A Prospective Analysis of Analog Audio Recording with Web Servers

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Abstract. *This paper analyzes the possibility of implementing a variety of analog and acoustical processes for music production as remote audio servers accessed by the World Wide Web. The opportunity is motivated by the simple idea of making a MIDI-controlled analog synthesizer available to the general public as a batched recording service, for which a prototype has been developed and described in [Johann and Zawacki, 2012]. As soon as the advantages of such system are considered, the question arises as what other instruments and audio processes could be implemented as servers, providing quality and cost effective remote access from anywhere, to anyone. The ultimate goal is to allow musicians to compose, record and mix their music from simple tools in their computers but having the opportunity to access also very high-quality analog an real instruments for final sound rendering. In this text, both digitally controlled and old analog synthesizers are considered, as well as adapted and custom instruments, acoustical musical instruments of many sorts, effects audio processing units, analog mixing consoles and a few others. Each different class of tools has its own context, requirements and some challenges, whose discussion is the main focus of the present work, that also highlights the many commercial and creative possibilities of such an ubiquitous approach to analog audio.*

1. Introduction

Along the history, humankind has produced a large variety of musical instruments, many of them tied to different styles, cultures or historical moments. Each instrument has its unique sound and aesthetics that can be explored in the appropriate context. Modern music seeks to embrace this entire diversity, oftentimes driven by the movies and gaming industries that cover a diverse cultural background in their works. The advent of computers and digital audio created new forms of sound composition and new instruments, which became part of our culture and additional tools at our disposal.

The demand for different sounds can be supplied in many ways. On the one hand real original instruments can be used, but they can be sometimes hard to access or expensive and the services of specialized studios may be necessary. On the other hand, computers can provide virtual instruments, and this has been a very popular option with software emulations in place of real instruments.

Both options have their advantages. Real instruments generally have the best sound quality and smooth control, while virtual instruments have lower cost while maintaining a relatively good quality. The big market for virtual instruments, mostly in the form of plug-ins for Digital Audio Workstations (from now called DAWs), show that the search for different instruments and aesthetics is ever more common in all kinds of productions. Furthermore the competition between different virtual instruments vendors evidences that users are always looking for the best of both worlds, flexibility and low cost of virtual instruments and a quality closer to the real ones.

Music production is nowadays a much more common activity and is done by professionals and amateurs alike, as can be evidenced by the growth of independent artists in online communities [Valladares, 2011]. In a sense we can say that the need for quality instruments and audio processes is shifting from niche to ubiquitous. So, we come to the difficult question of how to keep promoting ubiquitous music [Pimenta et al., 2009] and not being restrained to limited emulation of real instruments and equipments that is possible with current plug-ins. We do not want to avoid or dismiss virtual instruments completely either, but understand that both options should be available when needed.

To do so we propose a system that offers remote access to real instruments as well as to analog equipment and allows the recording of the resulting sound. There are many works that deal with the problem of live music using the web, real-time access to remote instruments, and all associated issues as for example [Orto and Karapetkov, 2011] or [Cáceres and Chafe, 2009]. This paper does not try to explore or tackle these problems, but goes in the opposite direction. Instead of real-time access and streaming, we propose a system that sacrifices these characteristics to gain flexibility, low cost and still maintain the best high quality sound. This system also uses online web access, but processes user requisitions in batch format and serves then by scheduling the jobs.

In our proposal, the system is not locked to a given user in a time frame, and there is no problem of simultaneous access, neither it has latency or streaming issues for MIDI or audio. The system behaves as a contract in which the users send their job requests, and after some time they receive back the resulting service in the form or a quality recording of a real analog or acoustical instrument. In this way, it can enrich the available toolset for professional and novice musicians, allowing ubiquitous access to real instruments, and, as it will be demonstrated, with a low cost as the system can be scaled in terms of utilization.

