

Homayoon Beigi

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Education

Feb 1991 Defended 9/1990	Columbia University, New York, NY Doctor of Engineering Science Major: Mechanical Engineering Thesis: Neural Network Learning and Learning Control Through Optimization Techniques
May 1985	Master of Science Major: Mechanical Engineering Kinematics, Dynamics, and Control Systems
May 1984	Bachelor of Science Major: Mechanical Engineering Machine Design

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Employment

Jan. 2025-Present	Department of Mechanical Engineering, Columbia University <i>Professor of Professional Practice</i> Joint Appointment between two departments of Mechanical and Electrical Engineering. Teaching and research in Control, Signal Processing, and Data Science
Jan. 2025-Present	Department of Electrical Engineering, Columbia University <i>Professor of Professional Practice</i> Joint Appointment between two departments of Mechanical and Electrical Engineering. Teaching and research in Control, Signal Processing, and Data Science
May 2025-Present	Data Science Institute (DSI), Columbia University <i>Professor of Professional Practice</i> Affiliated Faculty of the Data Science Institute (DSI) Sense, Collect, and Move Data (Center)
Jan. 2025-Present	Recognition Technologies, Inc. <i>Head of Research and Development</i>
Jul. 2003- Dec. 2024	<i>Chief Executive Officer and President</i> Duties: Research and Development of Human Biometric systems and Human Language Technologies. Architecture design and implementation of the research results into practical systems including engines and applications.

Consulting:

Expert evaluations on legal and forensic cases involving speaker identities and speech related topics for many legal entities and patent agencies.

Products:

Exclusive design and implementation of several recognition engines, fully developed in-house (containing over 5 million lines of original C++ code, written personally over the past 23 years – 20 years of research and development on code which was from 3 years of research at Internet Server Connections, Inc. and 3 years at Applied Mathematics Research)

RecoMadeEasy® Speaker Recognition Engine

Winner of the 2011 Frost & Sullivan North American

Speaker Verification Biometrics, New Product Innovation Award

RecoMadeEasy® Large Vocabulary Speech Recognition Engine

RecoMadeEasy® Face Recognition Engine

RecoMadeEasy® Audiovisual Recognition Engine

RecoMadeEasy® Automatic Language Proficiency Rating Engine

RecoMadeEasy® Interactive Voice Response (IVR)

RecoMadeEasy® Signature Compression and Verification Engine

RecoMadeEasy® Online Handwriting Recognition Engine

RecoMadeEasy® Keystroke Recognition Engine

Department of Computer Science, Columbia University

Adjunct Professor

Jan. 2012-

Dec. 2024

Multidisciplinary Graduate Courses:

COMS-E6998 (Fundamentals of Speech Recognition)

Overall Instructor Evaluations by Students:

2022 Spring : 5.0/5.0

2021 Spring - Fall : 4.5/5.0 - 5.0/5.0

2020 Spring - Fall : 4.1/5.0 - 5.0/5.0

2019: 5.0/5.0

2018: 4.0/5.0

2017: 4.8/5.0

2016: 4.9/5.0

2015: 4.6/5.0

2014: 4.13/5.0

See Detailed Evaluations and Students' Comments

COMS-W4995 (Mathematics of Machine Learning and Signal Recognition)

COMS-E6998 (Fundamentals of Speaker Recognition)

Overall Instructor Evaluations by Students:

2014: 4.9/5.0

2013: 4.6/5.0

2012: 5.0/5.0

See Detailed Evaluations and Students' Comments

Department of Mechanical Engineering, Columbia University

Jan. 2003-Present *Adjunct Professor*

Multidisciplinary course:

[MECE-E6620 \(Applied Signal Recognition\)](#)

2020 Spring : 5.0/5.0

2019 Spring : 4.0/5.0

Cross-listed course across mechanical and electrical engineering:

[EEME-E4601 \(Digital Control Systems\)](#)

Overall Instructor Evaluations by Students:

2019 Spring : 4.0/5.0

Department of Electrical Engineering, Columbia University

1995 and 1996 *Adjunct Assistant Professor*

[EE-E6820 \(Speech and Handwriting Recognition\)](#)

[Internet Server Connections, Inc.](#)

Feb. 2000-Present *Vice President and Chief Technology Officer*

Complete technical operation of [Internet Server Connections](#).

Duties include:

Research and development related to customized products and services for customized hosting and networking clients.

Design and implementation of complex networks using [Cisco®](#) (as a certified [Cisco®](#) vendor) and customized Linux routers using [BGP4](#) and other IP routing, load and redundancy optimization.

Network and IP resource management, telephony network design and implementation based on Dialogic T1/E1 telephony cards and the [RecoMadeEasy®](#) IVR engine.

Projects include:

[Portfolio Optimization algorithm](#) development for

[Merrill-Lynch Research](#) (Real-time, constrained non-linear optimization problem of over 38,000 variables)

The [complete creation, cross-referencing, indexing, specialized search \(specialized Unicode alphabet\) and management](#) of the digital libraries related to the [Encyclopædia Iranica](#), a thirty five year old scholarship endeavor at the [Center for Iranian Studies](#) at [Columbia University](#)

Projects with over 180 other Corporate clients in telecommunications, including customized in-house design, implementation, and hosting services in our dedicated data center with customers, some of which receive an average of over a million hits per day.

Feb. 1991- **[IBM T.J. Watson Research Center](#)**

Feb. 2001 *Research Staff Member*

Feb. 1997- [Human Language Technologies](#)

Research in the fields of Speaker Recognition (Verification and Identification) and Speech Recognition and Automatic Segmentation. Developed algorithms for the IBM Research Speaker Verification and Identification Engine which is now being used in an array of different products while conducting research for improving its performance. This system is completely Text Independent and is in addition Language Independent.

Feb. 1991-
Feb. 1997

[Pen Technologies](#)

Principal Investigator and Project Leader for [Pen-Based Music Editor](#). Research in on-line Handwriting Recognition: Developed and implemented Handwriting Recognition Algorithms in every area related to the topic. These areas include: Research and development of the Front-End, Search, and Language Models for Cursive and Unconstrained Recognition systems as well as Discrete and Run-on versions. System architect for IBM Unconstrained Recognition system.

Developed a model of handwriting and a model of human hand-dynamics for application in recognition of Cursive and Natural writing. Combined the above models in a Hidden Markov Model (HMM) framework. Developed a set of normalization, desloping and deslanting schemes for application to cursive handwriting recognition. Conducted research and developed on-line training capabilities for the IBM cursive recognizer.

Research in optimal clustering techniques and Neural Network Models of Handwriting. Responsible for a major part of search and language models in the IBM product ThinkWriteTM.

[Department of Mechanical Engineering, Columbia University](#)

Jan. 1997-
Dec. 2003

Adjunct Associate Professor

Cross-listed course between mechanical and electrical engineering:
EEME-E4601 (Digital Control Systems)

[Department of Electrical Engineering, Columbia University](#)

Sep. 1995-
Dec. 1996

Adjunct Assistant Professor

Graduate course EE-E6820 (Speech and Handwriting Recognition)

The first session was also made available through the [Columbia Video Network](#), with an additional 10 students remotely connected through satellite connection.

[Applied Mathematics Research, Sole Proprietorship](#)

Jul. 1993-
Jul. 1996

Software Development

Wrote the first Matlab[®] to C⁺⁺ translator. Wrote all internal matrix functions of Matlab[®] in C⁺⁺. Wrote a Matlab[®] parser and a C⁺⁺ code generator to produce C⁺⁺ code, translating any Matlab[®] code to 100% C⁺⁺ code. This project entailed optimal implementation of complex numerical matrix manipulation functions. The code libraries were later inherited by [Internet Server Connections, Inc.](#)

- Oct 1990-
Feb 1991 **Center for Telecommunication Research, Columbia University**
Research Specialist
Research in digital image coding, image data compression and transmission.
Developed and implemented schemes for lossless image compression and transmission, and ultra-fast methods of image display through low-level hardware control.
- Dec 1987-
Sep 1990 **Department of Mechanical Engineering, Columbia University**
Research Assistant
Doctoral Research in the field of Learning-Adaptive Control and Neural Network Learning – **Research abstract** enclosed.
Advisers: Prof. C. James Li and Prof. Richard W. Longman.
- Jun 1989-
Dec 1990 *Research Assistant*
Fault detection of mechanical systems and machine health prognosis, funded by the U.S. Navy and supervised by Prof. C. James Li.
Developed practical signal processing techniques for the health prognosis of mechanical components such as bearings, gears, cutting tools, etc. This project included the design and implementation of the sensors and the data acquisition apparatus, as well extensive pattern recognition algorithm design and implementation for the automatic detection of faults in different components.
- Sep 1988-
May 1989 *Teaching Assistant*
Instruction of Mechanical Engineering Laboratory (E3018, E3028, E3038).
- Jan 1986-
Sep 1986 *Research Assistant*
Worked with the late Prof. Ferdinand Freudenstein on a generalization theory on Kinematic Analysis of commonly used linkages
Publication: (**Freudenstein and Beigi 1986**).
- Sep 1985-
Jan 1986 *Departmental Research Assistant and Teaching Assistant*
Laboratory Consultant for Computer Aided Design (MECE E3408).
Teaching assistance in the lectures and laboratory instruction for a graduate level course entitled Introduction to Robotics (MECE-E4602).
- Sep 1984-
May 1985 *Research Assistant*
Digital image processing applied to fluid mechanics for the analysis of lubricants' behavior in zero gravity – An experiment conducted in conjunction with the **first NASA Spacelab project – STS-9**.
Designed and created the digitization platform using a sonic digitizer and wrote drivers for the digitizer in C, on an IBM PC platform. Digitized frames of 24-fps film taken of the spreading of fluids with different viscosities by the crew of the Columbia Shuttle in the Spacelab module. This data was used by Prof. Coda Pan to formulate the equations that describe the spreading characteristics of fluids on different smooth surfaces in zero gravity.

