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Empowering the Growth of Signal Processing

The evolution of the IEEE Signal Processing Society

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Signal processing (SP) is a "hidden" technology that has transformed the digital world and changed our lives in so many ways. The field of digital SP (DSP) took off in the mid-1960s, aided by the integrated circuit and increasing availability of digital computers. Since then, the field of DSP has grown tremendously and fueled groundbreaking advances in technology across a wide range of fields with profound impact on society. The IEEE Signal Processing Society (SPS) is the world's premier professional society for SP scientists and professionals. Through its high-quality publications, conferences, and technical and educational activities, the SPS has played a pivotal role in advancing the theory and applications of SP. It has been instrumental in promoting cross-disciplinary collaboration and knowledge sharing among researchers, practitioners, and students in the field. This article highlights the SP advances between 1998 and mid-2023 and the evolution of the SPS to empower the growth of SP.

Introduction

Without hyperbole, SP is behind much of the digital world we live in today. The field of DSP took off in the mid-1960s, aided by the integrated circuit of Kilby and Noyce in the 1950s, the microprocessors of Texas Instruments and Intel in the 1960s, and the increasing availability of digital computers. A big push into the field can be attributed to the fast Fourier transform (FFT), by James Cooley and John Tukey, which reduced from $O(N^2)$ to O(N log N) the computation time of the FT. This allowed many SP algorithms that were already available to be implementable in close to real time. Around the same time, the first book on DSP, by Ben Gold and Charles Rader, appeared [1]. Since then, the field of DSP has grown tremendously and fueled groundbreaking advances in technology across many fields with profound impact on society. For example, DSP has revolutionized the way we create, store, and transmit audio and video content. DSP has enabled digital audio processing, high-quality audio recordings, and streaming services. Similarly, digital video processing techniques, such as compression, have made it possible to transmit high-quality video content over various networks. DSP has played a crucial role in the development of wireless

communication systems and the smartphone, which has become so ubiquitous in all aspects of our daily life that it is difficult for most people to imagine life without it. Techniques such as channel coding, and equalization have made it possible to achieve high data rates and reliable wireless communication over long distances. These techniques led to the widespread adoption of wireless technologies, such as Wi-Fi, Bluetooth, and cellular networks. DSP techniques, such as array processing, have played determining roles in geophysics exploration, radar, sonar, and other related applications. DSP has been instrumental in the development of medical imaging techniques, such as magnetic resonance imaging, computed tomography scans, and ultrasound. These technologies rely on DSP algorithms to process raw data and create high-resolution images of the human body, enabling doctors to diagnose and treat a wide variety of medical conditions with greater accuracy and precision. DSP has also enabled significant advancements in speech and audio recognition. Techniques such as voice recognition, speech to text, and music recognition rely on DSP algorithms to analyze and classify audio signals. This has led to the development of many popular applications, including virtual assistants, transcription services, and music streaming platforms. DSP has enabled the development of advanced control systems for a variety of applications, including robotics, aerospace, and automotive industries. DSP algorithms are used to analyze sensor data and control the behavior of complex systems, with high accuracy and precision.

The SPS is the world's premier professional society for SP scientists and professionals. It has nearly 20,000 members across 120+ countries. Through high-quality publications, conferences, technical, and educational activities, the SPS advances and disseminates state-of-the-art scientific information and resources, educates the SP community, and, by bringing people together, catalyzes advances in the field of SP.

The SPS has had many names since it was established, on 2 June 1948, as the first Professional Group on Audio of the Institute of Radio Engineers (IRE). In 1963, the IRE merged with the American Institute of Electrical Engineers to form IEEE, and the Professional Group on Audio became the IEEE Audio Group, in 1964. In 1976, the IEEE Audio Group was renamed the IEEE Acoustics, Speech, and Signal Processing (ASSP) Society, reflecting the Society's expanding scope beyond audio processing to include SP in a broader sense. In 1989, the ASSP Society changed its name to the SPS, due to the growing field of image processing.

The SPS currently has 12 technical committees (TCs), 3 technical working groups (TWGs) and 2 megatrend initiatives that support a broad selection of SP-related activities associated with specific areas of study within the SP field. The TCs are actively involved in awards, conferences, publications, and educational activities. The Society's leadership leans heavily on TC members for their advice on specific areas within SP. The TCs are

1) Applied Signal Processing Systems TC
2) Audio and Acoustic Signal Processing TC
3) Bio Imaging and Signal Processing TC
4) Computational Imaging TC
5) Image, Video, and Multidimensional Signal Processing TC
6) Information Forensics and Security TC
7) Machine Learning for Signal Processing TC
8) Multimedia Signal Processing TC
9) Sensor Array and Multichannel TC
10) Signal Processing for Communications and Networking TC
11) Signal Processing Theory and Methods TC
12) Speech and Language Processing TC.

