SPATIAL ACOUSTIC-BASED REVERBERATION SIMULATION AS A REPRESENTABLE REALITY IN THE INTERNET ERA

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Abstract

The emerging internet has indicated that modern human civilisation highly attributed by the Internet of Things (IoT) which is characterised by the enormous 'big data' captured through device sensors and mediated communication platforms. Meanwhile, there is an increasing keenness in exploring the inception of reality in the Internet Era as the scholarly discussion on how IoT potentially changes the patterns of seeing, considering and representing the reality is in high demands at present.

This paper proposes workable means of representable reality by generating and re-generating acoustic data that reflect spatial properties of a designated environment through technical formulation of reverberation simulation. It also considers possible conditions of such representation, especially the process control through real-time accessibility of data directly collected from machine–machine communication via sensors, IP addresses and network connectivity. The methodological outcome of this simulation offers a result that a captured instrumental sound event can be played as if in a contextualised space, which in the past has to be physically constructed to accommodate a certain relevant technology in audio recording. With a new method that can feasibly rework any acoustic phenomenon, a physical construction of the desirable contextualised space is no longer required. Moreover, digital data captured from various geographical locations can be mapped in an internet-based platform of potential cartographic or site navigation in order to facilitate remote users in experiencing a representable reality.

This paper also discusses possible issues arising from the simulation framework and the impacts of IoT, which are concisely reviewed, as well as various approaches in the sense-making of contemporary sound studies.

Keywords

Internet of Things, Reverb Simulation, Spatial Properties, Representable Reality

Introduction

Since 1990s, the rise of the Internet and human's increasing dependency on the so-called 'big data' generated through device sensors and mediated communication platforms have significantly changed human behaviour and social interactions. Through the Internet of Things (IoT hereafter) emerging from a modern civilization in a time called the Internet Age, new ideas are enabled through the collection and preservation of information data. Through archiving, data or information are used as a feeder in completing certain tasks acquired by a mobile application in computation systems. At present, an archivist is no longer collecting data through fieldwork for the needs of a single social scientist as how it was done in the past. These systems of information and its dissemination of huge data were continuously initiated in our daily lives in many aspects. A career person who is busy with his daily schedule would still be able to shop for his household supplies, to get from one place to another, to do laundry and even to prepare for dinner via online transactions.

Similarly, in the context of sound studies, it is possible that spatial information of an acoustic environment can be collected. A possible future scenario is that it would be easy not only to see a house one would like to buy online from various perspectives but also to hear how sound would appear in different rooms, the porch or the garden. One could listen to music from various distances in acoustic simulation and could thus feel movements and journeys more than the visual dimension. All of these consequences made possible through technology and innovation shift human thinking and understanding of how sound is experienced thus sound becomes a forceful tool in memorizing history and community relationships (Musib 2015: 172).

From the perspective of sound preservations through data collection, archivists would be able to construct and preserve spatial information that made possible through the Impulse Response (IR hereafter) approach. The concept of preservation in the age of digital media is not limited to audiovisual documentation. Structural chronicling spatial data is currently turning into another exploratory territory for social researchers. These data incorporate video codecs for digitization of moving picture, contextual sound as spatial parameters of acoustic properties in order to provide some examples. A theoretical framework by Michael Gerzon (1975), a mathematician in Oxford and the founder of *Ambisonic*, at first proposed an accumulation of sonic conduct through Impulse Response made ready to characterize acoustic properties of a room. By utilizing this methodology, this research has possessed the capacity to structure a preservation scheme through the spatial data of acoustic properties.

This paper discusses a workable means of representable reality by generating and re-generating acoustic data that reflect spatial properties of a designated environment through technical formulation of reverberation simulation, as well as possible conditions of such representation. Possible issues mainly arising from the simulation framework and the impacts of IoT are also examined.

From the Internet to the Internet of Things

The internet is undeniably one of the most prominent revolutions in human civilization. With globalization in the 21st century that is brought into a new, radical, decentralized phase that increasingly transforms human interactions in the modern world, the internet has drastically changed the way things are done in the past in many aspects of living. The conception of the internet began in the United States after World War II when scientists envisioned a human–computer knowledge management systems that would help researchers to access a useful corpus of all knowledge. J. C. R. Licklider, a scientist who was keen to develop a collaborative modelling among human and computer, theorized a framework for an ‘intergalactic network’ (Hauben, J. 2007: 51). His concerns are to test whether intellectual and scholarly resources can be established by the society and shared by digitalized information holders without restriction (Hauben, J. 2007: 52), and whether being online is a privilege or a right of a citizen (Licklider & Taylor 1990: 40). He also visualized an online interactive community in the network in which members are congregated more by common interests or goals and not by a common location or accidental proximity instead (Licklider & Taylor 1990: 38–40).

