STRATIGRAPHICAL SOUND IN 4D SPACE

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This paper describes a framework to facilitate the authoring of sound with spatio-temporal relativity in virtual or augmented environments. It is based upon the premise that the interactor with the environment creates their own individual interpretation of 'narrative': as a result of their movement through the space, accumulating fragments of stimuli or content to create meaning. Inspiration is gained from the actions of the archaeologist, using stratigraphy as a recording practice, that records spacio-temporal paradigms. As the author of a spatialised soundscape composes a database of narrative fragments for the user to encounter, the paper proposes a distinct design process that reverses the excavation procedure, and re-imagines stratigraphical layers as phases of sound in the present tense.

INTRODUCTION

The ambition to create immersive audio-augmented environments raises issues of time in a spatial environment. This is particularly the case when sound samples are presented as context-aware, or as part of a narrative structure, referencing location position [1]. As the user moves and experiences the space, each 'triggered' sound plays, according to a combination of location data and reference to indexes representing user activity. During the period of time that the environment is occupied, a spatial data history, or memory, accumulates representing the interactive movements of the user – all that must be anticipated in advance by the creator/programmer of the immersive environment.

In consideration of the design process, the spatial positioning of sound sources within a XYZ coordinate system is relatively straightforward, using established graphical mapping techniques, applied in a computer-generated representation of the space. Yet 'history' occupies a further dimension, that of time, dividing the continuum of experience into different stages and events.

The impetus for this investigation was born in issues discussed during guest participation within the First LISTEN Expert's workshop [See http://listen.imk.fhg.de for general information on the project]. The following paper, as a distillation of this author's MSc thesis [2], introduces a process that assists the design and management of sound temporality or relativity within a 3D space, exploring the component stages.

1 PRELUDE

The dialectical nature of agency and narrative within interactive environments, has promoted structuralist-informed theory to understand how meaning is formed in such spaces. Referring to role-playing-game environments, it has been suggested that the transformation of basic consequential and consecutive narrative units into meaning, and therefore a sense of overview, is the result of "conscious work" in virtual environments by the nature of *participation* within it [3]. Or in other words, the interactor creates their own individual narrative from their own agency or activity [4].

In the scenario of an audio-focused virtual or augmented environment, the interpretation of the experience would depend upon the function of the content, be it informative or creative. For example an artistic application may use a dynamic combination of descriptive tropes, such as metaphor, metonymy and synecdoche, via spoken word, poetic association of noise, sound effect, and emotions from different musical elements. Immersed within a changing perceptual field, a constantly fluctuating semiotic association between sounds, environment, and spatial arrangement may develop. As the participant navigates through the space according to their attraction and mood, an individual accumulation of experience would evolve and be translated into a personalised soundscape. Thus the interactor creates their own constituted meaning of the work (consider [5] as a audio/visual example).

2 ARCHEOLOGICAL RE-PRESENTATIONS

The interpretation of a virtual or augmented site, based upon the exploration of the environment and the fragments of narrative encountered, suggests some metaphorical parallels to the action of the archaeologist, likewise charting and gathering items of interest from an excavation. The following sections are informed by, and gain inspiration from, the recording processes of archaeological stratigraphy, and explore its relevance in assisting creativity and the information management of time-relative audio-augmented projects.

2.1 The archeological record

Beyond the unique spatio-temporal aspect of its data, archaeology can be approached as the understanding of the past, through the representational metaphor of an *archaeological record*, treated as an independent and material representation of certain events and processes. Note it is normally asserted that archaeology can only study those aspects of the past that are capable of material representation in this record [6].

The purpose of the record satisfies three aspects for analysis. Firstly it transcribes the material (remains) in order to produce an *archive of representations*, consisting of a variety of textual comments, images and material samples. The representation is of a solely empirical nature, and in modern times accuracy has been of great importance. Secondly, the material record represents past events and processes at the site in question, analysing the material origins and the processes that have had an effect since, although the dynamics of change are seen as too ambiguous to offer observational evidence, and so are not part of the report. Lastly, it analyses the meaning of events of the record in the terms of historical process. In other-words, the remains are inadvertently a representation of the historical process, as they are the consequences of it, and can be interpreted as the basis of indication for the activities that may have taken place at the site of record. [6].

