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UnStumm | Augmented Voyage: A Platform for Telematic Live Performances in Augmented Reality

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UnStumm | Augmented Voyage: A Platform for Telematic Live Performances in Augmented Reality

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Abstract

UnStumm | Augmented Voyage is curated and developed by time-based media artist Claudia Schmitz and sound artist and guitarist Nicola L. Hein. It was programmed and developed by software engineer Sven Hahne. UnStumm | Augmented Voyage is also a mobile app and server infrastructure that serves as the artistic vehicle to realize telematic live performances with artists from around the globe. It consists of video art, music, and dance in augmented reality. Through the use of our software, the audience is able to view the video streams by video artists as 3D video sculptures and listen to the audio streams by the musicians through a virtual, multi-channel loudspeaker system. In the following text, we discuss the technical development, artistic aims, and realization of UnStumm | Augmented Voyage; we additionally present several projects that have already been realized with it.

Introduction and Context

UnStumm | Augmented Voyage is curated and developed by time-based media artist Claudia Schmitz and sound artist and guitarist Nicola L. Hein. It was programmed and developed by soft-

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ware engineer Sven Hahne. Since 2019, UnStumm | Augmented Voyage has taken shape as a platform for live, telematic performances consisting of video art, music, and dance in augmented reality. The platform includes server infrastructure and an app for iOS and Android mobile operating systems. With UnStumm | Augmented Voyage, we aim to develop a new vision of collaborative, live telematic performances in augmented reality.

UnStumm is a project for live video and sound art performances. It focuses on cross-disciplinary and cross-cultural collaboration between video artists and sound artists from Germany and other countries internationally. UnStumm aims to create an environment of cultural and creative exchange whereby a common, complex artistic language is invented and used to communicate narratives and textures, colliding and combining worlds of sight and sound. UnStumm has been performed in twelve countries around the globe: Japan, South Korea, Malaysia, Taiwan, Singapore, Hong Kong, Sweden, Germany, Mexico, Colombia, Argentina, and Ecuador. More than 65 different video and sound artists have been invited to collaborate with Nicola L. Hein and Claudia Schmitz.

These groups of artists work together in two different groups for four days to create an audiovisual performance that explores multidisciplinary improvisation as well as structure and narrative. The resulting artworks reflect on the themes of interculturality, cultural identity, cross-cultural communication, and the history of artistic thought in different cultures.

UnStumm | Augmented Aether uses the augmented-reality app UnStumm | Augmented Voyage to enable audiences to receive the telematic performances. Through the app, they encounter an augmented-reality experience with 3D video sculptures and virtual, multi-channel loudspeaker systems. The app's main goal is the equal communication of both video and sound artists as they perform live and telematically in augmented reality.

Figure 1: *UnStumm | Augmented Aether #6* (rehearsal). © UnStumm, VGBild-Kunst, Claudia Schmitz, Sue-C, Nicola L. Hein, and Laetita Sonami. Documentation by Claudia Schmitz, Dresden, Germany.

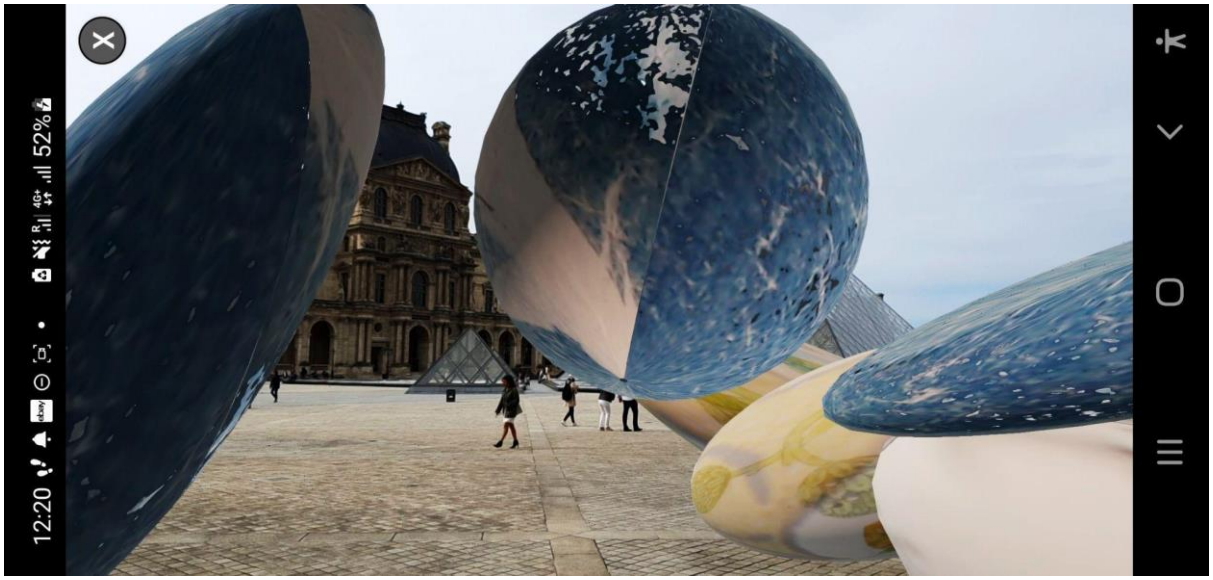

Figure 2: *UnStumm | Global Virtual Stages - Colombia | Germany*. © UnStumm, VGBild-Kunst, Claudia Schmitz, Juan Orozco, Nicola L. Hein, and Ana María Romano. Documentation by Jan Thierhoff, Paris, France.

