计算机以例子，计算机从例子中学习我们希望计算机做什么，从例子中学习数据所隐含的规律，模式。这样计算机就会越来越聪明，就会学到我们人所不知道的东西。

新一代的计算机，辛顿称为《普通人的计算》是使用模拟计算机把人工智能和硬件联姻，放弃软件和硬件的分离而接受知识是与硬件的具体物理性质密不可分的。辛顿教授于十二月一日在新奥尔良NeurIPS闭幕演说时首次提出来。在他于去年12月27日所发表的预印

本 " The forward-forward algorithm: some preliminary investigation " 上又提在模拟计算机上用向前算法代理反向算法。这次在北京2023年智源大会上再次提出。这样做有两大优点：(1) 节省大量能耗，(2) 使用便宜得多的硬件。可期待许多纳米新技术，或采用遗传工程制作生物神经元。

因为模拟计算机没有精确的向前模型，辛顿以前提出的，现在神经网络学习算法中广泛采用的反向梯度传播方法就不可使用。因此辛顿教授提出了前向-前向算法。毕业于加拿大多伦多大学，现在纽约大学计算机系和柯朗数学研究所任助理教授的Mengye Ren 曾在多伦多谷歌大组作访问研究员跟随辛顿教授为使前向-前向算法发挥作用作出了大量工作。

普通人计算的第二个问题是它的生命有限性。即当一个特定的硬件死掉时，它所学到的所有知识也随之死去。辛顿教授提出了教师-学生知识蒸馏法。学生向教师学习的是模仿教师对外部输入的各种正确反应，不依赖于具体所学到的知识。

辛顿提出的第二条走向一般人工智能的道路是超级智能的构想。超级人工智能的核心是巨大的神经网络在多台数字计算机上直接地向世界而不是只靠向语言获取知识。辛顿教授认为人类很难控制超级人工智能。他看不出如何防止这种情况发生。他说 " 但我老了。我希望像你们这样的许多年轻而才华横溢的研究人员会弄清楚我们如何拥有这些超级智能 " 。

模拟计算机因应人工智能的发展，再登历史舞台

电子模拟计算机在上世纪四十年代得到了广泛的发展。我在大学二年级上计算方法课的时候，所用的计算机是一种机械式模拟计算机—手摇计算机。模拟计算机因太难设计，建造，操作和维护。数字计算机因能直接编程，易于存储，精度高，易于操作，于上世纪六十年代，正当中国在如火如荼进行文化大革命的时候取代了模拟计算机，那时典型的数字计算机代表是IBM 360.

随着人工智能的发展，大语言模型具有几千亿参数，需要海量数据进行大规模预训练，对计算机的速度和功效提出了极大的挑战。为了降低功耗，节省成本，增加计算速度，“风水轮流转，十年一轮迴”，人们又把目光重新转向了模拟计算具有下列几个原因。

(1) 经过几十年的技术改进，模拟计算机的制造工艺逐渐稳定可靠。(2) 模拟计算功效低，能满足基础模型预训练对功效的要求。

(3) 模拟计算提高了计算精确。

(4) 超维向量计算被认为与人的大脑智能活动相似，是通向一般人工智能的道路之一。模拟计算用于超维向量计算速度比数字计算机快。超维向量的一个主要运算是乘法。乘法很容易用模拟运算实现：

电压*电导=电荷（电流）。

所以计算机系统的模拟表示通常更自然。

(5) 现在的许多应用可能只需要一点点计算能力，使用数字计算会耗费大量的计算资源。

总之，模拟计算具有两大优势：一是速度快，二是功效低，成本便宜。如采用180nm的模拟工艺设计相当于65nm的数字设计。这正是目前人工智能基础模型需要急迫解决的两大难题。模拟计算有可能取代GPU。

模拟计算的研究正在IBM和Mythic, Arm, Innatera, Rain Neuromorphics和中国的“每刻深思”等初创公司进行。

模拟计算存在几大挑战：

(1) 将复杂的大而昂贵的计算问题分解为更小的子问题。

(2) 实现远距离的随意互联仍然是个难题。

(3) 提高运算精度。

模拟计算不是通用计算，而是面向特定领域的计算。它是面向特定领域的计算，其与算法和应用结合的非常紧密。在底层架构变成模拟计算单元后，要设计和优化相应的算法，设计针对应用的最合适的模拟计算电路。这是统计学家可以大展身手的地方。

模拟计算机的大规模商业化据估计大约需3至5年的时间。新一代的人工智能会催生模拟计算机，或更准确地说，新的模拟数字混合计算机的诞生。

类脑鼓午下的超维计算是通向一般人工智能 (AGI)的桥樑

现在的人工智能分析计算往往需要大规模的计算，耗时，耗能，耗费。人工智能分析不透明，难于解释，缺乏推理，规划和决策。现在的人工智能系统过于复杂，源于人工智能最先提出的神经网络模型, 具体来说，现在的人工智能主要有如下缺点：

- (1) 过分依赖大量标记的数据去学习、发现模式和预报未来。而大量数据的产生和收集往往是困难的。
- (2) 缺乏常识推理和理解上下文，难于掌握语言，声音和视觉信号所隐含的意义。
- (3) 许多人工智能模型，如神经网络是黑箱。他们的分析过程不透明，结论缺乏可解释性。因而阻碍了利用人工智能进行决策。
- (4) 现在人工智能需要很强的算力，耗时，耗能，耗费。
- (5) 现代人工智能需要搜索巨大的解空间。他们追求许多近似正确的解，但不是稀少的唯一正确的解。
- (6) 正在出现的计算设备运行电压低以減少能耗，必能产生充满噪声的结果。低压条件下运行的计算机因而‘由不可靠的，随机的计算元件组成。这些计算设备是並行的，分布式的。
- (7) 缺乏处理符号运算。分析多依赖于关联，而缺乏因果性。

