The enigma of Vitruvian resonating vases and the relevance of the concept for today

Rob Godman

University of Hertfordshire

1. Vitruvius – the person

Marco V. Pollio Vitruvius studied Greek philosophy and science around the 1st Century BC. A practical exponent of his craft, he gained experience through his professional work and was the architect of at least one complete unit of buildings for Augustus in the reconstruction of Rome. As an indication of his diverse talents, he also oversaw developments in the imperial artillery and military engines – making Vitruvius an important figure in his day.

In modern times, Vitruvius has been regarded primarily as an architect but his explorations of science and art in the widest sense shouldn't be forgotten. The emphasis of books I-V is on architecture in the traditional sense of the word. The second five books contain information relating to Greek science demonstrating the background Vitruvius had during his studies and younger days. His research and experimentation is backed up by detailed methodology (for instance, using a lighted lamp as an indicator for poisonous air in wells; further tests for showing the danger of lead in fresh water pipes). Mathematical principles and geometry assisted the delivery of his discoveries. The inspiration of science was at one with art and literature (although this was not a philosophy specific to Vitruvius).

> *The science of the architect depends upon many disciplines and various apprenticeships which are carried out in the art.*

Vitruvius, on Architecture, Book I – on training of architects, Loeb

2. The Ten Books on Architecture

De Architechura is a collection of ten books detailing his practical experience with traditional Greek theory of the time. Exact dates for the composition remain uncertain but it is believed to have been written around 27 BC (towards the latter period of his life).

The complete treatise is detailed as follows:

Book 1: Architectural Principles

Book 2: Evolution of Building, Use of materials

Book 3: Ionic Temples

Book 4: Doric and Corinthian Temples

Book 5: Public Buildings, Theatres (and music), Baths and Harbours

Book 6: Town and Country Houses

Book 7: Interior Decoration

Book 8: Water Supply

Book 9: Dials and Clocks

Book 10: Mechanical and Military Engineering

There are a number of surviving manuscripts that have been used to create the current published translations. These date from as early as the 8th Century (London, British Museum). The text was rediscovered in the fifteenth century and has been studied by renaissance architects to a wider range of student in the current day. A number of translations of the text exist and are available in print. The two used for the purpose of this paper are:

Vitruvius, The Ten Books on Architecture, translated by Morris Hicky Morgon, Dover

Vitruvius, on Architecture, Books I-V and Books VI-X, translated by Frank Granger, Loeb

The Loeb edition is particularly illuminating as it contains both the Latin and English translation (needless to say, issues of translation are of paramount importance when dealing with technical information from such an early source). The history of architectural literature is taken by Vitruvius to begin with the theatre of Dionysus at Athens.

3. Theatre design

The design of a Roman theatre has much in common with its Greek counterpart. Before discussing the differences it is perhaps worthwhile thinking a little about terminology. It is a common mistake to name the semi-circular Greek and Roman theatres as amphitheatres. They are not! An amphitheatre is circular (think about the Coliseum in Rome) and a theatre is semi-circular (or at least close to it). The amphitheatre and theatre have vastly different uses.

The theatre of the Greeks was built on the slope of a hill, securing sufficient elevation for the back row from the naturally occurring landscape. The tiers were either cut directly into rock or if the land was soft an excavation was made in the hillside and lined with rows of benches. The steps were often faced with marble (as in the theatre of Dionysus at Athens). The theatre of the Romans and hence Vitruvius, was potentially a freestanding structure and therefore a much more complex design. The form of the Greek and Roman theatre also differs in terms of proportion, as Vitruvius states:

> *The form of a [Roman] theatre is to be adjusted so, that from the centre of the dimension allotted to the base of the perimeter a circle is to be described, in which are inscribed four equilateral triangles, at equal distances from each other, whose points are to touch the circumference of the circle. This is the method also practiced by astrologers in describing the twelve celestial signs, according to the musical division of the constellations. Of these triangles, the side of that which is nearest the scene will determine the face thereof in that part where it cuts the circumference of the circle. Then through the centre a line is drawn parallel to it, which will separate the pulpitum of the proscenium from the orchestra.*
>
> *In the theatres of the Greeks the design is not made on the same principles as those above mentioned. First, as to the general outline of the plan: whereas, in the Latin theatre, the points of four triangles touch the circumference, in the theatres of the Greeks the angles of three squares are substituted, and the side of that square which is nearest to the place of the scene, at the points where it touches the circumference of the circle, is the boundary of the proscenium. A line drawn parallel to this at the extremity of the circle, will give the front of the scene. Through the centre of the orchestra, opposite to the proscenium, another parallel line is drawn touching the circumference on the right and left, with a radius equal to the distance from the left point, describe a circle on the right and scene of the proscenium, and placing the foot of the compasses on the left hand point, with the distance of the right hand interval, describe another circle on the left side of the proscenium.*

Vitruvius, The Ten Books on Architecture, Book V, Dover

4. Greek/Roman Music

Before exploring the reasoning behind Vitruvius' concept of the resonating vases in Roman theatres it is important to have an understanding behind music principles of the time.

> *Harmony is an obscure and difficult musical science, but most difficult to those who are not acquainted with the Greek language; because it is necessary to use many Greek words to which there are none corresponding in Latin. I will therefore explain, to the best of my ability, the doctrine of Aristoxenus, and annex his diagram, and will so designate the place of each tone, that a person who studiously applies himself to the subject may very readily understand it.*

Vitruvius, The Ten Books on Architecture, Book V, Dover

The systems as described by Aristoxenus and Pythagoras are somewhat different in terms of technical information but particularly in terms of philosophy. Vitruvius (as can be seen from above) follows the musical theory of Aristoxenus and it is this that the acoustic vases are based upon. Whilst a detailed explanation of Greek and Roman musical theory is outside the remit of this paper, some knowledge is required to understand Vitruvius' thinking as regards the pitch of the vases.

Aristoxenus lived around the 4th Century BC and wrote a number of works on music and related disciplines (*Elements of Harmonics* still survives). He sets out a theory of scale structure and a method for analysis. At some considerable length he discusses the required terminology. His definition of *interval* is somewhat different to that of the Pythagoreans (which is based on ratio and proportion) in that he describes two pitches as being bounded or marked off by two notes of different pitch (*Landels*). An important definition is that of *system*. A system is a construction of intervals, the smallest group of which is known as a *tetrachord*.