The TWGs include

1) Industry TWG
2) Integrated Sensing and Communication TWG
3) Synthetic Aperture TWG.

The megatrend initiatives are:

1) Autonomous Systems Initiative
2) Data Science Initiative.

The SPS currently publishes several high-impact periodicals, including *IEEE Signal Processing Magazine*; *IEEE Open*

Journal of Signal Processing (*OJ-SP*); *IEEE Journal of Selected Topics in Signal Processing*; *IEEE Signal Processing Letters*; *IEEE/ACM Transactions on Audio, Speech, and Language Processing*; *IEEE Transactions on Information Forensics and Security*; *IEEE Transactions on Image Processing*; *IEEE Transactions on Signal Processing*; *IEEE Signal Processing Society Content Gazette*; and *Inside Signal Processing Newsletter*. The SPS publishes about 3,000 journal papers annually.

Reflecting the highly interdisciplinary nature of SP, the SPS publishes jointly with other IEEE Societies a growing list of journals, including *IEEE Transactions on Computational Imaging*, *IEEE Transactions on Signal and Information Processing Over Networks*, *IEEE Transactions on Multimedia*, *IEEE Transactions on Big Data*, *IEEE Journal on Biomedical and Health Informatics*, *IEEE Transactions on Cognitive Communications and Networking*, *IEEE Transactions on Medical Imaging*, *IEEE Transactions on Mobile Computing*, *IEEE Transactions on Wireless Communications*, and *IEEE Wireless Communications Letters*.

The SPS is also involved with a large number of IEEE-level publications, including *IEEE Sensors Journal*, *IEEE Control Systems Letters*, *IEEE Transactions on Affective Computing*, *IEEE Computing in Science and Engineering Magazine*, *IEEE Internet of Things Journal*, *IEEE Internet of Things Magazine*, *IEEE Transactions on Computational Social Systems*, *IEEE Life Science Letters*, *IEEE MultiMedia Magazine*, *IEEE Transactions on Network Science and Engineering*, *IEEE Reviews in Biomedical Engineering*, *IEEE Transactions on Smart Grid*, *IEEE Security & Privacy Magazine*, *IEEE Transactions on Artificial Intelligence*, *IEEE Transactions on Green Communications and Networking*, *IEEE Transactions on Quantum Engineering*, *IEEE Transactions on Computational Social Systems*, *IEEE Transactions on Machine Learning in Communications and Networking*, *IEEE Journal of Indoor and Seamless Positioning and Navigation*, and *IEEE Transactions on Radar*.

The Society also organizes several conferences and workshops each year as a sole sponsor [7]. The two flagship conferences are the International Conference on Acoustics Speech and Signal Processing (ICASSP) and the International Conference on Image Processing (ICIP). ICASSP was first held in 1976 and is, in a sense, the continuation of the Arden House workshop, which was first held in 1968 with a focus on the FFT. The first ICIP was held in 1994. Other SPS solely sponsored workshops, mainly focused on the areas covered by the SPS TCs and on new areas the SPS is exploring, include the IEEE Workshop on Automatic Speech Recognition and Understanding (ASRU); IEEE International Workshop on Computational Advances in Multi-Sensor Adaptive Processing (CAMSAP); IEEE Data Science and Learning Workshop (DSLW); IEEE Workshop on Image, Video, and Multimedia Signal Processing (IVMSP); IEEE Workshop on Machine Learning for Signal Processing (MLSP); IEEE Workshop on Multimedia Signal Processing (MMSP); IEEE Sensor Array and Multichannel Signal Processing Workshop (SAM); IEEE Workshop on Spoken Language Technology (SLT); IEEE Workshop on Signal Processing Advances in Wireless Communications (SPAWC); IEEE Workshop on Statistical Signal Processing (SSP); IEEE Workshop on Applications of Signal Processing to Audio and Acoustics (WASPAA); and IEEE International Workshop on Information Forensics and Security (WIFS). Several thousand people attend our conferences annually, and conference recordings are kept in our SPS Resource Center for later access.

The SPS also cosponsors a growing list of conferences and workshops, including the IEEE International Conference on Multimedia and Expo (ICME), IEEE International Symposium on Biomedical Imaging (ISBI), IEEE Conference on Advanced Video and Signal-Based Surveillance (AVSS), ACM/IEEE International Conference on Information Processing in Sensor Networks (IPSN), IEEE International Symposium on Signal Processing and Information Technology (ISSPIT), IEEE Workshop on Signal Processing Systems (SiPS) and IEEE Conference on Artificial Intelligence (IEEE CAI).

Over the years, the SPS has played a pivotal role in advancing the theory and applications of SP. It has been instrumental in promoting cross-disciplinary collaboration and knowledge sharing among researchers, practitioners, and students in the field.