The architecture of such a system can be seen in Figure 1. Users interact with it by means of sending a music notation file describing the musical piece and get the results back in the form of a high quality recording of the piece. There are many formats for music notation and transmission [Jensenius, 2007], and all of them can be employed. But MIDI remains the most popular and by far the most supported in musical interfaces that are available to end users, and therefore it is mandatory to support it, as it is done in the first prototype described ahead. The piece is executed and recorded in a real instrument, being stored in a web server, ready to be served to the user once it is done. Concurrent access to the service is regulated by a queue and the user sent file waits until the instrument is free to play and record it. It is important to notice that the system will not be reserved for long periods of time for each user, it will only be in use for the duration of the piece. This has implications in the number of users that can be served by the system and lowers dramatically the overall cost.

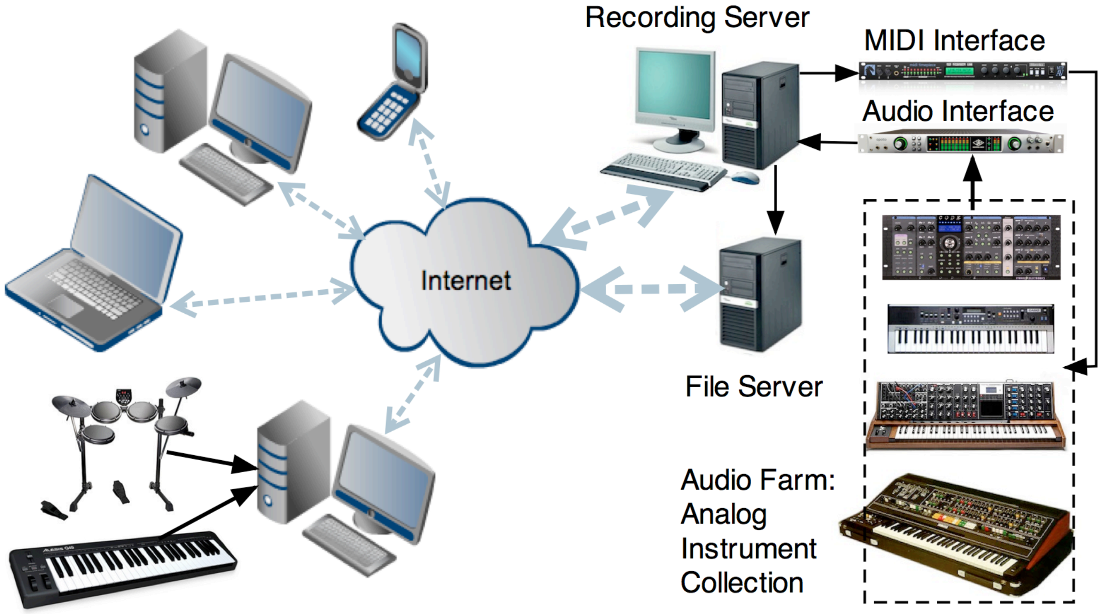

Figure 1. System Architecture and Access Model

The first prototype of such an analog server that can be used with the Web is briefly described in the next section. Based on the observations with that implementation, a set of wider possibilities was realized. The purpose of the present work is therefore to make a prospective study of what kind of instruments and analog audio processes could be accessed remotely, under which circumstances, and what are their main requirements.

Considering the entire project, the main contribution of this work lies in the concept of analog audio server, or analog audio farm, associated with the usage model, through which performance jobs are submitted to be rendered in a batched (not real-time) system, for higher quality rendering. In particular, this paper shows that there are many other audio processes besides analog synthesizers that can benefit from this model. We show that there is already available technology to implement many of these servers, and highlight what are the main challenges involved to seamlessly doing it.

2. A System for Remote Access to an Analog Synthesizer

In [Johann and Zawacki, 2012], a system for remotely accessing analog synthesizers as analog servers, using the World Wide Web is proposed, and a first prototype is described. In this section we shall summarize the contents of that paper, from the basic idea, implementation, challenges and possible solutions, to the market opportunities, so that we can analyze and develop the ideas further.

