Areas of remote music collaboration on the Internet:

Exploring constraints and possibilities through four

case studies

by

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1. Introduction

Global remote music collaboration is a new phenomenon, one that is constantly developing and providing varied and exciting ways for musicians around the world to connect and create music together. This treatise will be focused on the various ways in which it is possible to use the Internet as the interface through which to connect for the purpose of creating music.

Currently there seems to be no ideal solution for real-time Internet-based remote music collaboration. The main reason for this is latency - the delay between the sound being created and the listener hearing it which is inherently still a part of the system. However, the Internet does provide many opportunities for users to collaborate in a musical space that was not feasible or even possible in the past. This area of knowledge and practice is still very new and has only just started to be investigated.

Four case studies have been chosen to highlight what is possible to achieve in the current technological space and what its shortcomings are. These include the use of both synchronous (real-time) and asynchronous (non real-time) collaboration methods. Each case study focuses on a distinct area of online collaboration, highlighting a different set of processes and desired results. Some even challenge certain beliefs and aesthetics of what music is, in order to realise music collaboration in new ways.

The intention of this treatise is to highlight what is achievable in various aspects of our current technological situation and what the limitations are in each area. Once this has been established, the perspective gained in each study will provide some insight into the other cases, in order to identify trends in process, common challenges and to shed some light on the future of this industry.

Crucially, these technologies and methods extend beyond the mere employing of technology to bring musicians closer to each other to resemble a "live" musical interaction, for example where a performance is presented on a stage with an audience present. The Internet is a common space in which billions of people participate daily, one that transcends borders, language barriers and cultures. Therefore, the scope of what is possible to achieve musically is far beyond what is possible or feasible in the natural world. These emerging technologies, products, services and methods place the international community at the beginning of a new global music revolution that will challenge imaginations, perceived limitations and national and cultural identities.

2. Background

There are several objectives for this research. In order to answer the question of what is possible and what the constraints of the current technological situation are, we need to clarify the various methods of remote music collaboration. There are two categories in this field. Asynchronous collaboration occurs where the musical contributions are performed at different times and then combined at a later stage to create the combined musical result. The benefits of this type are that there are no synchronisation issues to overcome, and the scope of the project is less limited as there are no physical or technological limitations to the number of performances and performers that can contribute to the final musical result. This technique of collaboration is more popular than synchronous methods with several communities, software packages and techniques already becoming reasonably well known in recent years. Synchronous or real-time remote musical collaboration is the other method. The major challenge with this type of collaboration is the inherent delay (latency) that exists in the way that information is sent over the Internet. There are many examples

displaying innovative ways to work with or overcome this latency issue. The benefits of creating a system for real time music collaboration are vast. The ability to rehearse, perform and record with any musician in real time has far reaching cultural and commercial benefits and consequences. Some high performance networks which exist outside of the Internet have had successful results in this area. This is still to occur over the Internet. Hybrids between these two scenarios exist. For example, where a system caters for people to collaborate simultaneously but makes allowances for the effects of latency by delaying the inclusion of musical contributions.

It is also important to establish some of the many musical roles that stand to benefit from this field's development into a completely functional online environment. Recording session musicians, who traditionally were only able to work within the confines of a geographic region would be able to extend these boundaries to the online space to cater for a far larger number and variety of clients. Likewise, producers and artists would have access to a wider range of specialised instrumentalists and singers' recorded performances for their projects. In addition, record producers no longer need a recording facility as they would have access to players and singers and their respective recording scenarios on a much larger scale with a much larger variety of technical equipment. This access to talent in its locale is significant for the music industry both from the perspective of the players in more remote areas having more exposure, and in the authenticity and value that these genuine localised performances can add to a project. Music teachers and students would no longer rely on proximity to conduct effective tuition. Performing musicians would be able to perform their parts remotely for a live performance if required. Rehearsals and informal musical jams could develop perhaps through existing social media structures into a mainstream intercultural phenomenon. There are many more

examples detailing the development of this process and outlining why it is so important and how it is changing the musical world.

In order to benefit from these technologies, it is important to understand exactly what the current situation is from a technical perspective. This is explored in some detail in the case studies in order to provide a thorough understanding and context of the assessment that follows. Because the focus of this treatise is on remote music collaboration, a large part of the discussion involves removing latency or learning to work with the effects of it. Removing this issue of latency has not only immeasurable benefits for the international music community but many other industries and processes stand to benefit from the ultimate goal of a system without the effects of latency. For example: high speed telecommunications, remote medical surgery, remote controlling of technical or industrial equipment, and other forms of performance art.

From a personal perspective, I currently work as a composer in the online space and I am occasionally required to source musical performances from around the world. I intend to employ the techniques and technologies discovered in the researching of this treatise not only to fulfill these requirements but to benefit directly from the infinite opportunities for music collaboration, especially as a result of the ever growing access to specialised musical communities. Although the idea of asynchronous remote music collaboration is relatively established, with products and services catering for a wide variety of methods of music creation, the reality of a remote collaborative composition, rehearsal, recording and even performance orientated experience is still very much a dream for the vast majority of musicians.

This lack of integration is due to many factors. Firstly, education in the area of the respective technologies, software and techniques are largely underdeveloped. Secondly,

Internet services in certain geographical areas are not available or not equal to the offerings in other parts of the world. These two factors in particular have a negative effect on the collaborative experience, affecting the popularity of the process as a whole. Also, inconsistencies between product marketing information and reality of the collaborative experience is widespread, diluting the participants' experience and negatively affecting the popularity of the process as a whole. Finally, the techniques for online collaboration are still developing, as such few standards have been established, making it difficult to establish connections over coordinated systems.

In order for online music collaboration to develop fully, musical communities need to be formed or transferred from real world communities. Until recently music collaboration has not been possible in a widespread manner. This is because of Internet transfer speeds not being able to support high quality audio transfer in real time. In addition to this, the way data gets transferred is not ideal for low latency audio transfer. Data builds up on a network exchange and stored as a "packet", once these packets reach a certain size, they get transferred. Additionally, the route this data takes is not always the shortest geographical route. This would ideally need to be taken into account to maximise network speed. If the connection speed is consistently fast enough, these packets will reach their sending threshold faster and therefore the data will be sent over the network faster, resulting in lower latency.

3. Case studies

The case studies presented represent four types of remote collaboration. Music professionals have formed large online communities, such as Indaba Music [http://www.indabamusic.com]. These professionals represent a wide variety of technical

skills and musical backgrounds. These community websites provide a meeting place where different roles can be sourced, talent auditioned and hired and creative collaborations imagined and realised. This happens through an asynchronous process of contributions and can even be collated on this particular website. As a result of these online communities being formed, the professional music industry opens up across borders and cultures and provides a larger platform for the professionals involved. Secondly, mass collaboration has become not only possible on a far larger scale, but at a fraction of the cost and administrative overhead than before these networks were established. A growing trend towards integration into online communities has resulted in people connecting on a far larger scale than ever before. Thirdly, real time music collaboration may not be a reality on the Internet yet, but there are other high speed networks with higher specification hardware and protocols which have made remote collaboration a reality. The latency issue inherently part of the Internet is overcome and musicians can rehearse, perform and record as if they were in the same room. This interaction scenario provides an excellent example of what can be achieved in the future of the Internet, and even outlines in detail a technical blueprint for successful interaction. This network currently connects approximately 4000 research institutions in Europe [http://europa.eu/rapid/press-release_IP-09-407_en.htm]. Finally, the latency issues currently experienced when collaborating online may be considered another parameter to create music within. By using network latency as an unpredictable and non-linear modifier in the chain of remote collaboration, some unexpected results are realised as well as some concepts that lay the foundations for future developments. There have also been some fully functioning occurrences where people have worked with these latencies to connect in real time. One of these scenarios is through the use of cyclic compositions where the need for real-world latency levels is less of a requirement for successful collaboration.

a. *Virtual recording studio*

The commissioning of musicians and recordings online is perhaps the most established form of remote music collaboration. Already, large networks of musicians, engineers, studio owners and producers exist in online communities. Producers, composers, and arrangers are easily able to order recordings of commissioned performances from around the world.