Computer Skills

Extensive experience in [Linux](#) and other [Unix-like](#) operating systems, [Android](#), [Windows](#), [VM](#), [VMS](#), [OS2](#), and many other operating systems.

In excess of 40 years of experience with many languages such as [C](#), [C++](#), [FORTRAN77](#), [Java](#), [JavaScript](#), [HTML](#), [PHP](#), [XML](#), [ASSEMBLY](#), [LaTeX](#), and several shell scripting languages such as [AWK](#), [tcsh](#) and [csh](#), [ksh](#), [Bourne shell](#), etc.

Network Design, TCP/IP, [BGP4](#), Load Balancing, Telephony Network design, [Cisco®](#) Operating System, [Zebra](#) and [Quagga Routing](#), [GateD](#) routing.

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Awards and Honors

- Jan. 2026 ***IMAC Best Paper Award: Data Science***
“Real-Time Generalizable SHM: A Streaming Neural Network for Cross-Domain Damage Detection”
- Sep. 2023 *Nominations by 14 Columbia University Alumni for the 2024 Egleston Medal for Distinguished Engineering Achievements*
The results will be announced in May of 2024.
- Feb. 2023 *Finalist for Columbia University Presidential Awards for Outstanding Teaching*
One of only 11 finalists for 5 Presidential Awards for Outstanding Teaching across the entire Columbia University faculty.
- Jan. 2021 ***IMAC Best Paper Award: Dynamics of Civil Structures***
“Transfer Learning from Audio Domains a Valuable Tool for Structural Health Monitoring”
- Jan. 2012 *2011 Frost & Sullivan North American Speaker Verification Biometrics, New Product Innovation Award – For RecoMadeEasy® Speaker Recognition*
- 2003 *IBM Research Top 10% Valuable Patent*
Patent Number [6,421,645](#) was recognized by IBM Research as one of top 10% Valuable Patents.
- 2002 *Best of Show Award*
The Internet World Show, held at the Jacob Javits Center in New York City
In the E-Commerce category for the [CommerceMadeEasy®](#) software engine
- Oct. 25, 2002 *The Linux Journal Product of the Day Award*
For the [CommerceMadeEasy®](#) software engine
- 2001 *Third Plateau Invention Award, IBM Research*
presented to an individual with 12 accepted patent disclosures
- April 1999 *Adventurous System & Software Research (ASSR) Award, IBM Research*

- 2nd Extension of the ASSR award for further features of the speaker recognition engine
- 1999 *Second Plateau Invention Award, [IBM Research](#)*
presented to an individual with 8 accepted patent disclosures
- April 1998 *Adventurous System & Software Research (ASSR) Award, [IBM Research](#)*
Extension of the ASSR award for improving the speaker recognition engine
- 1998 *Research Division Award, [IBM Research](#)*
For the creation of the Virage transcription system
- 1998 *First Plateau Invention Award, [IBM Research](#)*
presented to an individual with 4 accepted patent disclosures
- April 1997 *Adventurous System & Software Research (ASSR) Award, [IBM Research](#)*
ASSR award for creating a speaker recognition engine for IBM Research
- 1997 *Research Division Award, [IBM Research](#)*
For the success of the Network Vehicle (speech enabled vehicle)
- 1996 *Research Division External Honors Award, [IBM Research](#)*
In Recognition of the honor of being elected as an Associate Editor of the Intelligent Automation and Soft Computing Journal
- April 1996 *Adventurous System & Software Research (ASSR) Award, [IBM Research](#)*
Extension of the [ASSR award](#) for another year to conduct adventurous research in the field of [Handwriting Recognition for CMN \(Common Music Notation\)](#).
- April 1995 *Adventurous System & Software Research (ASSR) Award, [IBM Research](#)*
The largest ASSR award (\$110,000) for research in the field of [Handwriting Recognition for CMN \(Common Music Notation\)](#).
- 1995 *[Extraordinary Ability Status by U.S. Immigration and Naturalization](#)*
Obtained U.S. Permanent Residence through the extremely rare [Extraordinary Ability category](#) which resulted in obtaining permanent residence in three weeks after submitting the application.
- 1995 *Research Division External Honors Award, [IBM Research](#)*
In Recognition of the honor of being elected as The Conference Chair for the Conference on Technological Advancement in Developing Countries
- 1995 *[Sigma Xi Scientific Research Honor Society](#)*
Elected to the Columbia University (Kappa) Chapter
- March 1994 *[IBM Research Division Award](#)*
For “Online Discrete Handwriting Recognition”

- 1993 [*IBM Research Patent Award*](#)
For the Invention of “A Post-Processing Error Correction Scheme Using a Dictionary for On-Line Boxed and Run-On Handwriting Recognition”
- 1990 [*IEEE Best Paper Award*](#)
Homayoon Beigi and C. James Li, “[New Neural Network Learning Based on Gradient-Free Optimization Methods](#),” 1990 IEEE Conf. on Neural Networks
- 1990 [*IEEE Best Paper Award*](#)
Homayoon Beigi and C. James Li, “[Neural Network Learning Based on Quasi-Newton Methods with Initial Scaling of Inverse Hessian Approximate](#),” 1990 IEEE Conference on Neural Networks
- 1984 Scholarship Award, [Mechanical Engineering Department, Columbia University](#)
Scholarship covering tuition and fees for the last semester of the senior year.
- 1981 [*Bausch & Lomb Science Award*](#)
Presented for academic excellence in science, rigor of courses taken in the sciences, and SAT Math and ACT Science and Math scores.
- 1980 [*The Maria Elena Arosemena Cup*](#)
Trophy is given to the international student who has gained the greatest command and understanding of the English Language
- 1980 [*The Bancroft Phinney Award*](#)
Presented to the Student with Highest Academic Standing

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Professional Activities

- 2012 [*VIPG Panel of Experts*](#)
Voted into an 8-person Voice Identification Policy Group (VIPG) of the United States Embassy in Mexico for the registration of the Federal police of Mexico.
- 2009 - 2010 [*Interoperability Committee Member*](#)
U.S. Government Interagency Symposium for Investigatory Voice Biometrics
[Federal Bureau of Investigation Interoperability Committee](#)
- Sep. 2009 [*Interoperability Panelist*](#)
[U.S. Government Interagency Symposium for Investigatory Biometrics](#)
- 2005 [*Invited Keynote Speaker*](#)
“[Challenges of Large-Scale Speaker Recognition](#),” *Keynote Speech* at the European standards, [COST275 Workshop on Biometrics on the Internet](#), October 27-28, 2005, Hertfordshire University, Hatfield, United Kingdom.

- 2003 – 2010 *Active Liaison*
Active liaison for the U.S. Delegation of [ISO/SC 37 JTC 1 WG3 \(Biometrics\)](#) standards development for the Common Biometric Exchange Format.
- 2003 – 2010 *Active Liaison and Driving Force for Speaker Recognition*
[ANSI/INCITS Standards development for Biometric Data Interchange Formats.](#)
- 2003 – 2010 *Active Liaison and Driving Force*
[VoiceXML Forum](#) standards development for Speaker Recognition (Speaker Biometrics) Data Format.
- 2002 *Guest Editor*
Special issue on Learning and Repetitive Control, Volume 8, No. 2, 2002
[Intelligent Automation and Soft Computing Journal](#)
- 1998 – 2010 *Chief Digital Editor*
[Encyclopaedia Iranica](#), Published by [Columbia University](#), New York City, NY
Managed, designed, implemented, and maintained the entire digitization and publication in digital form of the encyclopedia.
- 1998 *Organizer*
The Pattern Recognition Division of the [World Automation Congress](#), Alaska
- 1997 and 1999 *Organizer*
The World Manufacturing Congress
- 1997 *Technical Chair*
[The IEEE International Conference on Robotics and Automation](#)
- 1994-2013 *Associate Editor*
[Intelligent Automation and Soft Computing Journal](#)
- 1994 - 2010 *Advisory Board Member*
The Advisory Board Committee of the [IEEE Spectrum Magazine](#) on Technological Advancement in Developing Nations
- 1997 *Invited Keynote Speaker*
[Foundations of Distributed Information Systems \(FDIS 97\) Conference](#), Aspen, Colorado, Jun. 1997
- 1994 - 2003 *Editor*
For Applications of Soft Computing to Handwriting Recognition for the [Berkeley Initiative on Soft Computing \(BISC\)](#)
- 1995 *Conference Chair*
Third Annual Conference on Technological Advancement in Developing

Countries, Columbia University, New York, 1995

- 1991-1995 *Executive Committee Member*
The Society for Technological Advancement in Developing Countries
- 1991-1993 *Technical Chair*
Mechanical, Chemical, and Industrial Engineering Division of the Society
for Technological Advancement in Developing Countries
- Jul 23-24, 1993 *Organizing Committee Member*
The Annual Conference on Technological Advancements in Developing
Countries

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Scientific and Technical Review Committees

[Journal Reviewer Public Profile](#)