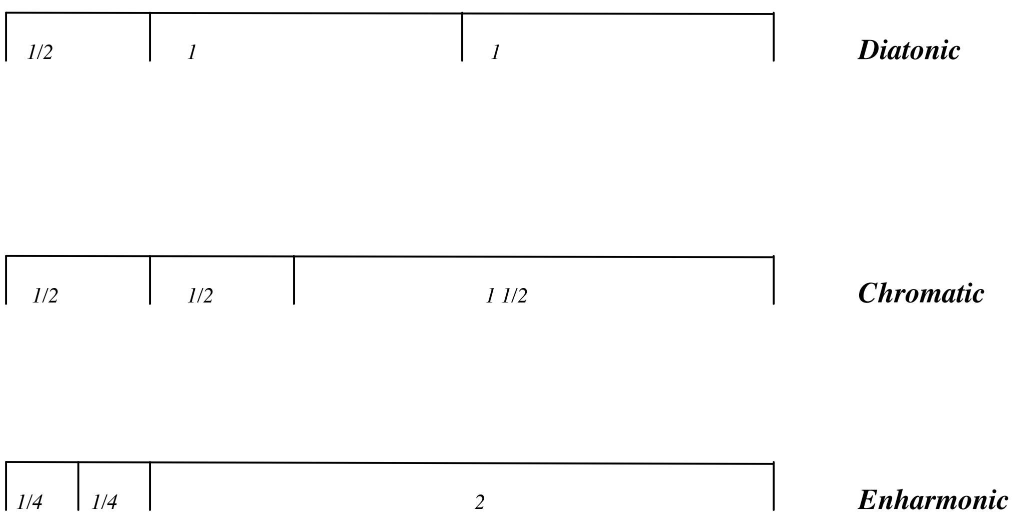


FIGURE 1

The groups of four pitches in each tetrachord are always surrounded by the interval of a fourth. Aristoxenus demonstrates three different types (diatonic, chromatic, enharmonic). He uses the term *hemitonion* to describe our interval of a semitone and more complex term of *diesis* for any interval smaller than a semitone (*Landels*). He does use mathematical ratios to assist with the concept of microtones but also spoke of them in terms of colour and other descriptive methods.

To make more complex pitch systems it is a simple matter of placing one tetrachord on top of another (giving tetrachords based on cycles of fourths). This developed into the *Greater Complex System* giving a two-octave construction and this is the method that Vitruvius follows for the tuned vases.

5. Acoustic problems, vases, concept

Anyone who has visited a theatre (Greek or Roman) cannot fail to be impressed by the overall clarity of sound without any kind of enhancement. A greater understanding of acoustics can be identified as early as the beginning of the 5th century BC (Dionysos at Athens and the theatre at Syracuse). The seats arranged in curved rows around the circular orchestra formed large horizontal reflecting surfaces. This ensures that the path of the sound waves travel from the source (the actor or singer) to each of the listeners in a direct path (i.e. without reflection). Ironically, the shape of the theatres was not based on scientific understanding but rather by accident. A site on the side of a hill, sloping down at approximately 45 degrees gave a good acoustic result. Other portable solutions also helped the acoustic. Backdrops helped high-frequency reflections (provided by painted skins). It is believed the propagation of sound to the audience was aided by the megaphone effect of the masks worn by the actors.

Further developments in the shape of theatres are all thought to have been due to attempts at improving the acoustics. An increased length of the seating area (whilst maintaining overall proportion) brought more of the audience close to the stage and thus improved the acoustics, especially as less of the sound could escape at the sides of the orchestra. However, the direction in which the actors were facing became of greater importance, and the height of the stage building was increased and made of stone to provide more reflection from behind and improve the distribution of the sound. A few centuries later, and with the aid of his knowledge derived from Aristoxenus, Vitruvius was attempting to solve other acoustical problems still prevalent in Roman theatres.

The Pythagoreans formulated the modern science of acoustics in Greece in the 6th century BC. Aristoxenus examined the study of musical sounds further by going beyond the source and propagation of sound to consider issues of perception. The work concerning acoustics of Vitruvius is largely based on Aristoxenus's writings.

> *In theatres, also, are copper vases and these are placed in chambers under the rows of seats in accordance with mathematical reckoning. The Greeks call them* ***Echeia****. The differences of the sounds which arise are combined into musical symphonies or concords: the circle of seats being divided into fourths and fifths and the octave. Hence, if the delivery of the actor from the stage is adapted to these contrivances,*

> *when it reaches them, it becomes fuller, and reaches the audience with a richer and sweeter note.*

Vitruvius, on Architecture, Book I, – on training of architects, Loeb

Vitruvius' understanding of acoustics is extremely impressive for its time. He was aware of an acoustical problem caused by the reflection of sound waves, namely that interference to the original source is created by reflections making the original less clearly audible or defined. Vitruvius called this reflection of sounds *resonantia* (which differs somewhat from our modern day meaning of the word resonance which implies a sound being bounced back and forth repeatedly at a specific pitch). Although such reflections were kept to a minimum by the very design of Roman and Greek theatres, the *resonantia* would still have been seen as a considerable problem. If any extraneous strong reflections come back to a listener at slightly different times, then speech, for example, would have become difficult to understand. As Vitruvius pointed out, an inflected language such as Latin is difficult to understand when the final syllables of words arrive at slightly different times. These theatres were outdoor venues often built into the side of a hill. The apparent dryness of the resultant acoustic was also a problem for Vitruvius when dealing with music and he went to considerable effort to invent a system that would counteract it. Resonating bronze vases were his solution to this problem.

> *...let bronze vases be made, proportionate to the size of the theatre, and let them be so fashioned that, when touched, they may produce with one another the notes of the fourth, the fifth, and so on up to the double octave.*
> *...the voice, uttered from the stage as from a centre, and spreading and striking against the cavities of the different vases, as it comes in contact with them, will be increased in clearness of sound, and will wake an harmonious note in unison with itself.*

Vitruvius, The Ten Books on Architecture, Book V, Dover

Arguably, the combination of vases might be considered an early artificial reverberation unit, with specific frequencies enhanced and others excluded. Obviously ‘real’ reverberation does not function in such a way. How well might these vases have worked? It remains unclear.

6. Vitruvius’ use of musical theory within the theatre

Whilst there are no known original resonating vases in existence, a number of sites show evidence of spaces (niches) where the vases would have been positioned.

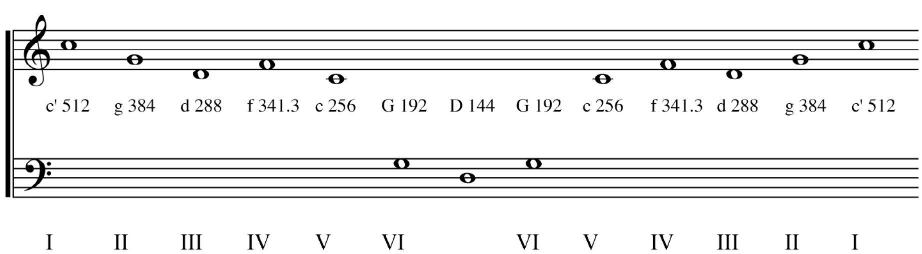
> *12 pairs of compartments corresponding to those described by Vitruvius have been found in the supporting wall of the uppermost row of seats of the Greek theatre at Aizani in Phrygia, eight in the podium of the Roman theatre at Nicopolis, and seven in the Greek theatre at Scythopolis in Syria. There are 20 niches in the upper part of the Greek theatre of Gerasa in Jordan; at Ierapetra and Gortyn in Crete the theatres have 13 niches each; and at Lyttos, also in Crete, there are three rows of 13 niches each.*

Grove Dictionary (Belli, 1854, Müller, 1886).