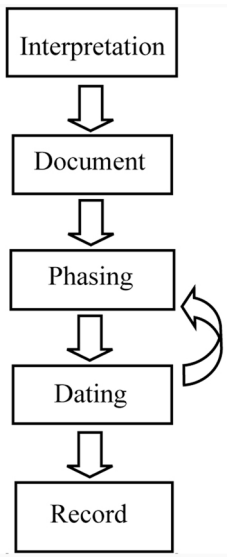
The creation of the archaeological record, and its stages of development, forms an archival process that begins, after a period of research about the site, with an excavation. Documenting with scientific precision, modern archaeology *records* the spatial dimensions and stratigraphic layers of the excavation site using plan and section diagrams, plus a detailed account of finds (artefacts) with photographs and illustrations. The following stage aims, using a relativity diagram called the *stratigraphic sequence* and radiocarbon dating of suitable artefacts, to create a time sequence of the site, identifying '*phases*'. This sequence then is subject to comparative research and analysis, of which the results are written into an excavation *document* or report. Usually this process ends with the archival of the portable finds, accompanied by a published report, with a public body, such as a museum [7].

The traditional process of an archaeologist, in summary, follows a process in which the details are recorded in 2D plans* and sequence diagrams, their relativity gauged and chronology investigated, resulting with an interpretation of the history of the occupied site. A narrative is supposed from the combined interpretation of fragmentary artefacts over a period of time.

*See [8,9] as examples of recent research into new VR / context-aware archaeological systems.

2.2 Reversed process

This paper proposes that the user of an interactive virtual or augmented environment acts in a similar fashion, exploring for, finding, and interpreting virtual 'artefacts' of interest, which may lead to an understanding of the experience. If the author is creating an environment for the interactor to experience, through their occupation over time, a design methodology such as the following - a reversal of the creation of an archaeological record - suggests itself as being a useful guidance (see fig. 1).



> Experience or function of virtual/augmented environment.

> Synopsis (history), Genre, Style, Narrative elements, Absent/Present Subject?

> Inter-related loop which defines distinct phases/ periods/chapters of development. Identify 'artefactual' sound sources as historical, cultural and environmental clues to narrative.

> Record and chart all sound, indicating spatial boundaries, for each phase in 3D space.

Figure 1: The reversed archaeological process.

As 'interpretation', 'documentation' and 'recording' (data spatially) are all familiar processes within sound design for 3D computer spaces, the following section will elaborate upon the definition of 'phases' and how it may be applied for the afore-mentioned purpose.

2.3 Stratigraphy and phasing of content

Due to the destructive, irreversible approach of investigation, the removed deposits of an excavation dig, and whatever contents found within each context, are recorded empirically as the first step in the process of creating an archaeological record of a particular site.

Using stylized section and plan diagrams to illustrate *boundary contours*, the spatial limits of each unit of stratification in both the horizontal and vertical dimensions are defined. Hard drawn edges mark the distinction between one deposit and another, and include layer numbers, numbered as each different stratum is encountered (fig. 2).

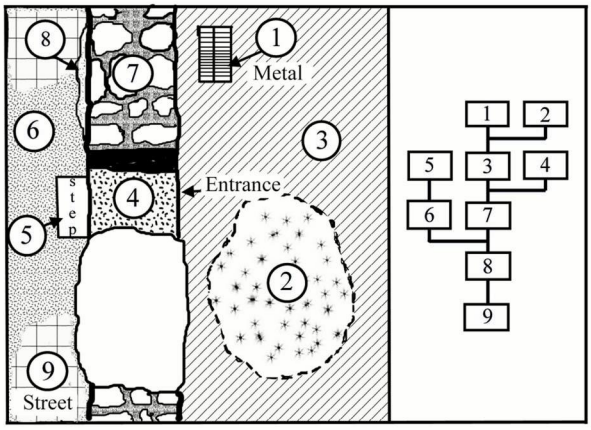


Figure 2: Example of stratigraphical plan diagram after [7].