The main motivation for that work was found in the importance that analog synthesizers have for today's music production along with the increased prices of both old and newer such machines. That makes them hard to acquire and maintain, specially considering that each model has its unique possibilities as a musical instrument, so that the musicians are frequently willing to access a variety of them. As many analog synthesizers currently in production have MIDI-control built-in, and it can be installed in older models as well, a system is proposed to allow accessing them as analog servers for high quality recording. The paper describes an initial prototype, in which a MIDI file with the user performance is submitted to the site, where it is put in a queue, being played with a Studio Electronics ATC-1 [Studio Electronics, 2012] analog synthesizer, and a 24bit/48KHz recording is made available back to the user.

This was a simple idea implemented with existing tools and a dedicated software system that commands the playing and recording. There is an intrinsic big advantage of the batched access strategy compared to the other options of real-time access or physical access (renting instruments or studio time). With batched access, the system usage can be kept high, avoiding waiting times, the limitation of arrangements for time slots, and preventing expensive equipments from being idle most of the time.

Put in other words, be it in a bedroom studio or in a very expensive facility, there are many expensive synthesizers (or other musical instruments) that are turned off, not being used, idle, in the majority of the time. That translates to large potential waste, and also to high costs. When someone is renting a studio, he is paying for the contents (its capabilities, equipment) and most of the resources are not being used. Even the instruments that need to be used will be accessed sparsely, due to setup times, experimentation, trials and fails. We also need to take into account the constraints for studio time allocation. The user needs to find and to adapt himself to the available slots, he has to spend transit times and waiting time, so from his perspective there is even more sub-optimality. The only way to avoid those constraints is to acquire instruments and studio equipments. This is obviously expensive. While there are many artists that can afford to have their own high-quality equipment, it does not represent the typical user or musician. This is far from being popular, ubiquitous, far from encouraging widespread use of the instruments that humankind could develop along the history.

In the proposed model, the equipment that is operated as an analog audio server can be kept running with a high utilization rate, provided that there is public interest, demand. In this way, it potentially alleviates the aforementioned problems. Notice, however, that we must not consider it as a pure replacement model. This is not being proposed as an alternative to people that can afford and effectively use instruments in an intensive way. As an example, a prominent keyboardist that studies everyday and gives frequent concerts with his band would not be expected to avoid having his own preferred synthesizers at home or in the studio. But a producer can perhaps access the sound of different synthesizers not available in his studio, for a given production or composition, from an online collection, that otherwise would be hard to find, or to pay for, if not operated remotely.

The major drawback of using a system that renders the sound not in real time is the lack of instant sound feedback, feedback which is both expected and sometimes absolutely required by the musicians so that they can produce the sound they want. A set of options is listed in the aforementioned paper to solve the feedback problem, as follows:

1. Simple sound samples showing different sounds and nuances of the synthesizer
2. The development of calibrated plug-ins that could preview the result from the performance parameters, although with an inferior quality. The user can adjust the sound of the composition and anticipate the result with relative precision.

3. The option for the user to preview a few seconds of the recording before the final piece is processed. He can then choose to resubmit the file changing the parameters used.

In [Johann and Zawacki, 2012] there is also some initial assessment for commercial exploration of such service, which would be at the same time extremely low-cost for end users and profitable for the operating company. A set of distinctive advantages and possibilities is presented, starting with the recording quality. In a dedicated server, the quality can be not only superior to what home studios can afford, but also surpass what can be achieved in top quality studios as well. This is possible with custom and expensive hardware that would be only affordable with dedicated high-usage systems.

The modification of instruments is another possible advantage. The technicians of top artists occasionally work with instrument makers or implement custom modifications by themselves that improve on the quality of a particular instrument compared to the outcomes of a large scale production. In other words, it is possible to employ both custom recording hardware and custom instruments. The possibility comes from the fact that in large-scale production, there is always a compromise between price and performance, yet to implement a single server unit, non-compromised components may be employed, as the scale comes from the higher utilization. The system can allow widespread and low-cost access to systems built with no compromise, with the best sonic performance, not attainable in units from large-scale production.