The following case study is a project which I worked on in 2010. My brief was to write and produce a theme song for the online casino slot game 'Voila'. The song was to be written in French and sung by a well known French singer and, therefore would almost definitely be living in France. Musically, the requirement was for it to sound authentically French as well as being able to loop seamlessly and indefinitely. I decided to use two stylistic references: the music of Django Reinhardt and the soundtrack to the film "The Triplets of Belville". This would ideally result in an energetic French gypsy style jazz track.

This project created some considerable challenges. I had not written or performed music in this style before. I do not speak French so, instead of writing the song with a translator, I decided to write lyrics in English and then find and work with a translator. I don't know of any well-known French singers, so I would have to find one. The recording took place in Paris, so I needed to hire the singer and provide creative direction remotely, as well as find a recording facility and sound engineer. It was important to establish their ability to deliver a high quality product up front. In addition to these challenges, the following factors would also have to be taken into account. The project's deadline was immovable and was not negotiable. The costs were to remain inside the project's budget and I had to schedule my own time on the project to allow for focus on other concurrent projects as well as this one. Finally I was required to deliver the project to the quality expecations of the stakeholders.

Once the recording facility and technical and creative talent had been sourced, I assumed that this process would work very much like it does in non-remote collaboration scenarios but I intend to show that this is not the case. There are many assumptions and grey areas that need to be addressed before a project can have a good probability for success.

The major challenges of this project are in assessing the level of both the ability of the singer and the recording facility's capacity to provide a high quality product at the end of the session. By focusing on the process involved in this project, I intent to shed light on some of the mistakes I made and some of the solutions I discovered.

Technical setup

The first challenge was to source the singer. The brief stated that I needed to find a female singer who is well known in France. A contact in the UK provided a French artist named Julie Bataille who has a well known voice in France, where she works as a singer and voice actor. She became well known in 1983 for singing the song "3 petits singes" and has worked in the entertainment industry since then.

The next step was to source a convenient recording facility. Bataille provided me with the contact details of a studio that she uses regularly. I attempted to establish if the recording studio could provide us not only with a high quality recording but also the creative and stylistic direction necessary to make the most of this track. I requested some examples in various styles of the work they had created in the past. After assessing the technical and creative aspects of these recordings, I decided that the quality of the offering was acceptable for my requirements and so I could go ahead.

Backing tracks including temporary vocal tracks were sent via email to the singer. What was required was a high quality, completely isolated vocal performance which could then be inserted into the final arrangement on the digital audio workstation and mixed and mastered accordingly. It was not stated up front that any post production was required on the recorded parts, but delivering technically accurate assets was an expectation. In order to achieve this, the tracks may have required the use of compression, EQ, tuning or timing edits. However the imperfections of the tracks were not addressed before delivery and so these processes formed part of the post production processes.

The studio which was hired in Paris used a Pro Tools system with a selection of high quality microphone preamps and Neumann microphones. There was also a variety of good quality outboard audio processing equipment.

Process

After writing the music and lyrics in English, I requested the vocal range of the singer, and then created the arrangement that the singer would use. I worked with a local translator over email in order to create a French version of the English lyrics.

The studio was booked and the finished lyrics were emailed to the singer who was asked to familarise herself with the material. She was also sent the work-in-progress music arrangement so that we could ensure that she could sing the song comfortably and optimise the studio time booked for the project. The melody was represented by a piano that had been placed very loud in the mix. She was also sent a demo recording of the

English version of the song that had been sung by a colleague of mine. This was in order to keep the delivery of the performance as close as possible to the original song. Everything went ahead as planned, and several takes of the recording in 44.1 kHz, 24bit format were emailed to me from the recording studio in Paris. 24 bits of dynamic resolution is the professional audio industry standard. I used 44,1kHz sample rate because all my samples and sound effects banks exist in this format and I would prefer not to do any sample rate conversion purely for convenience. Added to this is the fact that the final audio will be exported as a 64kbps mp3, which is a relatively low quality, output format compared to other professional audio products such as CDs, console games, films and digital television. Despite this low quality format I believe that 24bit is still important as a format to work with in this project for several reasons. The summing engine produces far better results with 24bit audio than 16bit because the dynamic range of the recording is maintained right until the final export which will result in far better dynamic range of the final audio as well as increasing its signal to noise ratio. The audio can also then be exported at full quality for marketing purposes if necessary. Other aspects of the recording are also maintained at larger bit depth values, such as less quantization noise, more accurate stereo imaging and less degradation in the use of audio effects.

Assessment

The final results, if measured in terms of the meeting of deadline and quality expectations, were a success. However, there were also some significant shortcomings and many areas for improvement in the translation, recording, talent acquisition and post production processes.

The most challenging aspect of this project from a creative perspective was not a musical element but the writing of lyrics. Although not strictly in the same category as remote music collaboration, this is an important part of the process in that it still makes use of the principles of remote collaboration and outlines some of the challenges that exist in the auxilliary processes surrounding the primary goal of creating music. The lyrics needed to embody the spirit of the product that I was writing for, to celebrate France and everything French. Translating lyrics seldom works well and is considered more of an art than a science. As a result, even though expectations were met with the finished English lyrics (the imagery, cadence, rhyming structure and sonic properties seemed to work well) the translated lyrics would almost certainly have to compromise on some level. This process will almost certainly yield different results every time it is applied, and as such it is almost impossible to replicate the process.

While the English lyrics had been approved by the project owner, they seemed to lose a lot of the spirit of the song in the translation. The lyrics reflected the ideas presented in the English song, the syllables matched at about 80 percent accuracy, but the matching of the rhyming structure to the English version was only at about 40 percent accuracy. Perhaps the process was flawed in this case as I am not aware of another case where a song had been translated and managed to keep the lyrical content, syllabic and rhyming structures in tact. Bearing this in mind, based on the fact that I have no personal capacity to improve upon this result as I don't speak French, and because of budget and time constraints, I decided to keep the translation as it was presented. As such I am relatively happy with the final result, albeit that in my opinion this was the least successful element of the project.

The singer had been given some creative license to change lyrics where she thought it was beneficial. This created some problems, as the decisions that she made were based around the lyrical content and didn't always keep the syllabic rhythm of the original song. Fortunately these changes were reasonably small and the lines maintained their natural feel. This was achieved by some careful editing, specifically the speeding up of certain syllables and small changes to the melody through the use of Celemony's Melodyne Studio.

There were some errors on the actual recording. Some clipping occurred, resulting in distorted vocals. The lyrics had not been sung particularly accurately and there were significant timing and tuning errors. Some of these errors weren't just slightly sharp or flat notes, but actual changing of the melody. Finally, there was the issue of the quality of the recording itself. This is a highly subjective area, but I expected the actual recording to sound better. There was a general lack of dynamic range and the frequencies were represented in a more non-linear way indicating the use of substandard recording equipment - specifically acoustic room treatment. There were also a lot of vocal pops on the microphone, indicating that they did not use pop filters. Since this was a professional recording facility, I would have expected such basic issues to have been detected and fixed accordingly. As a result the product did not meet expectations.

The recorded parts were sent through via file transfer protocol (FTP) in the Internet. This delivery included enough takes to be able to composite an acceptable vocal track for the song. Then, through the use of state-of-the-art editing and adjustment techniques, notably Melodyne Studio, all timing and tuning errors were adjusted and fixed. This resulted in a vocal track that was at least technically correct, even if subjectively still a little sterile.

