Soundworks
A Framework for Networked Music Systems on the Web
State of Affairs and New Developments

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ABSTRACT
This paper presents a novel major version of soundworks, a framework dedicated to developing distributed multimedia applications on the web and entirely written in javascript. Since its first release in 2015, the framework has served as a basis for numerous artistic and research projects such as concerts, installations, workshops, teaching or experimental setups. These diverse use cases and situations permitted to validate numerous aspects of the framework but also showed some limitations—particularly in terms of inclusion of non-expert developers such as artists and researchers—leading to the novel version presented here.

The paper first presents some applications developed in the last year and show that, despite their idiosyncrasies, recurring problems have emerged during their elaboration and development (e.g. state-management). Second, we present new design and implementation aspects of the framework developed to overcome these issues. Finally we describe a simple testbed application—designed to summarize a number of recurring features and constraints encountered in Network Music Systems—and some elements of its implementation within soundworks.

We believe that this novel version will provide solid foundations for the design and implementation of higher-level tools dedicated to non-expert developers, and thereby, foster new artistic, technological and epistemic areas. The soundworks framework is open-source and released under BSD-3-Clause license.

1. INTRODUCTION
The recent specification and development of the WebAudio API—together with other APIs such as WebSockets and the developments of ubiquitous computing with smartphones and nano-computers—enabled novel possibilities in the area of Networked Music Systems. These novel tools, alongside with the possibilities offered by a full-featured and interactivity-centered language such as javascript permit to envision these technologies from several points of view. First, they can be considered as a new development and a natural extension in the long history of multi-source electro-acoustic music. Second, they can provide a novel platform for composition and performance. Third, they enable a wide range of possibilities in the creation of new interfaces for musical expression. In all cases, these trends tends to show that these technologies—with their simplicity, ubiquity and inherent networked nature—can play a central role in the evolution of Networked Music Systems.

In this context, the development of a dedicated framework, adapted to and designed for the specificities of the web platform is essential. In the last years, a number of such frameworks have been proposed by the community. For now, however, these solutions are far from the maturity of environments such as Max/MSP or PureData. While these environment have developed a number of key concepts along the years, we think however that adapting these concepts directly to the web tends to neglect the main specificity of the platform (and the novel possibilities it unfolds): the network.

soundworks is a framework dedicated to the development of distributed multimedia applications on the web. The initial version of the framework, released in 2015, has been written by S. Robaszkiewicz and N. Schnell. Since then, the framework has known two major revisions (in 2016 and 2017) and has served as a basis for numerous artistic and research projects (e.g. concerts, installations, workshops, pedagogical or experimental setups). Thereby, soundworks has permitted to explore Network Music Systems in many directions such as: participative performances, use of smartphones as speaker array or as new instruments, measures of movements in collective settings. While these achievements tend to prove the efficacy of the framework considered as an experimental platform, they also permitted to highlight some inherent and recurring difficulties. soundworks#v3 aims to address these difficulties as well as to provide solid foundations upon which environments that facilitate the inclusion and agency of non-expert developers can be built.

In Section 2, we review three recent soundworks applications implemented in close collaboration with multiple stakeholders, and present of some of their similarities despite their different aims and goals. In Section 3 we present the main conceptual and technical aspects of soundworks#v3, designed to provide a better support to the recurring needs described in 2. Finally, in Section 4 we describe a simple, yet not trivial, application that we consider representative of recurring aspects of Networked Music Systems, and shortly present elements of its implementation using soundworks.

https://www.npmjs.com/org/soundworks
https://github.com/collective-soundworks/soundworks
https://github.com/Fr0stbyteR/webaudio-patcher
https://github.com/petervdn/webaudiotool
https://github.com/collective-soundworks/soundworks
2. ACHIEVEMENTS AND RATIONALES

In this section we shortly present three applications that has been designed and used in several contexts (e.g. workshops, performances, installations, scientific experiments) in the last year. These descriptions focus on the features and strategies implemented to support the needs, agency and workflows of non-expert developer users (e.g. artist, researcher, performers) in working situations. We conclude with a formalization of these recurring patterns, leading to the developments presented in section 3.

2.1 Elements

Elements is an application that has been specifically designed to conceive and prototype movement-based distributed Interactive Machine Learning scenarios. The application has been iteratively tested and developed in several contexts such as workshops, artworks and performances or scientific experiments.

The key aspects for the appropriation of the application by non-expert developer users stand in two complementary elements:

- A JSON file dedicated at configuring the different clients in terms of interface, type of synthesis or mapping.
- A controller (see Figure 1(left)) that allows for both remote monitoring (e.g. plot sensors, decoding of the ML algorithm) and remote control of each client (e.g. mute, volume).