Vitruvius states that different numbers of vases should be used depending on the size of the theatre.

> *The method of marking out the positions in which the jars are to be placed is as follows. If the theatre is not very large, a horizontal line should be marked out, halfway up the slope [of the auditorium], and 13 vaulted cubicles built, with 12 equal intervals between them: then the sounding jars as described above are placed in them. So by this arrangement, the voice, radiating from the stage as from a centre, spreads itself around [the auditorium]: and, by exciting resonance in particular vases, produces an increased clarity and a series of notes which harmonize with itself.*

Vitruvius, The Ten Books on Architecture, Book V, Dover



<u>FIGURE 2</u> - vessel pitches for a small theatre

I	nëtë hyper bolaiön
II	nëtë die zeugmenon
III	paramese
IV	nëtë synhemmenön
V	mesë
VI	hypatë meson
in media	hypatë hypatön

FIGURE 2 shows the pitches (with Greek names) of the vases for a small theatre as specified by Vitruvius. Vase I *(nëtë hyper bolaiön*) would be placed at either side of the theatre with the *in media* vase (D 144) placed centrally. All others would be equidistant between.

Larger theatres required a greater number of vases arranged in three horizontal rows (one for the *harmonia*, a second for the *chromatic* and a third for the *diatonic*).

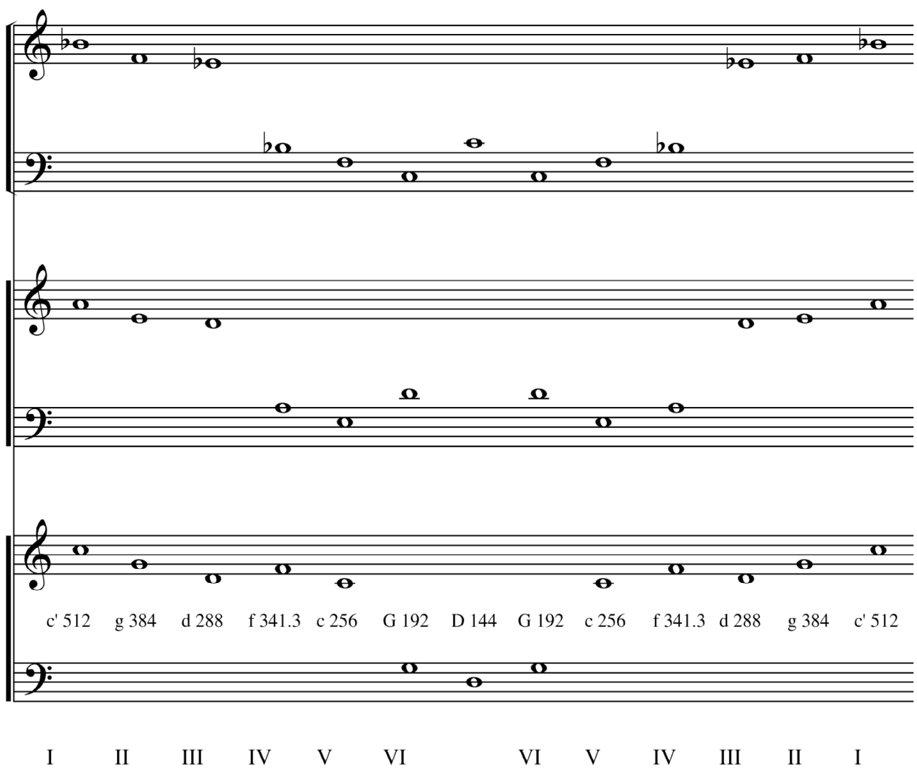


FIGURE 3 - vase pitches for a large theatre

Vitruvius discusses why acoustic vases were not used in the theatres of Rome. Owing to their wooden construction, singers who wished to increase the projection of their sound could direct their voices towards the scene doors (*valvae*). When a theatre is made of solid materials (such as stone) then it should be equipped with the vases as specified. Vitruvius states that there are many examples in Greek cities (Corinth). The expense of the bronze vases is also considered by Vitruvius:

> *'many clever architects who have built theatres in small cities, from the want of others have made use of earthen vases, yielding the proper tones, and have introduced them with considerable advantage'*.

Vitruvius, The Ten Books on Architecture, Book V, Dover

7. How did the vases sound?

It is likely that the function of the vases would have been to make some sounds louder than others by allowing them to sympathetically vibrate when certain harmonics 'hit' them. So, when a singer performs a perfectly in-tune scale, a number of vases would ring creating a harmonic chord. An artificial reverberation (RT60 time estimated as 0·2–0·5 seconds, *Landels*) containing only those harmonics listed in the vases pitches would be produced in an open-air theatre that would otherwise have none.

There may be another purpose for the vases other than those already mentioned. Some believe the acoustic jars helped singers and those relying on ear for maintaining pitch to keep to proper pitch. As indicated, the resonance of the vases would have given emphasis to important pitches leaving the others silent. If the artificial reverberation concept is difficult to accept, the assisted resonance idea is perhaps a little more attractive.

No definitive answer has been found to the question of authenticity and intent with regards Vitruvian resonating vases. It is known that many of the original bronze vases were later used for other purposes and even melted down. The earthenware vases are obviously more prone to damage making them more unlikely to survive the ravages of time.

We have only limited information as to how large and what shape they were and this information varies depending on which translation you use of the Vitruvian text. As a result, a lot of reasoning and occasional down right guesswork is required in order to begin piecing together the enigma of function and intent. However, a number of researchers have produced a variety of reconstructions.

7.1 Virtual reconstructions - additive synthesis method

I began designing software based upon the concepts of Vitruvius in 1999. Max/MSP was making real time synthesis on existing computers a practical possibility (a sixteen oscillator additive synthesiser taking up around 30% of the CPU of an Apple Macintosh G3 266 computer). My experiments began by building a synthesizer using the ratios specified by Vitruvius to see the types of sound I would generate. I made a number of assumptions as to how I suspected the vases would have sounded (based upon the knowledge I had gained as to the nature of the vases themselves and all other available documentation). My principle assumption was that the harmonics should be largely sinusoidal.