The internet was born in 1973 when researchers of the United Kingdom, France and the United States initiated an establishment of ‘a network of networks’. Computer systems across political borders were linked in order to serve as ‘a means for networks from diverse countries to intercommunicate’ (Hauben, R. 2007: 50). In the 1980s, networking researches and conferences were made common and the internet finally became a reality in the 1990s. In 2002, Web 2.0, an interactive social software was realized and has empowered a crowd-sourced innovation in communication technology. While the much-discussed Web 3.0 or the Semantic Web is still under development, the technological trend has moved towards the direction of the *Internet of Things* at the same time.

The term *Internet of Things* was first coined in 1999 within a research by the Auto-ID Centre and the MIT Media Lab, both situated at Massachusetts Institute of Technology. Kevin Ashton and Neil Gershenfeld attempted the incorporation of things into the internet in an active role (Mattern & Floerkemeier 2010: 2). They aim to 'make the world comprehensible for things, or allowing things to use the internet' (Mitew 2012: 1). Apart from the common understanding that IoT acts as the 'connection of usually trivial material objects to the internet' (Mitew 2012: 1), there are many other definitions for IoT. However, the following cover most facts about IoT:

1. 'Networked connection of physical objects' that becomes the 'internet of everything', which is a network of networks where 'billions or even trillions of connections' comprising things with added capabilities, more people, and new types of information data (Mitchell et al. 2013).
2. A dynamic, global network infrastructure with self-configuring facilities based on standard, interoperable communication protocols where physical and virtual *things* have identities, physical attributes, virtual personalities, and use intelligent interfaces, and are seamlessly integrated into the information network (Sundmaeker et al. 2010: 43).
3. The specific time when more 'things or objects' were connected to the internet than people. The birth of IoT is therefore traced back to a time between 2008 and 2009 (Evans 2011: 3), when the ratio of device connectivity to world human population has just exceeded 1:1.[1]

In the very near future, it has become a reality that the internet is extended to mundane, interoperable objects as interfaces to internet functions. AI-driven devices communicate with the system server and each other. Massive storage of information are digitally archived in the *cloud*.[2] A scenario realized by this convenience in telecommunication technology is that a human user no longer needs to physically move around to learn everything, because, with a smart device in hand, he can monitor the device processes remotely. Bruce Sterling, a novelist of the cyberpunk genre, has visualized life with IoT as the following:

> 'I no longer inventory my possessions inside my own head. They're inventoried through an automagical inventory voodoo, work done far beneath my notice by a host of machines. I no longer bother to remember where I put my things. Or where I found them. Or how much they cost. And so forth. I just ask. Then I am told with instant real-time accuracy. I have an Internet of Things with a search engine. So I no longer hunt anxiously for my missing shoes in the morning. I just Google them. As long as machines can crunch the complexities, their interfaces make my relationship to objects feel much simpler and more immediate' (Sterling 2005: 93–94).

The exponential growth of device connectivity in the recent years has empowered not just human but also objects to interact with each other. Figure 1 illustrates a web interface of

[1] The corporate's statistical data reveals that in 2003, there are about 500 million devices connected to the internet serving a world population of 6.3 billion people, but it is estimated to increase drastically in 2020 with 50 billion connected devices serving 7.6 billion people worldwide, that in average has each human to possess 6.83 devices connected to the internet (Evans 2011: 3).

[2] This metaphoric term in computing refers to a computer system operated by 'a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources' that can be immediately retrieved and released with the least effort or interaction within the management of the service provider (Mell and Grance 2011: 2).

‘Thingful’, a search engine of the Internet of Things that enables human users to securely discover and inter-operate millions of available public and private connected objects in cross-domain IoT search and accessibility. It enables IoT data owners to share secure data, to control how their data is used and to make effective decisions (Thingful 2016). On the other hand, being similar to humans at certain viewpoint when acquiring the ‘actuator status’ and form an ‘object–object’ interaction or even a coalition without human intervention (Mitew 2014: 9–10), mundane everyday objects, including ‘wearable electronics and multi-sensor platforms’ (Swan 2012: 220), become ‘tangible social actors’ by tweeting their contextual data in relation to twitter feeds of humans (Mitew 2012: 298; 2014: 18). [3]This means the IoT has facilitated the sociability of objects when they are capable to actively engaged with their locations (Mitew 2012: 297–298; Mitew 2014: 7). In responding to this consequence of the IoT, a short film entitled “Addicted Products” exemplifies how Brad the Toaster communicates with its server and the surrounding devices and to eventually leave its owner for a new one (Rebaudengo 2012).