Framework

We developed our own framework for streaming performances in augmented reality. We used JackTrip for audio and OBS for video to livestream to our server, which we would then

stream from our server to users' smartphones and tablets. The individual video stream, rendering of 3D models, and the projection of individual audio streams on virtual loudspeakers happens on the audience's smartphones. Downloading the UnStumm app allows audiences to use their own smartphone as augmented-reality glasses and thus participate in the live performances as well as retrospectively visit past performances in the internal library. Sound is audible via headphones and a binaural audio stream. The format we developed makes it possible to make all telematic performances by UnStumm accessible to the audience as a virtual exhibition unlimited by time and space, made accessible as fixed media works via the library of the UnStumm augmented reality app. This augmented-reality project transfers the stage space into virtual space while simultaneously integrating the real space in which the audience, i.e., the concrete user of the app, is located at that moment.

Performances and Examples

The first showing of UnStumm | Augmented Voyage took place under the name *UnStumm | Preliminary Conversation in Augmented Aether* on April 1, 2021. It featured the artists Katherine Liberovskaya (live moving image), Miya Masaoka (electronics, one-stringed koto), Seth Cluett (electronics), Axel Dörner (trumpet, electronics), Lillevan (live moving image), Claudia Schmitz (live moving image onto sculptures), and Nicola L. Hein (guitar, electronics). UnStumm | Augmented Voyage allowed for the realization of several performance series and projects that Schmitz, Hein, and a group of international artists performed as telematic audiovisual improvisations in augmented reality that could be viewed by an audience using the UnStumm | Augmented Voyage app.

The performances are accessible to the audience as a virtual exhibition in the UnStumm | Augmented Voyage app as fixed media pieces via the app's media library. In 2021, the projects realized with the UnStumm | Augmented Voyage app included the following:

UnStumm | Global Virtual Stages (sound and moving image)
June–August 2021

With *UnStumm | Global Virtual Stages*, Claudia Schmitz and Nicola L. Hein invited artists from Japan, Mexico, Colombia, Germany, and the United States to telematic, real-time performances in augmented reality. The international artists encountered each other in audiovisual interactions that were then projected onto augmented-reality sculptures and through virtual loudspeakers. The participating artists were Tetuzi Akiyama, Kim Alpert, Alexander Bruck, Axel Dörner, Lillevan, Lou Mallozzi, Toshimaru Nakamura, Akiko Nakayama, Juan Orozco, Elena Pardo, Ana

María Romano, Claudia Schmitz, and Nicola L. Hein. The augmented-reality stage concept was designed by Claudia Schmitz.

UnStumm | Augmented Movements (sound, moving image, dance)
August 2021

With *UnStumm | Augmented Movements*, Claudia Schmitz and Nicola L. Hein invited artists from South Korea and Germany to a telematic, live performance in augmented reality with dance, video, and sound. The international artists encountered each other through audiovisual interaction. Their audio and video streams were mapped onto augmented-reality sculptures and outputted through virtual loudspeakers. Infrared camera recordings of the dancers' moving bodies were projected onto augmented-reality sculptures as well. The participating artists were Mimi Jeong, Sejin Kim, Ingo Reulecke, Jin Sangtae, Nicola L. Hein and Claudia Schmitz. The augmented-reality stage concept was designed by Claudia Schmitz.

UnStumm | Augmented Aether (sound and moving image)
November–December 2021

This series of six performances involved seventeen artists from nine countries. These performances took place live on the Augmented Voyage app. They could also be watched via livestreams on YouTube and Twitch. The audience experienced the performances as an interaction of floating video sculptures and multi-channel soundscapes, which were realized in the audience's own living space. The participating artists were Constantin Basica, Alexander Bruck, Chris Chafe, Axel Dörner, Luis Negrón van Grieken, Gabriela Golder, Lillevan, Juan Orozco, Elena Pardo, Laetitia Sonami, Sue-C, Mariela Yeregui, Viola Yip, Nicola L. Hein, and Claudia Schmitz. The augmented-reality stage concept was designed by Claudia Schmitz.

UnStumm | Artificial Liveness in AR (Sound and moving image)
Performed live at the NIME Conference 2021, June 16, 2021

In this performance, Claudia Schmitz and Nicola L. Hein performed a quartet with two artificial-intelligence (AI) entities. The AI-machine artists performed with AI-generated electronic sound and video materials. The augmented-reality stage concept was designed by Claudia Schmitz.

Distancing in Augmented Reality

The main concern of the project UnStumm is conversation. We aim to overcome set boundaries. With our virtual extension UnStumm | Augmented Voyage, we extend our focus to the field of augmented reality and face the new problem of rapprochement.

How can distance be grasped in augmented reality? What does it mean and can it be overcome at all? What does distance mean in telematic augmented reality performances?

In many performances and rehearsal situations we have asked ourselves these questions. We continue to do so with new questions like: What forms of distance do we encounter? How is it possible to work when there is no physical encounter—no tangible sonic body, no physical immersion in the visual? Does the attempt to overcome distance in augmented reality make sense at all?

With UnStumm | Augmented Voyage, we created a new setting with new parameters: a real-time, audiovisual performance in augmented reality with a real audience. We are aware of the distance in augmented reality, accept it, and work with novelty by incorporating new possibilities. It is not about including the new setting in reality; it is more about exploring the new forms of performance and using their extended possibilities. It is about expanding the notions of space and community to encompass virtual spaces and telematic presence. As said by Donna Haraway: "Technology is not neutral. We're inside of what we make, and it's inside of us. We're living in a world of connections—and it matters which ones get made and unmade."[5]

Artistic Goals

UnStumm | Augmented Voyage is not only a technical endeavor, but also artistic research that aims to reconfigure our temporal, cultural, and topological identity and to create fluid forms of identity that attempt a reconfiguration of the relationship between human, machine, and sculpture through live audiovisual performances.

With this project, Hein and Schmitz aim to challenge the limits of contemporary practice and, at the same time, find new ways out of the past into the future by exploring the perceptual foundations of sonic and sculptural creation.