- 2025 - Present International Joint Conference on Neural Networks ([IJCNN](#))
- 2025 - Present IEEE Automatic Speech Recognition and Understanding Workshop ([ASRU](#))
- 2016 - Present European Intelligence and Security Informatics Conference ([EISIC](#))
- 2012 - Present [IET Signal Processing Journal](#)
- 2014 - Present [Journal of Phonetics](#)
- 2012 - Present IEEE International Conference on Acoustics, Speech, and Signal Processing
[2012](#), [2013](#), [2014](#), [2015](#), [2016](#), [2017](#), [2018](#), [2019](#), [2020](#), [2021](#), [2022](#), [2023](#),
[2024](#), [2025](#), [2026](#)
- 2010 - Present [Parsa Wireless Communications](#) Intellectual Property and
Patent Evaluation Organization
Patent Evaluation Expert for Speech and Handwriting related patents
- 2009 - Present [Qatar Foundation](#) Grant Review Committee
Review of grant proposals to the Qatar Foundation, including technical
correctness, budget review, and feasibility analysis
- 2009 - Present The Interspeech Conference – [2009](#), [2010](#), [2011](#), [2012](#), [2013](#), [2014](#), [2015](#),
[2016](#), [2017](#), [2018](#), [2019](#), [2020](#), [2021](#), [2022](#), [2023](#), [2024](#), [2025](#), [2026](#)
- 2006 - Present [Pattern Recognition Journal](#)
- 1991 - Present Regular reviewer for the following journals
[IEEE Transactions on Pattern Analysis and Machine Intelligence \(PAMI\)](#)

IEEE Transactions on Neural Networks
International Journal of Control
The American Institute of Aerospace and Avionics (AIAA) Journal

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Society Membership

2010 - Present	<i>Member</i> <i>The New York Academy of Sciences</i>
2000 - Present	<i>Senior Member</i> The Institute of Electrical and Electronic Engineers (IEEE) <i>Member, The IEEE Signal Processing Society</i> <i>Member, The IEEE Control Systems Society</i>
1988 - 2000	<i>Member</i> The Institute of Electrical and Electronic Engineers (IEEE)
1995 - Present	<i>Full member</i> <i>Sigma Xi Scientific Research Honor Society</i> Elected to the Columbia University (Kapp) Chapter
1991 - 2001	<i>Member</i> <i>The Canadian Society for Electrical and Computer Engineering (CSECE)</i>
1991 - 1995	<i>Executive Committee Member</i> The Society for Technological Advancements in Developing Countries (STADC)
1991 - 2001	<i>Member</i> <i>The American Society of Mechanical Engineers (ASME)</i>
1983 - 1991	<i>Student Member</i> <i>The American Society of Mechanical Engineers (ASME)</i>

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Artistic Foundations

2023 - Present	<i>Advisory Board Member</i> <i>ArtSee Community</i> , A free social platform to enable underprivileged artists from around the world to share their work.
2019 - Present	<i>Founder</i> <i>Artists 4 Peace</i> , A Non-Profit organization with a mission of promoting peace around the world, created to provide access to artists around the world who may have trouble accessing an audience. The mission is to promote worldwide peace

through artistic engagement. The artists are mostly underprivileged international artists, who may have no such access otherwise. However, the organization provides free access to all artists.

2010 - Present *Founder, Composer, and Music Director*
[Noavaran Ensemble](#), A musical ensemble, with a mission of fusion of music around the world and combining theory and practice of many genres of music in performance of innovative fusion compositions.

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Miscellaneous

Citizenship United States of America

Languages Native level fluency in English and Persian.
Studied Japanese, up to Intermediate Level.
Spanish, French, Turkish, and Arabic at Elementary Level.

Hobbies [Persian Classical Musical performance in Fusion with Modern Western Music](#)
Instrumets: Tar, Kamancheh, Dotar, Tanbur, and Barbat

Hobbies include Etymology and the study of Archaic Languages such as Middle English and Middle Persian.

Academics Participated in several courses in Statistical Speech Recognition and Advanced Information Theory at IBM T.J. Watson Research Center, over many years. In theses each participant taught a topic and attended the lectures of other participants.

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Publications

Books

Homayoon Beigi, *Mathematics of Machine Learning, Signals, and Control*, Springer, New York, 2026 (Expected).

More Information: This will be a textbook with over 900 pages of material. It has been solicited by colleagues who felt that background mathematics for machine learning and pattern recognition were not easy to find in a comprehensive manner with a single source. This book is nearly complete and is set to be released toward the end of 2026.

Homayoon Beigi, *Fundamentals of Speaker Recognition*, 2nd Edition, Springer, New York, 2026 (Expected).

More Information: Due to the success of the first edition of this book and the dynamic nature of the topic, this edition will provide the original text plus coverage of many new topics and techniques. The 2nd edition will be release toward the end of 2026.

Homayoon Beigi, *Fundamentals of Speaker Recognition*, 1st Edition, Springer, New York, 2011, ISBN: 978-0-387-77591-3.

More Information: This is the first and only textbook on speaker recognition. It contains a comprehensive coverage of the subject, with an inclusive treatment of all the prerequisites in 26 chapters and about 1000 pages of material. This book has consistently ranked as the top 25% downloaded E-Book on the Springer (publisher) site. This book took 4 full years of active research and writing, at an average of 10 hours per day. Over 100,000 downloads have been recorded so far.

Downloads: 90,000 downloads as of September 2024 – According to Springer.com. This does not include the number of e-books and hardcopies sold. Interestingly, this book is becoming more popular every year. here are the statistics of the downloads for each year since it released:

- Downloads in 2018: **6,793**
- Downloads in 2017: **7,157**
- Downloads in 2016: **8,745**
- Downloads in 2015: **11,409**
- Downloads in 2014: **12,566**
- Downloads in 2013: **6,914**
- Downloads in 2012: **3,598**
- Downloads in 2011: **667** (only in the last 6 days of the year since it was release at the end of December, 2011)

Homayoon Beigi, “*Neural Network Learning and Learning Control Through Optimization Techniques,*”, *Doctoral Thesis*, School of Engineering and Applied Science,

[Columbia University](#), New York City, New York, 1991.

Book Chapters and Encyclopedia Articles

Homayoon Beigi, “[Speaker Recognition](#)”, In: Jajodia S., Samarati P., Yung M. (eds) Encyclopedia of Cryptography, Security and Privacy, Third Edition, pp. 2479–2495, . Springer, Switzerland AG, 2025, ISBN: 978-030-71522-9, [10.1007/978-3-030-71522-9](#)

Kyle L. Hom, Homayoon Beigi, and Raimondo Betti “[Application of Speaker Recognition x-Vectors to Structural Health Monitoring](#)”, In: Mao, Zhu (ed), Model Validation and Uncertainty Quantification, Vol. 3, Ch. 13, pp. 139-148, isbn: 978-3-030-77348-9. Springer International Publishing, Berlin, Heidelberg, 2022, [10.1007/978-3-030-77348-9_18](#).

Eleonora M. Tronci, Homayoon Beigi, Maria Q. Feng, and Raimondo Betti “[Transfer Learning from Audio Domains: A Valuable Tool for Structural Health Monitoring](#)”, In: Grimmelmann, Kirk (ed), Dynamics of Civil Structures, Vol. 2, Ch. 11, pp. 99-107, isbn: 978-3-030-77142-3. Springer International Publishing, Berlin, Heidelberg, 2022, [10.1007/978-3-030-77143-0_11](#).

Homayoon Beigi, “[Speaker Recognition](#)”, In: Jajodia S., Samarati P., Yung M. (eds), Encyclopedia of Cryptography, Security and Privacy. Springer, Berlin, Heidelberg, 2021 [10.1007/978-3-642-27739-9_747-2](#).

Homayoon Beigi, “Andranik Aroustamian,” *invited article entry* in the [Encyclopædia Iranica](#), Center for Iranian Studies, Columbia University, 2021.

Homayoon Beigi, “[A Hybrid Approach to Automated Rating of Foreign Language Proficiency](#),” Where Humans Meet Machines – Innovative Solutions for Knotty Natural-Language problems, Amy Neustein and Judith Markowitz (Eds.), Springer, New York, 2013, ISBN: 980-953-307-576-6.

Homayoon Beigi, “[Speaker Recognition: Advancements and Challenges](#),” New Trends and Developments in Biometrics, Jucheng Yang and Shan Juan Xie (Eds.), 2012, ISBN: 980-953-307-576-6 DOI: 10.5772/52023.

Downloads: 3,533 downloads as of Jan. 6, 2022 – According to intechopen.com.

Homayoon Beigi, “[Speaker Recognition](#),” *invited article*, Encyclopedia of Cryptography and Security (2nd ed.), Henk C.A. van Tilborg and Sushil Jajodia (Eds.), Springer, New York, 2011, pp. 1232–1242, ISBN: [978-1-4419-5906-5](#), DOI: [10.1007/978-1-4419-5906-5_747](#).

Homayoon Beigi, “[Speaker Recognition](#),” [Biometrics / Book 1](#), Jucheng Yang (ed.), Intech Open Access Publisher, 2011, Ch. 1, pp. 3–28, ISBN: [978-953-307-618-8](#).

Downloads: 3,902 downloads as of Dec. 15, 2014 – According to intechopen.com.

Homayoon Beigi, “[Pre-Processing the Dynamics of On-Line Handwriting Data, Feature Extraction and Recognition](#),” Progress in Handwriting Recognition, A.C. Downton and S. Impedovo (eds.), World Scientific Publishers, New Jersey, 1997, pp. 191–198, ISBN: 978-981-023-084-5.

T. Fujisaki, H.S.M. Beigi, C.C. Tappert, M. Ukelson, and C.G. Wolf, “[Online Recognition of Unconstrained Handprinting: A Stroke-based System and Its Evaluation](#),” From Pixels to Features III: Frontiers in Handwriting Recognition, S. Impedovo and J.C. Simon (eds.), Elsevier Science Publishers, B.V., 1992, pp.297–312, ISBN: 0-44-489665-1.

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Patents (granted)

Patent Number: US 10,042,993 B2

Homayoon Beigi, [Access control through multifactor authentication with multimodal biometrics](#), Filed: June 23, 2015, Granted: August 7, 2018.

Patent Number: US 9,495,646 B2

Homayoon Beigi, Raimondo Betti, and Luciana Balsamo, [Monitoring Health of Dynamic System Using Speaker Recognition Techniques](#), Filed: June 5, 2014, Provisionally filed: June 5, 2013, Granted: November 15, 2016; Joint filing between [Recognition Technologies, Inc.](#) and [Columbia University](#).