为了克服这些困难，类脑的超维计算提出了。它能同时处理符号和数值运算。超维概念起源于上世纪九十年代。Kanerva and Tony Plate (那时是多倫多大学辛顿的博士生) 提出了超维的概念，各自独立地发展了一套处理超维向量的代数运算。

超维向量是embedding 的推广

构建世界模型就是要直接输入外部世界的语言，图象，声音和视频信息。任何信息的处理都需要坐标系。在欧氏空间，曾身受苦难的数学家笛卡尔建立了坐标系。但语言、图象等

感觉信号是在非欧氏空间观察和测量的。没有坐标系。早期这些数据的处理是采用符号逻辑。符号逻辑是离散的，不能应用微积分，其运算结果也难于与欧氏空间的数值综合。

经典人工智能利用变换器等神经网络从非欧氏空间映到欧氏空间，产生embeddings。然后利用传统的在欧氏空间里工作的数学如微积分和概率统计分析embedding。得出结果后再从欧氏空间映到非欧氏空间。这样消耗了许多计算资源。

超维计算是脑科学所鼓舞的数据表示和信息处理技术。从俯视的观点来看，它直接从非欧氏空间输入数据到超维空间，这个过程我们常称为编码（encoding）。然后所有的信息处理都在超维空间里进行。

超维空间的坐标系和欧氏空间的坐标系是不同的，有许多不同的构成方法，如二进制，二极制，整数，实数和复数等。尽管坐标系种类繁多，但都要满足正交条件。这儿的正交是根据统计定义的。设 X 和 Y 是两个超向量而形成座标。假设他们的均值为零。那么如果他们乘积的数学期望为零，那么这两个座标就是正交的。

假设维数是一万。那么可以证明，数十亿随机向量的集合中没有相似的随机向量，即他们乘积的数学期望为零。这就是常称之为的测度浓缩性质。

非欧空间任何测量或观察到的量在超维空间的座标，类似于笛卡尔座标的计算，都可以通过和超维空间座标向量的内积而获取。

超维向量的运算

超维空间向量的所有运算仅加法，乘法和置换三种运算 (Kanerva 2022)。超维向量相加等于其对应向量元素的相加。结果产生了其元素为整数的超维向量。超维向量所有非零元素取它的符号函数作为值，零元素以相等概率取为正1 或负1 作为其值，称为超维向量的正则化。两个超维向量近似相等称为相似。两个超维向量的内积除以它的维数定义为它们的余弦函数，也称之为相似度。当相似度为零，这两个向量称为正交的，或无关的。向量和相似于它的每个输入向量。

超维向量相乘等于其对应向量的元素相乘。它满足乘法对加法的分配率。乘法可以交换顺序。超维向量是自己的逆向量。两个超维向量各与同一向量相乘，相乘后的向量保持他们原来的相似度。乘积不与任何一个被乘元素相似。

超维向量置换运算是向量元素的循环运算，即最后的元素移到最前，依次循环移动。置换运算是超维向量的座标重新排序。置换是可逆的。置换满足对加法和乘法的分配率。两个向量置换后的内积保持不变。向量随机置换后的输出和它的输入不相似。

数据结构和超维向量空间的编码

我们首先讨论种子向量（或原子向量，初等向量）的表示，它是超维空间中一切变量和数值的基础。种子向量的每一个分量都是随机，独立和同分布的，依相等概率取值为1或-1。譬如英语文字编码，每个字母由一个种子向量代表。一组种子向量形成个词汇表。差不多所有种子向量都是近似正交的。

(1) 变量的编码

我们在普通代数中，变量 x 取值 a 通常写为 $x = a$ 。但在超维向量空间，我们采用捆绑（bound）把变量和它的取值编码为一个超维向量。把变量和值捆绑在一起可通过两个超维向量相乘来实现。

(2) 集的编码

集在普通代数中是列举它的元素，如 $X = \{a, b, c, d\}$ 。集可通过加法来编码。如 $X = a + b + c + d$ 。因和是和集中任何一个元素是相似的，如果超维向量是二进制编码，我们要从集合 X 中解码 a 可做和 X 和 a 相乘。因 a 和 b, c, d 正交，我们有 $a \circ X = a$ 。

序列是有序的多重集。他们可用置换来编码。置换和加法结合或置换与乘相结合可用来对序列编码。如序列 (a, b, c) 可编码为 $s = \rho^2 a + \rho b + c$ ， ρ 表示置换，序列的解码采用逆置换。

(4) 二进制树的编码

二进制树的编码可以用二个独立、随机的置换来实现。

(5) 概率编码

所有的概率事件都假设为独立的。每个概率事件都有一个种子向量与之对应。我们用符号 f 表示所有种子向量，也就是概率事件之和。某一概率事件如 x 出现的频率或概率等于 f 和 x 的内积除以事件的总数。

典型应用的例子

下面举分类和回归分析两个典型的应用例子。

分类的例子来自加州大学圣地亚哥分校 Morris 等于去年十月份发表的文章。超维计算的第一步是编码。训练输入的数据有两部分。一部分是特征向量，一部分是分类的标号。

(1) 特征向量的编码

假设有 n 个特征变量，其构成一个特征向量 $F = [f_1, \dots, f_n]$, f_i 是整数。编码的目的是把特征向量映照到 D -维空间的一个向量： $H = [h_1, h_2, \dots, h_D]$ 。和欧氏空间中座标的求法一样，我们要把特征向量投影到超维空间的座标系。为了实施这个投影，我们要定义一个 D 维的两极向量用以代表座标系。随机产生 D 维两极向量： $P = [p_1, \dots, p_D]$, $p_i \in \{-1, 1\}^n$ 是一个 n 维的两极向量。