I made no attempt at modelling the amplitude envelope of the vessel, as I was initially interested in the pitch relationship of the harmonics (although a 'musical' fixed envelope shape was used for each oscillator). This proved to be a very enlightening way to proceed as it made me address issues of authenticity in the modelling process. Clearly this was an artistic reconstruction based upon the Vitruvian principle where many of the physical constraints (decay time and other naturally occurring acoustic phenomena could be largely ignored as a result of being in the digital domain). My vases do not need to be 'touched' in order to make them sound. They can simply be triggered by an algorithmic process, an external triggering mechanism (sensor, video feed etc.) or rely on external sound being analysed in order to trigger the appropriate oscillator. The code shown in FIGURE 4 (updated in February 2004) is largely derived from this initial idea.

Experiments were carried out using ten, sixteen and thirty-eight oscillators. These numbers were based up the number of vases found in theatres depending on their size. In the early experiments, one oscillator was used to represent one vessel. Clearly, a great many more oscillators would be needed using the additive method if an accurate representation was to be made as it is highly unlikely that a resonating vessel would resonate with only one audible harmonic!

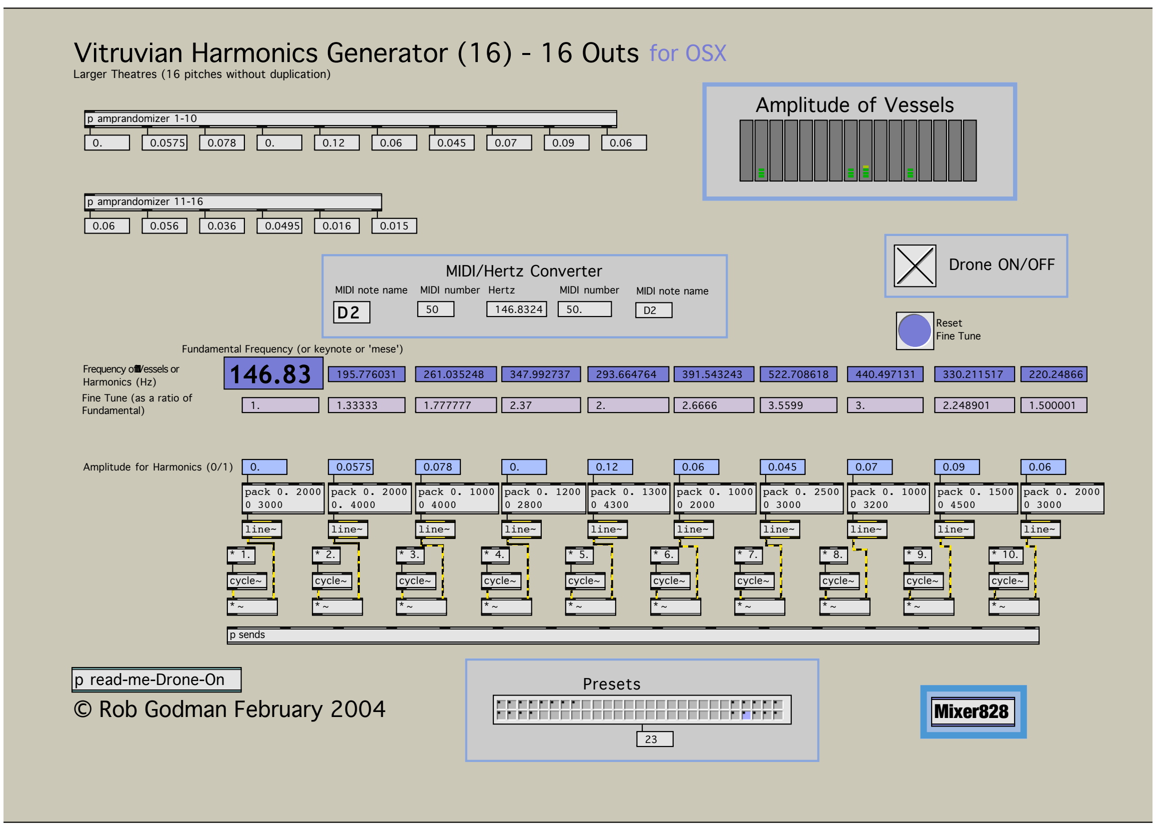


FIGURE 4 is an additive synthesis patch consisting of sixteen oscillators (ten shown here). The programme can be used to trigger the oscillators via external sound (using percussive or pitch detection objects, [bonk~] or [fiddle~] for example), which would be close to the original function of the Vitruvian

vases. Video input via SoftVNS, other sensor input or via a quasi-random process for automatically ‘sounding’ the oscillators are also possible. As we are in the digital domain, we are not dependant upon further physical constraints – my Vitruvian vases do not have to decay once ‘struck’, nor are they dependant upon external sound sources to resonate! Ironically, what began as an experiment (what would these vases really have sounded like?), turned into something of an obsession. The assisted resonance has featured in most of my work over the past four years, whether it is virtually or physically through the use of musical instruments.

Touching the vases…

We can assume that the word ‘touch’ as used by Vitruvius means to make the vases ring sympathetically when the vibration of a sound source with a particular frequency in its harmonic series comes into contact. As has been stated, being in the digital domain frees us from such physical constraints and we can experiment with how the vases may have sounded in a variety of conditions. My first experiment was simply to see what they sounded like being triggered without the need for an external sound source. FIGURE 5 shows such a patch with the triggering taking place via a pseudo random algorithm. This created a continuously changing drone whereby all of the harmonics would sound at different times.

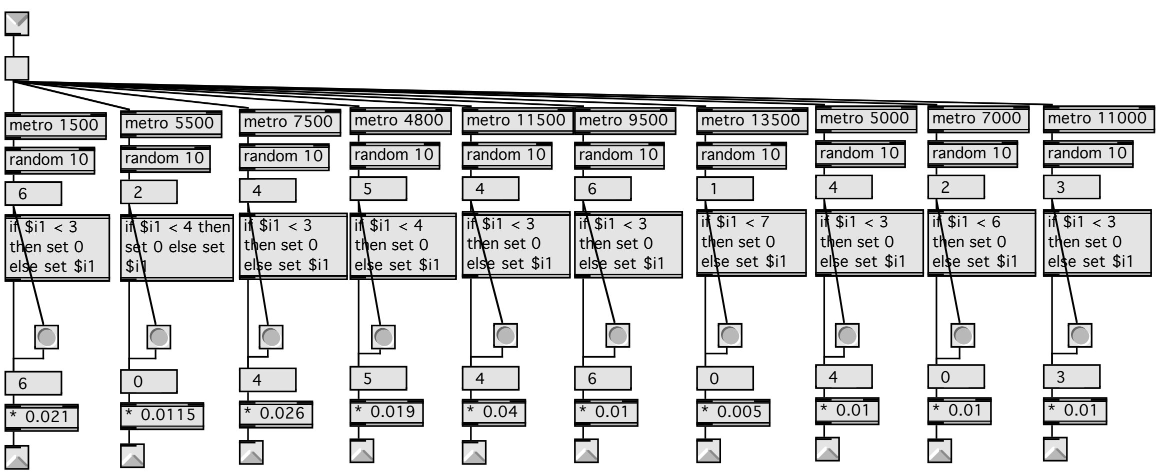


FIGURE 5

[p amprandomizer1-10] - a sub-patch for Vitruvian Harmonics Generator 16.