As the spatial boundaries of deposits excavated are mapped, so also are the relationships and interfaces between the deposits in consequence of their extraction [7]. The resultant abstraction is illustrated on the right of figure 2, as a *Harris Matrix* - the units encountered first are positioned at the top, being the most recent deposits in history, and the lowest represents the earliest. Each unit is positioned according to its relative relationship to its neighbour, so that in total there are 5 possible states: *Before*, *After*, *Contemporary*, *Equivalent* and *No-relation* (or no determinable relativity). Hence Fig. 2 describes unit 9 as the earliest (and first) unit in the stratigraphy, followed by 8, and later by 7 which is the temporal contemporary of 6, and so on, so that 1 and 2 are the most recent stratigraphic units, positioned above 3.

On the basis of this relativity, via date analysis or cross-examination of found artefacts within the stratum, the stratigraphic units illustrated in the Harris Matrix are divided into groupings or *phases*. These phases may represent the interpretation of distinct structural development, activity use within the space, or periods of narrative history, depending upon the evidence present.

When the end of one phase, and the start of another, is identified, essentially an occupied surface is defined, which has for whatever reasons been abandoned, built upon, or adapted, and lies below the present surface. Therefore each phase has been occupied at different depths (and so at different times) in the history of the site. The history of the site can stretch over long periods of time, often hundreds and thousands of years.

Of course, virtual and augmented environments are not designed to be occupied for such a timescale. However, the principle of divisible periods of occupation within the space can be applied. Regardless of what each phase may represent, be it *relative narrative time* – a consequential ordering of events – or *continuous real time* [3], the interactor's continued presence within, and so occupation of, the environment may be managed as relative or context units, and 'bundled' as phases. From the author or sound designer's point of view, the phases may be conceptualized, not as depths in layers at the site, but as successively changing 'overlays' (fig. 3).

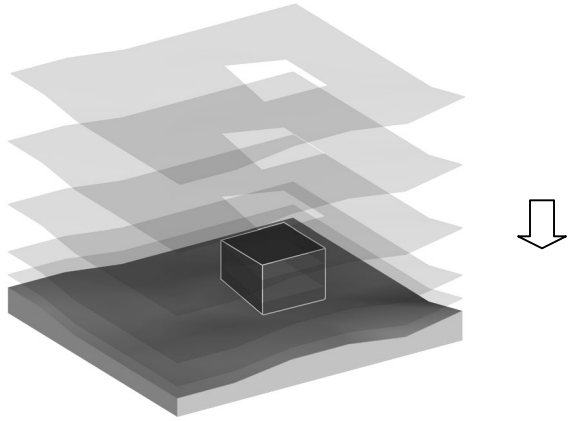


Figure 3: Conceptualizing augmented sound as consequential and consecutive overlying phases.

Imagine that the stratigraphic sequence of sound passes down through the virtual or augmented site, so that the earliest phase (and its associated sounds) is initially synchronized with the first occasion of occupation. Thus through the progression of the stratigraphic sequence, the most recent section disappears, conceptually downwards, to be replaced by the sounds associated with the following phase, and so on, in a

manner similar to the space-time cube system used in temporal GIS systems [10]. Further, the conception of the layers may be elaborated, maintaining the metaphor of stratigraphy, by using the Harris Matrix diagram to assist the authoring of the sequential and consecutive detailed units of the sound design.

2.4 Agency in an archaeological virtual space

Allowing the interactor a sense of agency - that their actions affect and shape the environment they are present within - appears at odds with, and strains the usage of, the stratigraphical record as a useful metaphor in virtual and augmented environments.