Despite the many challenges and imperfections in the process, and the considerable time spent fixing technical and performance issues, the final song was delivered at an appropriate level for the product.

There were many valuable lessons learned during this process. This has resulted in the use of completely new processes when carrying out remote recordings. More time and effort needed to go into establishing the quality of the recording facility and the credibility and experience level of the professionals who work there. Since this project there have been far more contacts established in various places for the purpose of establishing credibility. These trusted professionals also have considerable networks of trusted contacts in the industry. Through this expanded network it is hopefully far easier to establish a facility's ability to deliver a high quality product through referrals.

No matter how trusted a producer is, there will always be differences of opinion in decisions made regarding a certain performance. Because of this, the final product is always better with studios that have a phone patch facility. This process allows the producer to call a specific phone number provided by the recording facility. This call then gets patched into the recording studio as an input and an output channel. The studio engineer can control the audio feeds just as in a normal recording session. Thus, the caller can speak directly into the artist's headphones if routed in such a way and the artist's microphone can be both recorded in the studio and used as a communication microphone for the producer on the phone. In addition to this, he can also hear what the artist is hearing (for example musical tracks, sound engineer's microphone, etc). This facility makes use of voice over Internet Protocol (or VoIP) and so, decisions regarding compression formats and rates, the appropriate use of stereo or mono and optimum mix

levels for the compression type can be made to allow the remote party to have the best interactive experience possible. This process allows the producer to make decisions on performances during the session. It also allows them to provide detailed and specific direction and feedback, resulting in far less chance of subsequent recording sessions. This method is so effective that what is heard over a normal phone line provides an extremely accurate impression of the high quality version of the recording that is sent via a FTP download after the session is complete.

A large part of the success of this project was the value added by the local talent in Paris. Without her performance the finished result would not have had the feeling of authenticity that could only be provided by a professional French singer.

Considering Paul Simon's *Graceland* as an example of using recording studios as "nodes" for the various aspects of a recording project, Théberge (2004, pg 772) states that:

> if Simon had to go to places as far removed as South Africa and Louisiana to find new musical collaborators, it is perhaps because it is in such places where one still finds the vestiges of an earlier modernity. Even if one accepts the idea that these remote facilities are more rooted in local contexts and traditions, the articulation of those localities into the global production process is perhaps new, the studio functioning more as a kind of 'node' in a larger communication network than as a destination - a place - in and of itself.

This view corresponds with this case study in that it valiues the uniqueness and authenticity which is added by sourcing local performances in situ.

Tanzi (2001, pg. 431) suggests that:

> the mobile and immaterial architecture of cyberspace leads communication away
> from a sequential and linear style, compelling subjective time to flow again and
> again around decisions already made to modify phrases and implications. This
> causes a combination of known properties (density, priority, linearity, parallelism
> ramification and circularity) and creates complexes of temporal intervals with
> different orders.

However, given the nature of this particular project, it is in our best interest to make the
music feel as spontaneous and "live" as possible. The recording and editing process may
therefore be counterproductive to this project's goal of perceived authenticity as
experienced by the final audience.

This presents a contradiction in that sourcing and commissioning a singer in France
provides our final product with a level of authenticity considered unachievable without her.
By changing our process to allow for the fact that she is in another geographical location,
we are adding processes of recording selection, comping, editing, tuning, signal
processing, etc to our production that, according to Tanzi, will diminish the authenticity of
the original live performance. However, even if the singer was local, with modern recording
techniques including the separating of performances for greater control, there would still be
issues surrounding temporality as it is unlikely that the recording performances would have
been performed as a live group, playing together in one space.

b. *Crowd Sourcing*

This occurs when a large mass of people participate in an informal (often unpaid) manner to complete a task that traditionally would be completed by an employee or a specifically commissioned group of people.

The example chosen is Eric Whitacre's 'Virtual Choir 3: Water Night', a project in which he conducts individual choral performances over the Internet through his website [http://ericwhitacre.com/the-virtual-choir]. He then downloads all the performances and mixes them into a choral arrangement comprising of 3746 voices from 73 countries. All sharing of information was done using the Internet. 99% of the participants he had never met in person. The final recording is broadcast on the video sharing website YouTube [http://www.youtube.com/watch?v=V3rRaL-Czxw] as well as being shown as an HD audio visual experience mixed in surround sound at various custom installations around the world.

This example was chosen because of its exclusive use of established Internet methods as a means of communicating the vision for the project. In addition, the quality of his results are unequalled in large collaborative projects. The project therefore provides an ideal example of what can be achieved through the use of crowd sourcing.

Technical setup

In order for contributors to create and upload accurate performances, various pieces of information are required. The musical score including lyrics for all sung parts was provided

for the singers to perform their parts correctly. A digital version of this was made available for download from Whitacre's website. In addition to having the score, for the singers to sing together in a realistic way they would need to be conducted. Hence, a video was created of Whitacre "conducting" to the audio recording of a "real" choir singing 'Water Music'. Four versions of this video were made for the individual soprano, alto, tenor and bass parts respectively. At the bottom of each video were the words and melody for each part. The singers could therefore read their parts and watch Whitacre conduct them on the video while listening to a full choir sing the combined parts of the song. These three elements make for the most accurate reproduction of actually singing each part in a live setting, with the advantage of far more people taking part than would be feasible in the real world. Each video began with Whitacre asking the singers to clap three times. This acted as a means to synchronise the videos in the post production phase of the project. These videos were made available on YouTube and on his website for download. Practical recording guidelines were given. For example, singers' faces should be well lit for the video recording of their part, all fans and air conditioning should be turned off, etc. Technical instructions were also provided. For example, in order to create a successful recording of only their part without extraneous sounds, singers would need to listen to the accompaniment video with headphones. Finally, creative direction and performance instructions were given also using a video where Whitacre talks the singers through the score, explaining where diction is most important and how it should be sung, where the overall dynamics shift and where individual parts are doing something that requires specific direction. This larger perspective of what the overall result should sound like, helps singers perform more musically and more sensitively to achieve the final desired result.

Process

For the individual performances, the singers downloaded their respective conductor video, learned their parts, rehearsed with the video and finally made their recordings. Their finished video was then uploaded to YouTube and the best performances were then selected for use in the final arrangement and multimedia performance.

On the receiving end, the videos that were to be used were selected and each of the selected video's audio was then extracted from the video and placed into a multi-track digital audio workstation. The three claps (and specifically the third clap) were used to put all of the performances in time with each other. The performances were separated into soprano, alto, tenor and bass parts. Each performance was cleaned of any extraneous audio, compressed or expanded where necessary and equalised in order to optimally fulfill its role in the final recording.

Although undocumented, a software program such as Antares Autotune or Melodyne Studio may have been used to correct any notes that were inappropriately sharp or flat, or to adjust slightly the length of each word. However I find this unlikely given the fact that a fairly relaxed appproach was taken on consonants that didn't fall together. These were left unedited in the recording. In popular music these would have been edited to perfect timing unison. But given the stylistic nature of the arrangement this does not detract from the final results, in fact this gives the impression that the audio was left largely as sung. The parts are mixed together in a natural sounding and balanced way

Assessment

The final result is largely indistinguishable from a live choral recording. In contrast to Whitacre's previous collaboration projects, where the artefacts of audio compression were overwhelming, the listener is now able to hear relatively high degree of audio fidelity. This is surprising, especially considering that the source material was largely recorded on consumer equipment in singers' bedrooms. Although these artefacts of compounded audio file compression are still audible, particularly in the higher frequencies, I propose that the end result is successful for the purpose it was intending to achieve.