Following Vilém Flusser's concept of space and its configuration by human beings, which he understands as "tubes"—"We . . . are tubes through which the world flows in through one opening and flows out through the other"—we want to investigate the potential for augmenting spa-

[5] Hari Kunzru, "You are Cyborg," *Wired*, February 1, 1997, https://www.wired.com/1997/02/ffharaway/.

tial configurations through the means of virtual-reality technology.[6] Understanding human beings as "tubes," we can be seen as constructed and constructing beings who artistically attempt to configure their own condition. The project works along this concept by introducing virtual-reality technology into live audiovisual performances, bridging limitations of physical space and time.

We wanted to develop the work with augmented-reality technology as a means to facilitate and open a virtual space of international, intercultural, and intermedial communication that does not bear the "trace" (to borrow Derrida's term) of one single culture that could be defined through a paradigm of topologically distinct nation states. Following Flusser, the virtual space is a space of "probabilities" where "nothing is true or false, but everything is more or less probable."[7]

UnStumm | Augmented Voyage: Diagrams and Technical Information

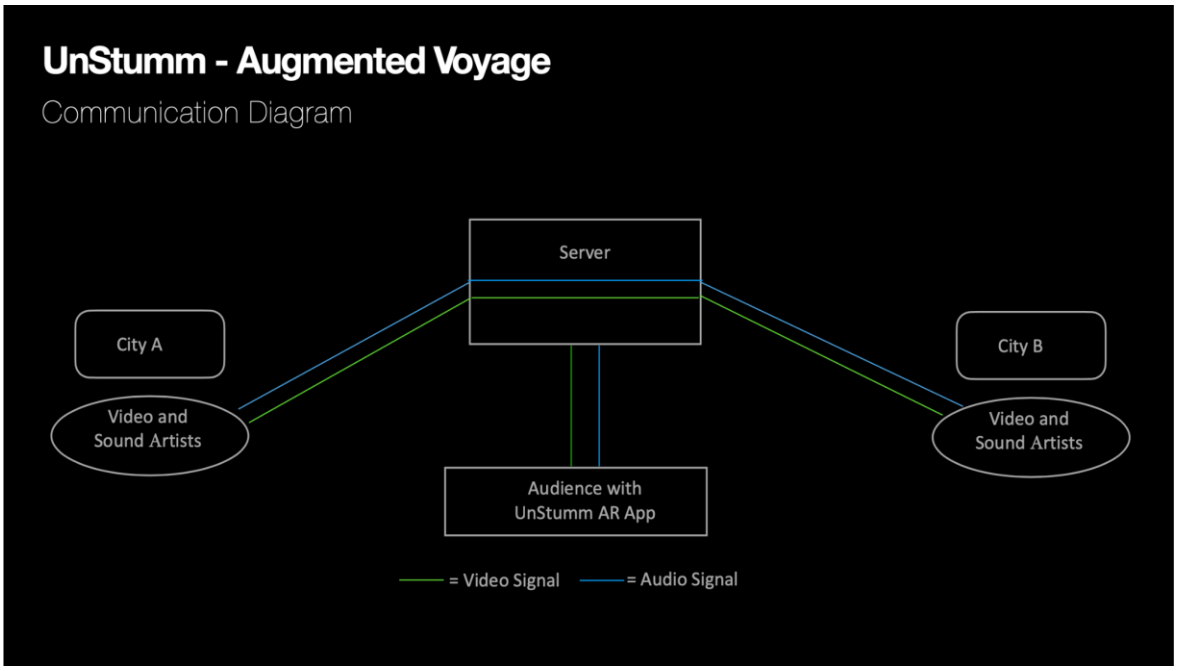

Figure 5: Communication diagram

[6] Vilém Flusser, "Räume," in *Raumtheorie: Grundlagentexte aus Philosophie und Kulturwissenschaften*, ed. Jörg Dünne and Stephan Günzel (Berlin: Suhrkamp, 2006), 146. Translation provided by author, Nicola L. Hein.

[7] Vilém Flusser, "Räume," 277.

Technical Details

Our setup can be roughly separated into 3 parts:

1. The sender side (video and sound artists)
2. The server
3. The receiver (mobile application and monitoring applications)

The basic task of the system is to send video and audio streams that have been produced by an artist from any internet connection anywhere in the world through an internet server to a user at any other place in the world. This task required the choice of a suitable format for streaming audio and video on the internet. In our case, our first attempt at finding a suitable format involved the consideration of several streaming formats that could provide all of the following: the lowest latency possible, easy setup for the sender side, and the best compatibility with the mobile application side. Unfortunately, these considerations resulted in mutually exclusive choices.

HLS (HTTP Live Streaming): HLS is an HTTP-based protocol developed by Apple that was released in 2009. It segments audiovisual input data into chunks, typically 3 seconds for H.264 video and AAC audio formats. Compared to most other streaming formats, it can traverse firewalls and at the point our development started, it was the only streaming format that was supported out-of-the-box by Apple's AVPlayer and Android's MediaPlayer. For this reason, it was chosen to resolve the sending part from our server to the mobile app clients. The big downside of this was the very high latency, typically around 10 seconds (although there is low-latency HLS which implies a compatibility problem).

RTMP (Realtime-Messaging-Protocol): Originally developed as a proprietary protocol, though later released in an incomplete version for public use by Adobe, RTMP was chosen for the sender side. Under the hood, it also typically works with H.264 video and AAC audio encoding, which allows unwrapping RTMP packets on the server and rewrapping them into HLS packets without the overhead of transcoding. The easiest to use, cross-platform and open-source software we found was OBS, which provides RTMP support as its main streaming protocol. Typically, it needs around 3 seconds of prebuffering, resulting in a much lower delay than HLS; however, it provides the same quality. Unfortunately, it's not supported by Android's MediaPlayer and also causes some issues when used with iOS's AVPlayer.