Key developments in SP and the SPS

The developments in SP and the evolution of the SPS up to 1998 are described in [2], which was published on the 50th anniversary of the Society. In this article, we summarize some of that history and expand on developments after 1998 until mid-2023.

The 1940s and 1950s: The advent of DSP

The Wiener filter, in the 1940s and 1950s, and Kalman and Kalman-Bucy filtering, in 1960, addressed the processing of noisy signals with many applications, from radar to communications and guidance and control. In the 1960s, SP techniques were developed in geophysics exploration for oil discovery, with Burg developing his linear prediction algorithm that also found wide application in speech processing. Array processing techniques, such as Capon's, detect seismic events and track underwater targets. The analysis of time series motivated by detection of underground nuclear explosions led Cooley and Tukey, at IBM, to propose, in 1965, a new fast implementation for the FT, the now ubiquitous FFT. The FFT reduced the computation time of the FT by orders of magnitude. This allowed many available SP algorithms to be implementable in close to real time. Around the same time, the first book on DSP appeared, by Gold and Rader [1]. Toward the end of the decade, the statistical theory of SP was finding more and more applications, with detection and estimation as major areas of activity. In 1968, Harry L. Van Trees penned the seminal book on detection, estimation, and modulation theory, summarizing the main tenets of the theory with applications to radar, sonar, and communications [3]. But these SP developments were happening in parallel to the core of DSP, as DSP was then emerging from speech and audio and radar applications through work, for example, at Lincoln Laboratories and Bell Labs.

The 1970s: DSP receives public attention and the rise of personal computers

The invention of the integrated circuit, by Jack Kilby, of Texas Instruments, in 1958 [8], and also independently by

Robert Noyce, of Fairchild, in 1959, significantly accelerated the development of digital computers. In 1971, Texas Instruments introduced the TMS 1802NC, and Intel created the Intel 4004, the first microprocessors with a 4-bit chip and a clock speed of 108 kHz [9]. In 1981, IBM introduced the first personal computer with a built-in hard disk, the IBM PC 5150 [10]. It had a 5.25-in floppy disk drive, 16 KB of random-access memory (RAM), and a 4.77-MHz Intel 8088 processor. In the 1970s and early 1980s, typical RAM sizes were in the range of a few hundred bytes to a few kilobytes, while the read-only memory (ROM) sizes were of the order of kilobytes. Hard disks were not yet widely available for personal computers, so data were typically stored on floppy disks with capacities of a few hundred kilobytes to a few megabytes. As computer technology advanced throughout the 1980s, clock speeds and memory capacities increased rapidly. By the end of the decade, personal computers were running at speeds of several tens of megahertz and had RAM capacities of several megabytes. These developments paved the way for the emergence of DSP and image processing, which rely heavily on fast processing speeds and large amounts of memory.

In the 1970s, DSP started receiving increased attention from the general public. During that time, in Britain, the BBC began using eight-track digital audio recorders with error correction [2], [4]. Thomas Stockham showed how DSP could restore old recordings of Enrico Caruso. In 1978, Texas Instruments designed a popular toy called Speak & Spell, which taught spelling by pronouncing a word and providing input on whether a spelling attempt was correct. Key DSP technologies were crucial to those advances, such as speech compression and the availability of the first integrated circuits for SP. During that decade, landmark books on DSP by Alan V. Oppenheim and Ronald W. Schaffer (1975) and Lawrence Rabiner and Ben Gold (1975) as well as the first book on digital speech processing, by Rabiner and Schaffer (1978), appeared [11], [12], [13]. Toward the end of the decade, Ralph O. Schmidt, with his MUSIC algorithm (published in the open literature in 1979), [14], and Georges Bienvenu and Laurent Kopp (1979), [15] introduced high-resolution subspace-based techniques to detect and localize nearby sources.

During that decade, the ASSP Society membership grew from 5,299 to 8,619 members. SPS publications included *IEEE Transactions on Audio and Electroacoustics*; *IEEE Transactions on Acoustics, Speech, and Signal Processing* (*T-ASSP*); *IEEE Newsletter on Audio and Electroacoustics*; and *IEEE Acoustics, Speech, and Signal Processing Newsletter.*

The 1980s: DSP a key player in data storage, image and video processing, and medical imaging

With the emergence of personal computers and cellular phones, array SP and digital communications became major areas of activity. Increasing levels of recording density required sophisticated new detection algorithms to read back accurately the recorded bits. Wavelets also appeared on the scene along with the first CDs, offering a new digital format for storing and playing music. The CD quickly replaced vinyl records and cassette tapes as the dominant music format. Biotechnology emerged as a significant field of study, with the development of new techniques for genetic engineering, gene sequencing, and biopharmaceutical production. This decade also witnessed much interest in digital image processing that laid the ground for video processing growth and led to important advances in a wide variety of applications, including multimedia, computer vision, medical imaging, image and video compression, virtual reality, and biometrics and facial recognition, to mention a few. The Society's journals and conferences were the publication of choice for much of the work on wavelets.