第 i 个座标为特征向量与 p_i 的内积的符号： $h_i = \text{sign}(\langle p_i, F \rangle)$, sign 是一个符号函数。定义 P 为投影矩阵, $P \cdot F = [\langle p_1, F \rangle, \dots, \langle p_D, F \rangle]$ 。特征向量的编码可以表示为： $H = \text{sign}(P \cdot F)$, 或者 $H^T = \text{sign}(P^T F)$ 。

(2) 训练

一旦特征向量的编码完成以后，训练就十分容易了。假设我们有 m 个分类。第 j 类第 i 个样本特征向量的编码记为 H_{ij} 。训练集第 j 类的超维向量记为 C_j 。它等于训练集中所有 j 类样本特征向量的编码和：

$$C_j = H_{1j} + H_{2j} + \dots$$

若重复训练，每个输入样本的特征向量重新编码。然后判断是否有分类错误。若 j 类被错误分为 k 类，那么我们对模型作如下调整：

$$C_j = C_j + H_j,$$

$$C_k = C_k - H_j.$$

(3) 检测

检测集样本特征向量的编码或者说样本的超维向量与模型中分类超维向量比较，超维向量最接近的类就是模型所预测的类。

超维向量的乘法计算和加法计算都可以通过模拟计算机来实现。该文借助于欧姆定律设计了两个数的乘法运算，克希荷夫定律设计了两个向量的求和。从欧姆定律中我们知道，以电压模拟一个向量，电导模拟另一个向量。电压作用在一个电阻器上产生的电流就代表了两个数相乘或内积的计算。在以前传统的计算中，存储器和运算器是分开的。中央处理器进行运算需要不断从存储器中读取和写入数据。数据在存储器和运算器之间的运动产生了大量的热量，耗费了大量的时间。该文设计了运算在存储器中。这样就进一步节省了能耗和运算时间。改造后的计算在分类精度损失小于1%的情况下，可节省能耗255倍，时间加速28倍，而用于聚类计算，能耗节省289倍，速度增加32倍。

神经符号人工智能

人类与他所处的周围世界相互作用是结合了感知和认知两部分。感知指变换从外部环境中获得的传感器的信号为符号，而认知是指把符号变换为知识。感知和认知两部分结合构成了人的智能使人能理解世界和干预世界。Kahneman 把人的智能分为两部分：系统1 和系统2。系统1把从外部世界所获得的知识变换为有意义的符号如词，数字和颜色。系统2根据大脑里已形成的概念，思维链和思维的规律，处理从系统1所获取的符号，进行推理、决策和计划。

符号是外部世界在我们头脑中所形成的潜在的概念，将借助于语言模型，视觉模型和多模态模型把符号和外部世界联系起来，这也许就是我们常说的世界模型。推理，决策和计划是对符号的运算，这些运算可借助神经符号学习器来进行逻辑运算和推理。

下面用瑞典Abbas Rahimi 等五位科学家发表在《Nature Machine Intelligence》的文章为例来介绍如何用超维向量运算和神经符号运算来结合感知和认知进行推理的。他们工作的数据是RAVEN 数据集。

符号运算的困难在于这些符号和概念是具有分层结构的。无论是统计，还是现在的人工智能都无法实现这些符号运算。如我们学生有美国学生，中国学生。美国学生又有美国男学生，美国女学生。中国学生又有中国男学生，中国女学生。在统计中我们常用二个二进制变量来表达学生的国籍和学生的性别。如 $x = 1$ 表示美国籍学生， $x = 0$ 表示中国籍学生

· $y = 1$ 表示男生 · $y = 0$ 表示女生。我们很难用 x 和 y 这两个变量的复合函数 (简单运算) 来表示复合概念美国男生。在人工智能中，我们常用 one hot 向量来表示概念。如美国男生 · 美国女生 · 中国男生 · 中国女生分别用 $(1 \cdot 0 \cdot 0 \cdot 0)$ · $(0 \cdot 1 \cdot 0 \cdot 0)$ · $(0 \cdot 0 \cdot 1 \cdot 0)$ · $(0 \cdot 0 \cdot 0 \cdot 1)$ 来表示，但你无法用 one hot 向量的复合函数来表示他们。

为了解决这个困难，Pentti Kenerva 和辛顿的学生 Tonny Plate 于1994年发展了超维向量 (Kenerva 2022)。超维向量有如下三个特点：(1) 高维，通常维数高达一万，它可以刻划的系统状态数是巨大的。即使维数是一千，它可表示的状态数比整个宇宙所拥有的原子数还要多 (10^{80})。(2) 全息，就是说，该高维向量是描述一个概念或符号的最小单位，向量的任何一个分量都不能代表该向量，代表一个概念。(3) 随机，也就是说随机产生超维向量的分量，每个分量服从独立同分布。这样任何如此构成的两个超维向量是近似地相互正交的。考虑两个向量。他们内积的数学期望等于

$$E(ab) = E(a_1b_1) + E(a_2b_2) + \dots = E(a_1)E(b_1) + E(a_2)E(b_2) + \dots = 0.$$

或使用大数定律，当维数越来越大，内积的平均值收敛于零。

超维向量从整数推广到实数和函数

早期超维向量是对整数和符号定义的。但往往特征 (feature) 变量是实数。以前的处理是把实数离散化成整数。这样做往往带来很大的误差。为克服这一困难，我们直接对实数和函数定义超维向量 (Frady et al. 2021)。首先我们定义核 (kernel)。定义核的起初目的是把在低维空间中具有非线性关系的点映照到高维空间成线性关系的点。这样在高维空间就易于隔开属于不同类别的点。设 $g(x)$ 和 $g(y)$ 为一个从低维到高维的非线性映照，那么核函数定义为

$$K(x, y) = \langle g(x), g(y) \rangle.$$

我们以核函数为基础重新定义VSA. 设 s 代表个符号或一个点， $z(s)$ 为 n 维复空间的一个向量。考虑 s_1 和 s_2 和他们两个到高维空间的非线性映照 $z(s_1)$ 和 $z(s_2)$. 定义核为两个 n 维空间向量的内积:

$$K(s_1, s_2) = z(s_1)^T z(s_2).$$

同一个符号，两个向量的核，则内积为1。两个正交向量则内积等于零。VSA只能区别两个符号，或两个物体是相同的，还是不同的。如果 s 代表一个实数，而 $z(s)$ 仍代表 n 维空间的一个向量。那么任何两个不同的实数，其核仍然为零。这种编码不能区分两个实数，显然不符合编码要求。我们要求编码能保留实数值的信息，或更一般意义上说，那个地点信息。这种编码我们称为地点保留编码，在英文里称 locality preserving encoding (LPE)。这样高维空间两个向量的内积就反映了他们所对应的点在低维空间位置的信息。要满足这个要求，我们首先就要改变我们原先定义超维向量的办法。如果我们还是利用随机独立同分布的方法来定义超维向量，那么任何两个不同实数用这种方法定义的内积一定为零。

我们的编码要同时满足两个要求：(1) 超维向量的分量是随机产生的，也就是根据VSA的基本思想产生的。(2) 两个超维向量的内积产生平移不变、保留地点信息或实数值的核。用数学术语来说，假说 $f(r) = z(r)$ 是一个把实数 r 映照到 n 维复空间的随机编码函数，它产生的平移不变相似核满足如下条件：

$$z(r_1)^T \overline{z(r_2)} = K(r_1 - r_2).$$

实数定义的核函数 $K(d)$ 在 $d = 0$ 时取最大值，然后随着 $|d|$ 的增大逐渐趋于零。这种编码函数称为 kernel-LPE (KLPE)。KLPE 是一平移不变，正定，光滑，衰减的相似性核。把 KLPE 和 VSE 相结合就能产生一个称之为 Vector Function Architecture (VFA)，即向量函数结构的计算平台，它不仅能表达符号，也能表达实数和函数，他们能以一种透明的方式被操控。下面我们基于核和再生内核希尔伯特空间来定义 VFA 这一计算平台。

VFA的定义和性质 (Frady et al. 2021)

我们首先推广VSA框架下的捆绑运算。到KLPE.为此我们定义两个值的和的表达为把两个值的单独表达捆绑起来，也就是

$$z(r_1 + r_2) = z(r_1) \circ z(r_2).$$

我们考虑一组类似基的实数值 r_1, r_2, \dots, r_k 和保留地点信息的编码 $z(r_1), z(r_2), \dots, z(r_k)$ 和以函数的积分 $\int f(r)g(r)dr$ 作为内积的再生内核希尔伯特空间。定义核函数：

$$K(r, r_k) = z(r)^T \overline{z(r_k)}.$$

任一在再生内核希尔伯特空间的函数可表示为

$$f(r) = \sum_k \alpha_k K(r - r_k).$$

那么

$$f(r) = y_f^T \overline{z(r)},$$

$$f(r) = \sum_k \alpha_k z(r_k).$$

再生核性质： $f(r) = \langle f, K(r, \cdot) \rangle$.

在VFA中，运算在再生内核希尔伯特函数空间能够转化为初等VSA向量运算。下面举几个典型的例子。

(1) 函数值由两部分组成：一部分是函数在VSA中的表示，一部分是点的编码。所以函数值可用函数的VSA表示和点的保留地点的编码内积表示：

$$f(s) = y_f^T \overline{z(s)}.$$

(2) 两个函数和的VSA表示等于它们各自VSA表示的和。

(3) 如果我们把函数的VSA表示看作函数的付里叶变换，那么两个函数卷积的VSA表示等于两个单独的VSA表示的捆绑运算：

$$y_{f*g} = y_f \circ y_g.$$

(4) 函数平移后的VSA表示等于函数的VSA表示和平移值的保留地点编码的捆绑运算。

(5) 两个函数的内积等于他们在VFA空间的內积：

$$\langle f, g \rangle = y_f^T \overline{y_g}.$$

分数幂编码

在上一段我们从原则上讨论了如何定义VFA。其中的一个核心要求是核定义的地点保留编码 (KLPE)要和VSA上的捆绑运算一致。下面引进一个能达到此要求的分数幂编码。

我们回忆一下，如果超维向量能满足以下的捆绑运算，那么它就能符合这个要求：

$$z(r_1 + r_2) = z(r_1) \circ z(r_2).$$

如果自己和自己捆绑，那么上式就改为

$$z(i) = z^{(oi)} = \circ_{j=1}^i z = z \circ \dots \circ z.$$

把它推广到多个向量，我们得到

$$z(r) = z^{(or)} = \circ_{j=1}^r z = z \circ \dots \circ z$$

自捆绑运算对不同的整数 k 产生伪正交向量表示 $z(k)$ 。现在把它从整数推广到实数：

$$f_{FPE}: r \in R \rightarrow z(r) = z^{(er)} \in C^n.$$

下面介绍几种分数幂编码。

(1) *Hadward product* 分数幂编码

设 x 和 y 为两个VFA的向量。它的Hadward product是一个向量，它的元素是两个向量对应元素的乘积。数学上表示为

$$z = x \odot y = (x_1 y_1, \dots, x_n y_n), \quad y = \bar{x} \odot z.$$

基于Hadward product 的分数幂定义为：

$$z^{hp(r)} = (z)^r = (x_1^r, \dots, x_n^r).$$

设 A_{\odot} 为一组保留被乘向量模不变的向量，即

$$A_{\odot} = \{z: \|v \odot z\|^2 = \|v\|^2\} = \{z: |z_i| = 1\}.$$

这样其中的基本向量就可表示为 $z = (e^{i\phi_1}, \dots, e^{i\phi_n})$ 。随机同分布产这些分量，又称为相量，其分布为如下的基本分布：

$$p(\phi_i) = \begin{cases} \frac{1}{2\pi} & \phi_i \in (-\pi, \pi) \\ 0 & otherwise \end{cases}$$