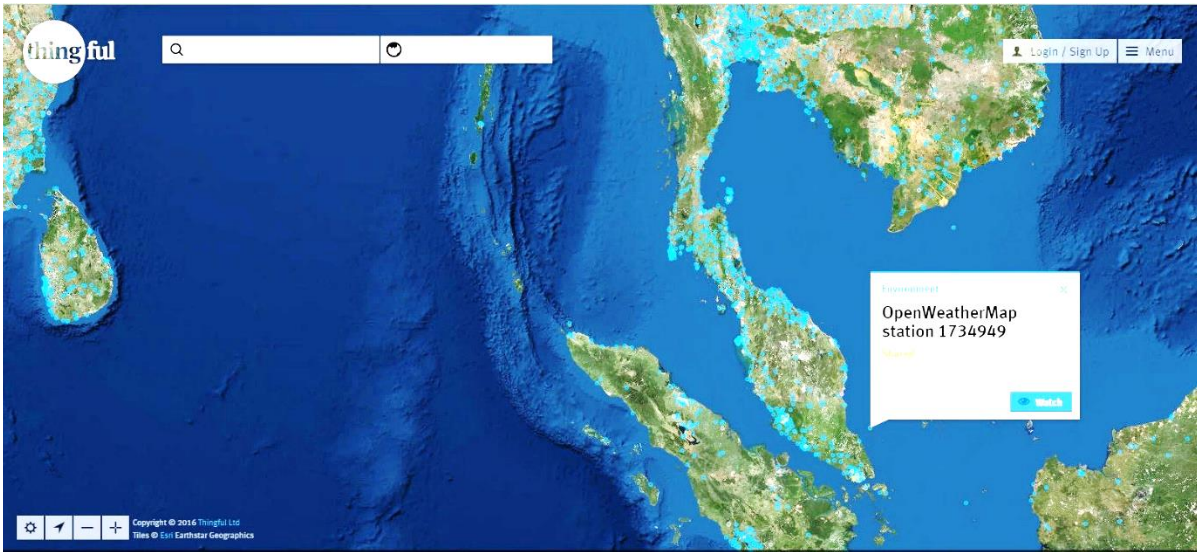

Figure 1: A screenshot of Thingful, a search engine for the Internet of Things (Thingful 2016).

Impulse Response (IR)

The Impulse Response Function (IRF) of a dynamic system in signal processing is its output when presented with a brief stimulus signal called an impulse. An impulse response is generally the reaction of any dynamic scheme of rules or system responding to some external change. In both instances, the impulse response describes the reaction of the system as a function of duration. In all cases, the dynamic system and its impulse response can potentially be actual physical objects, or a mathematical system of equations describing such objects. All frequencies are contained in the impulse function, and the impulse response therefore defines the response of a linear time-invariant system for all frequencies.

Spatial Properties in Acoustics

Most audible sound, whether it is produced in a context, or through pre-recorded materials, would normally comprise of spatial information. The term ‘information’ means that

3 These emerging ‘object societies’ equipped with sensory and computational abilities are made capable to ‘explicitly collect, discard, locate, measure, transmit, alter, and store information’ (Mitew 2014: 13), being able ‘to share, augment and understand all the context information they acquire’ and making these data ‘readable for, and visible to, other entities’ that are either human or non-human (Mitew 2014: 10).

information is a conceptual and non-figurative term used to relate an organism to its environment; it can be categorized into two aspects which are the visual information and the auditory information defined by the perceiver in form of spatial layout such as depth, position and dimension (Wightman and Jenison 1995). An example that promotes this type of archive access and use is the study on sound profiling, such as the usage of audio files in sound banks collected from different positions at a definite location of Annah Rais in the Pedawan District, Sarawak. This study on the contextual sound preservation of two selected local string instruments, namely *sape* of the Orang Ulu and *pratuokng* of the Bidayuh, enables a user to experience an acoustic space through listening without being physically present in that very space. Furthermore, recordings in a sound archive enable the user to hear sound in a space with its multi-layered dimensions (Jähnichen et al. 2018: 59).

Reverberation Simulation

In the past, recording engineers simulating a 'context', such as a hall or a large room ambient incorporated to the vocal or instrument tracks, without the artist being physically present in such context. The acoustic phenomenon develops by having those pre-recorded tracks sent from the studio to a separate room called the echo chamber[4] where the signal sent from the studio was played through a good quality of loudspeakers. A microphone is also equipped in the echo chamber to pick up the sound derived from the loudspeakers made of reflected surface, hence creating an acoustic phenomenon known as 'reverb'. The affected audio tracks with 'reverb' were then picked up from the chamber and back to the studio for a proper blend of other musical parts in an audio mixing console.

Methods and Techniques

In preparation of collecting acoustic properties, firstly, one should identify the venue. The acoustic properties captured through IR can be collected and preserved from all important spaces such as the Amphitheatre in Kuala Lumpur, recital halls of a Music School, or a prominent performance hall in any country. Spatial information collected can be of a treasured resource, as the collection of the acoustic properties enables the reformation of simulated acoustic environments. This can be done through preservation of standard measurement through IR data. The methods derive through the following process as shown in the workflow in Figure 2. In carrying out the project, a series of tests was conducted to inspect if the acoustic properties of a space can be collected.

