Greco-Roman Music in Context;
Bringing Sound and Music to Virtual Pompeii

Jon Hawkins Berklee College of Music, Massachusetts, United States
jhawkinsmusic@gmail.com

Jeffrey Jacobson, Ph.D. PublicVR Massachusetts, United States
jeff@publicvr.org

John Franklin, Ph.D. University of Vermont, Burlington Vermont, United States
john.franklin@uvm.edu

We are advancing humanities education by learning how to recreate ancient Greek and Roman music, and place it in its architectural and cultural context. Specifically, we put new musical compositions and existing pieces in our 3D computer graphic model of the Theater District of the ancient Roman city of Pompeii. The music is (virtually) located at the grand Theatre, the Temple of Athena, and other appropriate locations. This is an important first step towards placing the music within its cultural context. The software can run on a desktop, digital dome theaters, or a web browser. Our Virtual Theater District of Pompeii is open source and free to the public, along with supporting materials. This project was conducted with donated time from leading scholars and interns. The current arrangement of music and ambient sound was a student project.

Introduction

Ancient Greek and Roman music has attracted much recent study from historians, musicologists, and other scholars. Luckily, several dozen fragmentary and a few complete ancient pieces have survived from antiquity (Pöhlmann & West, 2001). Although these use Greek notation and poetic texts, Greek music occupied an important place in the larger Roman musical culture. Studying the ancient melodies and their harmonic workings offers some understanding of ancient theory and composition, revealing many possibilities for composing original music in the ancient style (J. C. Franklin, 2002; John Curtis Franklin, 2006; J. C. Franklin, 2008). There is also a variety of very informative secondary sources for the various schools and trends of Greek (hence Greco-Roman) music theory and composition (Barker, 1984–1989; West, 1992). Archaeological remains of actual instruments, especially of double-pipes (see below), are also a vital

Figure 1: Virtual model of the Grand Theater

source of information about tonal structures, and recent breakthroughs now permit quite precise replicas of these instruments (Hagel, 2010). Major progress in the analysis of all relevant sources has given scholars an increasingly clear command of these ancient instruments and musical styles. Reconstructing ancient music can also settle questions by reviewing contradictions in theories that look good on paper but do not work in practice (see especially articles in the series *Studien zur Musikarchäologie*).

Similarly, archaeologists have been using three-dimensional computer graphics to reconstruct ancient monuments and dwelling places. The visual representations are based on theories of what the buildings may have looked like, and the resulting simulations are highly educational for the public. Like other 3D models, the Virtual Theater District can be used as the basis for an educational game, in a classroom presentation, or embedded in a document about the space (Jacobson & Vadnal, 2005). Most of these virtual environments, however, are empty, silent, and lonely—despite increasing scholarly attention to ancient soundscapes, including the acoustical properties of buildings (Scarre & Lawson, 2011). If the purpose of historical study is to understand ancient culture, we need to do more than simply *look* at the architecture.

In this project, we will place musical compositions inspired by ancient Greco-Roman music and ambient sounds in our Virtual Theater District of Pompeii. (The city was preserved under volcanic ash in a cataclysmic eruption in 79AD, and unearthed nearly two thousand years later.) The viewer can traverse our three-dimensional reconstruction on a computer, moving a virtual viewpoint through the space (Weis, Jacobson, & Darnell, 2010). The

sound and music is interactive, with layers of sound evolving as the user changes position within the model. Currently the virtual Grand Theater and Temple of Athena are points of particular sonic interest. Our ultimate goal, however, is to reconstruct the entire cultural context around the music, including the musicians, the instruments, the audience, local events, and many of the other trappings of Roman life. By combining these elements, we hope to present a more vital picture of Greco-Roman culture.

For his Spring 2011 student internship at PublicVR, Jon Hawkins, a college senior at the Berklee College of Music, created an initial soundscape for our 3D virtual theater district model. Jon Hawkins (1) researched ancient Greco-Roman instruments, theory, and the cultural significance of music, (2) studied the implied acoustic properties in the virtual model while trying to recreate them digitally, and (3) constructed the audio layers consisting of music, civilization sounds, and ambient background sounds. While studying and planning the implied acoustics of the areas. It was his idea to construct multiple overlapping layers of varying lengths, as opposed to placing one large audio file containing music, people, and ambient sounds. The majority of the time after studying historical materials was spent building the layers, and bringing out the sonic properties of each area in the layers.

