20 Years of IEEE SENSORS JOURNAL

THE IEEE SENSORS JOURNAL was born on June 1, 2001, when its first ever issue was published. The journal has grown exponentially over the past 20 years to become one of the world's largest journals in sensor engineering and technology as well as one of the largest among more than 200 IEEE publications. In these 20 years, the field of sensors has dramatically changed of course: Completely new areas have emerged, e.g., body sensor networks, the Internet-of-Things, memristive sensors, or the smart sensory dusts, while some others have enormously grown, e.g., mechanical sensors, fiber-optics sensors, or radiation sensors. In all these cases, the IEEE SENSORS JOURNAL has recorded and presented the progress and achievements of the field. As any engineering journal, IEEE SENSORS JOURNAL has also served the community by reporting extremely useful technical papers, in order to provide experiential knowledge. As well, the journal has published scientific manuscripts proposing new detection principles and novel sensing devices. After 20 years of activity, it is now the right time to look back critically at what the field has produced in terms of great achievements and, at the same time, to look ahead at the challenges for the next 20 years to come. That is the main aim of this Special Issue published to celebrate the 20th anniversary of the IEEE SENSORS JOURNAL. With this introductory article, we would like to give an overview of the past 20 years by commenting on their highly successful developments.

I. 20 YEARS OF IEEE SENSORS JOURNAL

Information is the lubricant of modern society and its economy. The availability of information depends crucially on the relevant data sources. In many cases, sensors provide the information with which processes can be monitored, controlled, or their states determined. Without sensors, neither industry 4.0 could become reality nor could the IoT develop as expected. Over the last 20 years, the number of sensors manufactured annually doubled every five years and now it amounts to several tens of billions.

This development was already foreseeable at the end of the 1990s. For this reason, the IEEE Sensors Council was founded in 1999, and its publishing activity actually started in June 2001 with the first issue of our IEEE SENSORS JOURNAL. At that time, the Founding Editor-in-Chief was Vladimir J. Lumelsky and John R. Vig was the Founding President of the IEEE Sensors Council. Since then, the IEEE SENSORS JOURNAL has become a highly recognized publication where this rapidly growing scientific community can virtually meet for exchanges about the most recent novelties. In fact, the journal has undergone an impressive development. According to the number of published papers, the IEEE SENSORS JOURNAL is one of the largest publications of IEEE, with more than 15 000 pages and more than 5300 submissions as published and received in 2020.

Actually, the fields of interest of the IEEE SENSORS JOURNAL are in the theory, design, fabrication, manufacturing, and applications of devices for sensing and transducing physical, chemical, and biological phenomena, with an emphasis on the electronics and physics aspect of sensors and integrated sensors-actuators. In particular, this comprises, but is not limited to:

- Sensor Materials for Chemical & Biosensors;
- Mechanical & Magnetic Sensors;
- Fiber-Optics Sensors;
- Radiation Sensors;
- Sensor Phenomena and Modeling;
- Sensor Applications;
- Sensor Data Processing;
- Sensor Interface Electronics;
- Sensor System Integration;
- Sensor System Networks.

To pay tribute to the 20th anniversary of our IEEE SENSORS JOURNAL, we have invited our Topical Editors and Associate Editors and some exceptional authors to contribute to this jubilee edition with Review Papers, Roadmap Articles, and Tutorial Papers. The main aim here is to provide reviews or tutorials of the best advancements on sensors now in the state-of-the-art of the field as obtained over the last 20 years, while featuring the new innovations we could expect in the next 20 years or so.

II. SCOPE OF THE IEEE SENSORS JOURNAL: TECHNICAL JOURNAL WITH CLEAR FOCUS ON THE SENSOR

As described in the contribution "How to Bridge the Gap Between Academic and Industry-Oriented Sensor Research," in this Special Issue [item 1) in the Appendix], there is no generally binding definition of what a sensor is. Accordingly, the term "sensor" is often understood to mean quite different things:

- sensor elements that convert the nonelectrical quantity into an electrical signal;
- devices with primary electronics close to sensors;
- devices with standardized, analog electrical output signal;
- smart sensors with analog-to-digital conversion and standardized digital output, particularly with adjustable characteristic curve, possibly also with self-X properties