Due to the archaeological record traditionally being an empirical construct, it has a conceptual base that lies on what has been found - the *result* of human activity. However, current debate within archaeological theory seriously questions this presumption: [11] states that if the material residues (recorded in the archaeological record) are treated as *representing* agency, then the concept of a situated activity over time and space, in-other-words *inhabitation*, is lost.

How is this debate relevant for sound design or engineering of virtual and augmented environments? It is the interactive-media author/coder's task to pre-empt, and plan the narrative potential of the virtual or augmented environment. As the above statement suggests: if the archaeological record is utilised *strictly* as a metaphor to construct an audio structure, although it may be dynamic in perception - as the interactor moves through space and time - it is essentially static in behaviour and location. The author has, in effect, planned the *result* of agency within the environment. Indeed there is a danger of re-grading interactive potential to a passive experience. In consideration of 'situated activity', the record or data structure would be better approached, "partly as medium, and partly as an outcome of agency's existence" [11]. The implication then is that structures should not be simply regarded as constraining or restricting, rather they should be perceived as a field of possibility, reproduced by the practices that occupy that field.

This philosophy may be applied, for example, as location or context-aware trigger areas (collision volumes), which facilitate change in non-sequential content development, moving forward, reversing, or even 'jumping' between phases [2]. Further, if the system consulted an index of visits the interactor made to each position, or programmable behaviours (e.g. AI) are attributed to the virtual sound-object as a consequence of the interactor's agency, complex narrative potential [3] may be possible.

3 APPLICATION

3.1 Content

The above process, and the re-presentation of archaeological method applicable to sound, was applied in the construction of a creative audio-augmented virtual environment, entitled '*Garden Monologue*', consisting of spoken word and sound effect samples [2]. The content can be interpreted as a spatialised poem, presented in layers of constructed 'narrative', and aims to be an intermediate stage illustrating the creative potential of augmenting space with sound or spoken word.

Spoken word, in particular, was chosen as sound content because it offered the greatest challenge to consecutive and consequential aspects of narrative. The intention was to put the methodology into real practice, to analyse its effectiveness and flexibility for application, its limitations, and elaborate upon unconsidered problems relevant specifically to the creative process of virtual environment design. As a test environment, the Unreal™ engine [12] and editor was used to design the environment, and facilitate, via custom-scripted code, the stratigraphical management of the sound.

3.2 Relativity

An independent Harris Matrix constructing program (ArchEd [13]) was used to assist the design process and relative layout of the sound samples. This program is normally used by archaeologists to assist overview of the various strands of relativity in context layers. However in this case, it offers a flexible mapping system which can assign relationships – *earlier*-than, *later*-than, *contemporary*, *equal* - between narrative elements and sounds as they would be experienced through the passage (or inhabitation) of time in the environment (fig. 4). The most obvious disadvantage of the tool for the described purpose in this paper is the limitation to chronological arrangement in 2D rather than 3D space.

Once the whole arrangement was placed to a suitable degree, the sequence was then assessed to determine which samples might be grouped together into data lists of sounds at the same position (fig 5.). This part of the process mimics the creation of textual recorded or archival information gathered during the excavation of an archaeological site. It also acts as a transitory archive to be applied into the virtual or augmented environment: bundled together as a virtual sound-object to be activated by the interactor's agency.

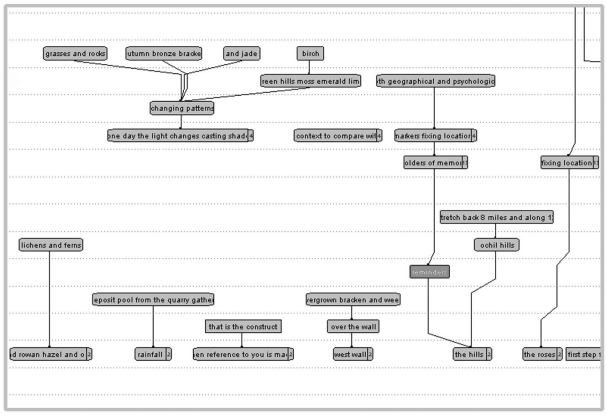


Figure 4: Content arranged into relative temporal sequences using the ArchEd Harris Matrix program.