JackTrip and UDP (User Datagram Protocol): Probably the most low-level and low-latency way to send data over the internet, JackTrip uses UDP for ultra-low latency sending and receiving of audio. The effort to set it up is reasonable. In our benchmark tests, we ended up with delay times

close to the delay times arising from audio to digital and digital to audio conversion (depending on configuration and connection quality, 64 and 512 audio samples were tested by this method). Unfortunately, JackTrip is an audio-only solution, but we choose it to approximate real-time audio connections for our sound artists.

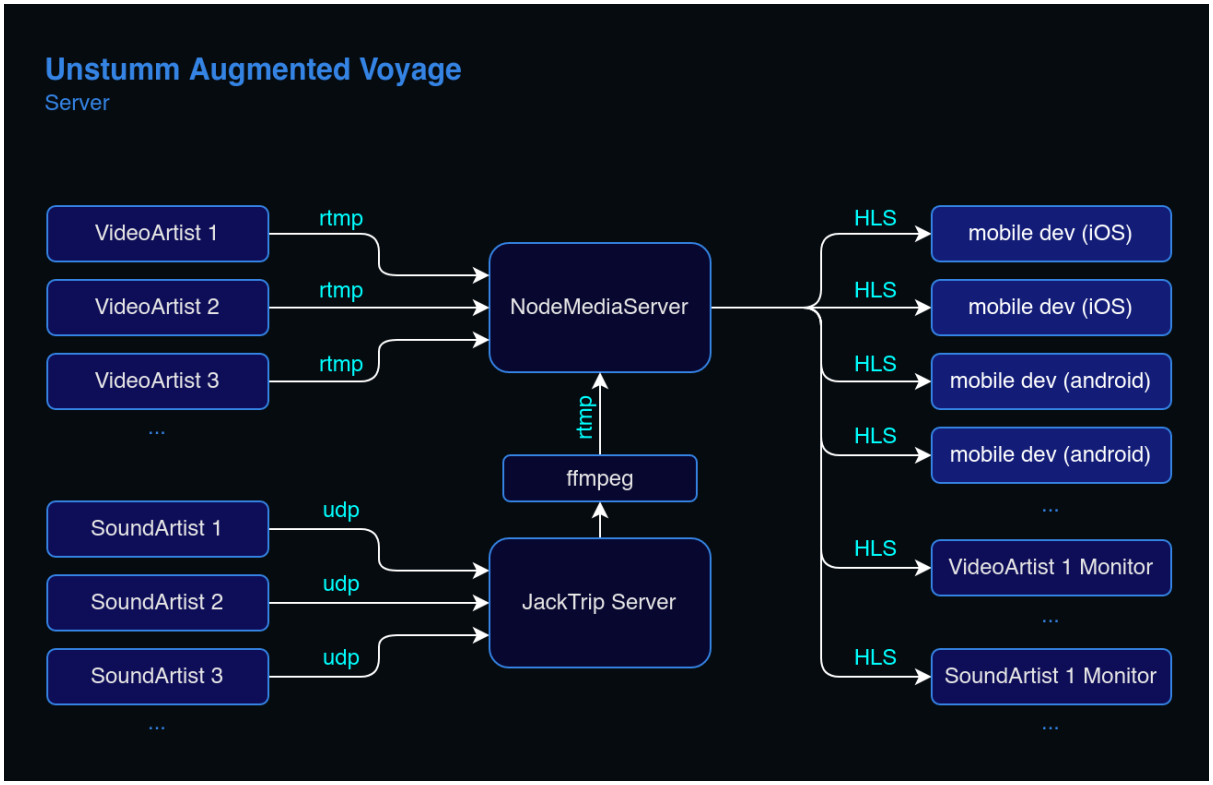

Figure 6: UnStumm server: audio and video

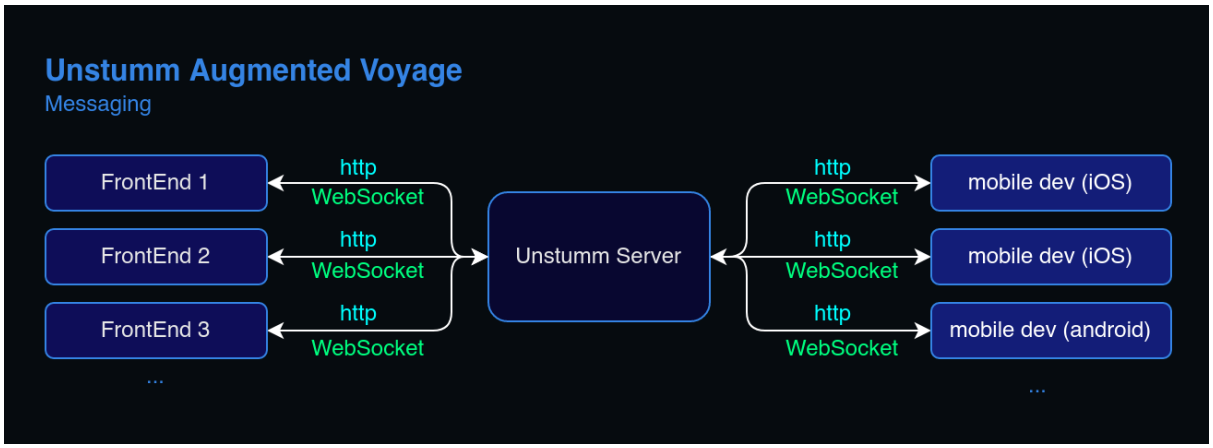

Figure 7: UnStumm server: messaging

The core of our system is a server written in Node.js containing:

- a REST API for sending performance parameters to the mobile application
- an audio-video server (HTTP, HTTPS, RTMP, RTMPS) based on the Node Media Server package
- a WebSocket server for communication performance parameter changes in real time
- a control interface for JackTrip and JACK audio server, as well as stopping and starting of FFmpeg-based conversion from JackTrip to RTMP
- a session management system for offline and live session delivery
- a recording mechanism for live sessions