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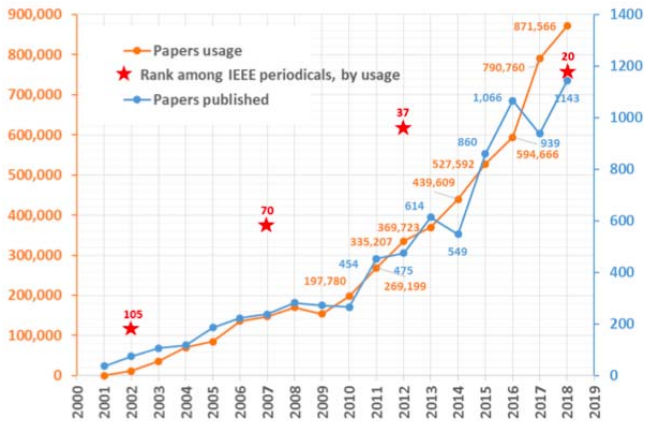

Fig. 1. Exponential growth of the journal over the last 20 years in terms of published papers, increased rank among IEEE periodicals, and number of downloads (paper usage).

(e.g., self-calibration, self-monitoring, self-diagnosis, and self-reconfiguration) and integrated signal processing (e.g., optimal filtering for noise reduction, image processing, and artificial intelligence evaluation).

That sometimes makes it difficult to precisely define the scope of our IEEE Sensors Journal. We usually receive a lot of papers that deal with signal and image processing as well as with pattern recognition, proposing signals and data as coming from sensors, but which focus is no longer on the sensor itself. Here, the question is often what still fits into the scope of our journal or where the scope of our journal could be diluted. This question is—as everywhere when there is not only black and white, but also a gray area in between—often difficult to answer.

A simple approach to answering this question is then often: *Is the scientific or technical novelty on the (physically real) sensor itself or somewhere else?*

III. Development of the Journal Over the Last 20 Years

As cited in item 1) in the Appendix, it was estimated that the number of sensors fabricated annually doubles about every five years. This means that the annual sensor production has increased 16-fold in the 20 years of existence of the IEEE Sensors Journal. Of course, the IEEE Sensors Journal has closely followed this explosion (see Fig. 1). Almost all areas of sensor technology, including the traditional ones, have experienced rapid growth over these past two decades. Therefore, it is our aim to present in detail this enormous development in the Special Issue by publishing review papers by sensor experts in the respective fields. In addition to world-renowned experts, we were able to draw on a very special treasure of our IEEE Sensors Journal: our 11 Topical Editors and our 90 Associate Editors, who certainly are among the top-recognized experts in the field.

For reasons of space, it is not possible to deal with each individual review paper in the frame of this editorial, but we would like here to highlight a few important aspects that occurred over such a period.

Although a very traditional area, the appearance of new ideas, methods, and fabrication techniques was still very spectacular in the field of *Mechanical Sensors.* The obtained progresses are well summarized with reviews about *Tactile Force Sensors* and *MEMS Resonators*.

The use of optical effects for sensory purposes has been experiencing a huge upswing and disproportionate growth for a long time now. The area of *Fiber-Optics Sensors* has shown an enormous success as well, where *Backscattering Optical Fiber Distributed Sensors*, *Long Period Fiber Gratings*, or *Fiber-Optics Biosensors* have been largely reported by literature and, in this Special Issue, highlighted in the section titled *Fiber-Optics Sensors*.

Another good example for a rapid growth is represented by *Radiation Sensors*, which have shown the appearance and expansion of new technologies for *Terahertz Plasmonic Sensors* as well as of special sensors dedicated for and then in use in *Synchrotron Radiation Sources*. On the other side, the same area has seen an explosion of *Radar Sensors* for the consumer market, e.g., in automotive.

However, the past two decades have also seen the emergence of entirely new areas that require sensors. Most prominent examples here are the *Body Sensor Networks* and the *Internet of Things* (*IoT*). After they first appeared in literature at the end of the 2000s, the number of corresponding publications has then experienced a true explosion. This can be read in the two papers titled "Wearable Body Sensor Networks: State-of-the-Art and Research Directions," and "Social Sensing in IoT Applications: A Review." It is worth mentioning also the birth of the new concept of *Smart Dust*, the forerunner of the IoT concept, first, and then generating the further concepts of neural dust and body dust. This is well demonstrated in the article titled "Body Dust: Well Beyond Wearable and Implantable Sensors."

A final example of a completely new area that has emerged recently is *Memristive Sensors*. Since the discovery of the memristive effect in several nano-scale materials in 2008, its application for sensors has also been intensively studied. This interesting story is described in the article "The Birth of a New Field: Memristive Sensors."