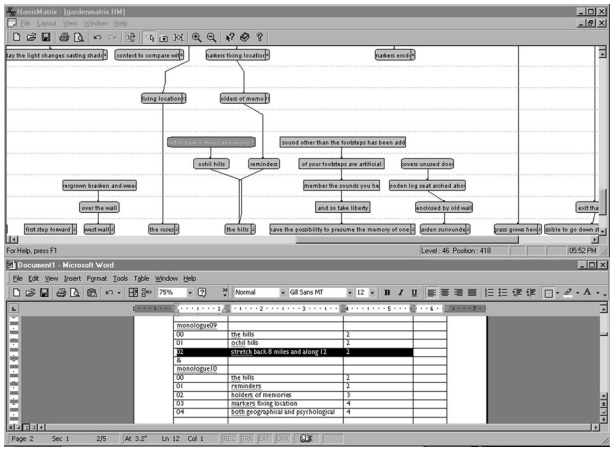


Figure 5: Transferring relativity to data lists for application in sound-object arrays.

3.3 Object data structure

The Unreal™ engine can be adapted and enhanced using the proprietary language, UnrealScript, which is similar to a combination of Java and C++. A custom-coded object-orientated class - `ArchaeSoundTrigger` - was scripted as location-aware with two possible states, either 'one-shot' i.e. plays once, or 'rollover' i.e. follows through a sequence. These states facilitated both consequential and consecutive dynamics, respectfully, in the soundscape. This virtual sound-object is placed in a 3D position within the virtual or augmented space, and upon the interactor entering its location collision radius, plays sounds according to its state. The `ArchaeSoundTrigger` class essentially consists of two related data arrays - one array holds a rack or sequence of sound samples, each with its own feature data such as volume, collision radius, loop/single play etc; while the other, a corresponding relativity index and time/pause counter:

```
struct StructSound {
     sound sound;//sample sound
     byte volume;//0 → 255 value
     float radius;//heard radius of sound
     float pitch;//normal = 1.0
     bool bLoop;// loop or play once?
};

StructSound SSound[x];
//Stratigraphical sequence of x num. of sounds


struct Relativity {
     int phase; //phase object exists within
     float pause;
     //length of time between samples,
     //used during consecutive (rollover) state
};

Relativity SRelate[x];
//Array that co-relates to each sound (x) in
the SSound array.

int PhaseNow;
int CurrentSound;
```

As the interactor enters the collision radius, the class checks if the current phase index, `PhaseNow` (initially 0, and incrementing 1,2,3 etc. upwards to a pre-defined limit) matches the 'exists in phase' value of the current position in the sound relativity data-list (also initially 0 → x). If true then the object plays the sound and depending upon the state, increments the counter `CurrentSound` to the next sound in the data array `SSound`, and the checking process is repeated again until all sounds in the sound object are played accordingly.

Another virtual object class was scripted, `PhaseChange`, to be placed within the augmented space. If the collision radius of this object were entered, a change in the development of the phase narrative, i.e. forward, backwards or to a particular phase, would be triggered. At the time of writing, a process that manages the passing of continuous *real* time, through the phases in a linear fashion, has not been fully developed.

3.4 Sound design

Once development of the sound-object characteristics were complete, and in conjunction with the relativity data-lists mentioned previously, the matter of positioning the sound-objects *spatially* began. Using the combination of plan and 3D perspective view - to most easily associate sound-object with spatial position - it became clear that issues regarding 'agency' and 'archaeological record' also relates to the process of the sound design and the reversed archaeological methodology self-styled above. The record or

sequence, applied for creative or narrative purposes is, due to its fabrication, free from the confines of empirical representation. Flexible and adaptable to change, the record, in this case, is reflective of the creative potential of the digital medium for construction, the nature of the authoring tool, and therefore also process. Creativity and design, especially in experimentation, often relies upon taking steps backwards, revising and adapting to experience.