A basic analysis is also made about possible applications. Perhaps the most typical use comes in a regular audio/MIDI production. The music has many MIDI tracks, some recorded with actual keyboards, probably most of them with virtual synthesizers in the form of plug-ins. With the proposed system, the user can ask some selected tracks to be recorded with an actual analog synthesizer. An analog synthesizer is usually able to provide increased articulation, smoothness, fatness, presence, to many different sounds ranging from basses, lead synths, flute-like sounds and many others. If the cost is low, even novice users can experiment with different sounds, while an experienced producer can refine its production by submitting the same part while fine-tuning the desired parameters. Experimentalists can use the system to get more unpredictable results, and some can access the server to get samples to process further.

A system like this extends the notion of ubiquitous music to include access to analog instruments. The areas of ubiquitous music and computer music usually employ modern interfaces in the form of new hardware designs or consumer products as new ways to make music. But the sound generation is usually either locally produced or digitally simulated. In our proposal, we open the possibility to accessing analog and real instruments remotely from anywhere, no matter which kind of device is being used. In a simple example, a person can create a music while operating his cell phone or tablet in a bus, sending the notes to be played with a vintage analog synthesizers, and listening to the resulting sound in just a few seconds or minutes.

The existence of analog servers can help promote the use of analog synthesizers, increase public knowledge about them, increase the need for modeling plug-ins and provide funds for the conservation of older instruments in operating conditions. Finally, it is speculated that a similar approach can be employed to access real acoustic instruments, as it will be considered in the remaining of this work.

3. Possible Audio Servers

The main purpose of the present paper is to verify which other audio processes can be treated as analog or acoustical servers for remote and batched access targeting high quality sound rendering. We also want to check the needed technology and the challenges that must be undertaken.

The first step, which justifies and defines the contribution of the present work, is to understand that there are many audio processes or activities that cannot be performed remotely, in principle.

3.1 What cannot be done

Starting with the processes or equipment, we can easily see that the following individual items cannot be used remotely: microphones and preamplifiers. It is not possible to have a remote microphone available for use, because it is not possible to mechanically transmit the sound to be captured without being previously captured by a microphone. That same simple principle applies to the preamplifier need to increase the tiny microphone signal to appropriate power/voltage levels that run regular electronic audio, called line-level. In practice, good studios have a large set of different microphones and preamplifiers with different technologies and sound signatures. Therefore, those two items alone represent a significant part of the studio equipment.

Guitar cabinets or preamplifiers lie in a somewhat grey category. As they are actual preamplifiers, needed to increase the power of small signals, at first it may be difficult to capture the small guitar signal with accurate analog-digital conversion to transmit it into a preamplifier remotely located. But considering that guitars may have already an internal preamplifier, or the sound may pass through effect pedals, it may indeed be possible to design circuits that capture it, record, and then use the cabinet or last preamplifier of the path in a remote server. This can be hard to set up, it may work just under some circumstances, or may be considered just as a post-recording sound effect. It is, however, worth to mention that the musician could play using a local, low quality guitar cabinet, but with a system that is also recording the unprocessed (low power) signal to be feed through a higher quality cabinet later on.

Last, there are activities that would not be done remotely in a batched system because it does not make sense. The previous example of guitar amplifiers might fall into this category, as in many cases this type of music is intrinsically dependent on the sound that the musician is experiencing. For an example, a sensible performance that explores microphonic guitar tones is only possible with the actual equipment in front of the musician. Any activity that depends on fine nuances of the actual equipment will have the same situation. Another aspect is that many musical activities must be carried out instantaneously, what is somehow equivalent to saying that the fine nuances of the actual process must be immediately available. The musicians usually need to feel the actual instrument in its full richness to be able to perform well, as music is a sensible art form, whose interpretation depends both on technique and emotion.

Having identified the few things that are not possible or are inappropriate for remote use, it becomes clear that many things are indeed possible. In all the cases, we are considering the careful application of the concept of separate preview and final sound rendering. In other words, it would be only worthwhile to implement remotely processes that benefit a lot from the specialization a server can afford, and for which an "economic" preview can be provided with the required accuracy. Let us analyze the different possibilities in the next subsections.