DSP was a key player in these technologies, and the ASSP Society membership grew from 8,619 to 15,925. SPS publications included *T-ASSP*; *IEEE Acoustics, Speech, and Signal Processing Newsletter*; and *IEEE ASSP Magazine.*

The growth of the Society led to the development of the Publications Board, the Conference Board, and the Awards Committee. In 1981, the ASSP Society joined the IEEE Engineering in Medicine and Biology Society (EMBS), the IEEE Nuclear and Plasma Sciences Society, and the IEEE Sonics and Ultrasonics Society to establish a new quarterly journal, *IEEE Transactions on Medical Imaging.* To address the increasing need for more content, in 1984, ASSP newsletter became *IEEE ASSP Magazine*.

The 1990s: Distributed web and new organizational structure for SPS' rapid growth

The World Wide Web rapidly grew in popularity, revolutionizing the way people accessed and shared information online. Personal computers became more affordable and widespread, and mobile phones became smaller, more affordable, and more popular. CD-ROMs became a popular storage medium for computer software, music, and video, replacing floppy disks and cassette tapes. Through the decade, disk drives recording densities grew at faster rates than Moore's law allowing for storing ever increasing amounts of data and requiring new signal processing algorithms to retrieve the data. JPEG was standardized in 1992, followed by the H.261 and MPEG conference and video standards. Digital cameras began to replace film cameras. E-mail became a widely used form of communication, voice over Internet Protocol technology was introduced, and e-commerce emerged. GPS became available for civilian use, allowing for accurate location tracking and navigation. Advances in wireless communications and Wi-Fi allowed for communication and computing anytime, anyplace, anywhere. Again, DSP played a big role in those technologies. On the research front, among many other areas, compressed sensing techniques experienced significant activity, with many papers appearing in SPS journals and conferences.

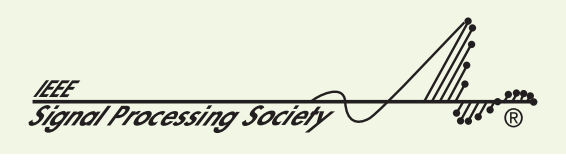
A new journal, *IEEE Transactions on Image Processing*, was introduced, in 1992, as a quarterly publication but quickly became monthly. Also in 1991, *T-ASSP* was renamed *IEEE Transactions on Signal Processing* (TSP). This was the year that the JPEG standard was established. *IEEE Transactions on Speech and Audio Processing* was introduced in 1993, *IEEE Signal Processing Letters* in 1994, and *IEEE*

Transactions on Multimedia in 1999. The SPS also cosponsored four other journals, including *IEEE Transactions on Evolutionary Computing, IEEE Transactions on Fuzzy Systems, IEEE Transactions on Medical Imaging,* and *IEEE Transactions on Neural Networks*. *IEEE ASSP Magazine* became *IEEE Signal Processing Magazine* in 1991. ICIP was established to address the rapidly growing field of image processing, and it was held for the first time in 1994.

During this decade, the ASSP Society became the SPS, and the membership grew to 19,835. The growth necessitated major revisions of the Society bylaws. A new administrative structure was approved, in 1993, so that the Society would be headed by a Board of Governors (BoG) consisting of the Society officers and 12 members at large. A smaller Executive Committee was created that would act on Society matters between the biannual BoG meetings.

In 1993, Mercy Kowalczyk became the first executive director of the Society. She hired Theresa Argiropoulos, in 1993, to assist with operational support. At that time, the three SPS publications were managed externally, by Peirce and Barbara Wheeler. In 1996, Nancy DeBlasi was hired to transition the publications operations in-house, and by the end of the year, Deborah Blazek was also hired to support the publications business. In 1998, additional staff was hired to address the growing workload in operations (Linda Skeahan) and publications (Kathy Jackson and Jo-Ellen Snyder). By 1998, the submission and peer review of papers of the *Transitions on Signal Processing* moved to the online management system Manuscript Control (MC).

In 1996, the Society selected its first logo, which was designed by Gabriel Thomas, at the time a graduate student at the University of Texas at Austin. This SPS logo was used between 1996 and 2019.



The Society took its first steps in electronic publishing, making the proceedings of the 1993 ICASSP available on CD-ROM—a first for IEEE conferences. In 1997, *IEEE Signal Processing Letters* was one of the first IEEE publications to be made available online. The following year, all Society transactions as well as letters were available online.