The list of new and exciting developments is, of course, far from exhausted. Another good example is the area described by the article titled "Signal Processing for Single Biomolecule Identification Using Nanopores: A Review." However, the intent here is not only to present the many new areas that have emerged in the last 20 years since the foundation of the IEEE Sensors Journal but also to look back critically to what has been discovered, invented, and engineered for practical applications while discussing and anticipating the new challenges that the field of sensors will face in the next 20 years to come. Just to mention a very few among them, let us here simply refer to autonomous driving and humanoid robots. It is absolutely clear that deep learning is in principle the key to the future usability of such technologies. Nevertheless, sufficiently accurate and reliable sensors must always be available so that, here too, further progress depends to a large extent on the future advancements in the field of sensor technology too.

IV. IEEE Sensors Journal Versus Predatory Journals

All these future advancements in the field of sensor technology must find a home to be disseminated. Toward this aim, the IEEE Sensors Journal is the IEEE's publication organ for the broad field of sensor technology and engineering. As we have seen before, sensors are an enabler for many areas of science and technology and, therefore, it is not operated by a single IEEE Society, but by the IEEE Sensors Council as an association of 26 different IEEE Societies. However, the IEEE Sensors Journal is not a singularity in the field of research journals about sensor technologies. Other journals, like Elsevier's *Sensors and Actuators* (A Physical, B Chemical) or the MDPI's *Sensors*, are as well big players in the market. All journals are either traditional journals, where the publications are financed by the readers who pay for the journal subscription to access the corresponding articles, or open access, where authors pay for the publication of their articles (like *Sensors*), or even hybrid journals combining both (like IEEE Sensors Journal).

However, the ever-increasing growth in scientific publications means that the market for research journals is also becoming interesting for new players. The worldwide market revenue amounts to more than 20 billion USD per year, only for scientific, technical, and medical journals. It is therefore not surprising that, for some time now, economically speaking quite aggressive new publishers attempt to penetrate the market. They only aim to exploit economically the market without taking care of a serious peer-review evaluation of the published content and, therefore, without paying attention to providing a high quality of their published articles. Unfortunately, following the so-called "publish or perish" principle that is pushed in many places of the scientific everyday life, these low-standard journals have seen an increase of submissions often associated with unethical practices [item 2) in the Appendix].

In the meantime, the scientific community has agreed on a binding definition of such publication bodies: *Predatory journals and publishers are entities that prioritize self-interest at the expense of scholarship and are characterized by false or misleading information, deviation from best editorial and publication practices, a lack of transparency, and/or the use of aggressive and indiscriminate solicitation practices* [item 3) in the Appendix].

Here, we see a clear mission for our IEEE Sensors Journal to distinguish ourselves clearly from such journals and their publication habits. In particular, this means:

- Ensuring high scientific quality: published articles must have a high degree of scientific novelty, the addressed research questions must be important and interesting, the research questions and the proposed methods must be clearly described, the conclusions must be compatible with the presented data, reported in a comprehensible manner, and all relevant scientific sources must be correctly cited.
- Ensuring the high quality of the review process: the selection of competent experts in the peer-review process is intended to ensure the scientific quality of our publications.
- Preserving the high trust of our authors and readers: we have to be transparent in our review process. Our review process is also intended in a manner that assures our editorial team works together with our authors to further improve the manuscripts in order to achieve the best possible scientific publications. And we must avoid any aggressive and indiscriminate collection of content as it happens in the unconditional hunt by predatory journals for as many contributions as possible.

To continue actively pursuing this important issue, the community beyond the IEEE Sensors Journal has established a focused group to offer a further space to keep going with the good habit of IEEE in publishing and advertising peer-reviewed content to the benefit of the scientific community as well as to the benefit of the society at large [item 4) in the Appendix]. This group has grown to a considerable size with more than 2000 involved members, many of whom are extremely active in regularly posting and promoting news about sensors and related technologies, and also about good practice in scientific publishing as well.

V. Development Trends in Sensor Technology

Information technology is often considered to be the most important factor in the further development of science, technology, and economy because information is needed for all processes in industry, medicine, and daily life management. At this point, we would like to put forward the thesis that information technology makes an important contribution to ensuring that the absolutely fundamental prerequisite is a reliable knowledge. This, however, is provided—along with other sources of knowledge, such as smartphone data for traffic control—by sensors. This means, however, that sensors and sensory systems are the most important basis for scientific and technological progress, since only they can provide the necessary reliable knowledge. This also leads to some further conclusions:

- Sensors must provide information sufficiently extensive (as sensor systems or sensor networks) and with sufficiently high accuracy (i.e., with sufficiently small measurement uncertainty).
- The best IT architecture, the networks, system models, and the best interaction of all components of a complex system become valuable only by the use of sufficiently reliable information from the real world.
- A bad sensor cannot be improved by even the best signal processing if the necessary information is not contained in the original sensor signal.
- Only the right sensor with the right properties at the right place of measurement can deliver reliable information.