The light use of editing was unexpected, especially when considering the high profile nature of this project. The consonants were noticeably out of time, often being scattered over the period of about one second. However it is possible that stylistically different backgrounds (eg classical versus popular music production), where emphasis on unison of pitch and timing vary considerably, would sway the listener's opinion on this matter significantly. Regardless, the impression that the choir members are slightly out of time with each other adds to the believability of the project and creates the impression that the parts have in fact remained largely unedited and what is being heard is 3746 people performing together in the same space.

There was a heavy use of reverb on the final mix. Given the stylistic nature of the material, this was not inappropriate and possibly added to the feeling of the water theme, as well as helping so many different types of voices work together and giving them a little extra smoothness. However, it is a matter of personal taste and certainly would not appeal to everyone. It also does not help the previously mentioned impression that the performances are represented 'warts and all' in the final result.

There was a consistent level of excitement from the participants. Despite not being reimbursed in any way for their contributions, everyone seemed genuinely excited about being part of this project. It seems that people will contribute to the best of their ability purely for the opportunity to be a part of something special. One could speculate that the more high profile the project is, the more people will be willing to share their time and skills. This observation on human behaviour opens many doors in terms of participation in mass collaboration projects. The most valuable result from this project is the fact that although nothing groundbreaking was achieved from a technological perspective, it represents a new way of thinking about collaborative projects online. It clearly shows that people are willing and excited to contribute for no payment thereby reducing budgets and increasing the scope of projects. In addiition, this project provides a high quality example of how the scale of projects has grown significantly beyond what is feasible or even possible in the real world.

As Whitacre intends to use this project commercially, he will need to ensure that he has the right to use the individual performances. Gieseking and Graf (1999, pg. 78) mentioned that "there is no doubt that the issue of copyright protection has become one of the main concerns when considering the impact of the global network". Whitacre would not only need to ensure that he owns the individual recordings and has a right to use them, but also is able to benefit financially from the combined result. This issue would also exist in a real world collaboration, but the ownership questions become less clear when individuals who are not governed by an institution decide to volunteer their musical performances towards a collaboration. The fact that these performances are created in thousands of individual locations around the world and uploaded to a third party website increases the possibility of abuse of content, and makes establishing intellectual property and tracing individual performances far more difficult. These factors are important in this scenario, not because

of ownership or payment expectations of performers, but because of the potential lack of trust in the use of uploaded content that the Internet presents in its degree of access and anonymity.

Théberge (2004, pg. 773) states that as recordings move away from conventional 'brick and mortar' recording studio environments they also move away from specifically designed acoustic spaces and the group of highly specialised individuals that come together to create recordings, to a scenario where anyone with a computer and some basic equipment is creating recorded performances. How we arrived at this scenario is less important for our purposes than the fact that this has become a widespread issue. This clearly underlines the issue of the degradation of audio quality in networked audio projects and has contributed very clearly to the end result of this particular project. From listening to the individual performances and the final result, it is clear that Whitacre encountered these issues in his project. One of the ways that he overcame them, to a degree, was to use high quality equipment and highly skilled professionals in the post production process.

Although the previously mentioned audible artefacts associated with audio compression have the potential to have a negative impact on the quality of the final result, it is worth mentioning that the audible effects of mp3 compression in some people's opinion is an enjoyable addition to the original audio signal, just as the crackle of vinyl is enjoyed by some audiophiles. Dougherty [http://radar.oreilly.com/2009/03/the-sizzling-sound-of-music.html] conducts an annual experiment in his classroom where "[h]e has them [students] listen to a variety of recordings which use different formats from mp3 to ones of much higher quality. He described the results with some disappointment and frustration, as a music lover might, that each year the preference for music in MP3 format rises. In other

words, students prefer the quality of that kind of sound over the sound of music of much higher quality."

Whitacre displays a good example of incorporating technology into art. While the focus during the analysis of this project has been on the technological aspects, Whitacre's focus remains on the the purpose of the project itself. According to Weil (2002, pg. 523), this shift of focus from "how" to "why" or in Whitacre's case, from technology to aesthetics and community, puts these aspects in their natural place:

> The ubiquity of technology has also affected its place in our Western, post-industrial culture: From subject, it has become object. No longer a wonder, its sole use cannot legitimize an art project. Rather, as digital tools become as readily accessible as the pencil or clay, mastery tends to be about pushing technology to the back of the stage, where it really belongs. With computing, the notion of representation is further established in the realm of filtering, editing, and reconstruction so as to create new meaning. The digital, in that sense, has established itself in the natural continuum of art history and in the ongoing relationship of art with technology, from the tube of paint to the camera - from the moving image to multimedia.

This volunteer-reliant system has both benefits and challenges. One benefit is that the scope of a project in terms of the number of people contributing grows exponentially through web communities and social media allowing information to flow more freely and often resulting in larger numbers of participants. Through these networks the visibility of a project grows in significance and proportion with the number of people participating. This added visibility results in greater access to professionals and highly skilled amateur technicians willing to work for less remuneration (sometimes for free) in the interest of

recognition or reputation. As such, large scale projects can be completed with far smaller budgets than was possible previously.

However, this approach presents challenges. There is no selection mechanism, nor any other type of control of the skill level of the participants. There are invariably large inconsistencies in the performances that were contributed. When dealing with large numbers of musical contributions from largely amateur musicians, there will undoubtedly be a wide variety of quality of performances. This will need to be allowed for and necessary decisions need to be made as to how to set the threshold for an acceptable performance. Also, because participants are contibuting freely towards a project, intellectual property and ownership structures need to be communicated clearly to all participants up front. There are ethical issues to consider too. For example, is it ethical for contributors to receive no payment for a commercially orientated project? Conversely, if contributors are paid for their contributions, this creates additional challenges. Wikipedia [http://en.wikipedia.org/wiki/Crowdsourcing] states that "because crowdworkers are considered independent contractors rather than employees, they are not guaranteed a minimum wage". Additionally, "Since crowdworkers completing microtasks are paid per task, there is often a financial incentive to complete tasks quickly rather than well". This also brings into question the motivation for participants' involvement. If there is a policy to pay for individual's contributions, this may attract people who are not necessarily contributing because of their emotional connection to the project. This could result in the seemingly unlikely scenario of receiving a poorer average level of quality if the performances are paid for as opposed to requesting performances from volunteers.

Each time a project like this takes place, the final results will be dramatically different because there are so many variables to consider when attempting to replicate this process

accurately. For example, because this project is based on volunteer contributions, the number of contributions made will be determined by how effective the motivation to contribute is. It will be a challenge to get similar numbers in different projects and it is important to understand motivational factors that encourage people to involve themselves in volunteer projects. Another aspect to consider is that there will always be a natural imbalance in the various parts. As this is a choral piece, one would hope to achieve a balanced number of soprano, alto, tenor and bass parts. This is not always going to be the case and therefore some contributions will need to be discarded in the interest of achieving balance between parts. There are technical issues too. Internet video storage sites such as YouTube store compressed versions of the videos uploaded. This has an effect on the final audio quality of the project and so uploading guidelines will need to be establised up front. It is also important that the technicians performing the post production roles in the project have a thorough understanding of how to minimise the artefacts found in modern compression techniques for the final product. Finally, each contribution is created in a unique technical scenario. In addition to the challenges this creates from a quality point of view, there is also an almost infinite set of technical specifications that, across the scope of a project with over 3000 contributions, would be impossible to replicate accurately.

c. *LOLA (Low Latency Audio/Video Conferencing System)*

Perhaps the form of remote music collaboration with the widest appeal, and certainly the one with the most commercial use is in the area of a real time, synchronous, low latency musical interaction. This scenario, which has the ability to emulate a real world musical interaction significantly, changes our musical landscape for rehearsals, recordings, performances and master classes. In addition, this technology can be used for many

applications beyond musical collaboration. One such application with significant benefits is in remote medical surgery.