Mr. Hawkins received historical guidance from another intern Charles Maher, and both of them benefited from consultation with John Franklin, Associate Professor of Classics at the University of Vermont. Franklin is a recognized expert on ancient music, a composer himself, and has produced a number of emulations of ancient music. David Hopkins is building the 3D model. Natthaphol Likhittaworn (intern) is making 3D models of musical instruments and other objects from Roman life. Heather Bloss drew the map in Fig2. Dr. Jacobson is managing the project, making sure all the pieces work together. The Virtual Theater District of Pompeii will be free to the public via the web and performance venues (http://publicvr.org/html/pro_pompeii.html).

Internship (J. Hawkins)

During my internship at PublicVR, I assembled and implemented the soundscape for the Virtual Theater District. It is composed of ambient sounds, music I composed with simulated ancient Roman musical instruments, and three pieces composed by John Franklin (Franklin, 2006). As our first task, Charles Maher and I researched ancient Greek and Roman instruments, theory, and styles. The Romans, as is well known, absorbed many aspects of Greek culture, including music styles and ideas, especially from the second century BCE onwards (Comotti, 1989; Landels, 1999; Sendrey, 1974; Wille, 1967).

Maher and I selected a variety of instruments to simulate through digital instruments: (1) the *aulos*, a double-chambered, double-reed instrument; (2) *buccina*, a looped trumpet-like horn; (3) frame-drums/finger cymbals; (4) the *kithara*-lyre; and (5) the *syrinx* (pan-pipes). Out of these instruments, I selected an ensemble based on general popularity in ancient Roman and Greek cultures, and on the fact that different instruments had different roles. For example, the looped trumpet-like horn, the buccina, had little use outside of the military, while percussion would be acceptable in any musical situation. The most generally accepted instruments for almost any situation (i.e, hymns, celebrations, and entertainment) were the *aulos*, pan-flute, *kithara*, and percussive instruments (West, 1992).

Simulating Instruments (J. Hawkins)

I simulated key ancient musical instruments in Logic (http://www.apple.com/logicstudio/), and constructed an ensemble consisting of *kithara*, *aulos*, pan flute, and percussion. Interestingly, samples of more contemporary instruments were usable in Logic's EXS24 sampler to simulate some of the ancient instruments (i.e, oboe-*aulos*, classical guitar-*kithara*, and flute-pan flute). The samples were chosen based on putative similarities with the ancient instruments in materials, mechanisms, and overall construction and sound. Choosing pairs of ancient and classical instruments that share so many aspects helped to make the digital instruments sound more authentic, placing less emphasis on digital effects (though the use of effects and digital editing was a necessary step).

With the exception of percussive instruments, each channel strip for the sampler instruments contained (at least) compression (which increases dynamic sustain), EQ (which reduces/increases volume at selected frequencies), exciter (which brings out harmonic frequencies and overtones), and clip distortion (which distorts sound quality). Using varying levels of distortion, dampening/brightening with EQ, and harmonic manipulation with the exciter, I was able to bring each sample closer to the original sound of the ancient instruments, so far as this is knowable from recordings of reconstructed instruments.

Constructing the virtual instruments for the ensemble required a great deal of manipulation of the contemporary instrument samples to create reasonable approximations of the ancient ones, except for the percussive instruments. The percussion ensemble consists of a collection of samples from different ancient and folk percussive instruments, including hand-drums, shakers, and cymbals from various regions surrounding Greece and Rome.

The settings on Logic's EXS24 offered many variables in manipulating the contemporary samples to simulate the virtual instruments. Using glide (the amount of "slide" into the target note) and filter functions, I gave

the *aulos* virtual instrument the aural illusion of air being blown through it, with a slight randomized imperfect glide into a note, to offer a more realistic aural experience. The envelope filters in EXS24 were also useful in turning the samples into a unique, pleasing, and plausible representation of ancient instruments. Because no one knows *exactly* what these ancient instruments really sounded like, we are not claiming perfect authenticity, but aim rather to create a more suggestive and stimulating user experience.