3.2 Synthesizers

The first prototyped system described in section 2 shows that it is quite straightforward to put a modern MIDI-equipped analog synthesizer online. Those are the first options to be considered, of course. There are many models of analog synthesizers in production today, with MIDI. Monophonic synthesizers and analog modules comprise the majority of the systems in production, while polyphonic machines, like the Alesis Andromeda, were almost all discontinued. Regarding their prices, while there is a set of analog synthesizers that sell for under a thousand dollars, they cannot be considered cheap. Those are the simpler generators, with limited resources, monophonic, and they are usually good in a specific type of sound, as most of the instruments. Therefore, no musician would be complete buying just one of those instruments. It has to be at least the second instrument, and will find a rather limited usage, turning a modest-looking investment into an expensive one.

While it seems simpler to implement a service using instruments currently in production, the system may help to preserve the entire sound palette that many generations of synthesizers could create by promoting the continuous use of real analog synthesizers of all times. The synthesizer must be MIDI playable, but many synthesizers that are not MIDI capable can be controlled with specific hardware. There are standard MIDI-to-CV converters (CV stands for Control Voltage) that can be used to play older analog synthesizers that do not support MIDI directly. Even synthesizers that do not have CV inputs and cannot be programmed remotely can be automated with a dedicated hardware work on them. With hardware work, it is also possible to make some instruments programmable, where they originally were not. There is a difference in just playing them through MIDI-to-CV interfaces or allowing different sounds to be programmed and accessed. The last level of integration would be to allow re-patching of modular systems, where the sounds must be configured by patch cables. This is naturally also possible with a set of automated relays.

The importance of automating, preserving and letting more people to access those instruments transcends the commercial application of the system and must be considered from a cultural an historical perspective. This investment might be key to help keep iconic instruments alive and working for future generations in an affordable and cost-effective way. It can be seen that old machines in good condition have been increasing in prices. In table 1, a small sample of some old machines that are available for sale on Ebay has been listed, together with some models in production. It can be observed that there are available units for the most popular synthesizers, as a consequence that they have been produced in a good scale in the past. On the other hand, theirs prices are relatively high. Those prices were averaged on the available listings on May 20, 2012, and can be compared to what is available in other records [Oppenheimer, 1995] [PrePal, 2004] from the past, exhibiting an expressive increase.

Table 1. A small sample of current and old analog synthesizers for sale. The price for used models was obtained from Ebay on May 20, 2012.

Model	Maker/Brand	avl	Price (US$)	Polyphony	Production
Voyager Rck	Moog Music	*	$2,795.00	monophonic	current
SE-1X	Studio Electronics	*	$1,679.00	monophonic	current
Omega8	Studio Electronics	*	$4,999.00	polyphonic	current
Prophet Five	Seq. Circuits	7	$4,258.00	polyphonic	used
CS80	Yamaha	2	$18,249.00	polyphonic	used
Jupiter 8	Roland	1	$7,160.00	polyphonic	used
Jupiter 8	Roland	2	$2,699.00	polyphonic	used
Odyssey	ARP	5	$2,529.00	monophonic	used

3.3 Acoustic instruments

Acoustic instruments are very different from electronic ones and require special setups to be automated, but there have been many successful works in the area - mixed with the field of robotics and artificial intelligence - like for example a robot percussionist that reacts to a human player [Weinberg, Driscoll, and Drive; 2005]. In 'A History of Robotic Instruments' [Kapur, 2005] we find an excellent prospection of the field and numerous acoustic instruments that are currently passive of automation. Some of these contraptions have even found their way into more mainstream music venues when Eric Singer's and the LEMUR group [Singer, Larke, and Bianciardi; 2003] have supplied Jazz musician Pat Metheny with his very own robotic band for the album Orchestrion [Metheny, 2010]. Most of these robotic instruments are MIDI controlled and actuate with the help of motors and solenoids. This scenario shows itself promising to the ambitions of our system.