It should therefore be presumed that the process of 'recording' in the design process set forth in this paper is not absolutist, and may actually be better described as a period of 'transference and modification', according to run-time test experience in developing the environment. For example, during the process of designing *'Garden Monologue'*, both content and stratigraphic relativity were adapted during the transference stages of creating the sound data-lists, after sequencing. Responding to the experience of listening to interactive tests of the soundscape, variables such as radius, and sound samples were further 'tweaked', and either the matrix sequence or data list record, updating to suit.

The resultant virtual or augmented environment, if the sound objects were visible, would illustrate a space populated by objects. Although they may not play until the phase matches the index of the first sound in the object's data array, they are positioned within the same field of navigation (fig. 6).

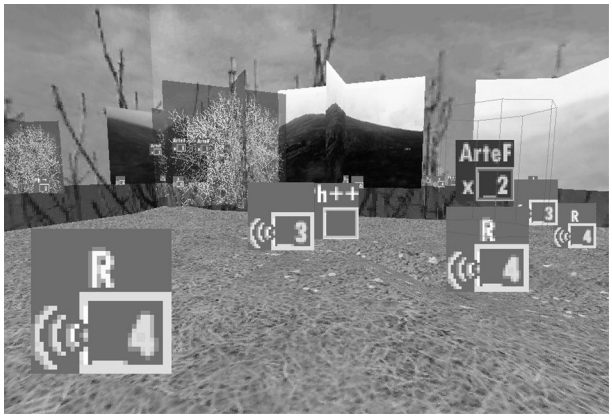


Figure 6: *'Garden Monologue'* virtual environment showing visible sound objects with existence index.

4 ANALYSIS

The success criteria of the custom-built virtual sound objects was to allow both *consecutive* and *consequential* dynamism of narrative, in other-words linear sequencing of sounds and non-linear interactivity of change.

As basic information structures, the `SSound` and `SRelate` data arrays of the `ArchaeSoundTrigger` object class satisfied the transference of relevant information characterising the sound from the data list. The class successfully offered a mixture of options to define characteristics to a series of sounds, and play them in real-time, dependent upon the current phase and the interactor's trigger of the collision radius. The different options available to the designer - looped, one-shot, rollover, sequential or once only - implemented in the *'Garden Monologue'* example - suggests the possible richness of sound collage or narrative that may be accumulated and layered.

A large part of the design process involves understanding and moving between different 'phase' plans, considering how agency and sound fragments may accumulate to form meaning. As each `ArchaeSoundTrigger` object was allocated to a group representing an origin of existence phase, it is possible to understand where within the temporal sequence the sound will be first triggered and so experienced. However, as some objects have a sound data-list which contains a combination of different assigned phases, it therefore means that those sounds which don't originate in the assigned 'base' phase are lost to sight on a plan view of each phase. It is this author's opinion that further work is necessary to develop a more suitable visual interface if a graphical design system like Unreal™ is used. Of course if the design interface with the computer is within a coding environment, then hierarchal data-lists are most suitable.

The `PhaseChange` class, an object of agency and consequence, operates successfully to change the current phase counter in each temporal actor. However, an attached sound (which plays when triggered) proves only to be a useful indicator of change if the sounds, or spoken word/s, used are consistant or markedly different from the others, so that the interactor learns to associate the potential change of soundscape with that sound. However, the notion of an audio interface indicating such abstracted agency is problematic and deserves further development or better solution, as it is not presently satisfactory.

This object in particular embodies the apparent disparities between linearity - archaeology or history - and non-linearity, agency and individual construction of narrative. It is possible, depending upon the assigned state, to jump from the beginning phase to middle, back and forward to the end phase of the sound data list, or even perpetually revolve through a loop of phases with little understanding of the full content. There is a danger that the interactor becomes frustrated with this situation, or indeed that they trigger all the 'one-shot' sounds,

leaving few or no sounds left to interact with, and an emphasised artificial environment that begs to be exited.