2.2 Future Perfect

Future Perfect is an immersive 3D audio visual performance and installation work developed by Garth Paine during a residency that took place in 2018 between Ircam and ZKM. The application allows the composer to perform on the audience smartphone’s speakers using several dedicated interfaces. Figure 2 shows the composer in performance situation with three iPads as well as screenshots of the different interfaces designed and used for composing and performing.

In this application, many strategies have been implemented to provide the composer a dynamic environment in which he could test sonic material (i.e. dynamic update of sound files, creation of presets), simply configure many aspect of the synthesis (e.g. granular synthesis parameters, fade times), but also have useful feedback on the state of audience’s smartphones (e.g. loading states, position in concert hall). Again, the key elements here were the remote monitoring and control interfaces that enabled a rapid feedback loop in both composition and performance situations.

2.3 Biotope

Biotope is an generative and interactive installation composed by Jean-Luc Hervé, realized at Ircam and exposed at the Centre Georges Pompidou, Paris in the context of the exhibition “La fabrique du vivant”. The installation is composed of 27 Raspberry Pi nano-computers (see Figure 3(left)) running soundworks clients written using NodeJs. The audio synthesis is achieved using a NodeJs wrapper on top of libpd.

In this system, many strategies have been implemented to provide a dynamic and testable environment to the composer and to the computer music designer. Among them, the more important ones are: a mean to easily update audio content, and a centralized controller dedicated at both monitoring the state of the application (for example, each square in Figure 3(right) gives an overview of their state in real-time) and at controlling the state and parameters of each client in real-time.

2.4 Recurring Patterns

We can see that these different examples—which span across a wide range of applications (from experimental system to performance or installation)—share common strategies. First, they all provide a dedicated client that allows to monitor and take control over every client of the system in a simple way. This point stands to be of primary importance to maintain the agency of the user working in a complex setup composed of many devices. Second, they all allow—at different levels of maturity and usability—to update content, mappings and synthesis parameters dynamically or from configuration files. Indeed, these applications implement a similar architectural pattern where the state of each client is synchronized.
in some way with the server, allowing to update every part of the distributed application from a centralized point.

This pattern— that appeared very effective for implementing versatile and adaptable tools fostering creativity—provide insights on the functionalities our framework must facilitate. More precisely, it shows the necessity of a robust and versatile distributed state management system, aimed at simplifying remote monitoring and control in an environment composed of many devices.

While the presented examples showed the feasibility of creating such systems using the current version of soundworks, the experience showed that these aspects were not properly supported by the framework, leading to overly complicated and redundant architectures. This is these drawbacks that the novel version of soundworks presented in the next section propose to overcome.

3. DESIGN AND IMPLEMENTATION

In this section, we present some design and implementation aspects of the third version of the soundworks framework. First, we present the scope and high-level aspects of the framework. Second, we describe in more depth the novel state management component that have been introduced to support recurring patterns described in Section 2. We briefly conclude by presenting the motivations and expected benefits of the novel packaging and distribution strategy.

3.1 Architecture Overview

Since its inception, soundworks is dedicated at simplifying the development of web-based and distributed real-time musical systems. Figure 4 presents a bird’s-eye view of a typical soundworks application. Applications created using soundworks follow a star network architecture centered around a NodeJs server. Clients can have multiple responsibilities (e.g. audio rendering, visual rendering, control) and be of different kinds (e.g. mobile, desktop, nano-computers).

Until now, the framework has mainly focused on mobile applications and has therefore privileged certain characteristics of these platforms (e.g. graphical user interface, usability). While these aspects remain important, it appears now that—to preserve its efficiency as an experimental platform and to support more and more complex applications and use-cases—the framework must evolve toward more modularity and extensibility, considering both software (e.g. integration of third party components and libraries) and hardware (e.g. integration of IoT elements).

In this objective, the scope of the framework has been refined and narrowed down to focus on three key aspects, namely: communications, service management and state management. As a consequence, some features such as templating, have been removed from the framework and are now delegated to external and specialized libraries. These developments also permitted to reduce the API surface area of the framework.

3.2 Communications and Services

While similar in their principles, the communication and service management components have evolved toward more simplicity and efficiency. Figure 5 summarizes the initialization process common to all soundworks clients:

- The init step consists in connecting two WebSockets to the server, one dedicated to string (JSON compliant) data and another dedicated to binary data. The API of both sockets is similar and expose a simple publish / subscribe interface.
- Once both sockets are connected, soundworks can start the services initialization. As services can depend on each others (for example, the clock synchronization process can rely on a resumed audio context), soundworks takes care of the services' dependency graph and start each service accordingly.
- Finally, when all services are in ready state the application specific code (called Experience in soundworks' terminology) can start.