The 2000s: Distributed information processing and new SPS technical activities structure

With the emergence and proliferation of sensor networks, smartphones, and social media platforms, cloud computing became available, making it possible to store and access data over the Internet, revolutionizing the way businesses and individuals store and access information. Streaming services, such as Spotify, were introduced, and Netflix expanded, changing the way we consume entertainment. The use of artificial intelligence (AI) became more prevalent in the 2000s, with advancements in signal processing and machine learning, and with applications such as speech recognition and image recognition. AI has since become increasingly important in many industries, including health care, finance, and transportation. Sensor networks entered the scene, leading to a burst of research in distributed and decentralized information processing and optimization that became significant new areas to utilize the way data are collected, stored, and processed.

In 2002, the first ISBI was held; it was cosponsored and run by the EMBS and SPS. To strengthen the Society's coverage of biomedical topics, the Bio Imaging and Signal Processing TC was established, in 2004. The Society's interest in security issues with emerging technologies led to the 2006 creation of the Information Forensics and Security Technical Community. In 2008, the Image and Multidimensional Signal Processing TC, which was established in 1991, changed its name to the Image, Video, and Multidimensional Signal Processing TC. The Neural Networks for Signal Processing TC, which was founded in 1990, became the Machine Learning for Signal Processing TC, in 2003.

In 2006, the scope of *IEEE Transactions on Speech and Audio Processing* was expanded, with the journal becoming *IEEE Transactions on Speech, Audio, and Language Processing*. Continued progress was made with the Society's efforts to publish high-quality and relevant periodicals. In 2004, *IEEE Signal Processing Society Magazine* was ranked number 1 among IEEE journals in the Journal Citation Report, and it has since remained among the top journals in the field of electrical and electronic engineering as well as computer science. The magazine is widely recognized for its high-quality articles and practical tutorials that cover a wide range of topics in SP.

In 2006, *IEEE Transactions on Information Forensics and Security* was launched, and the following year, *IEEE Journal of Selected Topics in Signal Processing* was introduced. In 2009, the SPS became a technical cosponsor of two new IEEE publications, *IEEE Biometrics Compendium* and *IEEE Transactions on Affective Computing*. That year, IEEE International Workshop on Information Forensics and Security (WIFS) was also introduced.

In 1999, the Society approved a plan to digitize all its content, including journals, workshops and conference proceedings, newsletters, and other publications sponsored by the SPS. This led, in 2002, to the Society's Signal Processing Electronic Library (SPeL), containing all material published by the SPS from its 1948 beginnings through 2005. SPeL was released on two DVD-ROMs and enthusiastically received by SPS and other IEEE Members. It was intended to be a useful travel companion for SPS members. But events and technology dictated otherwise, and the Society donated the SPeL digital content to IEEE to form the emergent IEEE digital library, now IEEE *Xplore*. In 2001, SPS became the first IEEE Society with submission and peer review of all the journal papers handled online through MC.

During this decade, IEEE witnessed a drop in its membership, and the SPS membership changed from 19,835 to 14,897, coinciding with a shift of journal subscriptions toward

institutional customers instead of individual subscribers. The launch of IEEE *Xplore* gave broad access to SPS digital content through universities' and companies' *Xplore* subscriptions.

Other Society changes included the 2007 formation of a TC review committee charged with conducting formal reviews of the TCs, chaired by the president-elect. From this experience, the Society reformulated its Executive Committee and created the vice president, technical directions position, and the Technical Directions Committee was elevated to the Technical Directions Board, in 2007.

In 2008, effective 2010, the Society decided that all fully sponsored periodical publications of the SPS would become available in electronic format for free to all Society members as a member benefit. To help authors search for papers of interest, the Society introduced the monthly *IEEE Signal Processing Society Content Gazette*, in 2010, which contained the table of contents pages of all the Society's periodical publications. The digital versions of *IEEE Signal Processing Magazine* and the Gazette were also provided free to members.

Over the years, staffing grew to support the Society's expanding operations and new initiatives. Staff worked closely with the volunteer leadership on all areas of the Society's activities. The conference business was also growing, and the first conference staff was hired to provide support to that activity.

The 2010s: Higher-speed communications and emphasizing membership services

The popularity of smartphones dramatically increased in the 2010s. The introduction of 4G networks made it possible to access high-speed Internet on mobile devices. Internet of Things (IoT) technology became prevalent with the increasing number of connected devices, such as smart homes, wearables, and the industrial IoT. Graph-based data proliferated, initiating a new area in SP, graph SP. AI technology continued to progress with advancements in signal processing, deep learning and machine learning. In commercial SP technologies, AI is now used in a wide range of industries, including health care, finance, and manufacturing. Cloud computing continued to advance in the 2010s, making it possible to scale information technology infrastructure efficiently, making it easier for businesses to grow. The development of self-driving cars emerged with the potential to revolutionize transportation.