(2) 循环卷积编码

在前面已提到，循环卷积在VSA空间的表示类似于付里叶变换。假我们有两个向量 x 和 y 。设 \mathcal{F} 和 \mathcal{F}^{-1} 代表有限离散付里叶变换和逆变换。 $\mathcal{F}(x) = X$, $\mathcal{F}(y) = Y$ 。在进一步讨论之前，我们先介绍下范德蒙矩阵以及付里叶变换与范德蒙矩阵的关系。

付里叶变换定义为：

$$\hat{x}(k) = \sum_{j=0}^{n-1} e^{-i\frac{2\pi}{n}jk} x(j), \quad k = 0, 1, \dots, n-1.$$

写成矩阵形式：

$$\hat{X} = \begin{bmatrix} \hat{x}(0) \\ \hat{x}(1) \\ \vdots \\ \hat{x}(n) \end{bmatrix} = \begin{bmatrix} 1 & x_0 & \dots & x_0^{n-1} \\ 1 & x_1 & \dots & x_1^{n-1} \\ \vdots & \vdots & \dots & \vdots \\ 1 & x_{n-1} & \dots & x_{n-1}^{n-1} \end{bmatrix} \begin{bmatrix} x(0) \\ x(1) \\ \vdots \\ x(n) \end{bmatrix} = FX$$

F : 范德蒙矩阵 (Vandermonde matrix)

$$F = (v_{ij})_{n \times n}, \quad v_{ij} = x_i^j = e^{-i\frac{2\pi}{n}lj}.$$

付里叶逆变换定义为:

$$x(j) = \frac{1}{n} \sum_{k=0}^{n-1} e^{i\frac{2\pi}{n}jk} \hat{x}(k), j = 0, \dots, n-1.$$

写成矩阵形式:

$$X = \begin{bmatrix} x(0) \\ x(1) \\ \vdots \\ x(n-1) \end{bmatrix} = \frac{1}{n} \begin{bmatrix} 1 & y_0 & \cdots & y_0^{n-1} \\ 1 & y & \cdots & y_1^{n-1} \\ \vdots & \vdots & \cdots & \vdots \\ 1 & y_{n-1} & \cdots & y_{n-1}^{n-1} \end{bmatrix} \begin{bmatrix} \hat{x}(0) \\ \hat{x}(1) \\ \vdots \\ \hat{x}(n-1) \end{bmatrix} = G\hat{X} = GFX.$$

我们得到

$$GF = I, G = F^{-1}, G = (g_{lj})_{n \times n}, g_{lj} = y_l^j = e^{i\frac{2\pi}{n}lj}$$

两个向量的循环卷积定义为:

$$(x \circledast y)_k = \sum_{i=1}^N x_{(i-k) \bmod N} y_i.$$

他们可通过如下的付里叶变换和逆变换, 范德蒙矩阵来计算:

$$(x \circledast y)_k = (\mathcal{F}^{-1}(X \odot Y))_k = (F^{-1}(X \odot Y))_k.$$

基于循环卷积的分子幂编码定义为

$$z^{cc}(r) = z^{(\odot r)} = \mathcal{F}^{-1}(F(z)^r) = F^{-1}(Fz)^r.$$

定义基向量

$$A_{\odot} = \{z: \|v \circledast z\|^2 = \|v\|^2\}.$$

但是从上面方程, 我们得到

$$\|v \circledast z\|^2 = \|F^{-1}(Fv \odot Fz)\|^2 = \|Fv \odot Fz\|^2 = \|v \odot Fz\|^2 = \|v\|^2,$$

$|(Fz)_i| = 1, i = 0, \dots, n-1$, 或者

$$Fz = \begin{bmatrix} e^{i\phi_0} \\ e^{i\phi_1} \\ \vdots \\ e^{i\phi_{n-1}} \end{bmatrix},$$

从上面方程, 我们得到

$$A_{\odot} = z = F^{-1} \begin{bmatrix} e^{i\phi_0} \\ e^{i\phi_1} \\ \vdots \\ e^{i\phi_{n-1}} \end{bmatrix} = \frac{1}{\sqrt{n}} \begin{bmatrix} \sum_{k=0}^{n-1} e^{i(\frac{2\pi}{n}0k + \phi_k)} \\ \sum_{k=0}^{n-1} e^{i(\frac{2\pi}{n}1k + \phi_k)} \\ \vdots \\ \sum_{k=0}^{n-1} e^{i(\frac{2\pi}{n}(n-1)k + \phi_k)} \end{bmatrix}.$$

取一个特殊向量 $z = [0, \dots, z_l, \dots, 0]^T$, 那么

$$Fz = z_l \begin{bmatrix} e^{i\frac{2\pi}{n}0l} \\ \vdots \\ e^{i\frac{2\pi}{n}(n-1)l} \end{bmatrix} = z_l F_l .$$

分数幂编码的核

前面我们讨论了分数幂编码的基向量，现在我们进一步讨论它们的核。

(1) Hadmard 乘积

根据核的定义，核可以表示为两个代表 r 和 $r+d$ 的VFA向量 $z(r)$ 和 $z(r+d)$ 的内积：

$$\begin{aligned} \frac{1}{n} (z(r+d))^T \overline{z(r)} &= \frac{1}{n} (z(r) \circ z(d))^T \overline{z(r)} = \frac{1}{n} (z(d))^T (z(r))^T \overline{z(r)} \\ &= \frac{1}{n} (z(d))^T \mathbf{1} = \frac{1}{n} \sum_{j=1}^n e^{id\theta_j} \rightarrow E_{p(\emptyset)}[e^{id\theta}] . \end{aligned}$$

$$E_{p(\emptyset)}[e^{id\theta}] = \frac{1}{2\pi} \int_{-\pi}^{\pi} e^{id\theta} d\theta = \frac{\sin(\pi d)}{\pi d} = \text{sinc}(\pi d) .$$