The ADSR (attack/decay/sustain/release) envelope was extremely helpful: for attack (the time between silence and sound after a key is pressed), decay (the time taken for sound to "settle" into designated sustain level), sustain (the volume/dynamics of sound while they key is being pressed), and release (the time taken for the sound level to reach 0 after key is released). Using these variables, I reconstructed each of the various instruments by matching the settings with the instrument's sonic properties. For example, the attack setting for *aulos* may be slightly longer than that of the *kithara*, because the breath needed to make the sound in the *aulos* takes more time than the picking of a string on the *kithara* (depending on the player's articulation, of course). The decay of the *kithara* is longer than the *aulos* because the string will vibrate after the attack is made, while once the air leaves the *aulos*, it is silent. Since a human player of the actual instrument can achieve a very wide array of tones using different levels of air and technique, these digital tools are an attempt to make the samples sound more natural and life-like.
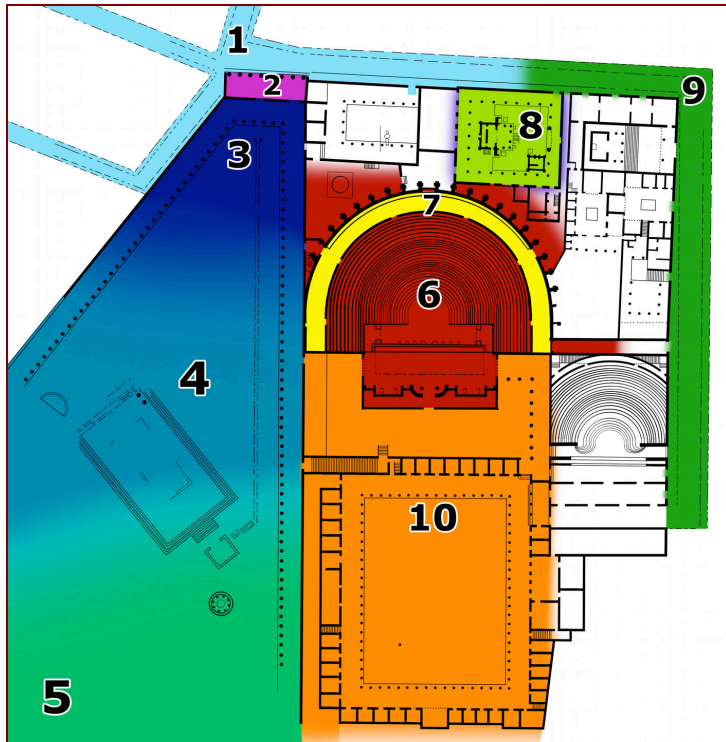
Soundscape (J. Hawkins)

The sound map consists of different aural areas, each with its own sonic properties. Using mainly factory Logic Pro plug-ins, I pieced together a variety of individual sound properties for each area. Then, I devised a plan to place multiple layers in every sound area. Each layer consists of different sounds engineered to fit the acoustic properties of the area it complements: animal sounds, wind/nature, people/civilization sounds, and music.

While the layer method was a space and CPU-efficient way to produce the "big picture" of the model, the different layers also gave a great deal of variation to the smaller scale experience in Pompeii. Each audio file in every layer was assigned content, length, acoustic properties, and 5.1 Surround Sound imaging (as shown by the sound map). The semi-randomized length and content of each audio layer presents a unique sound experience each time an area is entered, even if the area is entered twice.

The layer method also allows the development of different acoustic areas in the model. After going through the model without sound, studying the spaces and implied acoustic properties of each area, and testing various software effects, I began building the output channels in Logic for every audio file in the model.

Building the soundscape for the theater was an interesting task, as the process was drastically different from the rest of the spaces. The architecture and the resonators cause most of the sound to come from the back, if one faces the stage. While there is sound coming from the stage, the walls, seats, and jars reinforce the sound, directing sound from the back as well as the front, and minimizing bounce back to the stage. In terms of digital imaging and effects, getting the right sound for the space was a process of trial and error.

The output channel is the last thing for audio to go through in terms of digital signal-flow. All of the tracks, effects, and imaging will be affected evenly by what is on the output channel, so I kept output channel effects to the bare minimum. The majority of the spaces (with an exception to the theater) use only a limiter (which assigns a cut-off limit to how loud the sound can be) and reverb. With the output channel assigned to acoustic/spatial effects, each audio track in the project contains imaging effects to give the space more life. With automated 5.1 surround imaging and output channel effects, spaces like the streets have crowds distinctly coming from one side of the street, or a muffled celebration coming from As the process of constructing the layers and planning the various sounds for each space continued, Dr. John Franklin informed me of a system of bronze or ceramic resonating jars used in ancient theaters. These were used in the Greek world, but Vitruvius desired them for the new Roman constructions in stone that began to appear shortly before his time (Theatre of Pompey, 55 BCE). The specific configuration recommended by Vitruvius should be regarded as but one possibility, since other systems are implied by varying numbers of niches found in the remains of theaters throughout the Hellenistic and Roman world (Plommer, 1983; Saliou, 2009; Sear, 2006). The Vitruvian arrangement consists of three rows of jars, 38 in all, tuned to specific tones of the Greek 'Perfect System' (*systêma teleion*). (For an introduction to *systêma teleion*, see West, 1992.) Row 1 contains the so-called standing notes, that is, tetrachord boundaries common to all three genera (enharmonic, chromatic, and diatonic). Row 2 introduces the characteristic tones of the chromatic genus, and row 3 those of the diatonic. They are placed in a pre-designated order underneath the seats of the audience, facing out. These jars reinforce specific tones of music, without any extraneous reverberation of other frequencies which might obscure perception of speech (Canac, 1967), 110–13, 124–7; Landels, 1967).the inside of the Temple of Isis.