Patent Number: US 9,064,257 B2

Homayoon Beigi, [“Mobile Device Transaction using Multi-Factor Authentication,”](#) Filed: November 2, 2011, Provisionally filed: November 2, 2010, Granted: June 23, 2015.

Patent Number: US 7,474,770

Homayoon Beigi, [“Method and Apparatus for Aggressive Compression, Storage and Verification of the Dynamics of Handwritten Signature Signals,”](#) Filed: June 28, 2005, Granted: January 6, 2009.

Patent Number: US 6,748,356

Homayoon Beigi and Mahesh Viswanathan, [“Methods and apparatus for identifying unknown speakers using a hierarchical tree structure,”](#) Filed: June 7, 2000, Granted: June 8, 2004.

Patent Number: US 6,684,186

Homayoon Beigi, Stephane Maes, and Jeffrey Sorensen, [“Speaker recognition using a hierarchical speaker model tree,”](#) Filed: January 26, 1999, Granted: January 27, 2004.

Patent Number: US 6,538,187

Homayoon Beigi, [“Method and System for Writing Common Music Notation \(CMN\) using a Digital Pen,”](#) Filed: January 5, 2001, Granted: March 25, 2003.

Patent Number: US 6,421,645

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Homayoon Beigi, “Standard Audio Format Encapsulation (SAFE)”, *Panel Keynote Speech*, US Government Interagency Symposium for Investigatory Voice Biometrics, National Institute of Standards (NIST) Campus, Bethesda, MD, March 5, 2009.

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Invited Talks and Radio Interviews

Homayoon Beigi, “[Structural and Machine Health Monitoring Derived from Speaker Recognition Techniques](#),” Invited Seminar, *Sense, Collect, and Move Data center* at the *Data Science Institue*, and the *Electrical Engineering Department of Columbia Univeristy*, April 24, 2025.

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Homayoon Beigi, “[Deep Learning Explained](#),” *Invited Talk*, [IEEE Tappan Zee Subsection Joint Meeting with Westchester Chapters of ASME & SME](#), New York Medical College, Valhalla, NY, Oct. 15, 2017.

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Homayoon Beigi, “[The RecoMadeEasy® Speaker Recognition Engine](#),” *Invited Talk*, [Booz Allen Hamilton](#), Falls Church, VA, December 12, 2012.

Homayoon Beigi, “[Research Projects at Recognition Technologies, Inc.](#),”

Invited Talk, [Center for Language Studies, Brigham Young University](#), Provo, UT, U.S.A., December 3, 2012.

Homayoon Beigi, “The Status of Speaker Recognition Research,” *Invited Talk*, In Commemoration of the 40th Anniversary of Prof. Richard Longman, [Department of Mechanical Engineering, Columbia University](#), New York City, NY December 9, 2011.

Homayoon Beigi, “Pattern Recognition for Fraud Detection,” *Invited Talk*, [Analytics Group, Citibank Headquarters](#), Long Island City, NY, November 30, 2011.

Homayoon Beigi, “Automatic Large-Scale Speaker Recognition,” *Invited Talk*, [University of Florida](#), Gainesville, FL, U.S.A., September 28, 2011.

Homayoon Beigi, “Speaker Recognition, Anywhere, in Any Language,” *Invited Talk*, [Analytics Group, Citibank Headquarters](#), Long Island City, NY, October 24, 2010.

Homayoon Beigi, “Speaker Recognition – Practical Issues,” *Invited Mini Course*, [The SpeechTek Conference](#), New York City, August 5, 2010.

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Homayoon Beigi, “Large-Scale Real-Time Constrained Nonlinear Optimization,” *Invited Talk*, [Merrill-Lynch Research](#), World Financial Center, New York City, June 23, 2000.

Homayoon Beigi, “On-Line Unconstrained Handwriting Recognition,” *Invited Talk*, Electrical Engineering Department, [Sharif University of Technology](#), May 22, 1995.

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Products

I have designed and implemented many different engines and algorithms and in fact I have personally done all the coding related to all the products of Recognition Technologies, Inc. and Internet Server Connections, Inc. Jsut the products at [Recognition Technologies, Inc.](#) include in excess of 5 million lines of highly optimized C^{++} code with almost no duplication. All engines have a common API standard and provide results in XML, HTML, and Text formats. All engines share the vast libraries which I been developed over the last 23 years. These libraries are listed at the [bottom of this section](#).

RecoMadeEasy[®] Speaker Recognition Engine (2003 – Present)

Winner of the [2011 Forst & Sullivan North American Speaker Verification Biometrics, New Product Innovation Award](#)

I personally designed and wrote all the code related to this engine in C^{++} . This is a state-of-the-art language- and text-independent speaker recognition system (voice biometrics system) which has been developed to work in different environments. Large-Scale and Small-Scale versions of this speaker identification and speaker verification (SIV) engine have been developed over many years of research to work in telephone, as well as stand-alone environments.

The speaker recognition engine is the only engine in the market, capable of realtime large-scale speaker identification, handling hundreds of thousands of models in realtime. It runs on all Linux systems as well as iOS and Windows. It features its own efficient database and a very small footprint. Another very important discriminator of this product is related to the *amount of data* that is available to us in the training of the models. Having data from about 1.5 million speakers, the engine has been optimized to handle very large training samples and to allow for parallel processing in both training and testing scenarios.

This engine has been trained on the speech of about 1.5 million of distinct speakers, most of whom have more than one session of recording. Being a statistical engine, large amounts of data and ample variability among types of data are essential to its success. For over a decade, customers in the financial, education, security, and government sectors have been using this product and coming back for more licenses.

RecoMadeEasy[®] Large Vocabulary Speech Recognition Engine (2003 – Present)

This large vocabulary speech recognition engine was written in C^{++} and shares many libraries from the Speaker Recognition engine as well as many other mathematical libraries developed over the last 20 years. At the moment, this is the most active area of research at [Recognition Technologies, Inc.](#)

Many applications are aslo being developed in collaboration with customers who are using this engine for phrase spotting in financial applications and proficiency rating in distance learning settings, etc. The speech recognition engine shares an API with the rest of the engines at Recognition Technologies to make the job of fusion of different engines much easier.

RecoMadeEasy® Face Recognition Engine (2010 – Present)

The face recognition effort was started in 2010 to complement the speaker recognition engine, in providing an audiovisual fusion engine, as well as a standalone full-frontal face recognition engine. As with all other engines, it shares an API with all RecoMadeEasy® products and provides very robust recognition results which perform well in different lighting conditions as well as in discrepancies related to glasses and other anomalies.

RecoMadeEasy® Audiovisual Recognition Engine (2010 – Present)

Since the inception of the Face Recognition engine, it has been fused with the speaker recognition engine, as well as speech recognition engine. This engine is the most complete engine which allows for the use of speaker, face, and speech recognition. The speech recognition is used to allow for random prompts to test for liveness, as well as simple standalone speech recognition functionality. As far as I know, we are the only company which has all these engines integrated into a single engine with a shared API.

RecoMadeEasy® Access Control Engine and Android Application (2012 – Present)

The [RecoMadeEasy® Audiovisual Recognition Engine](#) which includes [speaker recognition](#), [face recognition](#), and [speech recognition](#) with an extra capability that allows it to communicate with different access control devices. This allows for the engine to be used to gain access to different physical or virtual locations. See [video demonstrations](#). The demonstration also shows the [Android](#) application which communicates with this engine and was also developed completely in-house at [Recognition Technologies, Inc.](#) See [video demonstrations](#).

RecoMadeEasy® Automatic Language Proficiency Rating Engine (2007 – Present)

Certain clients of [Recognition Technologies, Inc.](#), who are involved in performing enormous amounts of ratings for their own clients in over 100 languages started asking about the possibility of rating the proficiency of an oral test, preferably independent of the language. Aside from the fact that this would save time and money for the client, there was a much more important reason for needing this service. Human raters can only provide proficiency scores up to a certain granularity. Practically, about 80% of all the rated tests would fall into a single human-rated category. I was able to provide three subratings for Intermediate Mid range which allowed for practical rating of the proficiency of over 1.5 million tests since 2007. See the related [book chapter](#) and [related reports](#).

RecoMadeEasy® Interactive Voice Response (IVR) (2003 – Present)

The Interactive voice response application was the first product of [Recognition Technologies, Inc.](#). It has been designed so that even a top executive who knows nothing about coding would be able to create a new IVR process using a Graph language which I wrote, specifically for defining IVR processes. It resembles C syntax, but it allows for defining nodes of a graph and the relation between nodes. It allows for very complex graphs. This product has been in use, nonstop, since 2003 and has been used to record at least 30,000,000 minutes of conversational audio. It is capable of recording conversations in split channel settings and is fully compatible with the most popular [Dialogic](#) telephony cards.

RecoMadeEasy® Signature Compression and Verification Engine (2005 – Present)

The signature compression product implements the content of my [U.S. patent 7,474,770](#). This application allows for an aggressive compression such that all the dynamics of a signature are compressed into less than 54 bytes. This is the number of bytes of storage which is available on the back of standard magnetic credit or debit card. Since the dynamics are preserved, the signature verification engine uses this information to match templates for users.

RecoMadeEasy® Online Handwriting Recognition Engine (2003 – Present)

The handwriting recognition engine is capable of performing unconstrained online handwriting recognition on a series of sampled points, coming back from a tablet, for example a [Wacom tablet](#).

RecoMadeEasy® Keystroke Recognition Engine (2007 – Present)

The keystroke engine has been developed to allow for the identification of individuals based on their typing habits. It uses the timeline associated with keystrokes. It is text and language independent, although the enrollment in different languages would need to be associated with the corresponding test language in order to have higher accuracies.