The current development of sensor technology can be summarized in a few points that have been observed over the last two decades:

- New materials (e.g., nanoparticles) and new technologies (e.g., MEMS and nanotechnologies) expand the spectrum of new sensor principles. However, it is worth noting that new materials and technologies must prove their

significant advantage over established materials and technologies to have the chance of gaining acceptance.

- High-tech solutions are usually associated with high development and high manufacturing costs and—due to the usually higher complexity—also with lower reliability. In practice, the aim is therefore to achieve solutions that are as simple as possible (low tech). High-tech solutions are usually only an alternative in cases where the desired objectives cannot be achieved with low tech.
- More resilient sensor principles will replace less resilient ones. Resilience is usually achieved by corresponding materials (e.g., single crystals), technologies (e.g., miniaturized MEMS technologies), principles (e.g., piezoresistive pressure sensors versus capacitive acceleration sensors), or useful architectures.
- Specific methods will replace sum-parameter-based principles, e.g., using spectrometric principles instead of measurement of a single electric quantity.
- Self-X, i.e., self-calibration, self-monitoring, self-diagnosis, and self-reconfiguration of sensors increase the sensor's reliability and, hence, enhance its measurement uncertainty.
- New signal processing techniques, such as artificial intelligence and neural computing approaches, allow better extraction of information or better signal patterning from sensor signals.
- The use of semiconductor-based technologies, i.e., MEMS technologies, increases—as in microelectronics—reliability and hence maintenance efforts, enhances miniaturization, and decreases dramatically the costs.
- New noncontact sensor principles (e.g., optical or infrared sensors) decrease costs of installation and maintenance.

Another aspect has been observed for many years: there is only a small number of global sensor manufacturers targeting mainly standard sensors for standard applications. Up to now, the major part of the sensor industry is still small- or medium-sized, and is actually regional (country and continent). The reason is the use of sensors and sensor systems that is mostly very application-specific and complex.

VI. Special Issues as Mirror of These Trends

The Inaugural Issue of the IEEE Sensors Journal on June 1, 2001, was also the journal's first Special Issue, which, like this one, mainly consisted of review papers. Topics in that first issue, with nine technical papers, were SAW and resonant sensors, piezoresistive sensors, infrared imaging systems, sensitive skin, and chemical sensors for explosives.

Then, in the first ten years to December 2011, 20 more Special Issues were published, about two per year. It is interesting to take a look at the issues of the first ten years. Many of them were already shaped at that time by the sensor trends that are still important:

- Integrated Multisensor Systems and Signal Processing (Special Issue #3, 2002);
- Optical Fiber Sensors (#4, 2003);
- Intelligent Sensors (#10, 2007);
- Micro- and Nanosensors (#7, 2004; #13, 2008);
- Sensor Networks (#19, 2011).

The Special Issue #6 of the IEEE Sensors Journal was devoted to the very first IEEE Conference on Sensors (SENSORS 2002), held in Orlando, FL, USA, June 11–14, 2002. More than 650 scientists from around the world had attended that conference. Due to this huge success, the IEEE Sensors Council had decided to publish a Special Issue comprising expanded versions of selected conference papers. More than 130 papers were submitted for the Special Issue and had to pass the standard review process; 30 of them were selected for the Special Issue (published in Part I in October 2003 and in Part II in December 2003). This was the beginning of a long tradition of Special Issues on Selected Papers from the annual IEEE Sensors Conferences.

The Special Issue #21 on December 1, 2011, was the Special Tenth Anniversary Issue then celebrating the successful development of the IEEE Sensors Journal in its first decade by again publishing a larger number of review articles on different topics, including sensor management, physical sensors for liquid properties, agile sensing systems for tomography, energy harvesting electronics for vibratory devices in self-powered sensors, multisensor fusion and integration, graphene sensors, implantable sensors, and textile-based electrodes and motion sensors for smart clothing. From these examples, we can see that the attractiveness of certain topics has not diminished over the following ten years since then.

As mentioned above, 21 Special Issues were published in the first ten years of IEEE Sensors Journal, but about 50 more have been added since 2011. It is noteworthy that in 2012-2014, six Special Issues were published each year, and then this number dropped to four in 2015–2016 and two in 2017–2019. Then, since 2020, there has been an "explosion" in the number of new Special Issues: by the publication date of this anniversary issue, some 10 new Special Issues will have appeared!