[4] An 'echo chamber' is a room that was designed to create the simulation of reflected sound with a large number of reflections that build-up and decay. It acts as a 'device' that will produce a dry signal with a sense of space known as 'reverb'. Materials used in designing the chamber would have been shellac or tiles on all room surfaces, much like a shower, or of the same fixture in acoustic design (Granka, 2011).

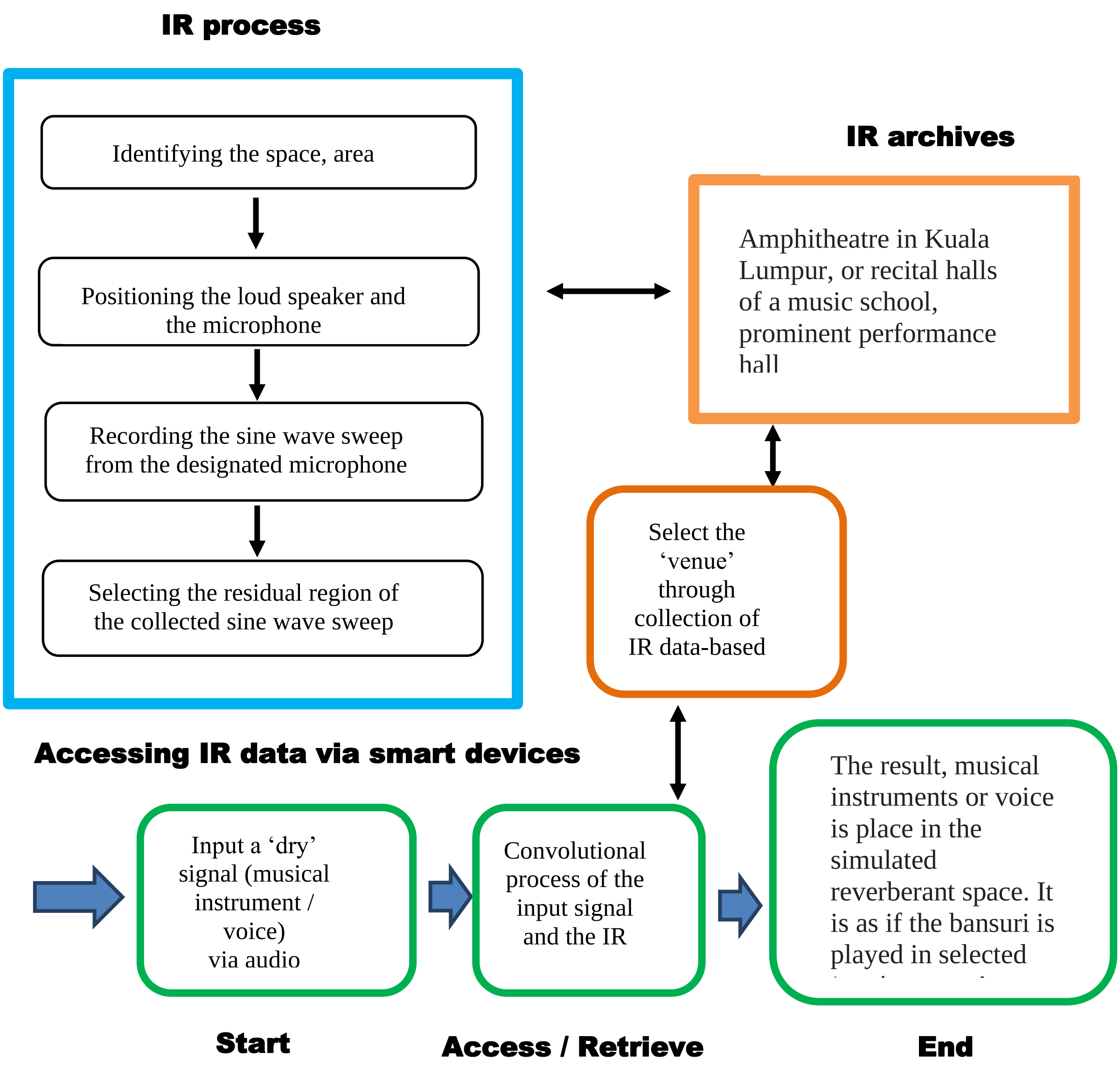

Figure 2: The workflow of capturing the acoustic properties through IR process, collected from Amphitheatre in Kuala Lumpur, or recital halls of a Music Schools, prominent performance halls as IR data that can be access as IR Uploads. Accessing IR data (IR uploads) via input a dry signal such as musical instrument or voice on smart devices.