CommerceMadeEasy® (2000 – Present)

Winner of the Best of Show Award at the 2002 Internet World Show, held at the Jacob Javits center, in New York City, it was also the recipient of the Product of the Day award for October 25, 2002 from the Linux Journal. [CommerceMadeEasy®](#) is a Linux-based server software, all components of which were developed in C^{++} for optimal performance and security. It is completely cookie-less and provides a secure Internet Wizard for creating new accounts. It provides services such as "Sales, Auction, Access and Contribution and now E-Learning." The Wizard may be used to quickly setup a commerce site from an existing website with advanced search, a credit card gateway, security, and many other capabilities.

[CommerceMadeEasy®](#) may be used to set up and create complex commerce sites in any industry, in a matter of days. As the package was developed entirely in-house and since it includes all components such as an optimal database interface, it permits easy customization.

Encyclopedia Digital Library (1998 – 2012)

[Encyclopædia Iranica](#) is a thirty five year old scholarship endeavor at the [Center for Iranian Studies](#) at [Columbia University](#). Over the course of 14 years, I developed the procedure for the conversion of classically written articles into articles in Unicode-16. This included working with the editors of the encyclopedia, in detail, to design a character set based on Unicode to be able to handle hundreds of Indo-Iranian languages (modern and archaic). In addition, automation software was developed for the conversion of articles, while indexing and cross-referencing then automatically. Created search mechanisms for searching the articles in any of the many nonstandard transcription techniques used by the readers to transcribe the relevant languages, such as Persian, into the latin alphabet. The unicode mapping, unicode search, and multiple transcription style mapping are quite

complex. The indexing included automatic indexing plus keyword references created manually by editors and incorporated into the search and indexing. The product was the creation of a fully functional digital library by which the print version was and is made available online.

Portfolio Optimization (1998 – 2001)

While working at IBM Research, I was approached by a team at [Merrill-Lynch Research](#), who had heard about my doctoral work on nonlinear optimization, to help them with a problem they had with optimizing portfolios. At the time, [Merrill-Lynch](#) was using a very expensive product, [the Barra Optimizer](#), for portfolio optimization. To conserve funds, they requested the creation of a portfolio optimization program that would do the job of Barra, as well as providing more features. After clearing it with IBM, I took on the optimization research while at IBM and then in February of 2000, I decided to leave IBM and work on this problem fulltime. My manager asked me to reconsider and to take a one-year sabbatical instead and see whether I would like to return to IBM. In February 2001, I decided to continue working on this challenging optimization problem and left IBM Research.

As the VP/CTO of [Internet Server Connections, Inc.](#), I wrote an optimization program, capable of optimizing portfolios based on constrained nonlinear optimization of 35,000+ international securities in realtime. I solved this problem using sparse nonlinear optimization techniques and was able to match the results obtained by Barra. Unfortunately, due to the unfortunate event of September 11, 2001, the Merrill-Lynch research group fell apart and the project was terminated. However, very useful optimization libraries were developed in the process and added to the [Internet Server Connections](#) mathematical libraries which were later transferred to [Recognition Technologies, Inc.](#) and made a lot of the basic functions possible for the development of the many recognition engines described above.

The very large-scale portfolios optimization project for [Merrill-Lynch Research](#) took place from 1998 to 2001.

Matlab to C++ Translator (1993 – 1996)

Wrote the first Matlab[®] to C++ translator. Wrote all internal matrix functions of Matlab[®] in C++. Wrote a Matlab[®] parser and a C++ code generator to produce C++ code, translating any Matlab[®] code to 100% C++ code. This project entailed optimal implementation of complex numerical matrix manipulation functions. The code libraries were later inherited by [Internet Server Connections, Inc.](#) and later by [Recognition Technologies, Inc.](#)

IBM ViaVoice[®]

Personally wrote the first version of the IBM Speaker Recognition Engine, from scratch, which became a part of the IBM ViaVoice[®] line of products. I worked on this project from 1996 to 2000 until I took a one-year sabbatical to work on the [portfolio optimization problem](#) at [Internet Server Connections, full-time](#). In the course of these four years, I created an engine which allowed for large-scale speaker identification, as well as the basic speaker verification modality. I created hierarchical algorithms for organizing speaker models, in order to be able to perform massive identifications runs by only matching a logarithmic number of models instead of matching all models, which was the norm at the time.

During the process of creating a large-scale speaker identification product, I formulated a *directed divergence method* between collections of probability densities, which may use any classic divergence or distance between two densities.

IBM ThinkScribe®(CrossPad®) (1993 – 1996)

Contributions to the underlying algorithms of the IBM ThinkScribe® products, Compression (sole investigator and developer), Handwriting Recognition Technology (principal investigator and developer). This product offered a very robust unconstrained handwriting recognition engine with over 85% word-level accuracy, in conjunction with applications which were shipped with the CrossPad®.

IBM ThinkWrite® (1991 – 1993)

Contributions to the underlying algorithms of the IBM ThinkWrite® products, Run-On and Discrete Handwriting Recognition Technology one of the principal investigators and developers.

Wholesale Inventory and Sales Control® (1984 – 1990)

Wrote a complete inventory and sales control application, originally in BASIC and translated it to C in 1985. The more superior C version ran on the Xenix® operating system (a flavor of Unix®) and was sold to 5 wholesale carpet companies which used it for well over a decade. The product featured a colorful menu-driven interface, written using *curses*. This interface was state-of-the-art at that time. In addition, I developed drivers for a wireless pen-based barcode reader with memory which could hold up to 100 barcodes, using a serial port interface. I also used serial communication to connect dumb terminals and serial printers in the different locations of the showroom and the loading zones. I wrote the whole application entirely in C, with the following flow structure:

1. Salesperson accompanies client to the showroom with a barcode reading pen in his/her pocket.
2. Client chooses different carpets and salesperson swipes the barcode using the pen.
3. They go back to the office and salesperson puts pen in a pen-holder which is connected to his terminal through a serial interface.
4. The salesperson brings up the client's account in an empty invoice and the barcode numbers are loaded into the sales slip.
5. The salesperson completes the sale and prints the invoice in the office.
6. In the meanwhile a loading receipt is automatically printed in the docking area and the pieces are prepared for pickup.

The above scenario is very simple to handle with today's technology, but with the technology available in 1985, there were many hurdles to handle. The system was so stable that even as late as 1995 one of the clients was still using the system.

At the time, DOS solutions were only capable of using Novell networks with very limited capabilities, at great costs. For example, a 5-station system would have used an IBM PC for each station and would only allow peer-to-peer networking and would cost around \$30,000. However, this pure multiuser solution only cost 6,000.

Products *(Libraries written by Homayoon Beigi in the last 23 years)*

These libraries contain over 5 million lines of code and include, but are not limited to,

1. *Encryption Library* – Capable of doing encryption/decryption, hashing, coding, etc.
2. *Database Library* – Includes completely inclusive database design, all developed in-house. This library is capable of 64-bit addressing, advanced regular expression searches. It is fully configurable through text configuration files and allows over 25 different types including Credit Card information, passwords, hash codes, basic types, Email addresses, URLs, etc.
3. *Common Gateway Interface (CGI) Library* – This library allows for the conversion of any C^{++} application to one operating as a CGI application which would run through a web interface. This library has been under development since 1996 and has great capabilities. It natively links with the Database and Encryption libraries listed above, to create a seamless CGI interface. This library is one of the core components of the **CommerceMadeEasy[®] product**, as well as other products.
4. *Error Handling Library* – This library allows for error handling and tracking, throughout any product that links with it. It is an essential part of all products and makes interactions quite practical.
5. *Mathematics Library* – This library contains a very rich set of mathematical functions which are based on the handling of matrices in a C^{++} setting. The interface to this library is very simple and all functions have been optimized over the past 23 years to provide very fast operations. It is an integral part of all product engines.
6. *Licensing Library* – This complete license management library provides licensing capabilities to all products. It makes the distribution of the engine possible. It is designed so that new modules may be easily configured into the license with full backward compatibility. It works in conjunction with the encryption library and it is an essential part of all products. This library supports different operating systems including Linux, Mac, and Windows, each of which require different techniques for handling the license management.
7. *RecoMadeEasy[®] Library* – This is a base library which is capable of handling configuration files, understands how to interact with the licensing library, includes most of the basic operations that any recognition would use. It is inherited by all product engines with this registered trademark name.
8. *Access Library* – This library provides functionality for access-control related applications. See [video demonstrations](#).
9. *API Library* – Since all engines have a unified API, this base library, once inherited, allows for all API functionality.
10. *Audio Library* – This most essential library handles all lower level processes related to handling different audio formats and codecs. It is used by any engine which requires an audio interface.

11. *AudioVisual Library* – This library works in conjunction with the audio and image libraries to allow the handling of a combination of these two media, including video codecs.
12. *Clustering Library* – This library handles all supervised and unsupervised clustering functionality. It is essential to all pattern recognition engines.
13. *Face Library* – This library provides all the lower level (algorithmic) functionality related to face recognition.
14. *Handwriting Library* – This library handles all handwriting and signature related functionality including algorithmic, capture, and feature extraction mechanisms.
15. *Image Library* – This library handles arrays of images, their representations, manipulations, algorithmic and input/output aspects. It is the analogue of the audio library in the image domain.
16. *Input Library* – This library handles all input related aspects including keyboard, tablet, etc.
17. *IVR Library* – The Interactive Voice Response (IVR) library is a complete library which includes agnostic IVR functionality as well as wrappers for popular cards such as most [Dialogic](#) cards. It uses a fully connected graph mechanism which is a part of the tree library. This is the most essential part of the IVR engine and has been in use at Recognition Technologies, more than any other library, in an intense use scenario. This library has been used to record more than 30,000,000 minutes of conversational audio within the systems of [Recognition Technologies, Inc.](#)
18. *Language Modeling Library* – This library is capable of loading and manipulating huge language models including NGram models and grammars in highly efficient proprietary formats, in the memory. It is an essential part of the speech recognition engine.
19. *Media Library* – The media library is an intermediate library which combines and understands audio and image formats and knows how to relate them to video codecs. It is an integral part of all audiovisual engines.
20. *Memory Map Library* – This library allows for the seamless use of memory-mapped files in place of regular memory, in any type of process within the RecoMadeEasy® family of engines and products.
21. *Search Library* – This library includes the implementation of several optimal and suboptimal search algorithms which, for example, are used for speech and handwriting recognition engines.
22. *Speech Library* – This library provides most algorithmic functionality needed by speech recognition, which is not in common with speaker recognition.
23. *Speech Front-End Library* – This library handles all signal processing, feature extraction, and feature manipulation for speech and speaker recognition.
24. *Speech Utility Library* – This library provides a large number of algorithmic and manipulation functionalities for use with speech and speaker recognition.
25. *Speaker Library* – This library provides higher level speaker recognition functionality such as different speaker recognition modalities.

