Developing a Framework for Understanding Reverberation Perception to Enhance Immersion in Virtual Environments

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Abstract
This study aims to develop a cognitive understanding of how reverberation characteristics are categorized with the intent to pair key sonic qualities in physical spaces to digital reverb parameters. Personal constructs [1] will be elicited from study participants through the use of repertory grids [2] to determine associative terminology between physical spaces and reverberation parameters. Principal component analysis will be applied to find correlative patterns between terminology that is similarly categorised. From this, abstracted parameter sets can be created. It is theorised that the parameter sets could be collectively enhanced to improve the feeling of immersive presence provided by the space.

Author Keywords
Immersion; Presence; Reverberation; Video Games.

Introduction

The physical properties of a real-world space assist in sonically defining a room's acoustic characteristics. With many design facets found more frequently in physical spaces (tiles in bathrooms or large, stone churches for instance), their reverberation profiles manifest subconsciously and provide a person with a precognition as to how spaces and materials should filter sound sources. [3] If a room filters sound how a listener expects it to, then it is perceptually viable to them, allowing them to feel more present in a location. However, though it seems fair to assume sound physics is experienced similarly by all, it is justified that a framework for the sonic qualities that define specific physical spaces should be developed. It is proposed that in doing so, insight will be discovered as to how common terminology used to characterise real world room acoustics can be reduced to mappable reverberation parameters in the digital realm. This paper seeks to develop a universal series of sonic profiles for physical spaces and utilise their key components to modify parameters in digital reverberation systems. In doing so, when designing virtual environments for interactive media, the immersive presence that the ambience of a space provides can be lessened or heightened through control of a generalised parameter. This project will extend further than the scope provided in this document. The preliminary tests will be outlined, with future work discussed.

Literature Review

Reverberation as an immersive system

Due to the diverse content experienced in video games, the term 'immersion' is difficult to apply holistically. Instead, it is more appropriate to assess game elements on an individual basis. Browns and Cairn [4] sought to develop a grounded theory into video game immersion, concluding on a three-tier system. '*Engagement'* is concerned with a user's initial interaction with a game system. This considers the investment of time, effort and attention, which is rooted within a player's preferences towards the initial elements of a game. '*Engrossment'* progresses from this to consider emotive response to elements within a game. In completing the prerequisite layer, a player's investment "makes [them] want to keep playing and can lead to [them] feeling "emotionally drained" when they stop playing" When considering reverb, it seems better suited to the final stage of '*total immersion'*. This is when players describe *"being cut off from reality and detachment to such an extent that the game was all that mattered"*. Results from Browns and Cairns experiment suggested *"what makes atmosphere distinct from game construction is relevance. The game features must be relevant to the actions and location of the game characters.".* Sonic game elements that exist within a virtual environment should be filtered with relevancy not only to the digital space they are housed in, however also to the player's precognition as to how that space should sound [3]. Successfully achieving this better creates a sense of presence within the digital location.

Kristine Jørgensen [5] expands on this through the origination point of sounds in video games. Sounds can exist to provide information to the player from both the virtual game world (*diegetic*), from the player's world (*non-diegetic*) or from the space between that creates a link between the constructed world and the player's world (*transdiegetic*). It is important to be aware of the role that reverberation plays in the compounding of a space's sonic build up. For some applications, the reverberation may exist to immerse, belonging to the game world, but for others they may exist to provide a creative quality, owing more to the enjoyment of the player in the player's own world. For this paper, it is decided that reverb will be tested for its immersive effect on a player, rather than for creative sound design.

Reverberation and understanding

The previous section relies on a universal perception on reverberation and the inherent properties that various profiles may contain. When listening to a sound, a plethora of information can be gathered from the reverberant properties provided by a space. However, it seems just to develop a basis in how various listeners interpret a space on a personal level. George Kelly proposed the theory of a personal construct, a schema that informs a person's perception of the world. [1] To gain an understanding into the effects of reverb on a listener, a framework should be developed to determine any correlation between responses. George Kelly also provided the Repertory Grid Technique, a method of elicitation used to gauge personal constructs from participants through varying procedures [2]. These procedures require a participant to discuss similarities and dissimilarities between two (dyadic), three (triadic) items, describing these with simplified phrases. Other procedures exist, but for the sake of this project, these two will be of focus. Similar research has been conducted into the enhancement of fear through sound parameter manipulation and confirmed that "differences between sound parameters can affect the degree of intensity an individual experiences whilst playing a survival horror game" [6].