LOLA is a software interface that is used in conjunction with several high speed networks around the world [http://www.geant.net/Users/ArtsandCulture/Pages/LOLA.aspx]. For example, the Géant IP network for most of Europe, the GARR network in Itay and the Internet2 network in the USA. These dedicated networks are far better equipped to handle real-time audio transfer than the Internet. The Géant network for example connects over 4000 universities around Europe with a very high speed, low latency connection. With a maximum round trip time (RTT) of 60 milliseconds from note played to the listener's ear, this system effectively allows musicians to play together as if they were in the same room when they are thousands of kilometers apart.

By using more advanced protocols and higher bandwidth than the Internet presently is capable of producing, this example provides a realistic idea of what can be expected from the Internet in the future in a working example which is already being used.

This case study analyses a performance which took place on the 4th of October, 2011 at the Internet2 Fall Meeting in Raleigh, North Carolina where Handel and Halvorsen's Passacaglia for violin and cello was performed live over the LOLA system. Marjorie Bagley was present in the meeting and played the violin part, while Cheng-Hou Lee played the cello part from another facility in DeKalb Illinois, approximately 800 miles away.

Technical setup

The LOLA system for most of Europe relies completely on the speed, security and reliability of the Géant IP network, a high-speed network connecting over 4000 universities.

This is because the infrastructure and the speed of the Internet is not yet able to cope with the bandwidth needed for ultra-low latency video and audio connections.

According to LOLA, the Internet is not able to manage real time remote music collaboration. Furthermore, in addition to the high speed audio transfer required, this system also makes use of a real-time video link in both directions. Therefore the system requires a high speed, powerful and reliable network. This network is provided by GARR, GÉANT and Internet2 and is the foundation on which the LOLA system exists.

In terms of performance, Bartlette, Headlam, Bocko and Velikic (2006, pg. 58) established that, in conjunction with other conditions, it is important for the amount of latency in the network to be below 86ms as this is the threshold above which we start to feel and/or hear the effects of network delay in the collaborative creation of music.

The minimum bandwidth requirements for the system to function effectively are considerable by Internet standards. For a video resolution of 640 x 480 pixels in black and white at 30 frames per second and audio quality settings of 44,1kHz, 24bit, stereo requires a minimum bandwidth of 94Mbps end to end. If the video is required in colour at 60 frames per second, over 500Mbps bandwidth is required. Other aspects which increase the need for bandwidth are multi-channel audio scenarios and higher video resolution settings. All audio and video data is transferred uncompressed. This network needs to be very stable. As there are no buffers being used, network jitter is measured at less than 3 milliseconds at 30 frames per second video and less than 6 milliseconds at 60 frames per second video. [Tartini, G. 2011. LOLA (Low Latency). Project Conservatorio di musica.Trieste.]

One of the reasons that LOLA is able to perform at below 60ms round trip time is because of its management of data along geographic paths. The further the data travels, the more latency is added into the system. Approximately 1 millisecond of latency is added for every

100 km over a multi-Gigabit network. What makes LOLA unique is that it takes "shortest geographic path" into account when deciding which route the data should take. The Internet currently doesn't allow for this decision to be made. This represents one of the challenges of overcoming latency online.

The high speed network upon which LOLA operates offers a service called Premium IP. This service can prioritise certain traffic over all other traffic, ensuring a consistent high speed connection.

Process

Using the technical setup provided above, musicians perform as in a recording scenario, with the appropriate microphones in place. These microphones are fed into high quality preamps and mixed into a single stereo audio stream. This audio stream is then converted into a digital format and transmitted via the Internet2 network to the remote performer. The same process happens on the other end of the network. Each performer has both their own audio feed and the signal from the remote performer on their monitoring system. In addition, there is a real time video feed of the remote performer viewed from each end of the network. This not only aids in communication but also gives visual musical cues that allow the musicians to connect in an even more intimate manner. Because this network is consistently available, students can rehearse together, attend remote master classes, create performances and recordings together and become accustomed to the dynamics of working remotely.

Assessment

The results represent the ideal scenario for remote music collaboration. They present as a perfect working example of what we can hope to expect for Internet collaboration in the future. This may seem subjective but when compared to every other service offered, nothing has offered anywhere close to the level of intimacy between participants.

Unfortunately these private networks only exist between educational institutions and so the general public doesn't have access to this facility. But because these networks aren't using a public network, they have complete control over the allocated bandwidth and traffic. Therefore the systems are completely replicable and similar results can be expected with each project using these systems. This is a great advantage which, if made possible on a public network, would completely transform our musical landscape. The fact that this is already a reality hopefully indicates that this connectivity on a larger scale is imminent.

The network latency is measured at 35 milliseconds, which, in physical terms is equal to the musicians playing on either side of a stage approximately 10 metres wide. In contrast to the Internet this is a remarkable achievement and represents the first network performances completely unaffected by network latency. In real but immeasurable terms, players themselves also mentioned that the performance felt like they were playing with someone in the same room. [http://www.Internet2.edu/arts/LOLA.html]

Audio quality – high quality microphones, audio hardware and audio monitoring systems were used to capture and transmit the individual performances. As a result this 24 bit audio is no different from the players using the same space.

Because this system offers a dedicated, high speed network, the results are repeatable and predictable. However, the bandwidth provided by this system varies significantly from

the network to which we are all connected – the Internet. Speeds upwards of 500Mbps are simply unattainable on our current system. In addition, both parties of a collaboration would need this sort of high speed connection for the collaboration to work successfully. Furthermore, the way in which the Internet packages and sends data makes it an inappropriate choice for remote collaboration. I suspect we will see some change in this area in the future, but until widespread bandwidth increases significantly at reduced cost and infrastructure conforms to higher performance standards that cater for the majority of users, widespread access to this form of collaboration will remain on specialised networks.

With a round trip time of 35ms, this falls far below the accepted discernable threshold of 100ms as discussed by Bartlette, Headlam, Bocko and Velikic (2006, pg. 49) where they state:

> Although the musicians chose different strategies to handle the latency, which resulted in different levels of success in maintaining coordination, pacing and regularity, both duets were strongly affected by latency at and above 100ms. At these levels, the musicians rated the performances as neither musical nor interactive, and they reported that they played as individuals and listened less and less to one another.

According to Pillay, D (1998, pg. 52) in *A wide Area Online Music Collaboration Emulation Platform*, "musicians can tolerate round trip network delays of up to 50ms when playing a musical piece. Musicians can tolerate a round trip network delay of up to 30ms when clapping in rhythm together. Round trip network delays greater than 60ms are detrimental to the jamming experience and musicians are no longer willing to jam inline at these delays." From this information, we can clearly see that LOLA's inherent network delay is more than sufficient for effective remote musical collaboration.

From my own experience in working in recording scenarios with latency as an inherent part of the system, I find that before one can physically hear that there is a delay between the instrument being played and hearing it in the monitoring system, it is possible to feel the disconnect created by a small, but discernable amount of latency. This calls for a study where player perception is paramount. It would be very useful to know if this perception of latency has an audible or measurable effect on the resulting musical performance.

One of the characteristics of this example is the project's attempt to recreate musical interactions as they appear in the real world by using the high-speed network as a vehicle to avoid the need for travel to connect musically. This example's contribution to the music world exists as a convenience, and as a tool for closer interaction with another musical culture, thereby bringing communities closer together and creating new musical territories as a result. However, what this example fails to do is take advantage of the fact that the actual interaction exists within a virtual space. This creates opportunities to connect in ways that would be difficult, expensive or impossible in the real world. For example, the resulting musical interaction could be easily broadcast in the same digital video format, as opposed to being shown in a physical meeting room, thus reaching far greater numbers of people, all in real time, perhaps even customised per location with different audiences receiving different combinations of musical feeds tailored to the specific needs of the project. The scope for numbers of musicians playing together also increases dramatically with these faster network speeds. We are also inclined to think of remote musical collaboration as useful over large distances. But connections over shorter distances are perhaps more useful as an auxiliary method of connecting to rehearse, learn and perform.

d. *Daisyphone*

Daisyphone is a remote music collaboration device where multiple users connect to a server on the Internet via a graphical user interface representing a 45-note loop. It overcomes the network delay problem inherent in Internet collaboration by its cyclic nature. Contributors can enter the notes they want to contribute and if the server delay is such that the notes can not be played in the current cycle, it will play them in time in a subsequent cycle once it has been processed. Strictly speaking, this is neither synchronous nor asynchronous but somewhere in between. The contributors may not have their contributions updated immediately but they are nevertheless contributing concurrently and simultaneously to the ongoing composition.