With such dramatic growth in commercial SP technologies, the Society focused its efforts on enhancing member services. In 2011, the SPS Membership Board was formed, and the position of regional director at large was created to bring regional perspective to the BoG and Membership Board. As a result of the Membership Board's formation, the vice president, awards and membership position was separated into the vice president, membership and Awards Board chair positions, and only the vice president, membership was a member of the Executive Committee. In 2014, the Executive Committee was further amended, with the president-elect also taking on the responsibilities of vice president, finance. With the increased emphasis on member services, SPS membership grew from 14,897 to 18,730 members in this decade.

Student membership was also cultivated. The first annual Signal Processing Cup (SP Cup) was established, in 2014. The SP Cup is a student competition in which graduate and undergraduate students work in groups to solve real-world problems by using SP methods and techniques. The program was expanded, in 2017, to include the Video and Image Processing Cup and, in 2020, the Five-Minute Video Clip Contest. The Student Career Luncheon at ICASSP was launched to help students explore job opportunities by connecting them with industry representatives. Since 2015, the Women in Signal Processing Luncheon has become an SPS-sponsored event at all major SPS conferences, and similarly, the Young Professionals (YPs) luncheon event launched in 2016, emphasizing the role of women and YPs in the Society. The Young Professionals Development Workshop was introduced at ICASSP 2019.

Other SP initiatives include the 2013 launch of the IEEE Global Conference on Signal and Information Processing (GlobalSIP) along with the IEEE China Summit on Signal and Information Processing (ChinaSIP). In 2018, the BoG approved discontinuing GlobalSIP after 2019, and beginning in 2016, ChinaSIP continued for a few years as the SPS Signal/Data Science Forum.

In 2013, Richard Baseil became the SPS executive director. That year, two special interest groups (SIGs) were established to address technical areas in big data and the IoT. In 2015, a third SIG was approved, on computational imaging, which was later elevated to a TC, in 2018.

In 2014, the SPS teamed up with the Association for Computing Machinery to jointly publish *IEEE/ACM Transactions on Audio, Speech, and Language Processing.* That year, two member benefits were introduced: SigView, an online portal of video tutorials with valuable educational content, and SigPort, an online archive of manuscripts, reports, theses, and supporting materials providing early exposure and peer feedback on work that is in progress. SigView videos were later relocated to the SPS Resource Center. Recognizing that data are a key element of SP, SigPort was duplicated and expanded to become IEEE DataPort, now an IEEE-wide product. Two new journals were added in 2015, *IEEE Transactions on Signal and Information Processing Over Networks* and *IEEE Transactions on Computational Imaging.*

In 2015, the Society also looked to popularize and promote SP and its applications to the general public. Target audiences included high-school and college students and other non-SP professionals. Several visibility videos were posted on the SPS YouTube channel: "What Is Signal Processing," "Signal Processing and Machine Learning," "Signal Processing in Free Viewpoint Television," "The Benefits of Spoken Language Technology," "Multimedia Forensics," and "Under the Radar." To enhance global reach, some videos were translated into Arabic, Spanish, and Mandarin. Videos about careers in SP were also created as well as other SP technology-related videos.

In 2016, the SPS created the IEEE Foundation Student and Young Professionals Fund, which is aimed toward enabling SP student and YPs programs and activities. In 2019, to promote student engagement, the student/graduate student Society

membership fee was set to US$1 annually. The Society also focused on diversity, equity, and inclusion (DEI), and its first diversity statement was created along with a diversity pledge and a DEI webpage [6].

Ethical use of SP techniques has always been an emphasis of the Society. Privacy is an ongoing concern among many SP-related fields, such as biometric data and datasets, so ethical guidelines continue to evolve for our publications and conferences.

SPS conferences started strengthening industry links. ICIP 2016 included an innovation program that featured state-of-the-art vision technologies, innovation challenges, talks by innovation leaders and entrepreneurs, tutorials, and networking. ICIP 2016 also launched a Visual Technology Innovation Award for industry leaders. ICIP 2017 also featured industry-focused keynote talks, panels, and programs related to several existing and emerging technologies. These industry initiatives have since been adapted by some ICIPs.

Another SPS change occurred in 2019. Historically, the BoG was responsible for electing Society presidents, but that year, it opened the vote to all members. A petition process was also instituted to give members additional opportunities to be heard. The Society also updated its logo to reflect the expanding world of DSP.

The 2020s: Autonomous systems, AI, data sciences, and new outlooks for SP

The first few years of the 2020s have been turbulent, to say the least. The COVID-19 pandemic impacted all aspects of life. Lockdowns and social distancing measures increased the demand for video conferencing, e-commerce, virtual events, online learning platforms, and digital health technologies, such as telemedicine and virtual care. Meanwhile, the rollout of 5G networks is providing faster and more reliable Internet connections, and the development of 6G is aiming to generate even higher rates to support autonomous vehicles and smart cities. AI applications, such as deep learning, natural language processing, and predictive analytics, are being used in a wide range of industries, including health care, finance, and transportation. Quantum computing technology promises to solve problems that are currently unsolvable with traditional computers, in areas such as cryptography, drug discovery, and weather forecasting.