There are a number of reasons for this. The most important is certainly that the pressure and competition at universities has increased immensely in recent years. For personal promotion in the scientific system, participation in the scientific community is becoming increasingly important, in addition to appropriate research achievements (e.g., acquired third-party funding as principal investigator) and high-ranking publications. Participation in the editorial boards of scientific journals is just as valued as leading guest editorships of important scientific journals. This is also clearly visible again and again when scientists repeatedly submit new proposals with ever new topics.

A second reason is found in the Covid-19 worldwide pandemic with the associated restrictions, in particular, on experimental scientific work by the summer of 2020.

The thematic spectrum of Special Issues (SIs) over the past 20 years has been very broad:

- Optical fiber sensors have been the subject of three SIs: #4, 2003; #14, 2008; #56. 2021.
- Sensors for medical applications are a perennial hot topic: *in vivo* sensors (#11, 2008), breath analysis (#16, 2010); neurophysiology (#31, 2013), magnetic sensing systems

for biomedical applications (#52, 2019), sensing of physiological parameters for human wellness and patient monitoring (#63, 2020), body temperature measurement, and monitoring in a time of pandemic (#68, 2021).

- For several years now, more and more sensor networks and systems with corresponding sensors have become the focus of attention: distributed smart sensing for mobile vision (#40, 2015), sensing technologies for intelligent urban infrastructures (#38, 2014), underwater acoustic sensor networks (#44, 2016), software-defined wireless sensor networks (#45, 2016), smart sensors for smart grids and smart cities (#49, 2017), and smart body networks (#53, 2019).
- The aim of the Special Issues is to focus on new trends or technologies, current developments, or new areas of application. This concerned for instance: Sensors for the prevention of terrorist acts (#9, already in 2005!), biomimetic sensors (#23, 2012), or printable sensors (#42, 2015).
- The first and probably only Special Issue on the Internet of Things (#33) was published in 2013. There will be no other one, because in 2014, the Sensors Council founded its own scientific journal for this extremely attractive field: the IEEE Internet of Things Journal.

Another development that occurred over these last 20 years should be mentioned here at the end: A significant proportion of new Special Issue proposals read like a dictionary of buzz words or even combinations of them (examples in alphabetical order): artificial intelligence (AI), big data analytics, cloud computing, cyber-physical systems (CPSs), deep learning, edge…. (sensing and computing), frontiers in…, the Internet-of-Things (IoT), mobile-crowd sensing, next generation, smart, etc.

One example of such a buzz word-driven proposal text might be: "The aim of this Special Issue is to stimulate discussions on the design, use, and evaluation of AI-empowered sensor system solutions for next-generation industrial CPSs. However, when integrating these two technologies, there are still some open issues, such as security and efficiency, accuracy, privacy, data trustworthiness and quality, and participation motivation and incentive that need to be addressed." One conclusion from this real example is: the quality of a good bid does not necessarily depend on the number of buzz words used in a proposal!

VII. Influence of the Publication Pressure

As described above, the pressure to publish in academia has increased enormously in recent years, especially in those countries where the promotion of one's own academic career is particularly dependent on publication parameters like number of publications and impact factor of the journals (the so-called "publish or perish" policy). A frequently used strategy to increase the numbers is to divide the scientific content in as much as possible pieces that can still be published individually, i.e., as much as possible smallest publishable units. This also explains partially the exponential growth of the number of published articles as described in item 1) in the Appendix.

One path is observed here particularly well in recent times and can be described in the following way by taking the example of a chemical sensor: take a well-known generic sensor principle (e.g., a fiber-optic sensor or a resistive semiconductor sensor), use m different sensing materials, modify these m materials in n different ways, and study these $m \times n$ specimen with p different gases to be measured. In the best case, this leads to a maximum of $m \times n \times p$ publications. The huge arsenal of different materials (variable m) and thin-film deposition techniques as well as the potential of nanotechnology (doping, nanoparticles, etc.) (variable n) enable an astonishing number of combinations. What sounds like a grotesque story here, is unfortunately encountered more and more often in literature. This is often visible in the fact that the standard similarity check that every manuscript has to pass now shows great similarities with other previous publications of the same authors, since the fabrication, characterization of the materials, sensor layers, and the investigation of the samples are often the same or at least similar.

Here, we must appeal to the academic ethos of our authors. Such behavior not only violates the rules of good scientific practice, but also ties up more and more of the capacity of our reviewers, who generally use their personal spare time for this purpose, which they cannot use for their own research!

We are trying to counter-balance this development by an increasing number of rejections on such manuscripts immediately after submission, without even going to the review process.

VIII. The Trend From Plagiarism Toward Self-Plagiarism

"IEEE defines plagiarism as the use of someone else's prior ideas, processes, results, or words without explicitly acknowledging the original author and source. Plagiarism, in any form, is unacceptable and is considered a serious breach of professional conduct, with potentially severe ethical and legal consequences" [item 5) in the Appendix]. To check this explicitly, every manuscript submitted to an IEEE journal or transactions is subjected to a similarity test.