Using a simple piece of C Code, random numbers are generated at timed intervals specified by [metro] (on for each oscillator). If the number is below the value specified in the [if] expression, a 0 is sent to the oscillators amplifier (turning it off). Otherwise the number is sent through, multiplied by a number to bring it into a range between 0 and 1 and this in turn creates a sound.

Other methods for ‘triggering’ have included the use of David Rokeby’s SoftVNS extensions for Max/MSP. Video is captured via a camera and the software detects movement as a series of vertical lines on the display. This movement is converted into a number dependant on the ferocity of movement and this is multiplied by another number to bring it into a range between 0 and 1, which in turn creates a sound in a similar way to above. This type of interactive system is particularly effective in exploring the relationship between movement and sound. The video camera and SoftVNS can easily be replaced by other sensor soft/hardware. I have experimented with a variety of sensor types for use as triggers (including touch, light, ultrasonic, infrared etc.)

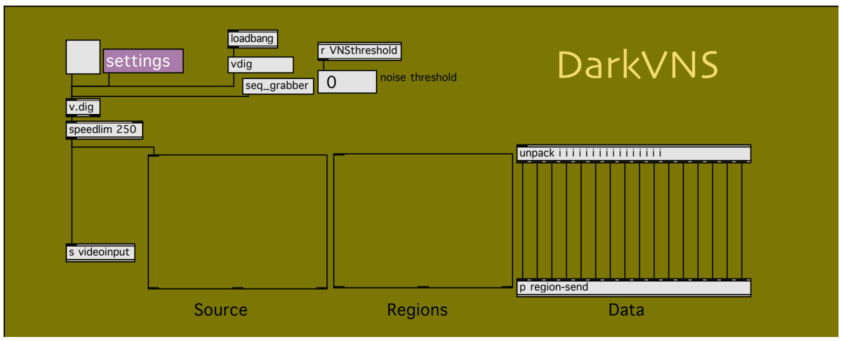


FIGURE 6 - shows a sub-patch used for video control (SoftVNS) of the Vitruvian drones. The video image (not shown) is placed into the 'source' window and then the image is subdivided into 16 vertical strands (under 'regions'). In turn, these strands are converted into numbers that appear in [p region-send] (shown in FIGURE 6). This DarkVNS patch was used for interactive control of other audio elements for *the dark* (http://www.thedark.net - Braunarts, Culture-Online).

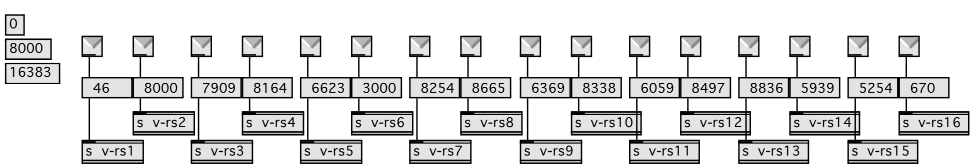


FIGURE 7 – [p region-send]. The numbers above the inlets are used to control the amplitude of the oscillators (the integers are divided by 16384 to bring the new float into the range of 0 and 1).

Neither of these methods bares any resemblance to how the physical vases would have functioned. To achieve this we have to understand what is happening to make the vases resonate in the first place. The resonance is dependant upon external sound being significantly strong enough to make the vessel vibrate. This is more complicated to model, as it requires analysis of the sound source to determine its fundamental frequency (this is because we only want specific vases to ring when they are 'hit' by these frequencies). As has been stated, it is possible to achieve this with the [fiddle~] object and also combine this with [bonk~] for detecting attacks. This is getting much closer, in terms of intention, to what Vitruvius specified (from a sympathetic vibration point of view).

Envelope Shape and Spatialization

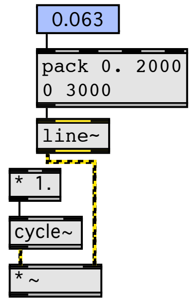


FIGURE 8

A single oscillator shown here can have its envelope shaped by a combination of the [pack] and [line~] objects. It can clearly be seen from this example that the sound will fade in over 2000ms and fade out again over 3000ms. The harmonics frequency is specified by a number going into the left hand input of [* 1.]. All the other harmonics are based upon ratios specified by Vitruvius to create the harmonics he has chosen. Although the harmonics are accurate according to Vitruvius, clearly we are a long way from a true reconstruction as the envelope shapes are far from reality.

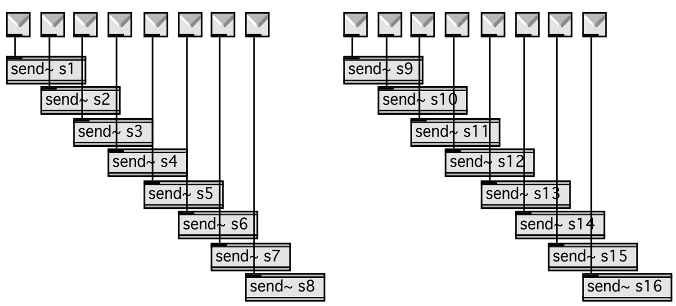


FIGURE 9

[p sends] was used to send the output of the oscillators to the [mixer828]. This enabled the oscillators to be sent to a multi-channel sound card. I have had the luxury of trying this patch with a 16-speaker system although an octaphonic system is very effective. Vitruvius is careful with the specifications of the localization of the vases. As can be seen from chapter 6 of this paper, it would be a simple task to place a speaker in place of a vessel within a real theatre. The spatialization of the vases is a little puzzling. Assuming that the basic sound is sinusoidal, the actual positioning of the vases themselves shouldn't be crucial owing to the relative lack of orientation of sinusoidal sounds from a psychoacoustic stance. As usual, Vitruvius is very specific in his description of the layout. Presumably, he simply felt that a semi-surround layout would be generally more effective in terms of coverage. In terms of the digital reconstruction, there was little difference between the 8 and 16 speaker systems in terms of localisation. Indeed, quad and stereo are also very effective in terms of the elusiveness of direction of source.