These scenarios posed the question - should the temporal dimension (in this case, 'phases') also be controlled by an overriding real-time variable? With the experience of producing spatio-temporal sound in virtual space, reinforced by contemporary theories of archaeology, it is a claim of this paper that: to realise a sense of *inhabitation* it is necessary for both consecutive and consequential temporal structures to operate.

During this investigation a serious limitation with the applicableness of the stratigraphical method to sound, was highlighted. Namely, the present system as it stands treats the sound to be played as an instance, with one node of existence, rather than what is essentially an entity with two nodes, i.e. a beginning and an end. The inclusion of a second relational node - the terminal point of the sound - would involve additional permutations of contextual relationships. For example beyond *earlier*-than, *later*-than, and *contemporary*, it would be necessary to have defining categories which considered asymmetrical synchronisation and potential relationships between the beginning and end of two different sounds.

During this author's initial research into archaeological methods, one source [14] considered the problem of temporal structures in medieval settlements, proposing categories that defined such relationships in light of ambiguous overlapping temporal evidence of occupation at a site. The approach aimed to identify relationships that would be useful for interpretative constructs and subjective evaluation. This author decided that it was important to lay foundations first using [7]'s rather more objective approach. Suitably this limited implementation has highlighted the expressed need to further address the temporal occupation of sound, and its relationships of relativity to other sounds that also have a temporal occupation of time.

Last, but not least, there appears to be a need to develop an *artefact* metaphor for non-interactive sounds, to compliment agency, which exist solely in a set time-frame of existence. Currently all relativity discussed in this paper has been based upon 'context' relationships. Within the field of computer-human interaction, the metaphor of 'context' is, of course, widely used to determine a specific interface with information or data. In archaeology, relativity, and so interpretation, is confirmed by the finds, i.e. artefacts, discovered within soil deposits or 'contexts'. An artefact can be one or all of the following: a clue, a treasure, an indicator of function or activity, or a linkage to the cultural, historical environment. Such a metaphorical tool would be a valuable addition to those presented in this paper, offering depth and elaboration within a sonic, narrative environment.

5 CONCLUSION

The reversal of archeological recording methods to assist the audio design process of a creative virtual or augmented environment has been presented in this paper through abstraction. Also, by touching upon issues of agency and the coded record, this investigation points towards theories that may further assist in the problematic issues of non-linear narrative.

Experience of production infers that computer-generated stratigraphical sequences are a helpful tool assisting flexible creation and visualization of relativity between units of narrative content. By breaking down the content into different groupings or phases, sequences of events can be planned, using the metaphor of stratigraphy. This is imagined, without depth, in virtual/augmented environments as layers of successive *present tense* 'overlays' of sound occupying the site. Hence, narrative development can usefully be managed by assigning sounds to exist in a particular phase. Each phase of the soundscape may contain the basic units of sonic narrative, namely consequential sounds, which reward *active* agency or movement, and consecutive sounds, which reward *passive* agency or standing still and listening.

Likewise, the multi-functional classes presented here fulfill the purpose of translating these relations in the terms of agency, although 'real' time remains to be addressed satisfactorily. It is recognised that further temporal relations have to be identified beyond the present approach that accounts for sounds two nodes of existence – the beginning and end. The lack of malleability of the record during run-time, indicates next step research is necessary to consider programmable behaviours or AI attributed to the sound actor, and how such features would develop narrative potential.

However, the overriding opinion gathered from the investigation is that, although the metaphor of archaeological record should be treated as a state of transference and modification, rather than empirical and static, it represents a structure of narrative potential that can be released by the interactor's agency.

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[12] Unreal™ Engine, the 3D graphics engine developed and licensed by Epic games. For further information, http://unreal.epicgames.com

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