Artists have full control over server tasks through accessing the HTTP front-end requests written in Vue.js. Functionality at this level includes:

- creating, renaming, and deleting of a session, i.e., providing HTTP access to session files on the server
- starting and stopping of JACK and JackTrip audio servers (running as a systemd service on the server)
- uploading of 3D models in the FBX file format; these are then converted to GLTF by the server in order to provide a suitable format for the Android Studio Sceneform 3D engine
- positioning of 3D models in space
- random movement and rotation of 3D models in space
- assignment of video streams to 3D models
- router matrix for audio streams (using the JACK API)
- starting and stopping of FFmpeg-based JackTrip to RTMP audio transcoding
- showing a message in the mobile app, e.g., announcing the starting time and date of a performance

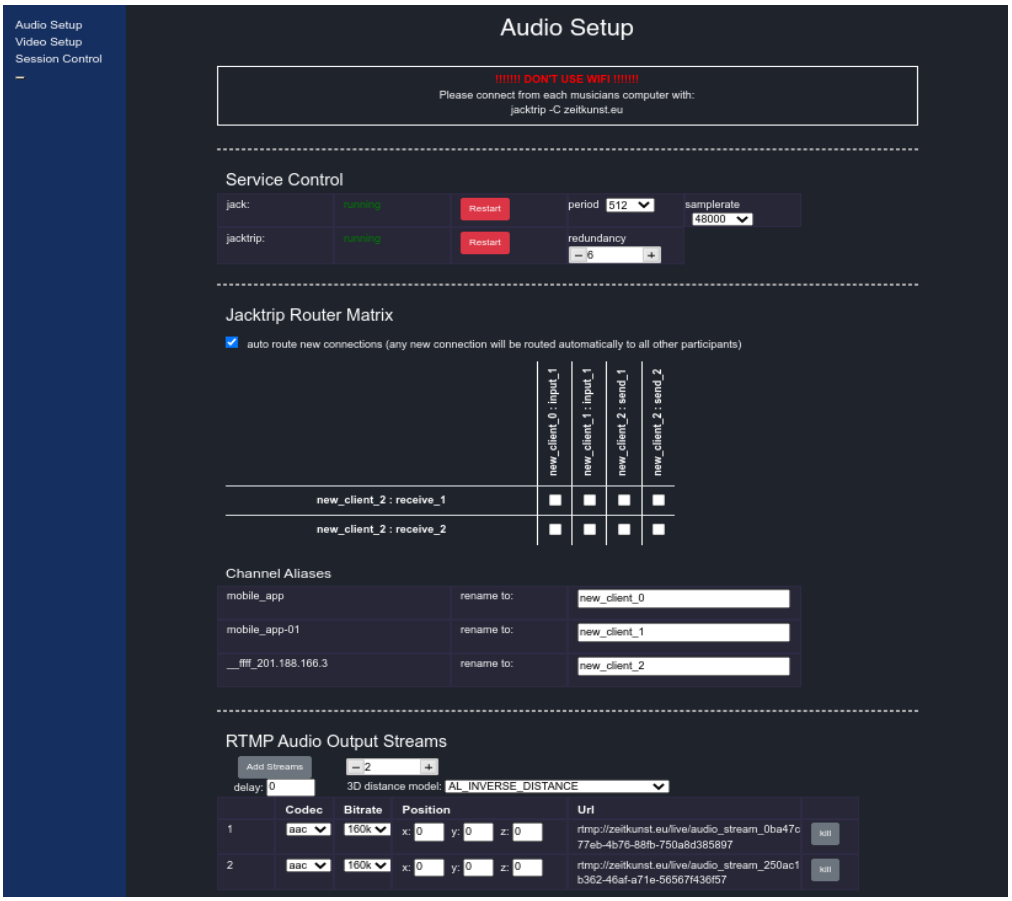

Figure 8: UnStumm server: front-end audio setup

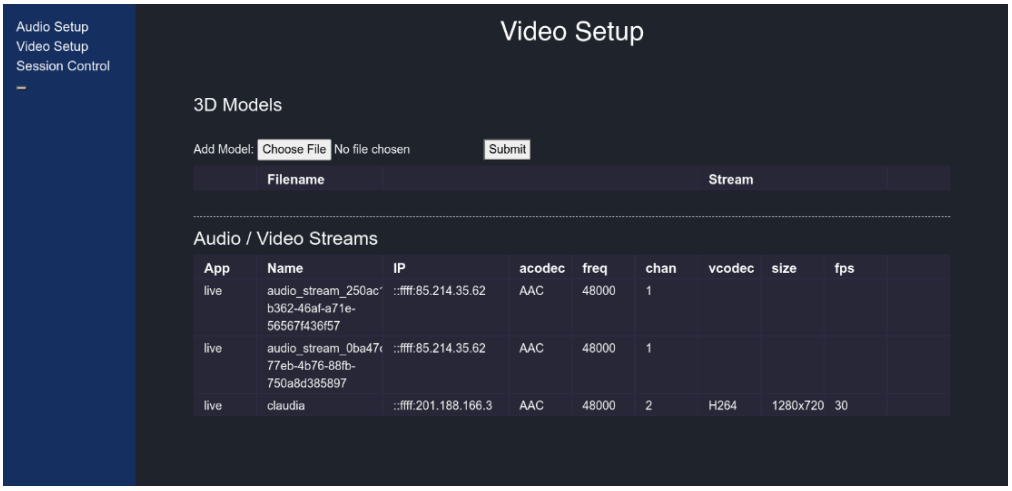

Figure 9: UnStumm server: front-end video setup

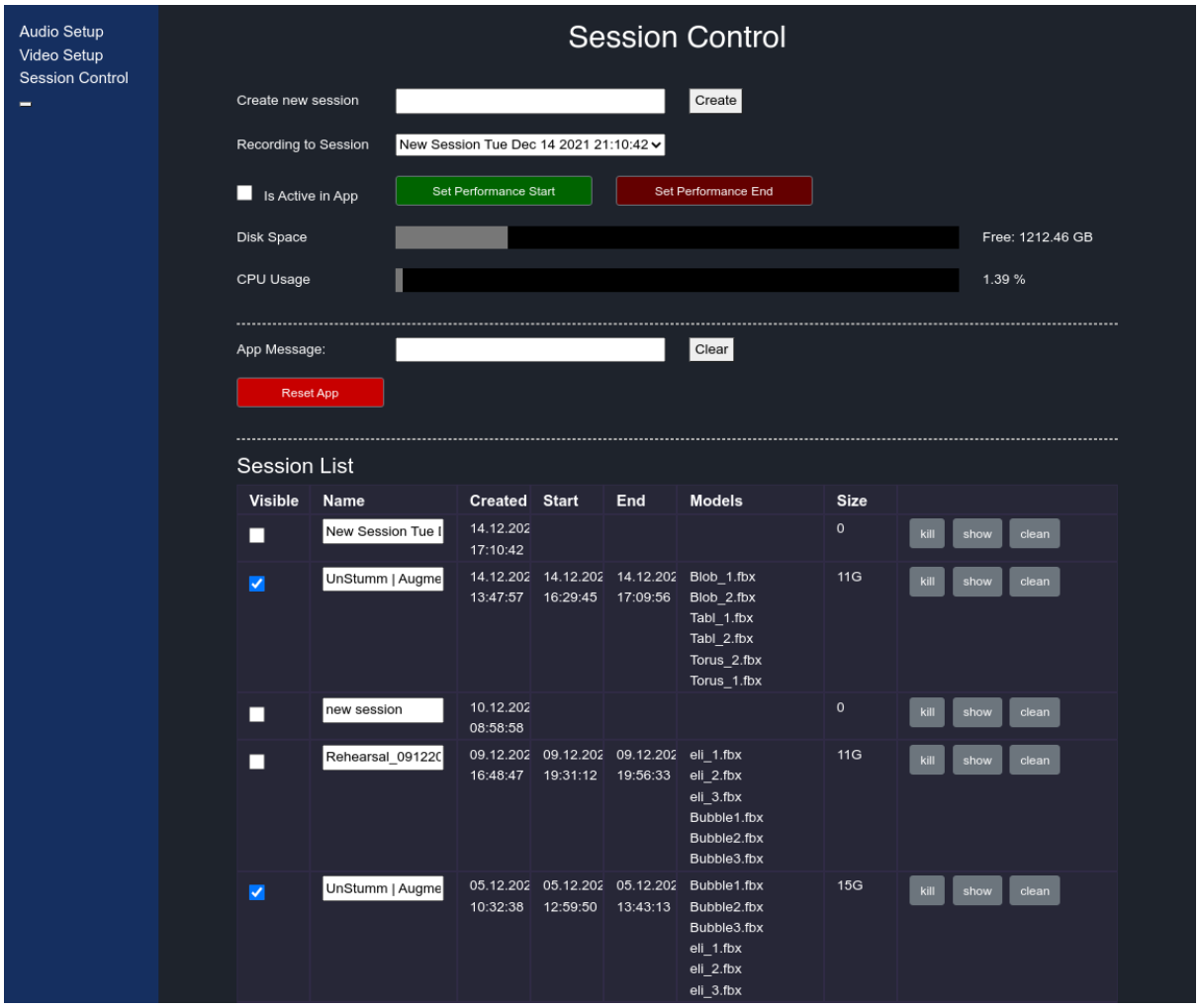

Figure 10: UnStumm server: front-end session control

3D Audio

A quite remarkable request for the audio side of the system was the ability to position audio in three-dimensional space the same way as the visual video-textured objects. Fortunately, there is OpenAL, an OpenGL-like framework for exactly this task that has been out there since 2009. It works across platforms and provides a remarkably high audio spatialization quality. Since it is neither part of Android SDK nor Swift or Kotlin on iOS, we needed to build it manually for each platform and use a native C++ library in combination with a natively built FFmpeg audiovisual encoding and decoding library. Here, the advantage is the direct use of RTMP streams provided by our server, which helps overcome the huge delay of HLS.