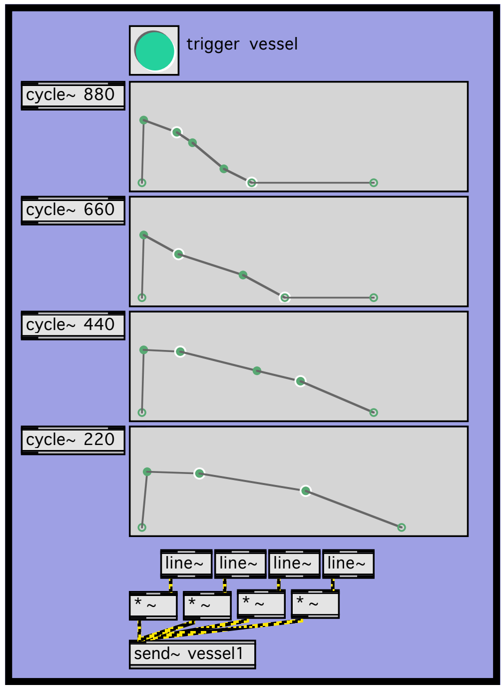


FIGURE 10

The patch above shows a relatively simplistic attempt at modelling a vessel with four harmonics. If a RT60 reverberation time of 0.2 to 0.5 seconds is to be created then clearly the envelope length needs to be of a similar order. In theory any number of harmonics could be introduced but it is worthwhile remembering that the more oscillators being used the greater the CPU load. For realities sake, a more detailed model rather than an educated guess is required.

But, how important is reality when it comes down to interesting sound design and composition? Issues that needed addressing were envelope shape and how to make this dynamic dependant on how the vessel would be sympathetically struck; and, a more accurate model of the vases actual resonance (it is likely the vases ring would have more HF content initially and then be left with smaller amounts of LF – in a similar way to the response of a bell). Additive synthesis is very inefficient at modelling sounds with large numbers of harmonics so a new method needed to be found and integrated into the programme.

At some stage I needed to make a decision as to my intentions behind this research - reality and intent of purpose or artistic ideas derived from an ancient past. One thing was sure; the sounds created using this system were very beautiful as they were and I have continued to use them in my compositional output!

7.2 Virtual reconstructions - impulse response method

By clapping your hands in a church, you are listening to the church's response to the impulse your palms have made. Commercially available convolution reverb software is now available for anyone with a processor fast enough to run it. What this means is that it is possible to 'sample' an acoustic and use it as a plug-in of your choice. Audioease have developed *Altiverb™* that allows the user the opportunity of combining a dry input sound with an impulse response created in a real acoustic environment. They have provided Impulse Response Pre-Processor software that allows the user to create their own impulse responses.

By clapping your hands near a Vitruvian resonating vessel (if one was ever found or reconstructed), you are listening to the vases response to the impulse your palms have made. Perhaps this is getting closer to an accurate digital reconstruction and a means of expanding into greater authenticity.

7.3 Physical reconstructions, building vases for analysis

Early in his career, Per Brüel attempted to duplicate the resonating vase concept by physically building a series of vases to experiment with. None of Vitruvius' original diagrams illustrating the size and shape of the bronze vases survive so Brüel's experimental vases were made of clay in a wine-beaker shape. Brüel claims his experiments showed that they enhanced reverberation at the resonant frequency (although the vases were not tested in a real theatre).

Ideally, a complete set of vases needs to be made. However, the sheer cost of a minimum of ten bronze vases has presumably prevented most researchers from pursuing the project.

A combination of all available methods (physical and digital) may provide a truer picture that is realizable commercially, scientifically and artistically.

8. A fusion of archaeology and composition?

With the aid of modern effects units that attempt to mimic real and imaginary spaces it may be difficult to imagine the importance of the Vitruvian idea. Vitruvius may have invented the whole notion of assisted resonance – an idea that is highly relevant today. Personally, I have always found the idea of creating different acoustic spaces very appealing. Clearly, my aims are very different from those of Vitruvius. I simply want to make an audience question the visual/aural relationship that they experience.

Early Works

FIGURE 11 - site-specific *installation* (1991) in collaboration with architect Jason Cornish, Cross Bath, Bath, Bath International Festival. We found the Cross Bath to be a fascinating space in terms of its location and imagery. Most appealing was the fact that the floor and roof had no fixed boundaries (i.e. the floor consisted of water with its source being a spring and the complete absence of a roof!). This allowed sound in and out of the space. The recorded audio reflected this by placing sound in juxtaposition and unison with the surroundings. Our aim was to capture the space in as many ways as we saw fit. My continuing work with Jason Cornish has been partly responsible for my fascination with Vitruvius.

FIGURE 12 - *Nova Sound System*, commissioned by @Bristol for the opening of the new car park in the @Bristol complex, UK. This was a somewhat tongue-in-cheek piece mimicking a teenager's obsession with inexpensive cars and big sound systems! However, this sound system was triggered via a series of sensors placed around the car that 'played' a variety of sampled car horns (amongst other sounds…). The work was primarily about juxtaposing sound with false and contradictory visual imagery. Despite the car clearly being stationary and the audience moving around it, the sounds gave the impression of moving

(using a distance-panner in Max/MSP). The Vitruvian resonances were again present, giving an artificial 'glow' to the rather austere and arguably modernist car park.

FIGURE 13 - *Cycle Sound System*, funded by Sustrains for the opening of a new cycle path in Bristol. Similar sounds and contradictory imagery, this work explored the tunnel acoustic with which we are all-familiar but also superimposed other 'false' acoustics on top of it. I wanted to place sounds back into the tunnel that would have been present before its conversion to a cycle tunnel. So, as the cyclists went through, they were chased by mechanical engine sounds, spatialised in such a way (again, using my distance-panner in Max/MSP) to give contradictory sensory experiences. Baring in mind that this was projected through a stereo two-speaker system, it was remarkable how encompassing the Vitruvian resonances were and how they worked with the other sounds already present.