Figure 2: Soundscape for the Virtual Theater District

Table 1: Key to the Sound Map

[1]Street-front Propylon:
Layer1-"streets1 pad"- pad, birds, wind, bugs
Layer2-"streets4 pro"- people, birds
Layer3-"streets 2"- people, animals

[2]Propylon:
Layer1- "propylon ftn3"- Fountain
Layer2- "streets1 pad"- pad, birds, wind, bugs (bleeding through from street-front Propylon)

[3]Forum hall-
Layer1-"forum hall2"-people, birds
Layer2-"streets5"-people

[4]Forum floor-
Layer1- "forum floor2"- pad

[5]Temple of Athena- (slight crossfade between "forum floor2" and "delphi hymn")
Layer1-"delphi hymn"- Delphic Hymn "Paean" piece w/digital ensemble

6]Theater-
Layer1-"theater wet1"- John Franklin's pieces, audience, put through resonator settings (bleeds through and crossfades w/ "forum floor2" in open areas surrounding theater)

[7]theater halls (inside)-
Layer1-"amp halls1"- people/conversation
Layer2- "amp halls2"- people

[8]Temple of Isis-(bleeds through to street)
Layer1- "isis1"- Asa's Piece with updated drumtrack

[9]Streets (Right Corner)
Layer1-"streets1 pad"- pad, birds, wind, bugs
Layer2- "streets3"- people, civilization sounds
Layer3- "streets5"- people
Layer4- "street6"- people
Layer5- "street7"- people

[10]Open Area-
Layer1-"open1"-pad

The final design for the theater involved the construction of two separate spaces. The "dry" audio file consists of the performance of three pieces by Dr. John Franklin (John Curtis Franklin, 2006), audience sounds, and various outside sounds; the "wet" audio file consists of the final "dry" audio file placed in a project with effects settings to match the space. While the "dry" project file contained most of the imaging information for the performance and audience in the theater, the "wet" project file contained effects simulating the sound properties of the architecture/objects (i.e, reverberations from the back and resonator jars).

Simulating the reverberations of the wall involved the use of multiple busses, a channel where you can "send" other tracks. Effects, imaging, and automation can be set to busses, and these will then play through the output channel, along with whatever tracks you have sent to the bus. Each bus was imaged to a specific place to emulate the sounds of the performance bouncing off the back walls and seats. Harmonic exciters and equalizers were also attached to each bus to bring out the frequency of each resonator jar. (For another attempt to simulate the Vitruvian jars, through additive synthesis, see (Godman, 2004). With the use of bus settings, imaging in both "dry" and "wet" projects, and reverb, the audio playing in the theater space model comes from both the front and the back. While it was a long process to emulate the complicated acoustic properties of the theater, the most important parts of the construction of this sound-space were keeping the effects subtle, and providing an aesthetically pleasing and acoustically accurate soundscape.

The soundscape also includes a rendition of an extant Greek musical piece, and an original ambient pad based on ancient scales and theory. The surviving ancient Greek scores are readily available, transcriped into standard notation, and present an excellent opportunity for studying elements of theory and melodic construction. Using these sources and the virtual instruments in Logic, I recreated the first Delphic Hymn, inscribed on a wall of the Athenian treasury at Delphi in 138 B.C. It is intended as a live performance in the Temple of Athena.

I also borrowed common intervals from these pieces for the ambient pads in the streets, forum, and open area. The scale is based on the Dorian 'mode' (*harmonia*), consisting of the notes D-E-E*-F-A-B-B*-C-E, with "*" being a quarter tone above the designated notes. (Letter names designate relative, not absolute pitch.) A quarter tone is quarter of a whole step, for example the note between D and D#. The Dorian *harmonia* was also one of the most widely-used scales in ancient Greek music, as it was appropriate for processionals, religious ceremonies, songs, and theater (West, 1992)

One problem in translating ancient Greek theory to standard notation is that the Greeks sometimes used quarter-tones (and other microtones), whereas modern notation—and so the MIDI protocol—uses only the half-tone chromatic scale of equal temperament. To avoid the minor quarter-tone dilemma, I used heavy intervals of perfect fourths, fifths and octaves, which were popular and pleasing to the ancient Greek and Roman ear (West, 1992). The ambient pad in the forum, open area, and streets is meant as an ambient backdrop, not a "live" performance.