Technical Setup and Process

The circular user interface consists of 45 rows of small circles radiating from the centre of the circle. These circles represent a range of midi notes starting at MIDI note 68 (the G# above middle C or G#3 on the Yamaha numbering system) at the outer edge to MIDI note 80 (G#4) at the centre of the circle. The fact that the notes get lower the further away from the centre they are, gives the impression of a string of varying length between the circle's centre and the note's pitch. [see Figure 1]
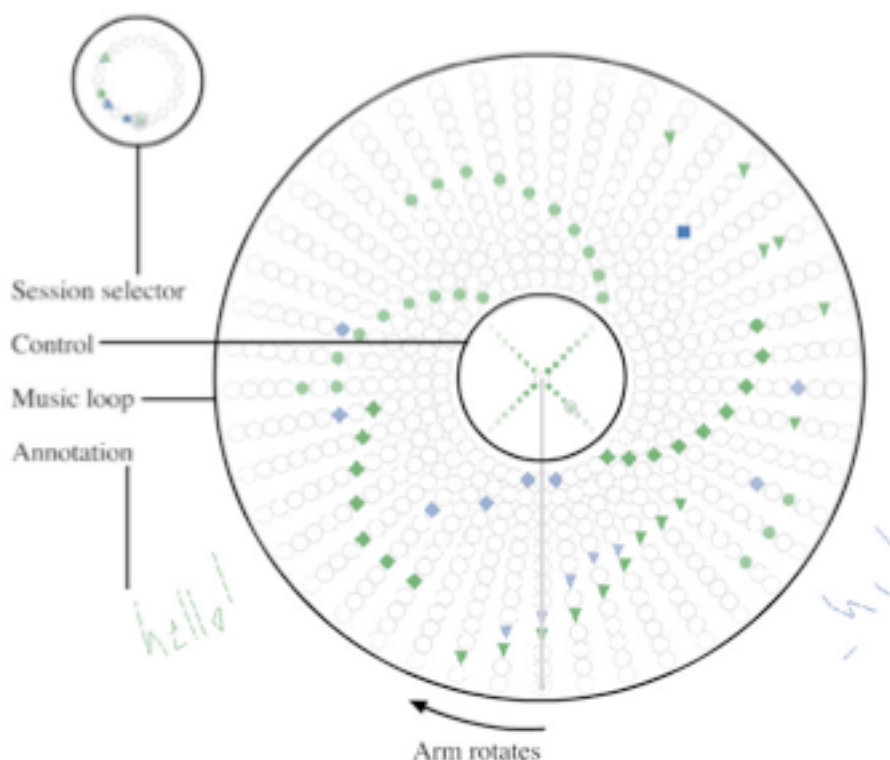
Figure 1: Daisyphone's graphical user interface, displaying musical data and annotation feature. [Bryan-Kinns and Healey, 2004]

Figure 1 shows a radius line from centre to circumference, which rotates clockwise around the circle. This line is essentially the play head and plays the notes it encounters at each of the 45 points. This and other interactions are accessed from a session selector window, in which the user can listen to ongoing collaborations as well as join in if they decide to. Another method of interaction possible thorough the graphical user interface is an annotation feature whereby each user can write or draw on the interface to describe visual ideas or make comments. The interface is based on general MIDI and the user therefore has the choice of a selection of four General MIDI instruments that have been preselected. These instruments are represented by different shaped objects. Each user is represented by a different colour. Four velocity values are available from the selection ring in the middle of the interface. These are represented as different shades of the user's identification

colour where light shades represent low velocity and darker shades increasingly higher velocity.

Each user has the ability to create notes, delete any notes, including those not created by them, and make changes to any note that exists on the interface. There is no method of tracking data which has been changed, nor is there any method of publishing individual contributions or ownership.

There are two modes of this system. In the "Persistent version" users create musical data which stays inside the interface until removed or changed. The "Decay version" keeps the user's musical data for a period of time before automatically deleting it by fading it out over a period of time. This period of time is determined by a user's level of experience on the system and will decrease over time as the user becomes more accustomed to inputting musical data. The concept behind this is to keep the interaction challenging and dynamic. In my opinion, this Decay version places the emphasis heavily on user experience, whereas the Persistent version places the emphasis more on the final result. According to Bryan-Kinns (2004, pg. 10) there are plans in place to improve the organisation of the user interface and to develop the "Decay" model further as well as to do further studies over longer periods of time. However, this has not yet been realised.

Assessment

According to Bryan-Kinns and Healey (2004, pg. 3), results were measured on the analysis of ten post-graduate students completing coursework involving various tasks within Daisyphone. The sessions were measured at an average of 16 minutes for the Persistent version and 12 minutes for the Decay version of Daisyphone.

In the Persistent version, there was some initial exploration of the user interface after which users tended to stick to one instrument, thereby performing the role of a virtual band member. Typically, one of the users would take the role of the leader of the session and dictate the direction of the composition by initiating musical ideas which were then supported by the contribution of the other users in the group. Users seemed to be relaxed about making adjustments to others' contributions. This may have been because they knew each other relatively well and had worked on projects in the past together.

As there is no authorship or ownership information in the Daisyphone interface, users tended to write their names on the interface with the Annotation tool, as a method of saying "this is mine".

According to Bryan-Kinns and Healey [2004], in the Decay version of this software the decaying nature of the musical contributions were not as effective as the software creators had hoped. The rate at which the musical data faded was not in line with the ability of the new user to create new data. As a result, the sessions became less structured and less coordinated. Predictably, the more experienced the user was in creating musical data in Daisyphone the easier they found the Decay version to use.

The Decay version seemed to display a more focused approach to the actual music as it required continued maintenance in order for it to keep going. This resulted in less discussion around the results and more graphic gestures attempting to notate what was presently playing so that it could be recreated when it had faded away.

There was a tendency for users in a session to start to create similar style phrases and musical ideas. This suggests that perhaps the Decay version encourages users to connect more quickly and establish a musical theme for the session. There were also more notes

contributed per user in the Decay version, this was as a result of the need to create ongoing contributions in order to keep the music going.

The generally accepted results are that users became bored quite quickly in the Persistent version as a result of the process not being challenging enough to keep their attention. But in the Decay version, although users were initially apprehensive, the users that were able to increase their skill level were able to achieve a sense of consistent "flow" in their sessions.

In terms of musical results, the system's granularity is not fine enough to represent musicality in any really expressive way. In addition, the graphical user interface, while allowing for the basics of musical data gives no real gestural control, so vital for creating music that feels "human". That being said, the architecture of Daisyphone is an elegant solution to the effects of network latency. The user experience is also one of genuine simultaneous creative collaboration. There is a strong community feel to the sessions, and this gives us a good idea of how future remote musical collaborations may feel, if not sound.

There are some challenges with this system. Firstly, not every contributor will have the same speed Internet connection, as this can be affected by traffic, time of day, actual connection speed, etc. This creates some variation in the speed at which the individual contributions are logged on the server and relayed to the individual contributors causing some inequity in the individuals' ability to contribute.