Identifying the space and the area

Music House 1 Lab has been chosen as an area for the experiment. The selection was made based on the characteristics of the lab made of tile flooring and its flat surface wall without any acoustic treatment as shown. The visual of the empty Music House 1 Lab of is taken from the loudspeaker position as shown in Figure 3 as well as from the microphone position in Figure 4.

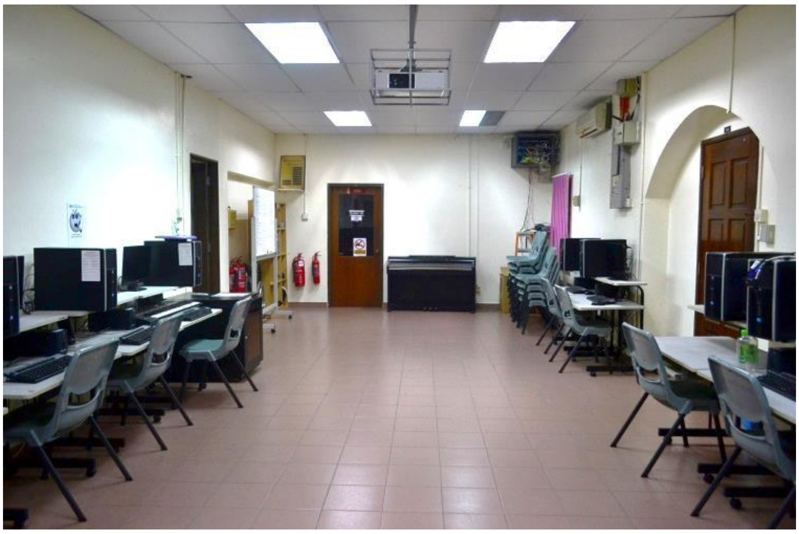

Figure 3: The visual of the empty lab of Music House 1 is taken from the loud speaker position (photograph by Musib, 2017).

Figure 4: The visual of the empty lab of Music House 1 showing pair of loud speaker (photograph by Musib, 2017).

Figure 5: Placing a pair of AKG C414 condenser microphones to pick up the sine wave sweep from the loud speakers (photograph by Musib, 2017).

Recording the Sine Wave Sweep from the Designated Microphone Position

The purpose of using sine wave is that it only contains a fundamental frequency. Unlike other geometric wave shapes contain series of harmonics and its fundamental frequency that might distract the process of data collection of the Impulse Response. Figure 6 is a sine wave sweeping from 20 Hz to 20 kHz through the loudspeaker from one end of the room radiates a series of sounds picked up by the microphone at the other end of the room.

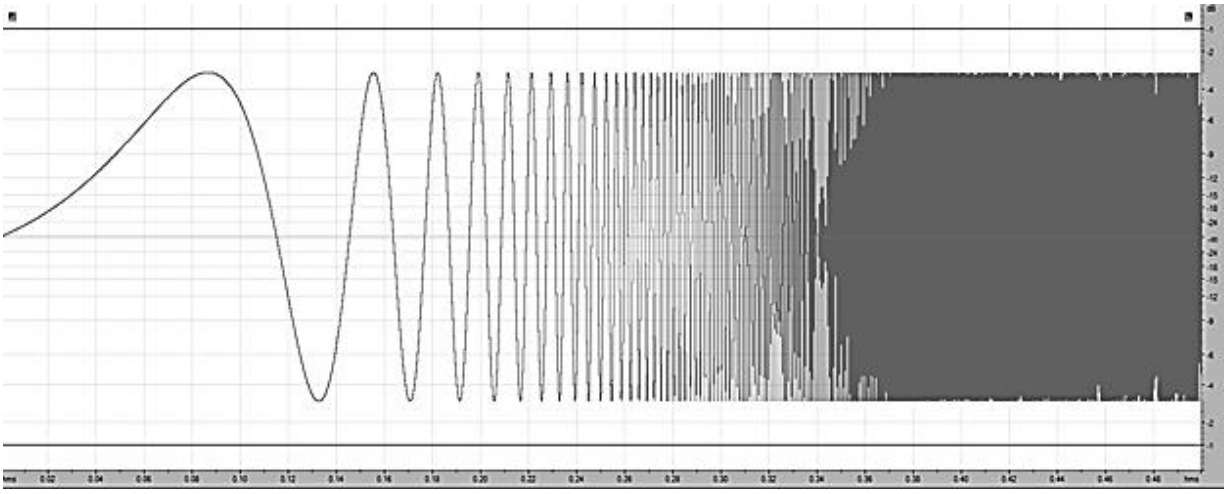

Figure 6: The actual sine wave sweeping from 20 Hz to 20 kHz as a source that was generated from the loudspeakers.

The method is similar to the process of getting a reverb from an echo chamber. As the sound that derives from all angles, audio waves were captured and plotted using the Impulse Response. Figure 6 shows the sine wave sweep and Figure 7 is how the sine wave sweep looks like after it diffuses through fittings and fixtures in the Music House 1 Lab.