Later Works

inside the eye of silence - a collaboration with Vivienne Spiteri

The following is a programme note by Vivienne Spiteri for *inside the eye of silence*. It demonstrates our preoccupation with the Vitruvian concept and how we pushed the principle away from a purely practical 'problem-solving' idea.

where does sound stop and silence begin, end,
sound,   begin?

one of the harpsichord's best kept secrets lies hidden within her chambered spaces between the notes, between those plucked strings (the sound of a harpsichord is like two skeletons making love on a corrugated iron roof) whose piercing sting obliterates all potential revelation of the secret :   her resonance jiuces.

to isolate a single sound, to let the time-life of a solitary plucked string linger, live and rise through to its natural end, is to reveal all :   birth, breath, life, death and rebirth.   all swell with song.   skeletons no more this full-bodied dancing sound, laughing and rejoicing, these rich spectra liberated, escaped from their string prison, these wingéd frequencies, free as air.

air
ah, air
space
air-space   and time
where do air, space and time unite?
"and time is te space your mind movs through" (gwendolyn macewen :

*"vacuum genesis" from <u>afterworld</u>**s** 1987-88)*

sound. sound becoming silence through air-travel, through open air, through air within a space. an enclosed space? of time? time, ah time. sound's phantom vessel.
where does it wander? what is its voyage?
***what** is its voyage, never lowering anchor?*

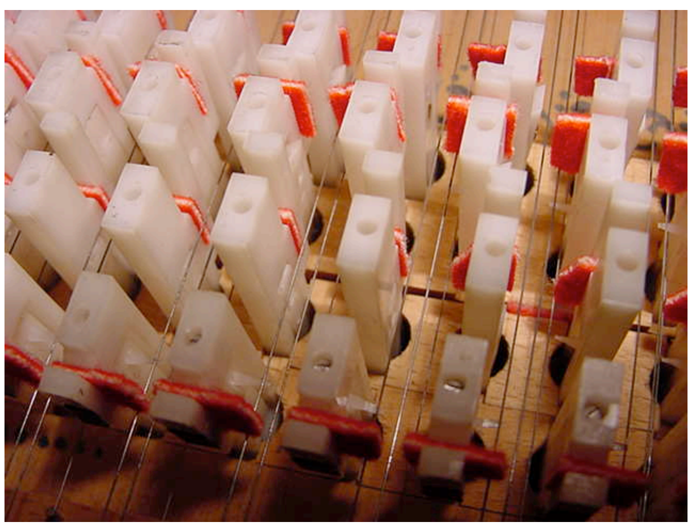
to step inside the eye of silence is to listen deeply, to feel it at your ear. for as long as air and time give it wing, sound-in-silence-in-sound births and breathes itself, expanding, contracting, like the lungs of a whale, huge and light as air.

enter vitruvius, ah vitruvius. he who knew the secret of the wingéd. his siren-song, embodied in resonating bronze inside semi-circular spaces of another place, an other time, drew forth, beguiled and captured the wild and wandering waves, colouring them lively : live, alive, life. long life. longer still. unending
.
enter the spider, weaver of webs, silent siren temptress, vitruvius-collaborator inside the eye, along her radii.

toronto. chemistry building. hanlan's point. harpsichord as siren temptress inside the eye, weaving through space, resonanting her chambers.

listen, dive, fly, let the air wing you
around
space
is time
is sound is
silence
is

infnity's music



<u>FIGURE 14A</u> - images from the DVD version of *inside the eye of silence*.

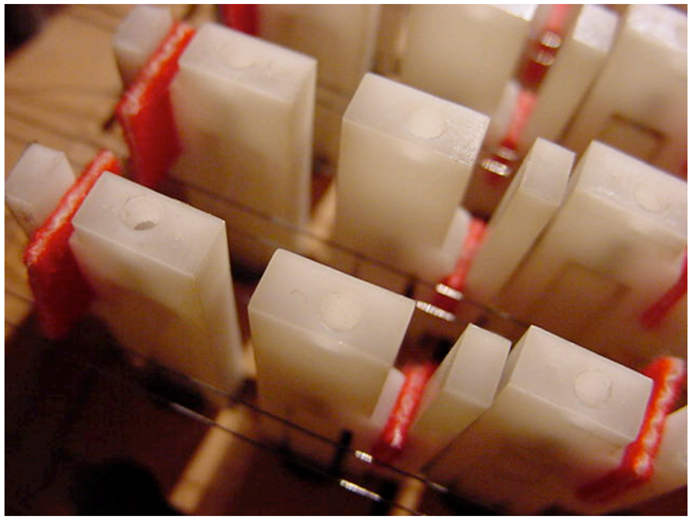


FIGURE 14B - images from the DVD version of *inside the eye of silence*.

Commissioned by New Adventures in Sound Art for Sign-Waves, *inside the eye of silence* was first shown in a multi-room environment using an octaphonic system at The Chemistry Building, Toronto Island, Canada in August 2002. The concept behind the work was to explore an imaginary resonance of the harpsichord. Rather than listening from a traditional space, a few metres from the instrument, the aim was to give the impression of listening and being able to navigate in almost microscopic detail, as if you were completely within the instrument or even within the material it is made of. A number of 'real' and imaginary resonances were explored and in common with many of my works from around this time, the work made use of the Vitruvian resonances, giving the harpsichord source sounds a space to exist in.

Ephemeral Cube/Solid **- a collaboration with Colin Reid**

Written shortly before *inside the eye of silence,* this work follows many of the basic ideas in terms of space and how it is intended to be heard. Much of my previous work had explored what happens to sound when it enters the atmosphere and reflects off different surfaces.

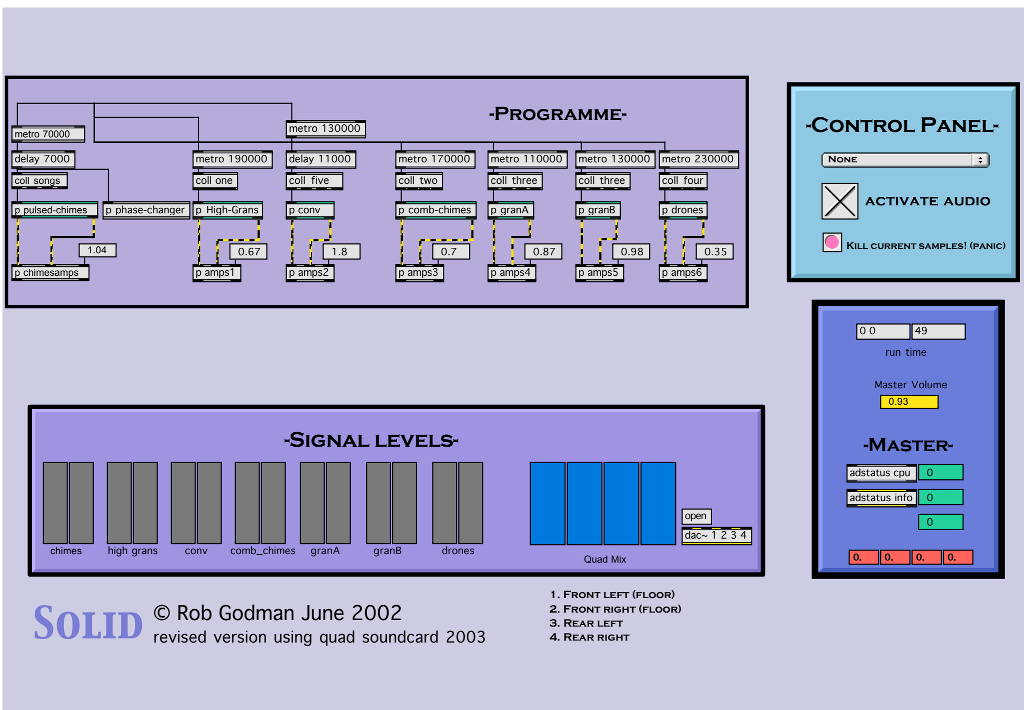
> *"Ever been to the Taj Mahal in India? At the bottom of the building there's a chamber totally enclosed in white marble, with one tiny entrance. The surfaces only reflect sound and there is little opportunity for it to escape or to be absorbed.*
>
> *Imagine; a room where carpets are imperceptibly laid down, rolled up again, the thicknesses change; where the rooms surfaces change material, shape and design; where the sound you hear is deep inside your head or coming from miles away in a cavern. The sound source is no longer absorbed (with a decay) but it expands and evolves organically."*