Secondly, as discussed above the system is still very rudimentary and thus presents a challenge to create meaningful musical connections and results.

Thirdly, the interface is not one of a musical instrument, and because the graphical user interface and required input method is quite unique it presents a barrier to entry that traditional musicians may find limits their ability to create musical phrases as they would on an actual instrument. Musicians often need to "hear" a line conceptually before it is performed. This staggered approach to phrase writing removes the musician from the performance significantly.

Bartlette, Headlam, Bocko and Velikic (2006, pg. 50), outline the problem we encounter in Daisyphone of oversimplifying music to an octave of notes on a rigid grid with four velocity options.

> Musicians use terms such as rubato, feel, and swing to indicate expressions that arise from timing; the effects range from changes in overall tempo to the varying of pacing between hands (in Chopin's piano music, for example) to microdurational shifts in beat divisions. Changes in pacing and attacks allow performers to group musical sections and to convey musical structure through emphasis on notes, motives, themes, and phrases. The importance of such expressive timings to the musical effect is evident in the problems found in early electronic and computer music, where the lack of such expression sounds "unmusical" and "lifeless." To play musically, a balance of timing variance and coordination must be achieved.

Although the authors maintain that the more experienced the user of Daisyphone is, the more successful the musical results will be, I believe that the system itself is too simplistic to create music expression in the traditional sense. However, this does not take anything away from the fact that the interface remains a functional musical collaboration tool, and however simplistic the controls are, it remains an effective, "real-time" collaboration

system. For this reason I believe it is important and worth analysing for future endeavours in this field.

The restrictions of this system may seem substantial in the analysis of tangible musical results, but they are certainly not fundamental issues. In fact, as Internet bandwidth increases, as infrastructure improves to reduce network latency and as interactive music systems develop more complex interfaces, capable of collating more detailed musical performances there is good reason that the basis of this system would be the ideal platform for group musical interaction, although sheer numbers of users are invariably going to affect Internet performance at certain times for the forseeable future. Teasley and Wolinsky (2001, pg. 2255) mention the challenge of peak Internet traffic times affecting performance if reliable high speed connections are a vital part of the interaction (a scientific interaction in their case). This is certainly a challenge for the future of Daisyphone too. "Although the Internet has sufficient capacity, there is no assurance that the high bandwidth and rapid response time required for sustained performance will be consistently available when needed as other traffic competes for the same capacity at the same time". Moreover they state that interface design is still in its infancy, reinforcing my view on Daisyphone's user interface. "Other limitations of the Internet are those inherent to the available applications, especially when used across platforms. In addition, many of the available collaboration tools are still somewhat awkward to use, primarily because deigning software effectively for group use is a new area."

Another unique aspect of this project is the way in which musical interactions form and reform over time. Shelemay (2011, page 364) proposes the following as a definition of a musical community:

A musical community is, whatever its location in time or space, a collectivity constructed through and sustained by musical processes and/or performances. A musical community can be socially and/or symbolically constituted; music making may give rise to real-time social relationships or may exist most fully in the realm of a virtual setting or in the imagination. A musical community does not require the presence of conventional structural elements nor must it be anchored in a single place, although both structural and local elements may assume importance at points in the process of community formation as well as in its on-going existence. Rather, a musical community is a social entity, an outcome of a combination of social and musical processes, rendering those who participate in making or listening to music aware of a connection among themselves.

If we are to adopt Shelemay's view on what a music community is, then Daisyphone certainly fits well into this category, especially considering its recent availability in mobile device online application stores. I believe that because of this perspective it is elevated from a slightly awkward and simplistic tool to connect musically on a fundamental level, to the beginnings of a real-time global musical community. And this, in my opinion is the most challenging and the most vital of the four elements required for a perfect collaborative scenario These are increased Internet bandwidth, improved Internet infrastructure to reduce jitter and latency, well-developed, gestural and musical user interface for a more expressive and meaningful musical interaction and, crucially, an established musical community.

Daisyphone, therefore, exists in as close to an ideal position as is possible in our current scenario for effective collaboration on the Internet. There are improvements and development still required but the current interactive system is supported perfectly by the

infrastructure and bandwidth of the Internet as it exists currently. As long as Daisyphone continues to develop at the same rate as the Internet and in the right areas, it could eventually become a widespread tool for meaningful musical interaction. This positions Daisyphone as one of the pioneers and founders of an active and meaningful global music community.

4. Conclusion

These four case studies showcase individual scenarios that illustrate some of what is possible to achieve in this area in the present day. In each case there has been some areas of significant success and areas that could be improved. Having four very different scenarios to compare provides an opportunity to analyse if one area of practice could have benefited from the knowledge gained from another area. It also provides the opportunity to address any contradictions discovered in information presented in the various case studies.

Community is an issue that keeps reappearing in these scenarios. Much has been mentioned about the need to develop new musical communities unbound by geographic location, and focused instead on areas of interest, skill and function. The fact that these new musical communities will affect the way our established musical communities understand and practice music is undeniable. This is not something that should be resisted in the interest of preserving localised music communities but embraced in its unique ability to communicate our individual understanding of music in an ever more expressive and efficient way.

Crowd Sourcing and Daisyphone scenarios both attempt to create temporary musical communities around the needs of their particular projects. But once these projects are

completed, the temporary musical community disappears as its function is no longer required. Both of these scenarios require participants to engage through a medium which is a new experience for them. This approach does not assist in the development of sustainable, functional communities. Although we live in a digital environment of absolute interconnectedness, the way in which we connect is converging on a daily basis. Facebook, Twitter and Google+ are established networks in which millions of communities exist. Using these established interfaces for community interaction not only allows the user a comfortable and familiar experience when interacting with the project but also allows the user to share the information, the opinions regarding it as well as the final results on his or her own series of networks. This will drive the message of a well-conceived musical project to a far greater audience of potential participants in far less time and far more efficiently than creating a unique, temporary, standalone community specifically for the project in question as well as maintaining the established community for subsequent collaborative projects.

The Virtual Recording Studio case study outlines some of the challenges involved in sourcing and recording remote talent. Certainly, providing creative direction in the form of Whitacre's (Crowd Sourcing) highly successful conducting video would have been a useful measure for the artist to use as a way to connect with the song in a manner more closely representing the wishes of the project owner. As mentioned in my previous point, the use of talent sourcing is far less effective as a series of emails to contacts in various countries. It would have been far more effective to create an account with access to the portfolios and showreels of working musicians on a well established network. It would also be possible to use this interface to hear performances in mid-session because of the multi-track arrangement feature in many of these interfaces.

The majority of the perspectives present in the referenced academic literature revolve around overcoming the effects of network latency. Daisyphone is a system built to overcome the limitations of network latency. This is by far the largest challenge in the area of real time collaboration in music and in other scientific and medical areas, but LOLA has shown us a perfect working example of real-time musical collaboration through the use of high speed networks, the necessary hardware and appropriate Internet protocols. In addition to this the organisation Internet2 is touting this specification as the future of the Internet and working hard to gain influence in this area. www.Internet2.edu/about states that "Activating the same partnerships that produced today's Internet, our members are forging the future Internet through community, an unsurpassed innovation platform, and transformative, above- the-network services and applications". As such it seems plausible that as the infrastructure of the Internet develops, these specifications will be consulted and network latency will be seen as a temporary inconvenience and that we will be seeing the sort of connectivity seen in LOLA's case study available on a broad scale in the near future.

In addition, the development of LOLA has far reaching influences on musical collaboration. Using the capabilities already made possible by the various high speed networks and LOLA in the Crowd Sourcing scenario means that every choir from every connected institution can perform together to create a choir tens of thousands of singers strong, performing in real-time to an online audience. This would be completely unprecedented, and is possible today.