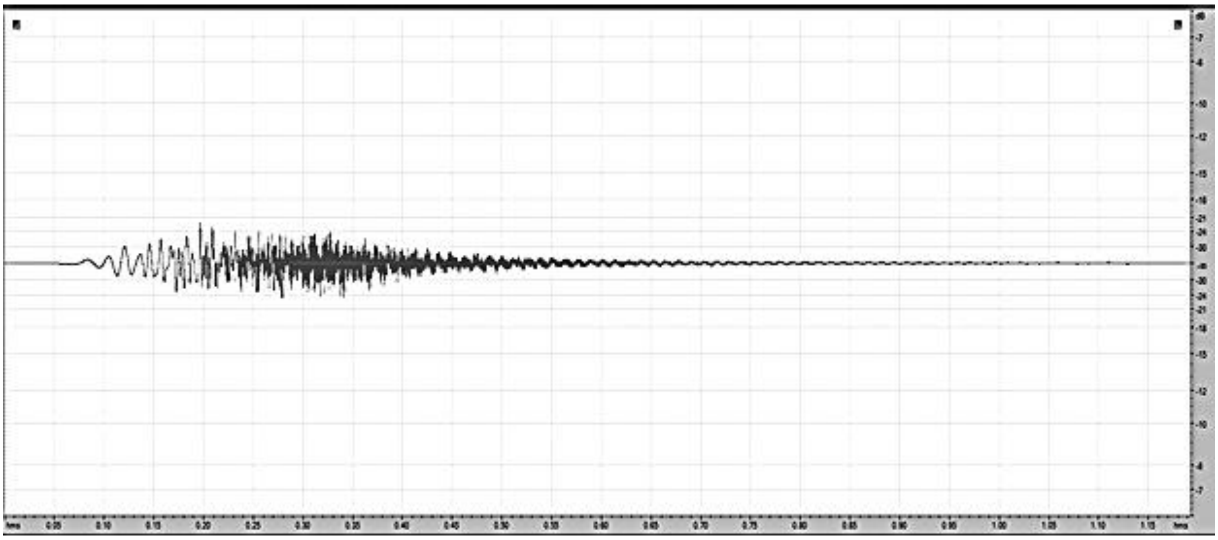

Figure 7: Sine wave sweeping from 20 Hz to 20 kHz that was generated from the loudspeakers.

Selecting the Residual Region of the Collected Sine Wave Sweep Signal

The collection of the IR is than use by selecting the decay region of the said IR as shown in Figure 8.

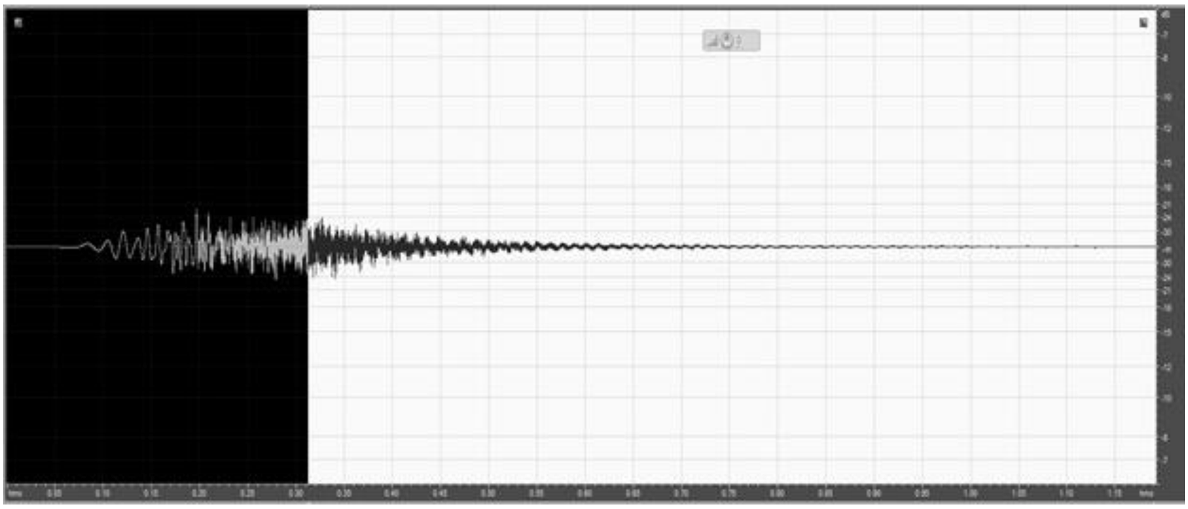

Figure 8: The collected sine wave sweeping from 20 Hz to 20 kHz that was generated from the loud speaker of Music House 1 Lab. The white highlight shows the residual region from the sine wave sweep.