Two obvious choices of instruments to be considered at first are the piano and the Hammond organ. The widespread use of both is an indication that there will be high demand for their use. Since the appearance of the piano, the instrument has captured the attraction of most of the music genres. It is equally used in traditional and modern classic concerts, for jazz and blues, popular music, rock, as well as many local music styles. Its importance at the same time mean that it will be well used if made available online, and also signifies that different types of piano sound exist, that would be appropriate for specific purposes. Despite of that, its automation does not have the parameter preview problem that synthesizers have. The user will still need sound preview to select one piano if many are available, but there are no parameters to set.

Pianos are maybe one of the oldest forms of automated instruments. Piano Rolls were rolls of perforated papers, a format introduced before 1900 that could execute prerecorded performances in special pianos. Today there are alternatives like the Disklavier [Yamaha Corporation of America, 2012] and Bösendorfer CEUS [Yamaha Corporation of America, 2012]. The reliability of the Disklavier and the Bösendorfer SE for expressive playing reproduction (recorded as a MIDI file) is analyzed in [Goebl and Bresin, 2002] and [Goebl and Bresin, 2003]. The pianos were found unable to precisely emulate recorded tempo and dynamics, for instance “soft notes” are played more loudly than they were originally recorded. Nevertheless the paper states that the tempo changes are in the order of less than 50ms and that in the course of the testing, the majority of midi notes velocity where between 40 to 80 and both pianos had no problem reproducing them accurately. Unfortunately there are no studies addressing the reproduction of the newer Bösendorfer CEUS model, only tangential works as for example [Traube, 2012] that suggests it is capable of recording expressive playing in a high-resolution notation.

With those instruments, there is already available technology to operate a system based on the remote recording of pianos and achieve a reasonable result in terms of performance accuracy. In fact it has come to our attention that a remote recording system, very similar to the proposed herein, is being offered in the Sparkworld Studio [Sparkworld, 2012], which provides high quality recordings with a Yamaha Disklavier Piano. They observe that by operating their studio as a "piano factory" for a few days in a month, it is possible to provide lower recording costs. On the other hand, it must be noted that their entire process is ad hoc, under human supervision and control. The piano is automated, but the job processing and recording is not. Their system is therefore dedicated to only professional musicians, and does not characterize a more accessible ubiquitous music approach.

The operation of the SparkWord piano in part time is the first strong indication of the available market and demand what we could find. On the other hand there is a new requirement to implement such a service in a larger scale, the problem of tuning. Piano tuning is not only a delicate and time-consuming task, but also takes the form of art. Different tuning systems exist, and a piano technician is often required to prepare the instrument to a particular composition and performer. Nevertheless, in a recent paper [Hinrichsen, 2012], a system was developed that better explains the many particularities and deviations that a human technician does, and it is able to mathematically optimize the piano tuning based on our psychoacoustic perception of the interaction among all harmonic frequencies in a particular instrument. While the tuning is usually performed manually, in such an automated instrument, it is possible to develop special hardware that mechanically adjusts the instrument from time to time, and there is at least a patent already developed for such a system [Gilmore, 1998].

The "miking", e.g., microphone selection and placement, is of paramount importance, as it will be for other acoustical instruments. A grand piano has a lid that must be open to better amplify and reflect the sound to the audience. As an example of sound capture option, an automated piano can be recorded with the lid closed, open, or detached, so as to avoid direct and reflect sounds to mix in different phases. This is just one of the many options and considerations to address. An automated system must of course be built on top of the best practices already used for recording pianos in today's studios. A set of different microphones, as well as some placement adjustments can be provided to get a variety of sound perspectives, and of course the most popular are the ones to be covered. Despite the challenges, as an educated guess we should say that a piano can be one of the most valuable instruments to offer online. There are plenty of modest home users that would be able to compose in their computers and then test their ideas with the sound of the real thing.

Hammond organs, being electrically controlled, can be modified to respond to MIDI messages, including parameters of the performance, such as the Leslie speaker rotation. Different levels of automation can be devised, for example the user may be able to choose from the organ presets or in a more complex setup adjust any one the instrument drawbars. The sound capture must be done taking in consideration the Leslie speaker. The electromechanical system on those organs is also beneficial as there is little overhead between performances, e.g. there is no need to re-tune the instrument.

