GUEST EDITORS' NOTE
Special Issue on Expanding Frontiers of Web Audio

The capabilities of web browsers to play, process, and record audio have been continuously improving over the last few years. With the Web Audio API being now an official W3C Recommendation [1] and supported by all major web browsers, rich audio applications in the browser, such as interactive sound experiences, sound editors, digital audio workstations, music live coding environments, and diverse types of collaborative music-making applications, are now available to everyone from the web browser, without the need of installing browser plugins or downloading separate applications.The yearly DAFx meetings are the connecting events for this community, which combine signal processing with audio applications. The crossbreeding of several disciplines from mathematical and numerical methods to physical models, the inclusion of audio processing and sound modeling has shown broad innovation in research and applications. In recent years, in particular, through the use of machine learning approaches, new and surprisingly effective methods have been designed. Through the use of virtual circuits, digital replicas of vintage analog electronics audio equipment can be realized. New models for sound spatialization are being discovered with particular attention to virtual reality applications and beyond. Numerous other developments exist.

FThe success of Web Audio API is due to a combination of factors, including a great community engagement across independent audio experts, the industry, and the academia, and the willingness of browser vendors to implement and incorporate the specification in their products. Since 2015, the Web Audio Conference (WAC) has been organized yearly in different parts of the world: Paris (2015), Atlanta (2016), London (2017), Berlin (2018), Trondheim (2019), Barcelona (2021, delayed because of COVID-19), and Cannes (2022). In Trondheim's edition of the WAC, the *Best Papers Awards* were introduced, whose awardees were invited to submit an extended version of their papers to the *Journal of the Audio Engineering Society* (JAES). That resulted in the publication of the JAES Special Issue on *Web Audio* (Vol. 68, No. 10, 2020 Oct.), which included six articles centered around topics such as web-based audio plugins and music production frameworks, applications to education, and spatial audio.

Widespread use of the Web Audio API has led to recent efforts focused on building new frameworks, tools, and applications on top of Web Audio technologies, which push the boundaries of Web Audio, increasing its potential and bringing it to new audiences. The present JAES special issue, which can be seen as a continuation of the previous *Web Audio* issue, has been titled *Expanding Frontiers of Web Audio* and focuses on advanced Web Audio–based tools, frameworks, and applications, which contribute to expanding the frontiers of Web Audio; enabling real-time networked music performances, innovative ways of interfacing with the Web Audio API; applications for education, annotation, and audio generation; and an introduction to the Web MIDI API. The articles selected for this special issue went through a thorough review process and were submitted to a JAES open call. Half of them are extended versions of the papers that were awarded a *Best Papers Award* at the Barcelona edition of WAC in 2021 [2, 3, 4], and the other half contain original research that was not presented at WAC 2021 [5, 6, 7].

The first article, "Web MIDI API: State of the Art and Future Perspectives" by Luca Andrea Ludovico and Adriano Baratè [5], presents an introduction to the Web MIDI API, covering its main functionalities, current state of implementation and support, showing example applications that make use of it, and identifying potential future applications. The Web MIDI API is currently less established than the Web Audio API, but it can expand the frontiers of web audio by providing standard methods to communicate web-based audio applications with non–web-based applications and all sorts of hardware music devices.

The second article, "Web-Based Networked Music Performances via WebRTC: A Low-Latency PCM Audio Solution" by Antonio Servetti et al. [2], presents an implementation to support high-fidelity audio streaming in the browser using WebRTC API and leveraging the Web Audio API and the AudioWorklet interface. Such implementation is capable of transmitting 16-bit PCM stereo audio with a latency that can go as low as 40 ms when transmitting over a local area network. This represents a very significant first step that can open many new possibilities for web audio applications featuring real-time audio collaboration.

The third article, "JSPatcher, A Visual Programming Environment for Building High Performance Web Audio Applications" by Michel Buffa et al. [3], presents *JSPatcher*, a web-based visual programming language that allows users to graphically design and run DSP algorithms, which will run as Web Audio graphs and also allow the use of domain specific languages such as Faust [8] and execute using AudioWorklets (a part of the Web Audio API specification that allows running DSP code in a high priority thread). JSPatcher presents a completely different interface to the Web Audio API, which will be very familiar to sound artists who have experience with other visual programming

languages such as Max [9] and PureData [10] and will allow them to easily build audio programs in the browser.

The fourth article, "Evaluating Web Audio for Learning, Accessibility, and Distribution" by Hans Lindetorp and Kjetil Falkenberg [4], is based on the authors' educational work in teaching sound and music computing over the last 20 years. It provides a great insight into how Web Audio might best contribute to a student's learning experience. The authors provide data from various student projects, consisting of source code analysis, reflective texts, group discussions, and online self-evaluation forms. The article describes the author's development of WebAudioXML (waxml), an open-source framework that offers an XML syntax for configuring audio objects and mapping user interactions to audio parameters. The article shows that Web Audio serves well as a learning platform and that an XML abstraction of the API helps students to stay focused on artistic outputs. The authors argue for an even greater need and potential for new online tools targeting audio application development, with improved accessibility and sharing features that, in turn, can contribute to an even better learning experience.

The fifth article, "Annotation and Analysis of Recorded Piano Performances on the Web" by Lawrence Fyfe et al. [6], introduces CosmoNote, a web-based citizen science tool for annotating musical structures in performed music. The tool features an advanced interface that enables the visualization and superimposition of synchronized discrete and continuous information layers such as audio waveforms, note data representations, audio features, and music score features. On top of that, users can annotate structural information such as indicating segment boundaries or grouping notes. Such an interface therefore takes advantage of web audio technologies to enable large-scale collection of annotations of performed music and exemplifies another different purpose for which web audio can be instrumental.

Finally, the sixth article of the special issue, "Expanding the Frontiers of Web Audio with Autoencoders and JavaScript" by Mateo Cámara and José Luis Blanco [7], introduces a web-based tool that is able to run a generative model (a Variational Autoencoder) trained to generate audio signals based on existing content from the Freesound audio sharing website [11]. This tool runs entirely on the browser without any server processing and therefore depends only on the client's processing power. This is an example of incorporating state-of-the-art generative models into the web browser, pushing in this way the frontiers of current web audio technologies.

We believe that the selection of articles in this special issue introduces relevant Web Audio research directions to the AES community, as well as to the Web Audio community in general, and serves as a consolidation of the importance of Web Audio technologies within the AES community. The expansion of the frontiers of Web Audio leads to new unexplored territory which helps establish the future requirements of Web Audio technologies, and the way in which people will interact with audio through technological devices in the future.

To finish this note, we would like to thank the reviewers for their thorough reviews without which this special issue could have not been published. We are also very thankful to the JAES editorial team, with special thanks to Vesa Välimäki (Editor-in-Chief), who has provided his expertise and professional advice and the opportunity to publish this special issue. Also, we would like to thank the guest editors of the previous Web Audio special issue published in JAES, Anna Xambó, Sara R. Martín, and Gerard Roma, who paved the way for this second special issue to exist. We would also like to thank the WAC 2021 organization committee for hosting such an interesting conference (formed by members of the Universitat Pompeu Fabra and SonoSuite) and the sponsors of WAC 2021 for making it possible: Dolby.io, Source Elements, Gather, and Audio Developer Conference. Last but not least, we would like to thank the authors of the papers published in this special issue for their contributions.

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