Recording Bansuri in a Controlled Environment (Secluded) Such as in a Vocal Recording Booth

In the process of the experimentation, a wind instrument called *bansuri* was recorded in a vocal booth (controlled environment) of a recording studio. The *bansuri* was selected as it is a monophonic instrument which shares a similar characteristic to a basic geometric-wave-shape. The *bansuri* was recorded using a large diaphragm condenser microphone for a high-fidelity signal. In a controlled environment such as the vocal recording booth, the *bansuri* sound was controlled with the aid of acoustic panelling to absorb any reflection. The outcome was that the *bansuri* was recorded with no reverberation also known as a dry signal.

Figure 9: The *bansuri* (left) was recorded using a large diaphragm condenser microphone (right) in a sound proof booth (photograph by Musib, 2017).

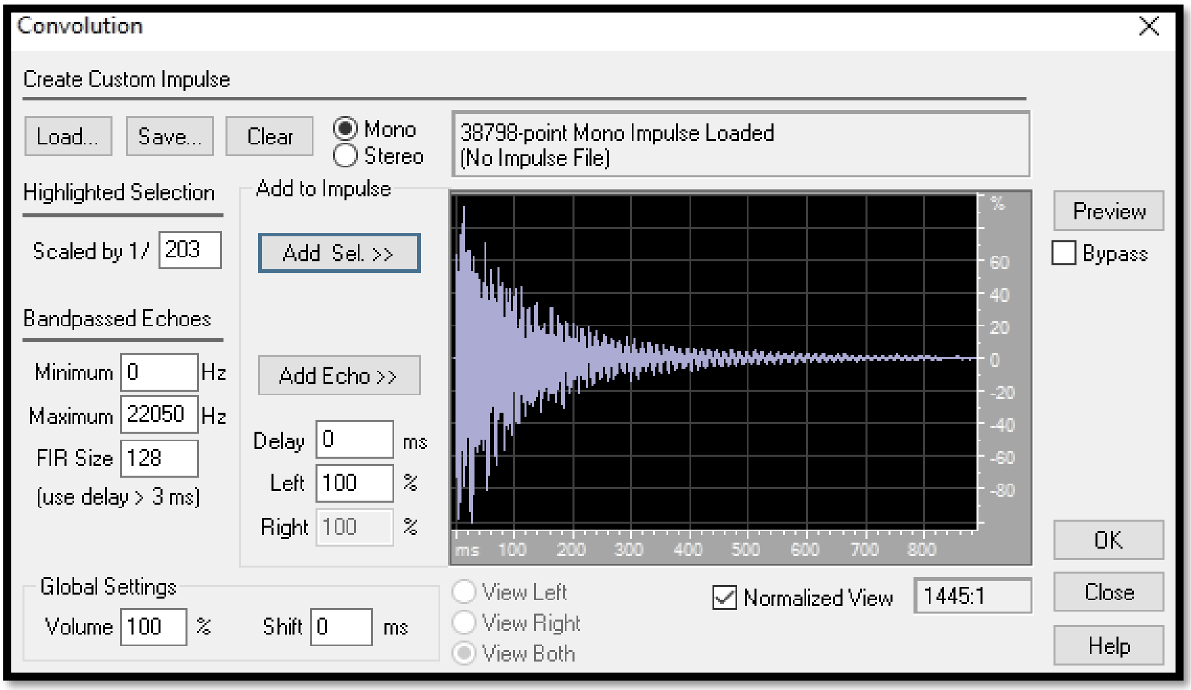

Figure 10: Plotting the *bansuri* sample on the IR which was once a residual region from the sine wave sweep collected from Music House 1 Lab.

'Dry' (without Effect) *Bansuri* Uploaded and the IR Applied to the Convolutional Process