Since the RTMP streams sent from our server provide pure audiovisual data, there was the need to provide the additional information of x,y,z coordinates for each audio stream. We re-

solved this issue on one side through the implementation of a REST API for event-based access from the mobile app as well as WebSocket connections from the server to all devices. In so doing, real-time updates could be provided to the front-end servers (otherwise the app would have to be restarted each time the 3D-position values are modified).

Recording

Although it might sound simple, the recording of live sessions for offline replay was a non-trivial task to implement in the system. Although the use of HLS streams offered the easy option to collect all segments and paste them together after a session ends, various issues had to be addressed.

First of all, a sound or video artist might start their stream at any point in time, so starting and stopping the streams needed to be tracked throughout the lifetime of a session. Everything that was played before the session start needed to be cut. As the stream can be started and stopped several times before a session begins, those segments need to be filtered out.

Secondly, a stream might be stopped and started again during the performance. In order to provide just one single file for offline playback, silence and/or black images were to be generated to fill possible gaps. Next, the resulting segments would still need to be pasted. Luckily the process of pasting segments is straightforward thanks to H.264's ability to create independent chunks of video. (H.264 doesn't consist of full frames, but partially updated frames in order to provide high compression efficiency.) The order of audio and video streams inside a HLS container might vary, so this order needed to be checked and, potentially, the streams would need to be swapped in order for the conversion process to succeed.