Methodology

Research Methods

The research for this project is derived from three core areas; reverberation and psychoacoustics, video game immersion, and elicitation-focused user study. A mixed method approach will be applied to the project as a whole, however with a focus in each topic area.

DEFINING PERSONAL CONSTRUCTS FOR UNDERSTANDING REVERBERATION PROFILES THROUGH REPERTORY GRID STUDIES

A test has been designed that will begin to develop a framework surrounding the precognitions held by participants surrounding various reverberation profiles that could exist in both the physical and video game realms. It is first important to note that the focus should not be on reverberation profiles that are designed emphasise particular reverberation parameters; the goal is to collect terminology and reactions relayed by the participant and to decipher their literal relation to parameters. Using impulse responses for real world locations means that accuracy and precision can be preserved to a higher degree as the interpretation of a sound designer is removed. Removing bias is key to understanding if a universal personal construct can be developed without prior knowledge of the specific reverberation characteristics and their function in creating recognisable virtual environment ambiences.

The chosen reverberation profiles are then used to filter a series of common video game sounds. In terms of sound identification, Lass et al found that human sounds yielded the highest accuracy [in being identified], followed by musical and inanimate sounds [7]. Having better identifiable sounds means focus can be on the way they are filtered by the room tone, rather than trying to work out what is being sounded. The three sounds are used for this: walking; a short voice sample; a UI indication, such as a menu beep.

In using a varying degree of sound sources, not only can the understanding for a commonality in reverberation profile interpretation be discovered, but also as to whether this is shared amongst sounds that exist in different states of diegesis. It is thought that sounds with differing diegetics will inform the player differently due to their purpose in the creation of an immersive environment; ambience will create a believable setting for the game's mechanics to exist in – *total immersion*, whereas the UI sounds provide an *engagement* level of immersion. Reverberating these sounds to improve immersion will likely require different degrees of intensity to create an overarching immersive ambience. For reference, dry control versions of the sounds are also included in this section of the study. The samples created will be void of reverb to the highest degree achievable.

This section of the project will utilise primary qualitative data, using transcriptions of verbatim speech from study participants. Users will be asked to partake in a triadic elicitation study. Three reverberated sounds will be played, and the participant will be asked to choose two similar sounding audio clips, verify why they believe them to sound similar, and finally why the third was disregarded. Audio recordings will be made of each study, and transcriptions produced.

ISOLATING KEY PARAMETERS THROUGH ANALYSING STUDY ONE RESULTS VIA PRINCIPAL COMPONENT ANALYSIS

This section will feature quantitative analysis of the qualitative data obtained from study one.The data will be subject to key component analysis to determine any significant correlation or clustering between the extracted answers and parameters that are commonly associated with ID3L2 digital reverberation systems [8]. The use of Factor Analysis was initially considered for reducing the input data from the initial studies. However, reverberation parameters exist as a multitude of information sources (pre-delay, frequency reference, decay time etc), rather than a collective 'reverberation' parameter. Furthermore, the initial study is designed to collect a vast array of thoughts surrounding reverberant spaces and may include answers that are expressed in different ways but are relating to the same sonic quality of a sound. Principal component analysis should allow for relations to be determined between the differing input variables, which can then be analysed in stage three to find the correlations between what participants heard and expressed, and the sonic qualities that were most present in the respective sound recordings.

Designing intuitive mapping between clustered parameters through spectral analysis of similarly categorised reverberation profiles

The results at this stage will have created clusters of terminology that relates to the key characteristics of various reverberation profiles. In order to fully understand the semantic information interpreted by each participant, samples that share a category will be spectrally analysed and compared to understand their commonality. This will allow for a consistent understanding between the wording that participants use to describe reverberation characteristics, but furthermore the parameters that those words correspond to. This section of the study will utilise audio analysis tools to produce quantitative data sets that will link the terminology from section one, and overarchingly the resultant principle components from section two, to parameters consistent on a digital reverberation unit. Spectrography will be used to analyse each audio sample in comparison to others that are found to have been classified similarly.

Results and Conclusions

It is thought that a common understanding of reverberation profiles and their constituent components exists amongst various listeners. Though the choice of expression may vary, the semantic information that is afforded to a listener by a reverberant sound should be consistent. With this being the case, the key characteristics that define a space can be extracted from this collective understanding through appropriate analysis. Then, through sonic analysis of the original samples, intuitive mappings between sonic quality, terminology and reverberation parameter can be made. This overall should allow for the key sonic components of a space to be enhanced to reinforce their immersive effect on a listener.

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