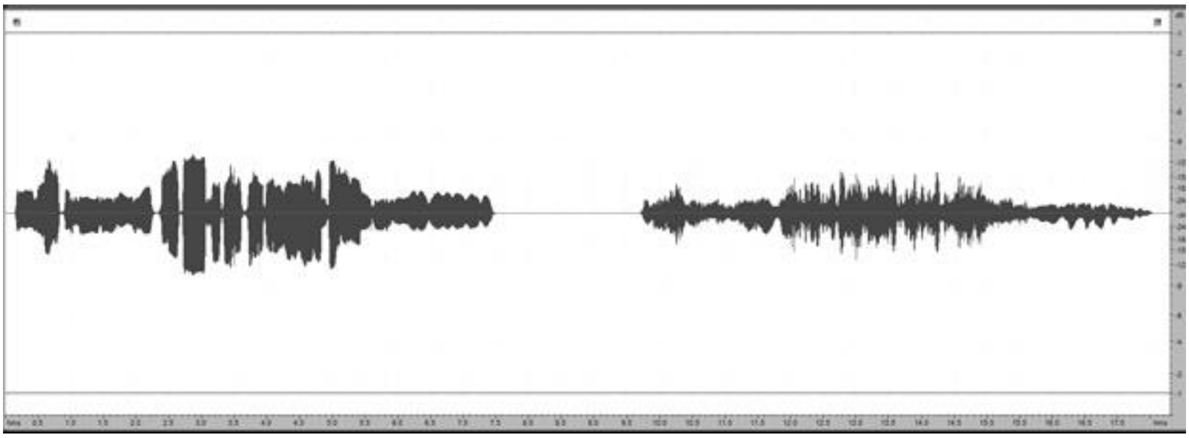

Figure 11: The 'dry' *bansuri* (left) and the *bansuri* with IR applied through the convolution process (right).

The exhibit in Figure 11 (left) is the representation of a mono dry *bansuri* waveform that was recorded in the vocal booth. The exhibit in Figure 11 (right) is also the bansuri waveform, except the amplitude, and the shape has changed. This is due to the transformation process of IR data. The IR data collected earlier in the empty lab of Music House 1 Lab was used in the process called 'convolution' in Figure 10. The procedure enables the *bansuri* performance to be heard through the simulation of acoustic environment of Music House 1 even though it was recorded in a controlled environment. The spectrogram reading in Figure 12 shows different amplitude as well as frequency intensities. The one on the left which is a dry non-reverberant bansuri exhibits more defined amplitude in each frequency harmonics, whereas the waveform on the right exhibits less amplitude in each frequency harmonics. These indicate the waveform is altered due to its environment which is the IR of the empty lab in Music House 1 Lab.

Through this process, the acoustic properties of an empty lab are now used as an environment to which the *bansuri* is played. It is as if the *bansuri* was played in the empty lab without the musician physically being in the empty lab itself.

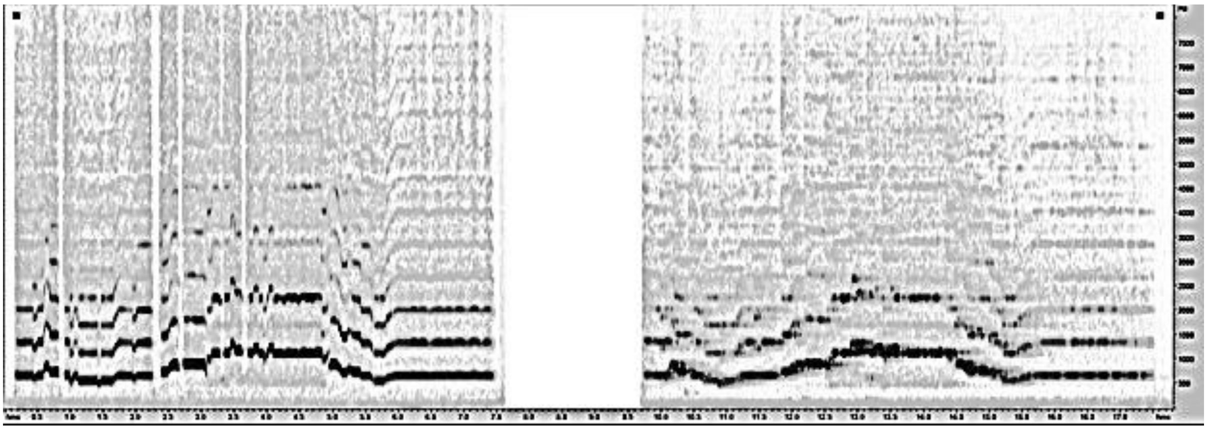

Figure 12: Spectrogram representations of the 'dry' *bansuri* (left) and the *bansuri* with IR applied through the convolution process (right).

Conclusion

The rising of the internet and the Internet of Things has enabled humans and smart devices to exchange data with stunningly instant accessibility, enhancing the decision-making processes in many aspects of life when human and devices are connected, mediated and communicating at the same time. Therefore, enabling the IR data to be accessible on an online mediated platform as a means of representable reality is inevitable in the Internet Age.

This study has shown that the proposed IR records model values the preservation of sound in multi-dimensional ways, rather than simply proposed through conventional two-dimensional sound collections (Musib 2015). It is not only about preserving the content but also preserving the sound properties. The collection of IR records is important data about significant acoustic space, such as prominent recital halls, echo chambers of an iconic recording studio.

As a response to an escalating concern of an impoverishment of the memory of mankind through the constant disappearance of a number of documents contributed by negligence, destruction, decay and the lack of resources (Springer 2014), the act of preserving sonic spatial profiles through collecting acoustic properties via IR could be a feasible solution to provide a contextual representation of the original acoustic settings. Although virtual reverb simulation is a newly proposed archive category, the archive material is not restricted to only audiovisual materials but to other content that is tangible to be preserved.

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