The causes for similarities can be manifold:

- Use of text passages from external or own publications. This is permissible as long as these passages are explicitly marked and reference is made to the corresponding sources.
- Pre-publication in a repository. Repositories are document servers in which scientific and scholarly materials are archived and made accessible worldwide free of charge, e.g., arXiv. This ensures that the authors can prove that they have published the content first and foremost, which is particularly important in highly researched areas. Such pre-publications are allowed in principle but must be linked to the published papers once the manuscripts are then accepted for publication.
- Use of scientific "standard phrases." Sometimes, the similarity reports show a clustered use of typically used terms or phrases, often half-sentence-wise. This cannot be really called plagiarism, since neither scientific ideas nor findings are reused.

Ten years ago, the number of plagiarism cases in the IEEE SENSORS JOURNAL was relatively high and amounted to several tens per year. At that time, in some parts of the scientific community, even the simple principles of good scientific practice have not been universally followed. The widespread use of plagiarism software in all the IEEE journals and transactions has made the plagiarised contributions visible and led to the rejection of the corresponding manuscripts. In particularly serious cases, sanctions have also been imposed on authors, e.g., a ban from publication in IEEE journals and magazines for several years. It is satisfying to see that—in the public perception—it has now become firmly established that similarity checks are relatively reliable in detecting plagiarism.

However, since then, we have seen another development that is similarly disturbing. Instead of plagiarism, we have been seeing more cases of self-plagiarism over the past decade. In 2019 and 2020, the proportion of serious cases of self-plagiarism has been greater than the number of plagiarism cases by a factor of four! We attribute this new development to the trend of the growing pressure to publish described in Section VII, which has greatly increased the need for as many publications as possible.

To disguise the fact that the newly submitted publication is very similar to previously published results, some or even many of these prior publications are often concealed. This then suggests a degree of scientific novelty that does not exist. Here, of course, there is no other option than rejecting such manuscripts.

In a few cases, authors have submitted their very similar manuscripts to different publishers and journals almost simultaneously. This was apparently to prevent the plagiarism software from detecting these cases of self-plagiarism. However, many of these authors did not take into account that different journals are always looking for the most suitable reviewers so that the same reviewers receive very similar manuscripts from the same authors for review at the same time. Luckily, such cases of self-plagiarism are detected since these reviewers inform both journals of the simultaneous and self-plagiarized texts.

All in all, the aspects of self-plagiarism can be summarized quite simply: good scientific publication practice means that the state-of-the-art must be described to the best of one's knowledge, and that one's own scientific contribution within the newly submitted manuscript must also be clearly recognizable. Around 40 serious cases of self-plagiarism in 2020 out of 1613 published papers are still 2.5%, each of these cases is one too many.

IX. GRAPHICAL ABSTRACTS AND COVER IMAGES

To follow the evaluation of both the society and the most advanced technologies in publishing, several innovations have occurred over the last 20 years at the IEEE SENSORS JOURNAL, also with respect to the manner of publishing the collected scientific information.

First of all, since 2016, the journal is no longer distributed as a printed edition, but is only published purely electronically. Facing the enormous amount of published papers (ca. 1600 in 2020) and, therefore, pages (more than 15 000 in 2020), and facing the modern manner for the worldwide community to mainly access scientific information, going online has been a clear must to be taken at that time. Here, it must necessarily be mentioned that the journal has not suffered by this decision while, on the opposite, it has taken the advantage in becoming one of the largest engineering journals in the vast universe of the IEEE publications, a true pillar of the IEEE Sensors Council's activities exceeding the threshold of one million downloads per year.

Another quite important innovation was the recent introduction of the graphical abstract with a colorful format of the published papers. This innovation on the format of the published papers was also due to the clear need, nowadays, to have "well-looking images" in front of the reader's eyes.

On the other hand, the introduction of the graphical abstracts addressed also the new needs for easier access to the core-content of the published papers and to better attract readers to articles as well as enabling readers and authors to share the papers' content in social media in an attractive and effective manner.

Another proposed innovation was that of changing the cover image every issue, now 24 times a year, in order to further promote hot topics and outstanding papers as well as to focus the readers' attention on some highlighted content in the journal. To the very same aim, the so-called featured article has been introduced right last year too. A featured article is an article offered for free in open access for six months with an aim to promote the manuscript content, on one hand, while increasing the access to readers from low-income countries, on the other hand.