26. *Transform Library* – This library provides many mathematical transformation libraries. This library is used by most recognition engines.
27. *Windows Library* – This library provides transformations in order to unify the code so that there is no need to write specific code to run on the Windows operating system. This library makes the job of maintaining a Windows engine much easier.
28. *Text IO Library* – This library provides many text manipulation and input/output functionalities which is at the heart of all other libraries. These could be parser functions for the language related to tree or graph definitions, configuration file definitions, etc.
29. *Tree Library* – This last, but by no means least library provides a very powerful set of functionalities for handling different types of trees and graphs. It has been optimized immensely through the past 23 years and it is used by most libraries, including the handling of recursive and cascaded configuration files, graph definitions for the IVR, etc.
30. *Neural Network Library* – This library contains the main deep learning algorithms for training and decoding for many different architectures including feedforward, Time-Delay Neural Networks (TDNN), Convolutional Neural Networks (CNN), Long Short Term Memory (LSTM), Recurrent Neural Networks (RNN), Transformers, Conformers, and some proprietary architectures. This library has been developed over the past 23 years and includes many algorithms that I have developed over the past 4 decades.
31. *CUDA Libraries* – This library provides mathematical alternatives for the functions in the Math library to utilize the graphic processing unit (GPU) for doing highly parallel computation.

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Research Projects

The following is a non-exhaustive list of the research projects, in which I have been indulging. They include work that started as far back as when I was doing my graduate studies at Columbia University. Many of the projects are still alive and there is ongoing research in all aspects. Because of the many years of work that has been done on these research projects and due to special attention to organization and generalization of the code, a highly efficient research effort has been brewing for many years. I owe most of this to the multi-disciplinary attitude that I have had, since the inception of my research effort. I believe that nothing should be done more than once and that it is important to generalize both formulation of a problem and its implementation so that a lot of the work may be reused for other problems that may come up.

Speaker Recognition (1996 – Present)

I started working on speaker recognition by developing algorithms and creating the first version of the [speaker recognition engine of IBM Research](#) [1]. I have developed a number of successful techniques for large population speaker recognition in addition to general research and development in the field of pattern recognition with applications to Speaker Recognition (Large-Scale Identification and Verification), Segmentation, hybrid systems with face recognition and text processing, large scale search techniques, etc. This work is still ongoing and has been turned into a [product](#) [2] at [Recognition Technologies, Inc.](#) which became the only winner of the [2011 Frost & Sullivan North American Speaker Verification Biometrics, New Product Innovation Award](#).

As a most important achievement, I wrote the first and only [textbook on speaker recognition](#) [3] and many other [book chapters](#) [4, 5, 6], [journal papers](#), etc. I have also extended these techniques to the problem of [structural health monitoring](#).

An important aspect, making the research results practical enough to be used in [products](#) [2] is the immense *data collection initiative* at [Recognition Technologies, Inc.](#) for the past 20 years. Due to the statistical nature of the algorithms, it is essential that large representative amounts of data are used. Due to this effort, [Recognition Technologies, Inc.](#) has the largest number of speakers recorded in natural settings with different sessions. This data has been used for the training of the speaker recognition models. This data entails over 1.5 million distinct speakers in many different settings, many of whom have been recorded in multiple sessions.

In the past few years, I have also hired an average of three interns per summer and a full time research assistant from the computer science and electrical engineering departments of Columbia University and have mentored them in conducting research and developing products in speaker [2] and speech recognition [7] engines.

Face Recognition (2010 – Present)

Developed very robust face recognition algorithms with practical implementations, used in the identification and verification of full-frontal faces in very large populations with great success. This work is still ongoing and has been turned into a [product](#) [8] at [Recognition Technologies, Inc.](#) As

with the rest of the research projects, I am reusing most of the [library functions](#) that I have used for speaker recognition, speech recognition, and other projects in the face recognition research. This is the main reason for the quick results obtained in this work, leading to product-level code.

Speech Recognition (1996 – Present)

Extensive participation in the research connected with the [IBM ViaVoice product](#) [1]. Research areas include all aspects of Large-Vocabulary speech recognition, speech segmentation, and Small-Vocabulary systems.

In 2003, I continued performing speech recognition research at [Recognition Technologies, Inc.](#) This lead to the development of several [speech recognition engines](#) [7], as well as a [language proficiency rating engine](#) [9]. The speech recognition and speaker recognition engines share as many of the [libraries](#) as possible. This allows for faster implementation of new algorithms across the two paths. Currently, most of my effort is on the improvement of the search engines and models. Currently a combination of Hidden Markov Models and Deep Belief Networks are being used in my research. The [nonlinear neural network learning algorithms](#) that I developed in the late 1980s and early 1990s are being used for the training of the networks. Also, techniques such as islands of high probabilities are being utilized for improving the search results.

Since 2012, interns from [Columbia University](#) have been helping with the large number of training and test experiments that need to be done for testing different algorithms.

Biometric Fusion and Multimedia Diarization (1997 – Present)

Speaker diarization is one of the most practical research projects which benefits any industry which archives and searches through multimedia files such as video and audio files. This has been a major focus of my work and has lead to my development of some of the [first speaker segmentation](#) [10] and [large-scale speaker identification](#) [11] systems. I have been creating the constituents of a good diarization system by working, for years, on speaker recognition, face recognition, speech recognition, and methods for combining the results. In the process, I have developed many valuable products based on fusing these systems at [Recognition Technologies, Inc.](#) such as [RecoMadeEasy® Audiovisual Recognition Engine](#) [12] and [RecoMadeEasy® Access Control Engine](#) [13] and many products at [IBM Research](#).

One of my major accomplishments at IBM Research was the [fusion of speaker recognition, face recognition, and speech recognition](#) [14] engines to produce quality diarization of video files. This produced meta data based on segmenting the media according to speaker change and a change in the output of the face recognition system. This produced labels for the video content. Simultaneous transcription through the speech recognition engine provided transcribed text. The combination of these knowledge sources produced searchable meta-data which allowed for further searches on specific content by requesting segments in which a specific individual spoke about a certain topic. This work produced many journal papers and patents. One of these patents was deemed as one of the Top 10% Valuable Patents (Patent Number [6,421,645](#)) at [IBM Research](#).

Mechanical and Structural Health Monitoring (1989 – 1990 & 2012 – Present)

Structural Health Monitoring (2012 – Present)

Joint (multidisciplinary) research with the civil engineering department of Columbia University on the use of speaker recognition techniques for the monitoring and prognosis of the health of structures such as bridges and buildings. This work was done with [Prof. Raimondo Betti](#) of the [civil engineering department](#) and it provided the material for a full PhD thesis [15], just defended by Luciana Balsamo. This work has resulted in a PhD thesis, as well as *several joint publications* [16, 17, 18] with [Prof. Betti](#) and Dr. Balsamo. [Prof. Betti](#) and I are still collaborating on this project and will be conducting a lot more joint research. In addition, at [Recognition Technologies, Inc.](#) I have rekindled the research on mechanical health monitoring and will be having new products for the market, in the near future.

Mechanical Health Monitoring (Jan. 1989 – Dec. 1990)

Fault detection of mechanical systems and machine health prognosis, funded by the [U.S. Navy](#) and supervised by Prof. C. James Li. Developed practical signal processing techniques for the health prognosis of mechanical components such as bearings, gears, cutting tools, etc. This project included the design and implementation of the sensors and the data acquisition apparatus, as well as extensive pattern recognition algorithm design and implementation for the automatic detection of faults in different components.

Information Theory and Language Modeling (1991 – Present)

I performed extensive research in information theory and language modeling, pertaining to usage with Text Processing, Handwriting Recognition, Speech Recognition, and Hybrid Search systems using Textual Language as well as Speaker Voice and Face information. This also evident from the extensive treatment of highly compressed dictionaries [19], statistical N-Grams [20, 21], Template Language models [22] and Decision-Tree-based Language Models.

Aside from my original work in the above topics, in my [textbook on speaker recognition](#) [3], I have given a very complete and detailed coverage to information theoretic concepts since they lie at the basis of most of the work in machine learning and pattern recognition. I have also made a lot of observations regarding different concepts that have baffled researchers in the past such as the relation between the definition of Information as presented by Wiener and Shannon in the same year (1948), along with in depth analysis of the seminal works in the field.

Education and Language Proficiency Testing (2006 – Present)

At Recognition Technologies, Inc., starting with [Language Testing International](#) (LTI, now a division of [Samsung](#)) and the [American Council on the Teaching of Foreign Languages](#) (ACTFL), I was asked to automate the rating of tests conducted on over 100 languages for assessing proficiency of professionals seeking to be hired by large multi-national corporations and government agencies. [ACTFL](#) is a nonprofit organization defining proficiency test procedures and [LTI](#) is a profit-oriented company administering such tests. [LTI](#) administers oral, conversational, and written tests in different capacities. In their oral tests, their best raters rate 80% of the population as Intermediate Mid level which is one of 10 possible levels (Novice Low, Novice Mid, Intermediate Low, Intermediate

Mid, Intermediate High, Advanced Low, Advanced Mid, Advanced High, and Superior. This had presented them with the quandary of handling ratings in a more granular fashion to produce more discriminability. In addition, they rate over 1,000 tests per day for just a single site in Korea. It was very important to automate this rating process.