![Figure 4: High-level view of the architecture of a typical soundworks application: clients of various types (e.g. mobile and desktop browsers, embedded hardware running a NodeJs client, external software communicating through OSC or MIDI) connected to a central NodeJs server.](image)

![Figure 5: Initialization process of a soundworks clients, here a mobile browser and a NodeJs client running in embedded hardware.](image)
3.3 State Management

An important novel feature of soundworks is the integration of a state management system.

Indeed, since the introduction of the Flux pattern proposed by Facebook\(^1\) a number of state management libraries\(^2\) have been proposed. The usage of this pattern is nowadays widespread and considered a good practice among the JavaScript community. However, existing libraries are not firstly designed for distributed applications and are difficult to adapt to our context for two main reasons. First, they do not formalize nor integrate the notion of discrete and volatile events very common in our applications (e.g. triggering a sound). Second, they do not provide out-of-the-box a simple way of synchronizing states across several nodes in the network\(^3\).

To tackle these issues, we created a novel protocol and implemented a novel component, inspired by the Flux pattern and adapted to the particular requirements of our applications.

Concepts and Requirements

In the context of real-time, audio-centered and distributed applications, the application of such circular pattern presents certain particularities schematized in Figure 6.

![Conceptual overview of a circular and distributed state management system](image)

The Figure particularly highlights two important requirements and implications for the implementation of this pattern. First, it shows that the state of every client has to be kept synchronized server-side. The rationale for this design strategy (see Section 2 for details) stands in the need to remotely monitor and control any client of the system from a centralized point. Indeed the possibility to dynamically interact with any node of the network, and the rapid feedback loop it enables, is of primary importance in working situations. Furthermore, it appears to be crucial in exploratory contexts (such as artistic and research activities) where the final application cannot be specified beforehand and emerges from an iterative process.

Second, the Figure highlights the need of a certain granularity in the definition and synchronization of the states. Indeed, while some variables and parameters (named globals in the Figure) needs to be accessible to every client (e.g. master volume, mute), the particular state a client (clients[2] in the Figure) should not be shared with all its peers. It only needs to be monitored or controlled by particular types of clients dedicated to authoring and performance situations.

Protocol and API

To fulfill these requirement while preserving the idea of circular flow between actions, data and rendering proposed by the Flux pattern, we designed a simple protocol and implemented a new library\(^4\). The main principles of the protocol we propose are:

- Allow any node to create a new state from a declared schema.
- Allow to keep the state synchronized with the server.
- Allow any node to observe new states created on the network.
- Allow any node to attach to a state created by another node.

![Example of the protocol implemented by the StateManager](image)

Figure 7 illustrates a generic scenario enabled by this protocol. A client (we name controller) observes the server and attach to the state created by another client (here, called player). When attached, the controller receives a notification each time the state is updated by its creator (or any other attached node), enabling remote monitoring. The controller can also update values of the attached state, enabling remote control. At any moment, the controller can detach from the state and stop to receive update notifications.

The protocol is abstracted behind a small and simple API illustrated in the pseudo-code example of Listing 8. This simple example also highlights two interesting aspects of the component:

- The complete abstraction of network communications, allowing users to focus on the application logic rather than routing of network messages.

\(^1\) https://facebook.github.io/flux/
\(^2\) For example: https://redux.js.org/ or https://vuex.vuejs.org/
\(^3\) The dop.js (https://distributedobjectprotocol.org/) library propose an interesting approach, however it aims at synchronizing a single state across every node which is not optimal (particularly in terms of bandwidth) in our context.
\(^4\) The dop.js (https://distributedobjectprotocol.org/) library propose an interesting approach, however it aims at synchronizing a single state across every node which is not optimal (particularly in terms of bandwidth) in our context.
The possibility to reflect on the schemas’ declarations to generate controls and monitoring interfaces, simplifying the implementation of dynamic and complex interfaces.

### 3.4 Distribution: Core and Services

A final aspect that we want to present is the novel approach for the packaging and the distribution of *soundworks*. The framework is now distributed behind its own npm organization namespace: @soundworks. Furthermore the core of the framework and the different services have been decoupled. As such, services are now imported in the application as plugins that must be registered in the ServiceManager.

We think this modular approach will facilitate future evolutions of the codebase, as well as maintenance of existing applications. Furthermore, this strategy should help to simplify the design and development of new components as well as their testing and documentation.

### 4. A TODO(NOISE) APPLICATION FOR DISTRIBUTED AUDIO FRAMEWORKS

In this section we describe a simple application, inspired by the *TodoMVC* project[^1][^2] that aims at providing a common basis to test and compare frameworks dedicated at building distributed audio applications. We first present the motivations and features of the application and, second, describe elements of its implementation within *soundworks*.