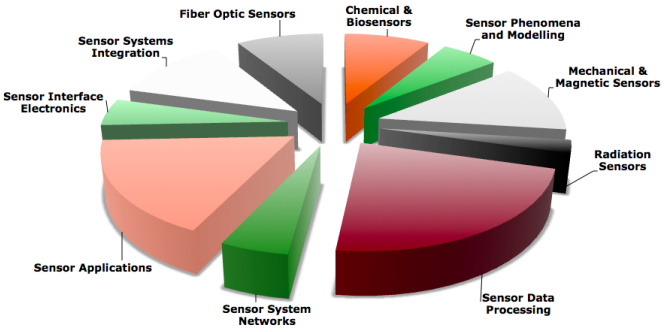

Fig. 2. Distribution of manuscripts submitted in 2019 according to the topical areas of the IEEE SENSORS JOURNAL.

X. OUTLOOK

In 2019, 5466 manuscripts were submitted to the IEEE SENSORS JOURNAL. Fig. 2 shows the corresponding distribution within the journal's Topical Areas. It clearly shows how diversified the large field of sensor technology is, and how the scientific and technical progress affects all related aspects, from sensor phenomena to operation principles, via system integration and networks embedding, up to interface electronics, sensor data processing, and application aspects.

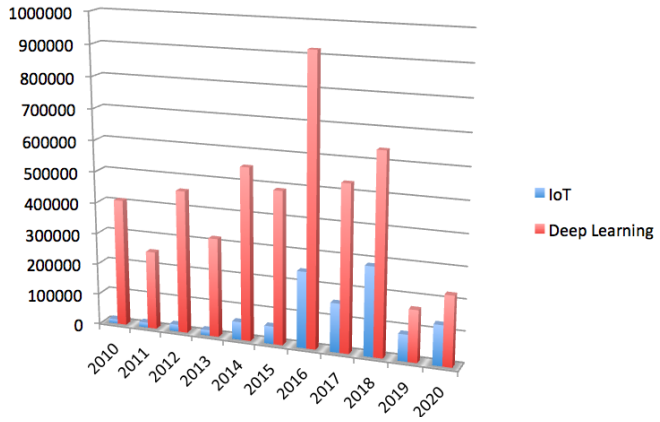

Fig. 3. Number of papers published in literature on sensors relationship to IoT (blue) and deep learning (red).

The split in topical areas as shown in Fig. 2 will undoubtedly change in the future with the emergence of new and innovative aspects, like the Internet-of-Things and deep learning. As already mentioned in Section III, IoT has developed in a completely unexpected and breathtaking way over the last decade (Fig. 3). This development has led to the fact that the number of publications on the subject of IoT now clearly exceeds that of sensors. For this reason, the IEEE Internet of Things Journal was founded by the IEEE Sensors Council in 2014 as a separate sister journal. The growth was also clearly exponential till 2016 and well justifies the review paper related to IoT presented in this Special Issue.

The same as for the IoT applies to deep learning (DL) and artificial intelligence (AI). At present, it is impossible to estimate the enormous potential of these new technologies and the impact this can have on new applications.

However, one thing can already be said: DL and AI allow the extraction of new information from signals that were previously inaccessible. The better the sensors are, thus, the sensor signals contain more information, and the greater is the gain in information. In other words, sensors whose signals contain only noise and no information will not provide any technical advantage, even with the best of DL and AI. Therefore, despite—or even because of—these new technologies, the goal will also remain in the future to develop sensors that are as good as possible, i.e., sensitive, low-interference, stable over the long term, and reliable, while bringing them into technical applications.

Like microelectronics, sensor technology is an enabler that makes new technical solutions possible in the first place, e.g., Industry 4.0 or the Internet of Things. However, sensor technology differs from microelectronics in one fundamental aspect: the integration density of electronic circuits decreases continuously in accordance with Moore's Law until it reaches physical limits. For many years, the scientific community has been discussing when these limits will be reached. The number of sensors manufactured each year is also growing exponentially [item 1) in the Appendix]. However, physical limits are not to be expected here.

When both authors of this editorial decided many decades ago to seek our professional and academic careers in the field of sensor technology, we were sure that this was an area with great development potential and almost unlimited growth opportunities. This assumption has been sustainably confirmed over the past decades. The development and growth of the IEEE Sensors Journal are always additional proof of this growth as well.