The SPS has two megatrend initiatives: the SPS Autonomous Systems Initiative (ASI) and the SPS Data Sciences Initiative (DSI). ASI aims at highlighting the central role of SP in the design and development of autonomous systems, a multidisciplinary area cutting across AI, robotics, and the IoT. DSI coordinates the activities of the various TCs on data science, another area at the heart of SP. SP takes a broad view of signals and data since, once digitized, signals are data. To address the new set of applications, SP journals and conferences capture much of the research activity in distributed and decentralized peer-to-peer and networked environments and, in graph SP (GSP), the new theories and applications of graph-based data. Our publications and conferences continue exploiting a priori information about structure in problems/data, connections to physical applications (such as 3D audio, radar, and ultrasound), social and other emerging applications, and connection to computational platforms and scenarios, e.g., distributed computing, edge computing, and processing at the device, through peer-to-peer communications, possibly with no cloud and edge connectivity. DSI launched very successful webinars on brain research and GSP and has established a working group that works with the Education Board on incorporating topics around data science in academic and postacademic education curricula. The SPS Education Webinar program also grew significantly in 2022, when we offered a total of 55 webinars on cutting-edge topics. Some webinars are author solicitations—invitations based on *Xplore* article analytics—and some are arranged by the various TC and SPS initiatives.

In addition to all its journals being hybrid open access, the SPS now has a fully open access journal, *OJ-SP*. *OJ-SP* recently introduced new paper categories; in addition to regular papers, it now accepts short papers (eight + one pages long), overview papers, and dataset/competition/challenges papers.

To date, the SPS has 20 financially and technically cosponsored journals. In 2022, the SPS added *IEEE Journal on Indoor and Seamless Positioning and Navigation* (open access), *IEEE Transactions on Radar Systems* (hybrid), and *IEEE Transactions on Machine Learning in Communications and Networking* (open access).

In 2019, TWGs were established, and three have been created to address the areas of industry, integrated sensing and communication, and synthetic aperture. With the creation of the Synthetic Aperture TWG, the SPS is now involved in the development of standards. The SPS Synthetic Aperture Standards Committee continues to experience steady growth and increasing interest from the research community, which is a testament to the need for market-driven standards in this technology space.

To alleviate global pandemic restrictions, in 2020, ICASSP provided free remote access for nonmembers and nonauthors. Over 16,000 attendees joined the ICASSP virtual platform, most of whom were not SPS members, confirming that ICASSP topics, trends, and technologies are increasingly popular and growing at a very fast pace. The global mainstream interest in SP highlights the strength, dynamism, and diversity of our community. Indeed, ICASSP is the home of cutting-edge research in many areas, including speech and language processing, audio and acoustic SP, machine learning for SP and communications, distributed optimization and information processing, graph SP, and image, video, and multidimensional SP. For the first time, ICASSP 2023 will host satellite workshops, which will foster cross-discipline exchanges of ideas and promote focused events in topics at the cutting edge of our field. We expect that these will become permanent features in future ICASSPs. ICIP is the premier forum for presenting technological advances and research results in the fields of theoretical, experimental,

and applied image and video processing, and it continues to attract high-quality research in these areas. It is increasingly becoming the conference venue of interest in research related to image and video deep learning methods.

With continued efforts to increase and strengthen industry participation at our conferences, industry involvement has progressively increased. At ICASSP 2022, an industry program was incorporated in the technical program. It included a full parallel industry track with a corresponding open call for participation, high-profile industry keynotes speakers, industry expert sessions, industry workshops, and the traditional show-and-tell demonstrations. The SPS is now participating in IEEE DiscoveryPoint for Communications, which is a platform to meet the technical information needs of practicing product design engineers working in communications.

In 2020, the SPS established the Education Board to serve members' continuing education needs and promote SP education broadly. It also set strategic goals to boost educational and training offerings. ICASSP 2022 offered education-oriented 10-h courses, providing in-depth and multisided understanding of a topic and a final quiz to cap each course. Upon completion of each course, attendees were provided professional development certificates for training hours. These courses are now offered on demand for SPS members in the SPS Resource Center. The SPS plans to continue offering such courses in future ICASSPs and ICIPs.

For SPS students, a new member benefit is the SPS Scholarship Program, launched in 2023. The SPS is now awarding multiple scholarships up to a total of US$7,000 for up to three years of consecutive support to students who have expressed interest and commitment to pursuing SP education and real-world career experiences. Students and graduate students from all 10 IEEE Regions are eligible for this program.