After constructing all the layers in Logic, making sure all the levels and imaging were at proper settings, and trimming any dead space in the loops, I began placing layers in Unity, the game engine used to create the Pompeii model. Working in Unity was an interesting learning experience, as I discovered the range of settings for sound sources in the program.

Using Unity's graphic roll-off and distance settings, I was able to manipulate how the layers are heard as one approaches, takes up space, and leaves each sound space. For example, by setting the distance of the Delphic Hymn at the Temple of Isis to *x,* and then setting the volume axis to decrease starting at 10-*x* with *x* being silent, when one walks away from the Temple it sounds natural and fades away, as opposed to the hymn just dropping off into silence. The graphic roll-off settings also include pan (how "fixed" in one place the sounds are when one moves around in the model) and spread (how wide the sounds reach in terms of audio imaging). While the pan setting played an important role in giving the layers a natural sound as one approaches or leaves each space, the spread settings were not as important since the majority of the imaging was done in Logic.

Working with PublicVR on the Pompeii model was a rewarding learning experience. As a history enthusiast and composer, I was intrigued by the material and motivated to develop an authentic (as possible) and interesting soundscape for the model. The research and analytical study of ancient Greek and Roman culture, instruments, and music has opened up for me new perspectives in composition, performance, and even appreciation of music. The technological challenges of designing and constructing the soundscape have presented new possibilities in my own career regarding digital production and sound design, plus experience working sound in game engines and unorthodox methods of production. Through planning, research, and hard work, we believe we have presented an interesting, unique, and enjoyable learning experience in the Pompeii model.

Conclusion: A Virtual Museum

The historical significance of the Pompeii project works on multiple levels. The architecture in the model is fairly accurate, representing our best knowledge of features from the period 10–79 CE (Weis, et al., 2010). We chose ambient sound effects from modern recordings to make the environment more realistic (e.g, running water). The music featured in the model includes renditions of actual ancient Greco-Roman pieces or informed emulations of them. The instruments featured in the pieces are either samples of physical replicas, or virtual simulations, of ancient instruments. The pieces by Franklin also include precise microtonal modifications in accord with ancient theoretical sources, using a 'Virtual Lyre' developed for the Reaktor platform (Franklin, 2008). The sound and music were spatialized to fit each area.

The original compositions were all inspired by ancient Greco-Roman theory and performance style. While a completely historically accurate soundscape is impossible due to lack of primary sources, Mr. Hawkins' contributions captured some of the known tradition of ancient Greco-Roman music. Besides the opportunity to write and digitally produce sounds and music, Hawkins had the chance to further his experience in working with 3D space, surround sound, and space emulation. The internship also allowed a great deal of time towards research of ancient music and culture, plus collaboration with Dr. John Franklin.

Hawkins' internship was beneficial to PublicVR because it showed us how to build a historically accurate version of the soundscape. It gave a clear picture of the technological requirements for future versions of the model, and provided a technical process, which could be used for other projects.

'Reconstructions' of ancient music have many of the same issues of representation and readability as reconstructions of architecture. Since perfect re-creation is impossible, scholars are obliged to interpret missing information from context and secondary historical sources. The final result often creates an unwarranted impression of authority for the unschooled viewer/listener, who cannot immediately distinguish the levels of certainty in different parts of the work (Champion, 2008). One should therefore educate the user as quickly as possible, preferably as part of the same presentation as the reconstruction itself.

With the Pompeii model, PublicVR aims to collaborate with experts and performers of ancient Greek and Roman music to create an environment showcasing pieces by these artists, and to present a highly interactive and individual experience where users can explore various areas of Pompeii and hear historically informed representations of ancient Greco-Roman music. We also plan to engage an expert on acoustics who can help us adjust the reverberations in both the music and ambient sounds to match the virtual architecture. By situating ancient music in its original architectural and other spatial contexts, we can better appreciate what the experience was like for the original audiences. Finally we plan to build the entire cultural context around the music, beginning with Mr. Likhittaworn's 3D models of the instruments used in our compositions.

Our long-term goal is to create a welcoming context—a virtual museum—for reconstructions of Greco-Roman music. We want to hear the music resonating in the space, as it did in ancient Pompeii, surrounded by the trappings of Roman and Greco-Italic life. The final result will be a virtual world, useful for education in music, history, and culture. We will distribute Pompeii as open-source for all, especially educators, students, scholars and game designers.

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