Godman, Programme Note for 'installation' (Year of the Artist), Prema Arts Centre, Glos, UK 2000

> *What might happen if we listen to these sounds under water? Or, what might happen if we are inside a solid, moving through the molecules and listening to how they relate to each other? Solid is an imaginary exploration of the resonance of a piece of glass, heard from within, rather than outside in the air.*

Godman, Programme Note for 'Solid' 2002

Again, a number of acoustic spaces were designed and superimposed with each other. Both *inside the eye of silence* and *Solid* are algorithmic works and use a series of permutation tables to constantly change the order of how these spaces are presented. This means the composition is likely to be noticeably different at different times of the day, week, month etc. *Solid* was derived from the sound of glass. By using granular synthesis it was possible to extend tiny fragments of sound and allow them to ride on the Vitruvian resonances.



<u>FIGURE 15</u> shows the Max/MSP patch used for operating *Solid*. The sub-patches [p pulsed-chimes] through to [p drones] (shown in green) contain a number of pre-processed sound files that are selected according to seven different permutation series. These series are derived from English Change Ringing Patterns and are stored in the patch as [coll] objects. The variables for these permutation series function as different sound files, no file (i.e. producing silence) and the ability to alter the phase of the signal.

Resonance types used for *Solid* and *inside the eye of silence*

1. High grains (with distance-panner)
2. Convolutions
3. Comb reverberations
4. Middle grains (with distance-panner)
5. Low grains
6. Vitruvian resonances
7. (silence)

FIGURE 16 – *Ephemeral Cube/Solid*, commissioned by Gloucestershire Digital Arts Forum

Nothing but drones…

It was always my intention to use the software to create sounds for installations. To my surprise, they have proved remarkably popular for listening, simply for the sake of it! As well as playback in gallery spaces they have been presented for radio broadcast. Feedback from listeners is often varied, ranging from those that find the continuous sound rather sinister to those that don't even notice they are there.

The Max/MSP code that I have written to create the drones is capable of different tunings and numbers of oscillators. It has been suggested that these sounds could have therapeutic properties. Whilst this is a long way from the original intensions of Vitruvius the effect of these sounds on peoples emotions should not be ignored. There will be people that find these sounds very relaxing and those that don't!

The intervals themselves are of course highly significant. Would these intervals have a special meaning for the listeners or even spiritual or psychological importance in Greek and Roman times? Music and science were an integral part of Greek (arguably less so for Roman) life and played a role in most aspects of their day-to-day activities. If this was more than a simple 'accompaniment' to these activities or the music (and hence the intervallic relationship) had a more profound affect on them is difficult to ascertain. It would be wrong for me to state that these digital reconstructions prove or disprove these statements.

9. Conclusions

We should at some point be brave enough to ask (and potentially answer) a simple question – did the vases as specified by Vitruvius actually do their intended job? There is now a large amount of evidence to support the concept. Other resonating vases have been found throughout history and some are still in use. There is no doubt that Vitruvius was the source for vases used in medieval churches. In Europe there are examples found in St. Clements, Sandwich, Kent, St. Peter Mancroft, Norwich, Fountains Abbey, York, UK and St. Martin, Angers, Bjeresjoe, Sweden. Most of these jars are between 20 cm and 30 cm in length with fundamental frequencies of between 90 to 350 Hz (nor far away from the pitches specified by Vitruvius). However, some of these examples of vases used in churches may have been used to *reduce* reverberation and echoes by absorbing resonance. Many were cemented into place and not placed loose as with the Vitruvian examples. This would greatly reduce their efficiency as resonators. So, with these many contradictions, it is hardly surprising that archaeologists are wary of the function of the vases.

More research is required into modelling the vases from the information we have available. As has been stated in this paper there are a number of options available. I suspect our only real way of knowing how effective such a system would be, would be to physically build some vases. Digital modelling using a variety of the techniques mentioned will give us further clues as to the resultant effect. With visual reconstructions a practical possibility, we should be able to build an accurate virtual reality of the Vitruvian space – a space that has great relevance for archaeology, science and art.

10. Bibliography

-Grove, Dictionary of Music (various) 1998

-Landels, John G. Assisted Resonance in Ancient Theatres - Greece and Rome XIV, Routledge 1967

-Landels, John G. Music in Ancient Greece and Rome, Routledge 2000

-Vitruvius. The Ten Books on Architecture, Loeb and Dover 1960

-Robert G. Jahn, Paul Devereux, and Michael Ibison, Acoustic Resonances of Assorted Ancient Structures (J. Acoust. Soc. Am. 99(2): 649-658. February 1996)

-Harrison, Kenneth. Vitruvius and Acoustic Jars in England during the Middle Ages, Ancient Monuments Society 1967-68

-Levin, F. R. The Manual of Harmonics of Nicomachus the Pythagorean (translation), Phanes 1994

-James, J. The Music of the Spheres, Abacus, 1993

-Roads, Curtis, The Computer Music Tutorial (for Granular Synthesis, 168-184), MIT 2001

-Roads, Curtis, Microsound, MIT 2003

11. Webliography

http://www.thedark.net (2004)

http://www.soundtravels.ca (2002)

http://www.digitaljourney.org.uk (2002)

http://www.philophony.com/pages (2001)

http://freespace.virgin.net/colin.reid2/ephemeralCube.htm (for further details on Ephemeral Cube/Solid)

http://www.cycling74.com (for information regarding the Max/MSP programming language)

http://www.audioease.com (for information regarding Altiverb)

12. Acknowledgements

I would like to thank Per Brüel for discussions in-person at the First Pan-American/Iberian Meeting on Acoustics in Cancun, Mexico, 2002; Aaron Watson for equally illuminating conversations at Reading University 2002 and private communication with John Landels and Sam Moorhead (British Museum).

Rob Godman

The University of Hertfordshire, UK

r.godman@herts.ac.uk - +44 (0) 1453 521895