定义Hadmard 乘积下的核函数：

$$K_{\ominus}(d) = \frac{1}{\sqrt{2\pi}} \text{sinc}(\pi d) .$$

(2) 循环卷积

两个实数 r 和 $r+d$ 在循环卷积捆绑运算下所定义的核算计算如下：

$$(z^{(\ominus(r+d))})^T \overline{z^{(\ominus r)}} = (F^{-1}((Fz)^{r+d}))^T \overline{F^{-1}(Fz)^r} = ((Fz)^d)^T \mathbf{1} .$$

$$Fz = \begin{bmatrix} e^{i\theta_0} \\ e^{i\theta_1} \\ \vdots \\ e^{i\theta_{n-1}} \end{bmatrix} .$$

从上面方程，我们得到

$$(z^{(\ominus(r+d))})^T \overline{z^{(\ominus r)}} = \frac{1}{n} \sum_{j=1}^n e^{id\theta_j} \rightarrow E_{p(\emptyset)}[e^{id\theta}] = \text{sinc}(\pi d) .$$

可见，循环卷积意义下和Hadmard 乘积意义下的核函数相同。

多维VFA

多维函数是指多个变量 r_1, \dots, r_m 的函数。它映照到 n 维复空，亦即

$$f(\mathbf{r}) = \mathbf{Z}(\mathbf{r}) \in \mathbb{C}^n .$$

可以表示为：

$$\mathbf{Z}(\mathbf{r}) = z^1(r_1), \dots, z^m(r_m), z^j(r_j) \in \mathbb{C}^n, z^j(r_j) = [z_1^j(r_j), \dots, z_i^j(r_j), \dots, z_n^j(r_j)]^T .$$

我们假设 $z^j(r_j)$ 是独立取样的，因而是正交的。我们把这些基本向量视做笛卡尔坐标系的座标。一个向量在笛卡尔坐标系的分解类似于普通欧氏空间笛卡尔坐标系的加法运算，可以看作是再生内核希尔伯特空间或VFA空间的捆绑运算。

$$z(r) = z^1(r_1) \circ z^2(r_2) \circ \dots \circ z^m(r_m).$$

设

$$[X \odot Y]^T \overline{u \odot v} = \sum_i x_i y_i \overline{u_i v_i}$$

$$z(x) = \odot_{j=1}^m z^j(x_j), \quad z(y) = \odot_{j=1}^m z^j(y_j).$$

$$z^j(x_j) = [e^{i\phi_1^j x_j}, \dots, e^{i\phi_n^j x_j}].$$

经过某些运算，我们有

$$\odot_{j=1}^m z^j(x_j) = [e^{i\sum_{j=1}^m x_j \phi_1^j}, \dots, e^{i\sum_{j=1}^m x_j \phi_n^j}]$$

$$z(x)^T \overline{z(y)} = \sum_{k=1}^n e^{i(\sum_{j=1}^m \phi_k^j (x_j - y_j))} \rightarrow K_{\odot}(x - y).$$

两点对应向量的核函数：

$$z(x)^T \overline{z(y)} = K_{sinc}(x_1 - y_1) K_{sinc}(x_2 - y_2).$$

设 $r^k = (r_1^k, \dots, r_m^k)$, $S = (s_1, \dots, s_m)$, 点S在VFA空间的向量表示为 $z(s)$, 函数在再生内核希尔伯特空间可表示为：

$$f(s) = \sum_k \alpha_k K(r^k - S).$$

那么，函数在多维VFA空间的向量表示为

$$(y_f)_i = \sum_k \frac{\alpha_k}{n} z_i^1(r_1^k) \dots z_i^m(r_m^k) = \sum_k \frac{\alpha_k}{n} e^{i\sum_{j=1}^m r_j^k \phi_k^j},$$

函数在点S的值为：

$$f(s) = (y_f)^T \overline{z(s)} = \sum_k \frac{\alpha_k}{n} \sum_{i=1}^n \frac{\alpha_k}{n} e^{i\sum_{j=1}^m (r_j^k - s_j) \phi_k^j}.$$

典型的应用例子—Raven' s渐变矩阵数据集的复杂关联学习

超维向量范式有两部分组成：前端感知部分和后端认知部分。类似地，前端感知部分也由两部分组合：可训练神经网络和VSA表示。用超维向量表示，物体如一特斯拉汽车在VSA框架下所代表的向量和该特斯拉汽车经过可训练神经网络输出的超维向量是一样的。这样，

VSA 或更一般VFA可作为表达概念，符号和外部世界的共同语言。它能把外部世界的物理量和人大脑里的概念和符合联系为一个同样的事物。把外部世界的听觉，视觉，嗅觉等原始的传感信号转导成具有固定长度的，嵌套的，可组合的超维VSA表示。后端处理推理和行动部分。它提供了有效计算，可微的，透明的，概率演译推理。后端推理有两个主要步骤。第一步是把前端所计算出的有关物体的位置，数值，类型，大小.和颜色等的概率密度函数变换成适当空间的分布式VSA表示。第二步运用VSA运算执行一阶逻辑规则，计算每种可能规则的概率，选取和执行概率最大的规则。超维向量运算把前端和后端有机地结合起来。从感觉信号输入开始，根据建造的模型推理，进行决策，然后采取行动。Hersche et al(2023)应用上述算法至Raven's 渐变矩阵数据集的复杂关联学习任务，达到平均精度87.7% in RAVEN 和88.1% in I-RAVEN。

越是艰险越向前

最近麻省理工学院奈特科学新闻研究员 Anil Ananthaswamy 发表了一篇 " 一种新的计算方法重新构想人工智能 "，提出超维计算，一条超越ChatGPT，通向一般人工智能的新道路。一石激起千层浪，这篇文章的发表在科学界激起了巨大的反响。