I worked on the problem starting in 2006 and by 2008 was able to modify our speech and speaker recognition engines to automatically rate oral tests at a rate of 10 times realtime, attaining three times the granularity of the human ratings (breaking Intermediate Mid to IM1, IM2, and IM3 levels). These granularities are not achievable by normal raters. In fact, in order to evaluate our engine's rating quality, [LTI](#) asked three of their top 1% most experienced raters to independently rate over 1000 tests at the higher granularity. Then our engine rated the same tests. For the ratings where 2 of the 3 raters agreed, the rating was over 85% correlated with our results. This was more than double the consistencies achieved by their best human raters. Also, the best their raters would do, in terms of speed, would be understandably at best realtime since they would have to listen to the whole test to make a decision. Whereas we rated each test at ten times realtime! (See the related [book chapter](#) [23] and [technical reports](#) [24, 25].

The success of this research warranted large grants over the past 7 years from [LTI](#), [ACTFL](#), and [the Center for Language Studies of Brigham Young University](#) for this and other research on written and elicited oral testing. Currently, I am utilizing our [RecoMadeEasy[®] Speech Recognition engine](#) [7] in conjunction with our [RecoMadeEasy[®] Automatic Language Proficiency Rating engine](#) [9] to rate elicited responses for English and Italian.

My research in this field has attracted two more companies (an Italian company and a [start-up company](#) created by two of my ex-IBM colleagues. We are in the process of creating completely automated rating systems for students of English and Italian, to be following with other languages such as Polish.

Optimization (1986 – Present)

At the heart of most of my research, lies a strong base of optimization techniques. My [doctoral thesis](#) [26] was mostly based on the application of different nonlinear optimization techniques to the [learning-control](#) [27, 28, 29, 30, 31, 32, 33] and [neural network learning](#) [34, 35, 36, 37, 38, 39, 40, 41] problems.

In addition to the thesis, many of my other peer-reviewed publications show the use of these techniques. This was the motivation behind the [Merrill Lynch research group](#) seeking my expertise in solving a very tough constrained optimization problem with over 35,000 variables, for realtime solutions. See the related [portfolio optimization product](#) I produced, as a result of this research.

Handwriting Recognition (1991 – 1996 & 2003 – Present)

Over 6 years of research in large-vocabulary, unconstrained (any free-form combination of cursive, run-on, or discrete) handwriting recognition. Extensive work on Feature Extraction [42, 43, 44], Language Modeling, Search [45, 46, 47], Compression [48], Segmentation and Normalization [49] leading to a fully operational system [50]. I am presently, active in this area area of research through

In the feature extraction area, I devised many different kinds of new features for run-on, cursive, and eventually unconstrained handwriting recognition, including the creation of **new dynamic features** [42, 43] based on an approximation of the hand motion with a time-variant second order differential equation and the use of the time varying parameters as truly compressed features of handwriting for each stationary part of the signal. This was complemented by the **fusion of these dynamic features with static features** [46, 45], as different codebooks, to increase the accuracy of recognition.

The orientation and size normalization of unconstrained handwriting is a very hard problem. I presented **break-through techniques** for finding and correcting the orientation of handwriting, slant correction, rotation of the handwriting to abide by principal lines and finally size normalization so that increased robustness to orientation, size, slant, and other transformations was achieved. [49]

Search was another problem that I addressed and achieved considerably great results in improvements made to our system at **IBM Research**. Using the techniques that were used in speech recognition, namely **beam and envelope search**, and modifying them to work with unconstrained online handwriting recognition, I made great advancement in the field. This made having unconstrained handwriting recognition possible and allowed us to leap from discrete and run-on techniques to unconstrained recognition. A very important problem that I addressed in this algorithm design and implementation was the handling of delayed strokes such as dots of “i” and “j” and the cross of “t,” etc.

Another one of my very important contributions was the creation of predictive language models based on a highly compressed representation of **character ngrams** [20, 21] with extremely fast access, **templates** [22], **predictive and postprocessing dictionaries** [19], and many other aspects which mean the integration of these techniques with my advanced search techniques.

This research has led to many publications which have been cited considerably. In addition, it produced a few products, both at **IBM** and at **Recognition Technologies, Inc.** Since the **handwriting recognition group at IBM Research** was a sister department with the **speech recognition group**, the first 6 years of research I did were in conjunction with the **speech recognition group** and most of the algorithms were shared. In fact aside from the front-end and the analogy of characters in handwriting recognition to words in speech recognition, the rest was pretty much the same. I worked on all aspects of the problem and this was a great opportunity for me to get to understand the details of speech recognition as well, helping me to transit into the **speech recognition group** for the last few years I was at IBM.

A segment of online handwriting is an analogue of a frame in speech, but far less number of segments come up in a sentence in unconstrained handwriting recognition. This gave me the opportunity to get a better understanding and visualization of the search process than starting on the speech problem. Later, extending that experience to speech recognition helped me excel beyond other researchers who may have started directly in speech recognition.

This is yet another milestone in helping create my multi-disciplinary background.

Neural Network Learning (1986 – Present)

One of the most important works that I presented was the tensor formulation of the problem of learning in general feedforward neural networks which enabled me to apply many different advanced nonlinear learning algorithms to learning in neural networks. This work was presented in many publications as well as my [doctoral thesis](#) [26]. This notation which I picked up from my background in mechanical engineering, namely the treatment of solid and fluid mechanics stress, strain, and energy equations, makes the mathematical representation of the output of a neural network to its input, weights, and activation functions much more manageable.

With this, I made break-throughs in highly efficient learning schemes using second order techniques in optimization for Feed-Forward Neural Network Systems, right at the onset of the subject, in fact just a year after Rumelhart's seminal paper on back-propagation. I produced several journal and conference papers in this field including **two IEEE Best Paper Awards** for two conference papers in the field [39, 40].

This work has been revived around 2005 and on, in the name of deep belief networks. Some of this work is using stochastic versions of well-known optimization techniques. My work, which were published in the 1990s, are now being reinvented for learning in deep belief networks. Examples were presented at the New York meeting in 2013 which were foreseeing the possibility of using nonlinear techniques for solving the multilayer neural network learning problem. However, I had published these and more complex techniques, in the 1990s, facilitated by my tensor-notation based formulation of the learning problem in multi-layered neural networks. [34, 35, 36, 37, 38, 39, 40, 41] Still many of these works have not been explored by researchers in the field, where they have already been published as part of my doctoral thesis in 1991 [26] and a few conference and journal papers, including the two that received the IEEE best paper awards listed above.

I have been working on extending the stochastic versions my learning theory for multi-layered neural networks, in order to produce much more efficient learning algorithms in deep belief networks (DBN). This work is quite useful in the training of our latest DBN-based (fused with HMM-based) speech recognition engine.

Another very important contribution to the field of neural network learning, which works well for deep belief networks is the better handling of local minima toward attaining a global direction. I handled this by creating a [dynamic architecture](#) [36] which helps reduce the chance of falling into local minima, while performing an [optimally conditioned quadratic optimization](#) [36]. This done by adding new neurons while going through the optimization process. This adaptive architecture creates experts for part of the optimization problem as it builds the hidden layers.

Learning Adaptive Control (1986 – 2002)

I formulated, *for the first time*, learning-adaptive control [32, 33] strategies and provided solutions based on Optimization Methods [29, 26, 31], adaptive ideas [28, 30], and new parameter estimation schemes [31]. This was the first learning-adaptive control strategy ever devised. It became a major part of my [doctoral thesis](#) [26] and became a breakthrough in the field. This was especially important for manufacturing processes. In fact that is why I was invited as the [guest editor of a special issue on learning and repetitive control](#) [51].

I also formulated a [continuous learning-adaptive control system](#) [28] with considerable improvement over existing techniques and theoretically sound control strategies based on my previous work on adaptive parameter estimation and optimization.

Another breakthrough came when for the first time, with the help of two colleagues, we extended my learning-adaptive control formulation the [continuous space in the space of repetitions, using a Hilbert Space mapping](#) [27, 30].

Pen-Based Music Editor (1995 – 1997)

I proposed the treatment of Online Common Music Notation using a Pen, while I was in the handwriting recognition group of IBM Research. This was in 1995 and was the beginning of a program called [Adventurous Systems and Software Research \(ASSR\)](#). The total grant allocation for the first year was \$250,000 which was allotted to be distributed among 5 finalists coming from hundreds of proposals which were given from different parts of the research division of IBM. My project received \$110,000 of the total and the rest (\$140,000) was distributed among the next 4 winning projects.

In the first year, I was able to create a complete editor using pen gestures, capable of inputting music common notation (CMN). This lead to another \$250,000 being allotted to my project in the second year. Unfortunately, since IBM decided to dissolve the online handwirting recognition group, the project was hybernated along with the rest of the handwirting recognition group. Sensing this, I had already moved to the speech group and had started working on speaker recognition.

This project is very close to my heart since [I am also a musician](#). I have been spuriously approached by several individuals who had read an article about my project in the IBM Research Journal, written in 1996. They have shown interest in what I was doing. I believe I will try to revive that work if I get a chance.

Image Compression (1990 – 1991)

In September 1990, after defending my doctoral thesis, I was hired by the [Center for Telecommunications Research](#) for two different, but related subprojects. These were part of a project with [the Library of Congress](#), designed to digitize and preserve works of art, at the library. Since the pieces of art were generally at museums, lossless images of them needed to be digitized and transmitted over the slow lines of 1990 to the library of congress to be preserved. This needed to be done for thousands if not millions of works of art. Speed was essential. In addition, this needed to be done on DOS with all its limitations including 640 MB RAM and lack of a windowing system.