Traditionally, pipe organs are enormous instruments located in churches or theaters and that has natural implications in their cost and difficulty of access. There are, however, smaller versions of pipe organs, like the chamber organs, and those could be attractive options to be considered for first automation projects. Recently there have been efforts to install MIDI receivers in these instruments [Edwards, 2009] and some of those are even at people's disposal, like for example the massive pipe organ at Melbourne Town Hall [Melbourne Town Hall, 2012]. The challenge lies in the allocation of a space that can accommodate the instrument and the automation system. The cost of such a setup could however be viable if such a system were to be employed and permitted a maximum utilization of the instrument.

3.4 Analog Mixing

Until mid 80's recording studios used pure analog recording processes, storing the sound signals in magnetic tapes. The very expensive tape machines represent the culmination of that technology, improved further by dynamic compression optimized to allow higher dynamics and separate the signal from the medium noise. While major studios still keep and occasionally use those tape machines today, digital technology replaced the majority of the storage and manipulation tasks. In the current scenario, for tracking or sound capture, the signal comes from microphones or directly from electronic instruments, passes through pre-amplification, is converted into the digital domain by an ADC (Analog-Digital Converter) and then stored and manipulated easily in the DAWs.

The Mixing activity is defined as the correct composition of the individual tracks with their relative volumes, panoramic positions, effect sends and other serial processing and is both a technical and a decisive artistic task [Izhaki, 2008]. For it to take effect, the individual tracks must be added together. Both the mixing and the addition itself can be done inside the computer (in the DAW) our "out-of-the-box". In smaller studios it is usually done inside the DAW for cost reasons, while large studios use a combination of operations in the digital domain together with the access of a big external mixing console. With this option of analog mixing in the external console, there are additional DA and AD conversion steps. While theoretically that could make the audio worse, the opposite is frequently considered as true, although there is much controversy as to why.

A simple understanding can be achieved if we interpret the mixing as another part of the art composition [Radanovitsck et al. 2011], where the mixer along with the other analog gear has a role as important as a musical instrument. In this sense, it is easier to accept that an analog mixing can sound subjectively better than a correct addition in a computer. Anyway, all those analog equipments took decades to evolve and be selected as good tools to make music. As a result, many people seek for the sound of analog mixing, and there are small, dedicated units to be used just for the analog "summing" in productions that do not have access to large mixing consoles. Despite of that, they are also expensive, and must be combined with expensive DA and AD converters, for obvious reasons.

Therefore, considering that the final mixing is another analog process already present in many production's signal path, and that there is much search for its subjective characteristics, it can be considered as a good candidate to be offered as an automated server. There are a few differences and challenges to implement it, as described below.

The first technical difference comes from the amount of information to be considered, specially transferred between the user and the server. While MIDI tracks contain just a few KBytes, and the final recording of an analog synthesizer will contain part of the duration of the song possibly in mono, the mixing activity requires that all tracks be individually transferred to the server and the resulting stereo or multi-channel mix be transferred back in full. Consider a basic 24-track production in 24bit/48KHz, in a 4 min song to mix down. That would require 829MB to be transferred to the server and approximately 69MB to be retrieved. While it does not seem too much traffic for today's parameters, and from the point of view of the user, we must emphasize that this was the amount of information estimated for just 4 minutes of processing in the mixing server, and a continuous flow will be needed for high-capacity operation. So appropriate care must be taken to implement the system communication mechanism.

There are many alternatives to transfer the audio tracks. The most simple would be to get independent audio files for each track in a standard format, all with the duration of the song. That would use much more information, as tracks are not usually sounding from the beginning to the end. But this simple interface makes the system independent of the DAW software and versions. On the other hand, it is possible to transfer the project files, and that may save size, except if different and unused takes are present and not removed previously. It also requires the service structure to acquire, support and start up different DAWs, what can be both expensive and complex to maintain.

The next issue is related to automation. It is absolutely necessary to implement what is called "mixing automation", which is the dynamic determination of mixing parameters during the composition. The automation is used to implement volume changes, panoramic effects, and is nowadays recorded as if it was another performance during the song. There are many options as to how the automation could be employed in a remote server, and we must consider some of their implications carefully.