#### 4.1 User Story

The proposed application purposely privileges the point of view of a user in a working situation (i.e. developer, designer, composer or performer) rather than the point of view of the end user (e.g. participant, audience). Indeed, while the later tends to be very application or artwork specific, we have shown in Section[^2] that the former embodies common properties—the need for remote monitoring and control of the distributed state of the application—that can be reduced to simple features.

To illustrate these features, we have designed a basic application composed of two different clients. The first client, we call *player*, can be envisioned as the client dedicated to the end users. The application can accept any number of *players*. Each *player* has access to the following functionalities:

- can trigger a sound
- can start and stop a synthesizer
- can update a parameter (i.e. volume)

The second client, we call *controller*, is dedicated to the user in working situation (e.g. design, composition, research, performance). The application can accept any number of *controller*. A *controller* can:

- control global parameters of the application (i.e. mute, master volume)
- take control over each *player* (i.e. volume, trigger and state of the synthesizer)

Globals parameters of the application (i.e. *mute* and *master*) must stay synchronized across every clients of the application (i.e. *player* and *controller*).

We think this minimal set of functionalities provides a good reduction of important and recurring aspects of distributed audio applications. We also believe that it could, after eventual refinements, provide a good basis for testing, demonstrating and compare different frameworks and approaches.

#### 4.2 Elements of Implementation

We implemented this application using *soundworks* (see Figure [9][9])

[^1]: [https://www.npmjs.com/org/soundworks](https://www.npmjs.com/org/soundworks)
[^2]: [https://github.com/collective-soundworks/soundworks](https://github.com/collective-soundworks/soundworks)

![Figure 9: Interface of the (a.) controller and (b.) player clients of the *Todo(Noise)* application. Here, the controller duplicates the interface of the *player* with id 32, allowing for remote monitoring and control of this particular client.](https://github.com/collective-soundworks/soundworks-todo-noise)

The application is composed of only two schemas:

- The *globals* schema contains the list of connected *player* ids, the id of the remote controlled user (if any), the values of the *mute* and *master* volume parameters.
- The *player* schema contains the current value of the player’s local volume, the state of the synth (*started* or *stopped*) and a volatile event dedicated at triggering a sound.
The main logic of the application is implemented in the controller client. Indeed this client (cf. Listing 10), in its subscription to the globals state, observes the value of the remoteControlled parameter and attach to the state of the corresponding player. When attached to the player state, the controller simply instantiate the player’s GUI to locally create a remote and synchronized monitor and control interface.

```javascript
// src/client/controller/ControllerExperience.js
this.globals.subscribe(async (updates) => {
  for (let [key, val] in Object.entries(updates)) {
    if (key === 'remoteControlled') {
      const playerId = val;
      // detach from previous player
      if (this.playerState) {
        detach this.playerState.detach();
        this.playerState = null;
      }
      // attach to new remote player
      if (playerId !== null) {
        this.playerState = await stateManager.attach
          ('player', playerId);
        // keep GUI synced with player state
        this.playerState.subscribe(this.render);
        // handle disconnection
        this.playerState.onDetach(() =>
          this.playerState = null);
      }
    }
  }
  this.render();
});
```

Figure 10: Main pseudo-code logic written in the controller to remotely monitor and control any player of the application.

5. CONCLUSION AND FUTURE WORKS

In this paper, we have presented the motivations, design and implementation of a novel version of soundworks, a framework dedicated at developing distributed multimedia applications on the web. First, we have presented three applications implemented or refined in the last year and discussed some of the recurring difficulties—that the current version of the framework failed to properly address. Second, we have presented the novel architecture as well as a new component dedicated to distributed state management and designed to address these recurring issues. Finally, we have described a simple application—designed on the model of the TodoMVC project—that summarizes recurring aspects of distributed audio applications, and some elements of its implementation within the new version of soundworks.

While we think this new version provides solid foundations to further explore the possibilities of the web platform for Network Music Systems, it also opens large areas of new developments. First, a cli tool for scaffolding applications would be an important addition. Second, the integration of node.js clients in the core of the framework should simplify testing and thus help to stabilize the framework. Third, and more important, it opens many paths for creating a more dynamic working environment, facilitating the inclusion of users with different backgrounds (e.g. artists, researchers) and transdisciplinary approaches.

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7. REFERENCES


[10] M. Puckette. Combining Event and Signal Processing in the Rapid-Mix Project from the European Union’s Horizon 2020 research and innovation programme (H2020-ICT-2014-1, Project ID 644862). It has also been supported by the Ircam project BeCoMe, which is featured in the Constellations residency of the STARTS program of the European Commission.

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