Of course, the successful growth of the IEEE Sensors Journal in the 20 years of its existence did not only need the optimism of its founders (John Vig and Vladimir Lumelsky) when they launched the journal and the spirit and perseverance of their successors (Troy Nagle, Evgeny Katz, and Krikor Ozanyan) to let the journal grow. The essential foundations of its success are, first and foremost, our authors, who provide the basis for a good journal, then our Topical Editors, Associate Editors, our reviewers (who are essential for ensuring the quality of our journal), and—last but not least—our readers, for whom we make our IEEE Sensors Journal: our heartfelt thanks go to all of them!

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Appendix
Related Works

1) G. Gerlach, "How to bridge the gap between academic and industry-oriented sensor research," *IEEE Sensors J.*, vol. 21, no. 11, pp. 12363–12369, Jun. 2021.
2) V. Dalen, "How the publish-or-perish principle divides a science: The case of economists," *Scientometrics*, vol. 126, no. 2, pp. 1675–1694, Feb. 2020.
3) M. Grudniewicz *et al.*, "Predatory journals: No definition, no defence," *Nature*, vol. 576, pp. 210–212, Oct. 2019.
4) *Discussion Group on Facebook About the Content of the IEEE Sensors Journal and Related Field of Engineering*. Accessed: Feb. 8, 2020. [Online]. Available: https://www.facebook.com/groups/596533514316437/
5) *IEEE Publication Services and Products Board (PSPB) Operations Manual, 2020, Section 8.2.1*, IEEE, Piscataway, NJ, USA, 2021.

Sandro Carrara (Fellow, IEEE) received the Diploma degree in electronics from the National Institute of Technology, Albenga, Italy, the master's degree in physics from the University of Genoa, Italy, and the Ph.D. degree in biochemistry and biophysics from the University of Padua, Italy. He is a Faculty Member with EPFL, Lausanne, Switzerland, and a Former Professor with the Universities of Genoa and Bologna, Italy. Throughout his career, he has published seven books with prestigious publishers, such as Springer/NATURE and Cambridge University Press. He has more than 300 scientific publications. He is the author of 14 patents. He is an IEEE Fellow for his outstanding record of accomplishments in the field of design of nanoscale biological CMOS sensors. He is a member of the IEEE Sensors Council and its Executive Committee. He was a member of the Board of Governors (BoG) of the IEEE Circuits and Systems Society (CASS). He was appointed as the CASS Distinguished Lecturer from 2013 to 2014 and the IEEE Sensors Council Distinguished Lecturer from 2017 to 2019. He was a recipient of the IEEE Sensors Council Technical Achievement Award in 2016, for his leadership in the emerging area of co-design in bio/nano/CMOS interfaces. His work received several international recognitions as Best-Cited Papers and Best Conference Papers. He has been the General Chairman of the Conference IEEE BioCAS 2014, the premier worldwide international conference in the area of circuits and systems for biomedical applications, while he is the General Chairman of the 16th Edition of IEEE International Symposium on Medical Measurements and Applications, IEEE MeMeA 2021. He is the Editor-in-Chief of the IEEE Sensors Journal, one of the largest journals among more than 200 IEEE publications, and an Associate Editor of IEEE Transactions on Biomedical Circuits and Systems.

Gerald Gerlach received the M.Sc. and Dr.Ing. degrees in electrical engineering from Technische Universität Dresden, Germany, in 1983 and 1987, respectively. From 1983 to 1991, he has worked in research and development in the field of sensors and measuring devices for several companies. In 1993, he became a Full Professor with the Department of Electrical and Computer Engineering, TU Dresden, where he has been the Head of the Solid-State Electronics Laboratory since 1996. Since 2013, he has been the Head of the DFG Research Training Group "Hydrogel-based Microsystems," TU Dresden. He has (co)authored more than 250 articles in scientific journals. He is a (co)author and a (co-)editor of ten textbooks and monographs. He is also the inventor or a co-inventor of more than 50 patents. More than 70 Ph.D. students have earned their doctorate under his supervision. His research interests include sensor and semiconductor technology, simulation and modeling of micromechanical devices, the development of solid-state sensors, especially infrared sensors and piezoresistive chemical sensors, and polymer-based actuators. From 2007 to 2010, he served as the President of the German Society for Measurement and Automatic Control (GMA). He was the Vice President and the President of EUREL (The Convention of National Societies of Electrical Engineers of Europe) from 2007 to 2008. From 2002 to 2009, he served as a member of the Advisory Board of the VDE (German Association of Engineers in Electrical Engineering, Electronics, and Information Technology). From 2001 to 2012, he served as the Chairman of the VDE's Standing Committee for Engineering Education. Since 2013, he has been a member of the Advisory Board of DVT—German Association of Technical-Scientific Societies (2013–2016 as the Chairman). Since 2012, he has been serving as the Associate Editor-in-Chief for the IEEE Sensors Journal.