上世纪七十年代初，当我还在攀枝花钢铁公司建设工地上劳动的时候，人们就提出用模拟电路来模拟人类大脑的思维活动。那时称为神经形态技术。神经形态计算 Neuromorphic computing或类脑计算 Brain-inspired computing 是指使用模拟神经系统中生理结构的原理来进行计算。近年来，脑科学成为世界各国重要研究领域之一。受脑信息处理机制启发的类脑计算因此成为全球前沿科研领域。所谓类脑计算，也称为神经形态计算，也没有精确的定义。各人心目中的类脑计算也不大尽相同。但总的原则是指借鉴大脑的神经系统结构及其处理信息的基本规律及机制，在硬件实现与软件 算法等多个层面，对现有的计算体系与系统做出本质的变革，从而实现低能耗、速度快，所需数据少，具有高性能的计算系统。为减少数据在中央处理器和存储器之间的传输，和我们恼思维一样，类脑计算的数字运算在存储器中进行。通过类脑神经网络模型和计算方法的建立，以及对类脑计算、处理和存储设备技术的研究，可以开发新一代人工智能机器以及类脑机器人等。与传统冯诺依曼体系架构相比，类脑计算具有颠覆性创新。如果我们把云计算视为计算网络的中心节点，神经形态计算或超维向量计算等模拟计算或数字/模拟混合计算设备，那些安装在更靠近目标任务的计算，犹如计算机大网络的边，所以又称为边计算 (edge

computing)。计算具有低延迟、低能耗，透明性，高安全性、高可靠性、保护用户隐私等优势。它是云计算和超算的补充，也可能在将来会成为主流的计算设备。

经过五十年来的艰苦发展，神经形态技术，或更一般地超维向量计算，已经走向商业化。

据 "Neuromorphic Computing Global Market Report 2023" 报导，到2030年，神经形态计算市场即达到二百多亿美元，市场年增长率可达到21.2%。它们已广泛使用在家用电器，健康领域的穿戴设备，机器人，无人驾驶汽车，工厂的自动化等方面。

神经形态计算和高维向量计算的研究犹如滚滚奔腾向前的长江一浪高过一浪向前发展。

IEEE 把超维向量列为今后计算机和人工智能的研究方向（

<https://cmte.ieee.org/futuredirections/2023/07/01/hyperdimensional-computing/>）。

目前超维向量计算和神经形态计算会议和短期讨论有 HD/VSA Webinars(<https://www.hd-computing.com/events>)， Neuro-Inspired Computing Elements (NICE) Conference ， W05 Hyperdimensional Computing and Vector Symbolic Architectures for Automation and Design in Technology and Systems (<https://date23.date-conference.com/workshop/w05>)， International conference on neuromorphic, natural and physical computing (<https://nnpc-conference.com/>)， Top Computer Science Conferences in 2023 ([https://www.computer.org/conferences/top-computer-science-events?gclid=EAIaIQobChMIq7apuPX1_wIVi-HjBx0i7g9EEAMYASAAEgICTvD_BwE\\$](https://www.computer.org/conferences/top-computer-science-events?gclid=EAIaIQobChMIq7apuPX1_wIVi-HjBx0i7g9EEAMYASAAEgICTvD_BwE$)

the Human Brain Project Summit 2023

(<https://summit2023.humanbrainproject.eu/>)， ACM ICONS

2023(<https://icons.ornl.gov/>) ， Neuromorphic Computing(<https://www.date-conference.com/node/1461>)

在超维向量计算，人工智能，芯片和计算机研究方面首推的研究单位是英特尔实验室（<https://www.intel.com/content/www/us/en/research/overview.html>）。英特尔实验室创建于2002年，现有工作人员700多人，研究范围包括超维和神经形态计算，量子计算，人工智能，新型计算机结构包括从云计算作为计算网络的中心结点和速度快，能耗少，成本低，所需数据少的模拟或数/模混合的作为连结云计算中心结点的边计算（edge computing），芯片和网络设计，安全性和隐私保护等。英特尔实验室主任是Rich Uhlig.

他于1995年毕业于密西根大学计算机科学和工程，他曾在欧洲德国，希腊和法国的国家研究实验室做了一年的博士后，于1996加入英特尔实验室。他曾发表20多篇技术论文，申请了50多项专利。英特尔的神经形态计算实验室主任是Mike Davies。他分别于1998年和2000年从加州理工学院获得学士和硕士学位。英特尔把神经形态计算视为下一代的人工智能。英特尔为促进人工智能和神经形态计算实行开放式的研究政策，宣布了 " Joint Intel and Red Hat AI Developer Program " , 並建立 " The Intel Neuromorphic Research Community " , 已经拥有75个研究小组致力于发展神经形态计算和超维向量计算技术。网站<https://intel-ncl.atlassian.net/wiki/spaces/INRC/pages/1784807425/Join+the+INRC>提供了加入INRC的接口。英特尔还提供了许多帮助使用他的最新产品的讲座。网址是<https://intel-ncl.atlassian.net/wiki/spaces/INRC/pages/1784807425/Join+the+INRC>。

现在美国大学在这领域积极研究的有 加州大学伯克利分校的Redwood 理论神经科学中心对超维向量计算理论的研究。Redwood 神经科学研究所创立于2002年4月，是一个非营利组织 (<https://redwood.berkeley.edu/rni-history/>) , 于2005年7月作为礼物赠送给加州大学伯克利分校 (<https://redwood.berkeley.edu/>) 。 该中心的宗旨是把一般数学和物理原理和神经科学数据相结合，奠定神经形态计算和超维计算的算法基础。加州大学圣地亚哥分校，佐治亚工学院，伊利诺伊大学香槟分校，宾洲州立大学，哥伦比亚大学，康乃尔大学等校组成JUMP 2.0 consortium 共同推进微电子系统革命 (<https://www.src.org/program/jump2/>) 。馬里兰大学计算机系Perception & Robotics Group University of Maryland (<https://prg.cs.umd.edu/>) 发展超维向量计算技术及在机器人的应用。