The Society has also provided initiatives to stimulate and grow entrepreneurship to enable SP-related discoveries to impact applications. The SPS is now offering an Entrepreneurship Forum in conjunction with ICASSP to promote entrepreneurship in the SP community by sharing entrepreneurship journeys, discussing challenges and opportunities in translating SP research into commercial applications, providing a forum for pitching, and, ultimately, training a new generation of SP entrepreneurs. The first Entrepreneurship Forum was held at ICASSP 2022 with great success; it included a pitching competition, where the SPS offered US$10,000 in prizes.

Diversity, equity, and inclusion have remained a key focus of SPS efforts. The SPS recognizes the importance of diversity and inclusion and has several ongoing efforts to widen the pipeline of women and underrepresented minorities interested in signal processing. Initiatives include outreach programs geared to pre-college students and, in particular, female and underrepresented students. The SPS understands that the key to increasing diversity in SP is a more diverse faculty providing opportunities, mentors, and role models that inspire students for excellence. In that spirit, in 2020, the SPS established the Promoting Diversity in Signal Processing (PROGRESS) Workshop to help women and underrepresented minorities pursue academic positions in SP. PROGRESS is offered to both SPS members and nonmembers every year, in conjunction with ICASSP and ICIP. In 2021, the SPS started offering Mentoring Experiences for Underrepresented Young Researchers, connecting them with established researchers in the field [5], [6]. Also in 2021, the SPS started planning K-12 outreach initiatives to increase the visibility of the Society and the SP discipline to young students worldwide by developing exciting impactful educational programs.

The SPS strives to create an environment in which women and underrepresented minorities members feel included and appreciated. It is encouraging to see that our efforts have been paying off; today, the BoG includes members from nine of the 10 IEEE Regions, and over half of the voting members are female. To enhance our commitment to diversity, the SPS has revised its governance documents, using gender-neutral language. ICASSP 2023 will provide a lactation room and nongender-specific bathrooms, and we plan to add those as permanent features to all our conferences and workshops.

On the ethics front, the SPS has formed a team of volunteers representing various TCs to develop recommendations for responsible research and the ethical use of technology. The team is focusing on guidelines for authors, encouraging them to consider not only the potential benefits of their research but also the potential negative societal impacts and to adopt measures to mitigate risk. It is also developing guidelines for promoting explainable machine learning and solutions with low computational and memory cost and ensuring that SP-enabled developments are compatible with human well-being.

So far in this decade, SPS membership has grown from 18,730 to 19,164 members and is expected to surpass 20,000 during the Society's 75th anniversary year.

The SPS has engaged IEEE at large, with its leaders assuming leadership positions within IEEE-level boards and committees. In the past 20 years, SPS volunteers have served almost uninterruptedly on the IEEE Board of Directors as directors of Division IX (at least eight directors), vice presidents of technical activities (four), vice presidents of educational activities (two), vice presidents of the IEEE Publications Services and Products Board (two), and presidents of IEEE (three). In these positions, they steered IEEE into financially sound operations, promoting a more diverse, equitable, and inclusive organization, adopting open access and open science, exploring new membership models, adopting an IEEE-wide mobility policy, and fostering new services for professionals in IEEE's areas of interest.

The beyond

The Society envisions that open access publishing will continue to grow, conferences will continue to expand both physically and virtually, membership activities will increase, educational opportunities will expand, and diversity and ethics will remain pillars in all aspects of our future commitments to our members and the general public. SP is a key ingredient in many new technologies and products, and its strengths continue to be enhanced by evolving computer and communications capabilities and novel algorithms. From digital and statistical to distributed and graph SP, from radar and communications to speech, images,

and language technologies, from the physical world to the social networks to space technologies, SP professionals are data scientists, AI developers and practitioners, and machine learning specialists, and SPS is stepping up in these areas to meet their needs. Opportunities abound!

The SPS staff

The SPS staff has always played an important role in maintaining the continuity of the Society. Its members are highly capable professionals who work harmoniously with SPS volunteers and have the knowledge and skills to turn ideas into reality.

The current composition of the SPS staff is as follows:

- *Richard Baseil*: executive director
- *Administration*:
  - *Theresa Argiropoulos*: director, operations
  - *Deborah Blazek*: administrator, committees and governance
  - *George Olekson*: chapter and operations associate
  - *Jessica Perry*: membership communications and experience specialist
  - *Jaqueline Rash*: administrator, membership program and events
- *Conferences*:
  - *Caroline Johnson*: senior manager, conference strategy and services
  - *Nicole Allen*: senior conference administrator
  - *Samantha Esposito*: conference administrator
- Publications:
  - *William Colacchio*: senior manager, publication and education strategy and services
  - *Rebecca Wollman*: publications administrator
  - *Michelle Demydenko*: society peer-review and education program administrator
  - *Nanette Januszkiewicz*: society peer-review and education program administrator
  - *Mikaela Langdon*: society peer-review and education program administrator
  - *Rupal Bhatt*: web administrator.

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