One of the major challenges in the Crowd Sourcing scenario was the fact that the singer's performances had been captured in a very low quality video format, generally using cheap equipment. My Virtual Recording Studio scenario, as well as many online asynchronous

music collaboration interfaces, present a far better method of mass participation than the creation of a highly compressed, low quality video recording of a singer's part for Crowd Sourcing. From a technical perspective, even if the video had been recorded in the same way, the fact that it had been compressed for uploading onto www.youtube.com means that virtually all of the dynamic range and a lot of the frequencies present in the original audio recording had been lost before the mixing process had even started. I think that using more established collaboration tools and methods would have created a significant improvement in the results heard in the final product.

Daisyphone presented a unique solution to the problem of network latency. Essentially placing simplified MIDI style objects with limited parameters on a cyclic grid, allowing a participant's parts to be played in time with the other participants' parts. If the network latency is too great, the part plays on the following cycle or, once the network operates effectively enough, it will make the update and communicate this information to all the participants involved. The collaborative experience is primitive but the architecture, when seen from the perspective of the LOLA case study, presents an interesting idea. If the same system could be implemented with the use of full MIDI or even audio recordings, the end results could improve significantly. As noted in the results section of Daisyphone, participants naturally gravitated towards different musical roles during this process. This presents a slightly more structured potential approach. If a remote jazz "band" played their respective parts in longer (eg. 32 bar) cycles that are only played once and then disappear (similar to the "decaying" model) they could have a musical experience very similar to the LOLA participants, except that, instead of monitoring in real time, they would be hearing the performances of the other participants from the previous cycle. To a traditional musician this may seem undesirable in the pursuit of real-time interaction. But I propose that perhaps this building on existing parts would create a more explorative, more

transitional and more expressive performance than actual synchronous collaborative results. This is because of the fact that performers are not only reacting to other musicians' musical ideas in real time, but they are reacting to reactions, which are in turn reactions, which in turn are reactions (etc, etc) to an original musical idea only heard many cycles before.

The combination of the facilities provided by LOLA and the communities and interfaces referenced in Virtual Recording Studio are the most powerful potential development for the future of remote musical collaboration. If www.indabamusic.com for example could provide a catalogue of professional and amateur musicians who could perform into the system's built-in multi track interface either in real-time with another performer or band, or along with a pre-recorded track, this would change the music industry as we know it today. It would affect the way we are able to practice, to perform and to record. It would also change the nature of bands and ensembles as geolocation would not be an issue. It would potentially provide more work for session musicians and certainly present their skills to a wider audience. It would mean that producers no longer need a recording studio to create recordings, but could commission performances and collate them online. It would create a platform for remote collaborative performances. Most importantly, this would create a diverse collection of communities providing musicians access to perhaps the most valued of all musical endeavours: local cultural authenticity – where my project as a producer no longer relies solely on simulated and imitated, but ultimately diluted musical performances of regional styles, but access to genuine pedal steel players in Nashville, oud players in Turkey and shakuhatchi players in Japan.

When focusing on the combined efforts of experiments in crowd sourcing, an unstructured exploration into sourcing regional musical performances, a simplistic, yet elegant multi-

user collaboration interface and a high performing but small scale specialised network for real-time interaction, it is clear that there is a movement towards a common goal as a global music community. These are the first steps towards a new reality of musical access, interaction and community.

These four case studies have focused on entirely different areas of musical collaboration. But when comparing the results of each example with the others, it is clear that each can benefit from the others' development. This indicates that they are on a convergent path and that by taking a multi-pronged approach and developing each of these areas, as well as countless others in this field, common goals of infrastructure and method are discovered that, when realised, will support the collaboration needs of the global music community.

There are many innovative and effective approaches to working around the limitations of network latency and synchronisation issues found on the Internet, yet it is currently possible to achieve a true to life interaction with a fully operating system in the case of LOLA, free from the challenges of Internet streaming. From the goals in the case studies presented, it is clear that this virtually latency-free scenario is the ideal solution for most applications. LOLA provides an excellent example in its infrastructure and protocols for the development of the Internet as a more effective means of real-time collaboration. However, this system only solves the problem of musicians not living near enough to interact in person. What I have discovered, through the analysis of these attempts to reduce the originally unwanted artefacts of network latency, is a series of new ways for people to interact. Through these systems musicians have found benefits and value that are simply not possible in real world interaction. Daisyphone, for example, creates some foundations for a system of interaction that is completely mobile. Crowd sourcing opens the scope of

our projects to numbers of participants that would be unfeasible or impossible in the real world. Virtual recording studios started as a means to record local performances in context, but has grown into an infrastructure supported by a community that provides limitless access to any recording project, reducing the need for facilities and encourages specialisation by increasing the traffic of concurrent projects over the network.

In a maturing state, this system of interaction not only allows remote connections with other musicians in an increasingly effective way, but also has both a converging and diversifying effect on the global music culture and communities.

5. Appendix

Audio compression

Digital audio files are compressed very effectively. This process allows us to create far smaller audio files. Through the controlling of export parameters we are able to decide how to balance the aspects of audio quality and file size. There are many formats and methods of compression. Because we are concerned with fast audio transfer, the appropriate balancing of audio compression is a major focus in this field.

There are arguments both for and against the use of mp3 compression in a professional context. Jonathan Berger has found, through a research project lasting six years, that there was a tendency for listeners to prefer the sound of mp3 compression over the same song in other musical formats.
[http://query.nytimes.com/gst/fullpage.html?res=9C06E5D8103AF930A25751C1A96F9C8 B63] This clearly shows the subjectivity with which we view the perceptible effects of the processes imposed on audio tracks in packaging music for different uses. Where some

may feel that the mp3 compression has a negative effect on the tone or fidelity of the finished product, others may feel that these artefacts have no negative effect on the experience of the listener, and may even affect the audio in a positive way.

Bandwidth

Bandwidth refers to a data rate at which information is being transferred. This is often directly proportional to the audible quality of compression of an audio file within a certain type of file format. For example, an mp3 file which has been compressed at 192kb per second will sound more accurate when compared to the original uncompressed file than one compressed at a rate of 128kb per second. This data rate also represents the Internet bandwidth required to transfer this file effectively.

Digital Audio

Digital audio is represented as a series of samples, which together represent an audio waveform where the sample rate determines the number of samples per second and the bit depth represents the number of equal values of amplitude available in each sample.

Latency

Latency is the main challenge with online musical collaboration. Although present in any recording scenario, the transfer of high quality digital audio over the Internet seriously exacerbates this problem. In IP networks (eg the Internet) the amount of network delay or latency is a result of two factors. Firstly data is divided into packets before it is transmitted over the network. These packets of data include a portion of data as well as the destination address. These packets may take different routes to the destination and when they arrive

they are reconstituted into the original format for the receiver to use. The speed at which these packets are transferred is determined by the available bandwidth of the network and the amount of traffic present at that particular time. The combination of the process of packeting information and the available bandwidth results in the amount of latency inherent in the network.

MIDI

MIDI file information is very small, and although we still need to deal with packet issues in transferring MIDI data over the Internet and the delays associated with these, I believe this is the most feasible method of transferring real time music information online. There are products available that allow low latency transfer of MIDI information over the Internet. However, this only solves the latency issue for a scenario where two players are using MIDI devices with no additional audio present. As soon as the performer needs to play the MIDI instrument while listening to some audio content over the Internet, the issue of network latency becomes much more of a problem. Because the scenario of using only MIDI instruments represents a very small percentage of musical interactions, few products have been developed to support this function.

Social media

The Internet has made significant changes to the way that we connect with other musicians. Initially it was used to assist in traditional musical interactions. But more recently, as the social aspect of the Internet has grown, the Internet has developed into a tool for mass participation, provided a broader audience, customer or client base through established online communities and helped produce ever more specialised projects due to a broader scope of specialists available.

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