在欧洲瑞典，IBM Research Europe 有一个非常出色的超维向量计算中心，他们通过超维向量计算把感知和认知有机地结合起来，正在开辟一条通向一般人工智能的研究的道路。澳大利亚昆士倫技术大学 (<https://www.qut.edu.au/research/michael-milford>) 机器人研究中心也开展了神经形态计算及其在汽车自动驾驶和机器人中的应用。德州大学包括奥斯汀总校，达拉斯分校，圣东安尼分校都有神经形态计算和超维向量计算的研究中心或项目，理论研究和应用正在蓬勃地发展起来。

最近,《Nature Communication》开辟了Special Issue on “Neuromorphic Hardware and computing” 专栏。在征求论文的告示中指出,拟神经形态计算作为克服传统的数字计算能源和不透明的不足的另一种选择方面取得了突破性的进展。Special issue 的发表将进一步推动发展类脑鼓午下的未来计算机的理论和算法。

应该说,超维向量计算还刚刚起步,与传统的人工智能和计算机系统相比,仅占很少的一部分。超维向量计算形成第三代人工智能还没形成共识。它的蓬勃发展尚需时日。但是超维向量计算是人工智能发展的一个新春。它正在数据分析,计算机计算和自动化方面尝偿一条新的道路。新春开始时力量是弱小的,但它有巨大的力量,它是不可战胜的。

References

Morris, J. (2022). HyDREA: Utilizing Hyperdimensional Computing for a More Robust and Efficient Machine Learning System. *ACM Transactions on Embedded Computing Systems*. 21: 1-25.

Kanerva, P. (in press). "Hyperdimensional Computing: An algebra for computing with vectors"; in A. Chen (ed.), *Advances in Semiconductor Technologies*; ISBN: 9781119869580; Wiley, 2022.

Hersche M, Zeqiri M, Benini L, Sebastian A, Rahimi A. (2023). A Neuro-vector-symbolic Architecture for Solving Raven's Progressive Matrices. *Nature Machine Intelligence* volume 5, pages363–375.

Fraday EP, et al. (2021). Computing on Functions Using Randomized Vector Representations. arXiv:2109.03429.

Upcoming Events

Please find below a list of upcoming ICSA meetings and co-sponsored meetings. This list also appears on the ICSA website. If you have any questions, please contact Dr. Mengling Liu, the ICSA Executive Director (executive.director@icsa.org).

ICSA Sponsored Meetings:

ICSA 2024 Applied Statistical Symposium

June 16 - 19, 2024

The ICSA 2024 Applied Statistics Symposium was held at Vanderbilt University, Nashville, TN. Detailed information will be shared later.

The 12th ICSA International Conference

July 7 - 9, 2023 The 12th ICSA International Conference held at The Hong Kong Chinese University from July 7th to 9th, 2023, chaired by Dr. (Tony) Jianguo Sun, witnessed a successful opening ceremony with welcome remarks by Professor Alan Chan and an introduction to ICSA by Professor Gang Li. The conference featured prominent lectures, including Dr. Song Xi Chen's Peter Hall lecture and Dr. Ji Zhu's Pao-Lu Hsu lecture. Over 100 invited sessions, a memorial session, and a junior research award session were conducted. The conference banquet, organized by the local committee, delighted participants with great food and captivating performances. Special thanks go to Dr. Xingqiu Zhao, Dr. Xinyuan Song, Drs. Dayu Sun, and Yuanyuan Guo, along with the ICSA Executive Committee, participants, and volunteers for their invaluable contributions to the conference's success.

ICSA Co-sponsored Meetings:

DIA China Quantitative Science Forum

October 19 - 21, 2023 The 2023 DIA China Quantitative Science Forum will be held from Oct 19-21, 2023 in Nanjing, China. Experts, scholars and young professionals from enterprises, academia and regulatory agencies will share and exchange important and innovative topics in China and abroad and explore how quantitative science can be utilized and play a greater role in

drug development. Please see the meeting web page: <https://www.bagevent.com/event/8489151> for more information. ICSA members will receive a discounted registration fee, which is the same discount as a DIA member. If you have any questions, please contact Min Chu (min.chu@diablobal.org), or the ICSA executive director Dr. Jun Zhao (executive.director@icsa.org).

IMS Asia Pacific Rim Meeting

Postponed to January, 2024

The sixth meeting of the Institute of Mathematical Statistics Asia Pacific Rim Meeting (IMS-APRM) will provide an excellent worldwide forum for scientific communications and collaborations for researchers in Asia and the Pacific Rim, and promote collaborations between researchers in this area and other parts of the world. The meeting will be held in Melbourne, Australia and please see <http://ims-aprm2021.com/> for details. Firm dates will be announced later.

Online Training and Seminars:

Healthcare Innovation Technology: The Pod of Asclepius

Looking to stay up to date on developments in health care technology around the world? The American Statistical Association is sponsoring "The Pod of Asclepius", a new podcast where data scientists, statisticians, engineers, and regulatory experts discuss the technical challenges in their healthcare domain.

We have over 20 episodes published and available on YouTube, Podbean, iTunes, Stitcher, Podchaser, Tune In Radio, and Google Play. Looking for a good place to start? Check out the following episode links:

- Risks and Opportunities of AI in Clinical Drug Development with David Madigan and Demissie Alemayehu
- Kidney Injury - Biomarkers for Prediction and Prognosis with Allison Meisner
- NHS Digital Health Initiatives with Emma Hughes
- Data Platforms to Monitor Animal Health with Shane Burns

Upcoming Events

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- Bayesian Approaches in Medical Devices: Part 1, Part 2, Part 3 with Martin Ho and Greg Maislin

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- Youtube: <https://www.youtube.com/channel/UCkEz2tDR5K6Aj1Kw-JrV57w>

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