Mobile Application

The most popular mobile phone operation systems are iOS and Android, while the market share of other companies is almost irrelevant. This results in the need for both an iOS- and Android-compatible application for enjoying the UnStumm - Augmented voyage performances. Although there are several SDKs which allow simultaneous development in iOS and Android, there is no possibility for unified augmented-reality development apart from big gaming engines like Unity or Unreal Engine. Neither of those engines provide HLS or RTMP streaming playback, which led us to develop our own applications with Android Studio and Xcode, respectively.

Apart from the aforementioned 3D sound, the playback process itself is straightforward. If there is a working internet connection, a request (containing a password and username) for an authentification key is sent to the UnStumm server. This and all further requests are signed with this authorization key. After that, a WebSocket connection is established. A list of active sessions can be requested from the server; live sessions are marked specifically. The downloaded session list is presented to the user. Upon selecting a session, its respective parameters are requested.

For each videostream, an AVPlayer or MediaPlayer instance is created and started. These instances decode the downloaded video frames and then store them in the graphics memory of the user's phone. Furthermore, the 3D models are downloaded and instanced into the 3D scene graph (Sceneform on Android and SceneKit on iOS). These decoded video frames are mapped onto the 3D models and are continuously updated. At the same time, audiostreams are opened via FFmpeg (built as a native C++ library on both platforms) and audio packets are decoded into memory.

For the projection of the sound, an OpenAL sound source is created for each audio stream and set to the position defined in the session data. The decoded audio packets are continuously copied to the OpenAL sound source buffer. Finally, the ARKit on iOS and ARCore continuously estimate the phone's orientation and position in space, updating the 3D scene graphs and OpenAL audio engine.

Monitoring

The playback process was also implemented in the form of a desktop application for macOS, Windows, and Linux. Here additional raw video streams are shown in separate views which can be maximized and minimized. Audio monitoring was done by direct JackTrip connections to Unstumm's JackTrip server (although we are still contemplating to include this playback in an automated form into the desktop application).

Communication between artists was done by running a Zoom session in parallel with the performance. This gave us the additional problem of needing additional bandwidth. This was out way to avoid implementing an own video conferencing system which would have meant a complete break of the projects timeframe and budget.