The first thing I did was to create a lossless compression scheme based on hybrid Huffman coding which I designed so that it would be able to minimize errors due to transmission. The algorithm used multiple codebooks with the usual variable length Huffman code. The codeboos related to the different color bins available in the art piece. This was done for true-color TIFF files with 32-bit color depth. I finished the algorithm and its implementation before leaving for IBM Research in February of 1991.

In addition, I wrote drivers in C for ultra-fast rendering of the images on a super-VGA screen which had just come out. Native drivers did not exist for it or were very slow. I implemented the driver by painting the 4 levels in fragments of memory and then dumping the contents onto the screen, using proper interrupts, etc.

Signature Compression and Recognition (1991 – Present)

Some of the experience from the image compression research, with the later work on handwriting recognition provided a natural mindset of compressing signatures to fit on the back of credit and debit cards. The magnetic strip on the back of a credit card can hold 54 bytes of data. It is a natural process to expect saving the signature information in whole on the back of a credit card. Also, developing dynamic features [42, 52, 43] and segmentation for handwriting recognition provided the means for coding the dynamics of signatures into a stream of features. These features are naturally possess the shortest code-length for describing online handwriting. This is because the **dynamic features**, that I derived, were based on parameters of differential equations approximating the segment of writing. Combining the two concepts, I was able to create a **very aggressive compression algorithm** [48] and **apparatus** [53] for describing all the dynamics and shape of a signature in less than 54 bytes, making it possible to store up to three dynamic signature templates on the magnetic strips on the back of credit or debit cards.

In addition, having these templates, I used statistical techniques similar to those used in speaker recognition to create useful signature verification and identification algorithms. This led to the creation of another **product at Recognition Technologies, Inc** [54].

Kinematics (1984 – 1986)

My concentration in my masters program at the mechanical engineering department of Columbia University was **Kinematics, Dynamics, and Control**. One of the greatest researchers in the field of Kinematics, known as the father of Kinematics, the late Prof. Ferdinand Freudenstein taught me three courses in the course of this degree. After completing my masters degree I approached Prof. Freudenstein and asked whether he had any research projects for me. He came up with the task of generalizing the equation of motion for the kinematic analysis of different 4-bar linkages into one single general equation that would cover the different types of 4-bar linkages, namely, “Planar, Spherical, Skew, and a special case of planar known as the plane slider-crank.” He said he was approached by the **Journal of Mechanism and Machine Theory** to provide original work as an invited paper for their anniversary edition. He asked whether I would be able to derive the equations and to program the equations of motions of each type of linkage with the new general equation as a comparison, before the deadline. I worked on the derivation and coding and produced my first paper [55], being a journal paper, with Prof. Freudenstein, a pleasure and a steep learning experience.

Image Processing for Fluid Mechanics Analysis (1984 – 1985)

Right at the beginning of my master program, I worked on digital image processing applied to fluid

mechanics for the analysis of lubricants' behavior in zero gravity – An experiment conducted in conjunction with the [first NASA Spacelab project – STS-9](#).

I designed and created a digitization platform using a sonic digitizer and wrote drivers for the digitizer in C, on an IBM PC platform. Digitized every frame of 24 frame-per-second film, taken of the spreading of fluids on different surfaces, with different viscosities, by the crew of the Columbia Shuttle in the Spacelab module. This data was used by Prof. Coda Pan to formulate the equations that describe the spreading characteristics of fluids on different smooth surfaces in zero gravity.

Doctoral Research Abstract (Jun. 1985 – Sep. 1990)

The problem of learning in general Feed-Forward Neural Networks has been formulated as a minimization problem. Several new algorithms have been developed for **learning in Feed-Forward Neural Networks** which are based on classical and modern **Quasi-Newton** minimization techniques. These methods achieve quadratic convergence by approximating the inverse of the Hessian of the objective function for neural network learning and thus providing Newton-like search directions. Benchmark simulation results have shown **two to three orders of magnitude improvement on the rate of learning** and **many orders of magnitude improvement in the accuracy** of these learning schemes when compared to the state-of-the-Art in Neural Network Learning which have previously been limited by steepest descent methods.

Due to the complexity of gradient evaluations even for a neural network of moderate size, learning algorithms requiring no gradient evaluations are called for. Learning algorithms have been developed based on **gradient-free** minimization **techniques**. These algorithms **require only the output of the network** to perform learning. Consequently, no analytical gradient expressions would have to be provided to the system, eliminating the need for a conventional computer to carry out the gradient evaluations. This makes the algorithms **independent of the architecture** of the neural network. As a result, negligible amount of computation and software/hardware is needed for learning. In addition, independence of the architecture implies that *if a neuron is damaged or a connection is severed, the learning could still be carried out to the full extent*. The result is a **more implementable network** which could *learn much more quickly and more independently*. Simulation results have shown a great reduction in the computation time and practicality of these algorithms.

The general **learning control of repetitive linear time-variant processes** (such as manufacturing processes) is formulated as a minimization problem. Many different minimization schemes have been evaluated for solving this problem. Finally, a **learning controller, which requires the theoretical minimum number of repetitions of the task for convergence**, has been developed **based on a Modified Generalized Secant method** of solving a set of linear equations. This controller has shown an **outstanding performance and robustness** when applied to the control of **nonlinear systems**. There is **no on-line computational burden** in the use of this controller.

Additionally, a **Recursive Learning Parameter Estimator** has been developed for usage in a **Learning Self-Tuning Regulator** applied to the *control of repetitive processes*. Simulation results show great improvement in the performance of conventional controllers when used with this

parameter estimator in the repetition domain. The on-line computational burden of this controller is only slightly higher than that of a PID controller.

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Standards Development

- 2003–2010 ***VoiceXML 3.0***
As an [active liaison and driving force](#), helped define the speaker recognition functionality of [VoiceXML 3.0](#).
- 2003–2010 ***Standard Audio Format Encapsulation (SAFE)***
Personally defined a [new standard for audio format encapsulation \(SAFE\)](#) which has been used by several standards committes for handling interoperability among government organizations and the private industry. This format ([SAFE](#)) was adopted by [ANSI/INCITS](#) and [ISO](#) without any modification.
- [ANSI/INCITS](#)
As an active liaison and driving force of the [ANSI/INCITS Standards Development for Biometric Formats](#), proposed [SAFE](#) to be considered as an [ANSI](#) standard. It was presented and underwent a public review. It has been incorporated into an American National Standard Institute (ANSI) standard for audio format of raw data interchange for use in speaker recognition without any opposition.
- [ISO](#)
As an active liaison for the U.S. delegation of [the International Organization for Standardisation \(ISO\)](#), proposed [SAFE](#) to the committe. The [SAFE](#) proposal has been incorporated in the speaker recognition data interchange draft standards by the [ISO/IEC JTC1/SC37 project 19794-13](#) (voice data).
- 1996–1999 ***Speaker Verification Application Programming Interface (SVAPI)***
Helped define and test [SVAPI 1.0](#) and [2.0](#) as an active member and driving force representing [IBM Research](#) in the [SVAPI](#) consortium including [IBM](#), [Novell](#), [Dialogic](#), [ITT Industries](#), [Motorola](#), [Texas Instruments](#), [T-NETIX Inc.](#) and some U.S. Government organizations.
- 1996 – 1997 ***SVAPI 1.0*** Definition and Implementation
Implemented the [SVAPI 1.0](#) standrd interface for the [IBM Speaker Verification](#) engine and identified missing functionality to be included in version [2.0](#).
- 1997 – 1999 ***SVAPI 2.0*** Definition and Implementation
Worked to define and implement the new functionality need to do identifcaion and classification.

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Legal Expert Consulting

- 2026** Currently Engaged in an Interpartes Review proceedings. Details will be released in the future.
- 2025** Samsung v. Cerence Operating Company, IPR2025-00457, filed expert declaration.
- 2024** Completed an ex-parte request declaration on behalf of Unified Patents regarding Information Discovery and Retrieval in the Summer of 2024.
- 2023** Completed an ex-parte request declaration on behalf of Unified Patents regarding Natural Language Human-Machine Interaction in the fall of 2023.
- 2023** WHATFIX INC. v. WALKME LTD., IPR2023-01368, filed expert declaration, was deposed.
- 2023** WHATFIX INC. v. WALKME LTD., IPR2023-01379, filed expert declaration, was deposed.
- 2023** WHATFIX INC. v. WALKME LTD., IPR2024-00065, filed expert declaration, was deposed.
- 2019** MModal Inc. et al v. Nuance Communications, Inc., IPR2019-00210, filed expert declaration, was deposed twice.
- 2019** MModal Inc. et al v. Nuance Communications, Inc., IPR2019-00306, filed expert declaration, was deposed.
- 2018** MModal Inc. et al v. Nuance Communications, Inc., IPR2018-01355, filed expert declaration, was deposed twice.
- 2018** MModal Inc. et al v. Nuance Communications, Inc., IPR2018-01291, filed expert declaration.
- 2018** MModal Inc. et al v. Nuance Communications, Inc., IPR2018-01337, filed expert declaration.
- 2016** Global Tel*Link Corporation v. Securus Technologies, Inc., IPR2016-01220, filed expert declaration, was deposed.
- 2015** Global Tel*Link Corporation v. Securus Technologies, Inc., IPR2015-01225, filed expert declaration, was deposed.
- 2015** Global Tel*Link Corporation v. Securus Technologies, Inc., IPR2015-01220, filed expert declaration, was deposed.
- 2015** Securus Technologies, Inc. v. Global Tel*Link Corporation, IPR2015-00155, served as an expert consultant.