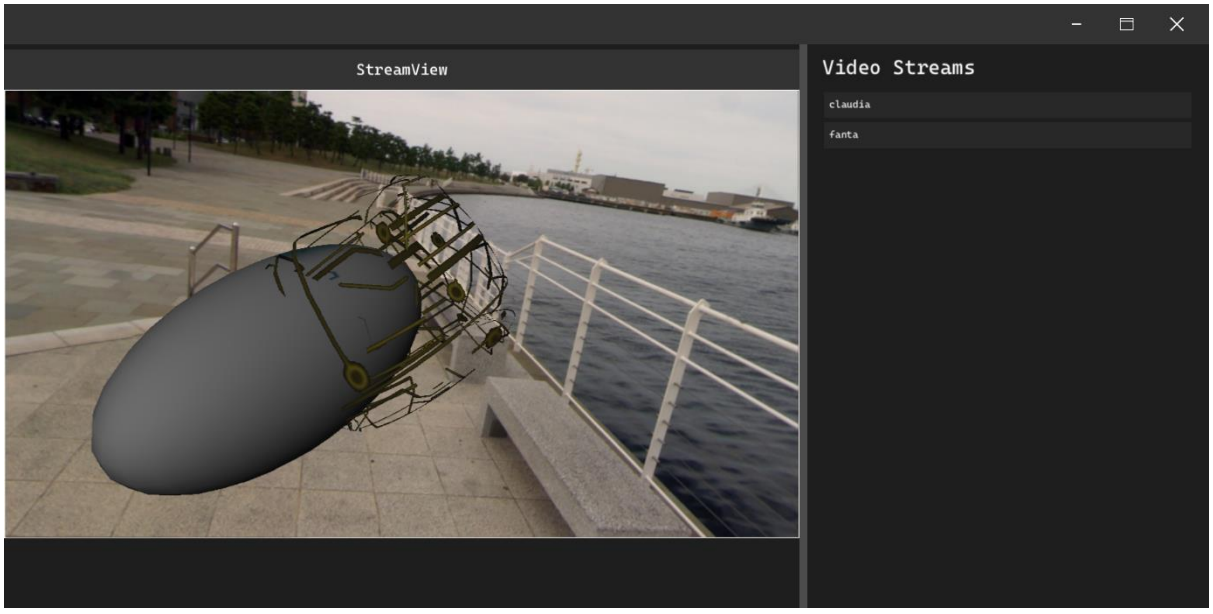

Figure 11: UnStumm monitoring app, single stream view

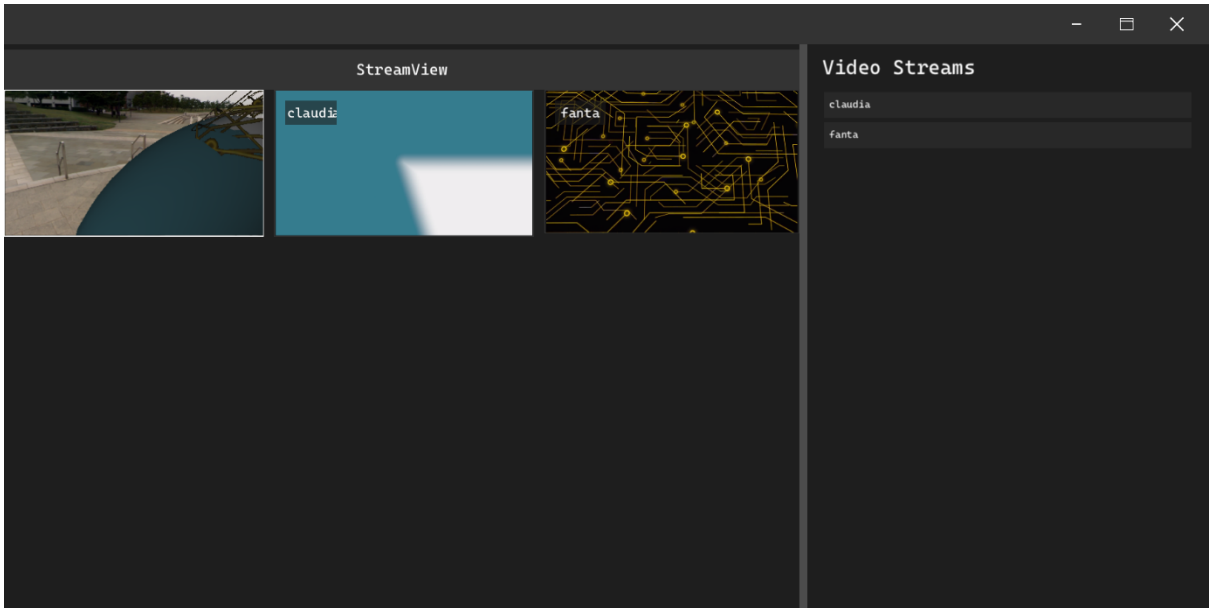

Figure 12: UnStumm monitoring app, all streams

Conclusion

With this paper we hope to have shown our artistic motivations and aims in developing UnStumm | Augmented Voyage. Furthermore, we hope that describing the technological process of making UnStumm | Augmented Voyage communicates not only technical challenges, but also, our technological and artistic solutions. We additionally hope that it enabled the reader to follow along with the different stages of development in realizing UnStumm | Augmented Voyage.

As we are moving into the future, new projects using the Augmented Voyage platform are being realized. Our upcoming program includes UnStumm | Cypher Mimesis, which investigates the interaction between artificial-intelligence artists and human artists in augmented reality. Furthermore, we are planning to premiere UnStumm | Augmented Movements, wherein we are developing our technological framework in augmented reality, but for dance. Another aim of our current development process is to realize in situ performances using low-latency NDI network protocols to enable mixed reality performances with artists and audiences joining each other in the same space.

Acknowledgments

UnStumm | Augmented Voyage has been supported by the *Kulturstiftung des Bundes* [German Federal Cultural Foundation], Goethe Institute, *Fonds Darstellende Künste*, NEUSTART KULTUR, *Beauftragte der Bundesregierung für Kultur und Medien* [Federal Government Commission for Culture and Media], *Kunststiftung NRW*, *NRW Kultursekretariat*, *Ministerium für Kultur und Wissenschaft des*

Landes Nordrhein-Westfalen (Ministry of Culture and Science of the State of North Rhine-Westphalia), *Ministerium für Wissenschaft, Weiterbildung und Kultur des Landes Rheinland-Pfalz* [Ministry of Science, Further Education and Culture of the State of Rhineland-Palatinate], *Ministerium für Familie, Frauen, Kultur, und Integration des Landes Rheinland-Pfalz* [Ministry for Family, Women, Culture, and Integration of the State of Rhineland-Palatinate], and CINETic at the National University of Theater and Film "I.L Caragiale," Bucharest.

Appendix

Links to videos, performances, and other apps mentioned in this essay:

UnStumm
UnStumm | Augmented Voyage app
NIME 2021 – New Interfaces for Musical Expressions

UnStumm | Preliminary Conversation in Augmented Aether
Description: 3-minute sample of a 40-minute performance held on April 1, 2021, featuring the artists Katherine Liberovskaya (live moving image), Miya Masaoka (electronics, one-stringed koto), Seth Cluett (electronics), Axel Dörner (trumpet, electronics), Lillevan (live moving image), Claudia Schmitz (live moving image on sculpture), and Nicola L. Hein (guitar, electronics); Augmented-reality stage concept by Claudia Schmitz and documented by Jan Thierhoff. Düsseldorf, Germany.

UnStumm | Global Virtual Stages
Description: Excerpt from a performance series held on June 19, 2021, with artists from Colombia and Germany, featuring Ana María Romano (electronics), Juan Orozco (video and performance), Nicola L. Hein (guitar, electronics), and Claudia Schmitz (live moving image onto sculpture). Augmented-reality stage concept by Claudia Schmitz and documented by Jan Thierhoff. Paris, France.

UnStumm | Augmented Movements
Description: Excerpt from a performance held on August 24, 2021, featuring the artists Mimi Jeong (dance), Sejin Kim (synthetic live video), Ingo Reulecke (dance), Jin Sangtae (prepared hard drives, electronics), Nicola L. Hein (guitar, buchla, electronics), and Claudia Schmitz (live moving image onto sculpture). Augmented-reality stage concept by Claudia Schmitz, documented by Jan Thierhoff and Sven Hahne. Brittany, France, Düsseldorf, Germany, and Santiago, Chile.

UnStumm | Augmented Aether

Description: Excerpt from a performance series with artists from the United States and Germany held on December 12, 2021, featuring Laetita Sonami (electronics), Sue-C (live-video), Nicola L. Hein (guitar, buchla, electronics), and Claudia Schmitz (live moving image onto sculpture). Augmented-reality stage concept by Claudia Schmitz, documented by Jan Thierhoff. Düsseldorf, Germany.

UnStumm | Artificial Liveness

Description: Excerpt from a performance held on June 14, 2021, featuring Claudia Schmitz (live moving image onto sculpture) and Nicola L. Hein (guitar, electronics) performing as part of a quartet with two artificial-intelligence entities. Augmented-reality stage concept by Claudia Schmitz, documented by Jan Thierhoff. Düsseldorf, Germany.

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Kunzru, Hari. "You are Cyborg." *Wired*, February 1, 1997. *https://www.wired.com/1997/02/ffharaway/.*