As a first option, the automation can be done digitally, inside the DAW, so that the actual mixing server has fixed settings. This is, however, the worst option. While the computations inside most of the DAWs use floating-point arithmetic, the DAC interfaces (as all audio interfaces) employ fixed-point numbers, and reducing the volume of the tracks in the digital domain, as usually needed, will reduce the resolution accordingly. It must be checked or investigated further in a real production facility if this fact will be perceived as loss of quality, but it is indeed worse than the DAW mixing and worse than an analog volume, technically speaking.

The other alternative is to read the DAW automation data and reproduce it externally in the server's mixing console. There is already technology used to do that implemented by major mixing console builders. In fact, this integration between digital and analog is already widely used. Our proposal is to make such integration independent of the location. There is also the potential need to access such data without being tied to specific companies that implemented it as proprietary technology. One must also be able to reproduce it to implement dedicated mixers that differ from the ones provided by existing companies, as addressed below. Besides the technology itself, there is also the question of DAW integration. Whatever the solution is best or just selected, it must be easy to integrate it with existing DAWs, except if the DAW's company is directly involved in the implementation. One example of such question is how to get the original, unprocessed audio, even when the project is being listened by the user (prototyped) with the final automated parameters. Even if the DAW routing allows it internally, it might be complicated to set in each user project, and it may discourage people from using it. An alternative way of integrating that would be through a dedicated mixer plug-in. As software plug-ins can receive an arbitrary number of audio and MIDI channels, the remote mixing server can be integrated as a dedicated mixing plug-in, relatively simplifying the user perception.

Finally, there is a very important matter regarding mixer quality, type, size and general options, closely associated with application and aesthetics. From a purist point of view, the analog mixer should sound as transparent as possible, while maintaining musicality. Classical music would normally call for such cleanest paths, employing class A tube designs with few stages. On the opposite hand, popular music used to prey the sound of vintage transistorized consoles, with their characteristic sound that came from audio transformers, old resistors, point to point connections and so on. Therefore, one must consider different mixing machines targeted for different applications and sound flavors. The market itself will strongly call to use machines that are already known, so that, as an example, a vintage Neve mixer online would have much more market appeal than a brand new and very clean design.

4. Conclusion

This paper made a first prospective analysis of possible instruments and operations that can be implemented as analog audio servers without instantaneous access. In the proposed access model, real instruments are installed as servers and accessed sequentially for processing jobs submitted by the users to obtain high-quality audio recordings. Such a system allows ubiquitous access to real instruments, from any device that can connect to the Internet.

The proposed model has many advantages. It can provide low accessing cost for end users even when employing expensive and specialized hardware, because of the high utilization rates attainable with a batched system that minimizes idle time. It can increase the variety of instruments that both novices and professionals can use, by operating collections of instruments from different types, brands, classes, and so on. The system can help to restore and maintain historical instruments, as well as custom and unique instruments created for community access. The proposed model works together with other options. Users that have good instruments can access others. Those that cannot afford to buy any instrument can access them remotely. Musicians that are used to work with virtual instruments may continue to do so, and benefit for an improved quality as they ask for a final rendering with real instruments. The culture and knowledge about real instruments and analog synthesizers can be improved as people are allowed to access them from wherever they are.

The main contribution of this paper was to check which other audio processes besides the analog synthesizers initially considered can benefit from the operation as audio servers, and which are the required technologies and challenges. There seems to be a very broad range of instruments and audio processing possibilities for such a system. Many kinds of synthesizers, acoustic instruments, and even mixing consoles can be remotely offered, and we found that there is available technology to operate most of those servers. Together, that should help promoting ubiquitous music creation while preserving the historical palette of music instruments and processes.

The concept of separating the sound preview from the final sound rendering is a key component that helps to reduce the cost and keep flexibility. In this way, users can focus on local music composition, recording and production, listening to sound preview, without requiring continuous live access to a remote server, and later on access high quality recording for final sound rendering.

The availability of musical software and processing power in consumer devices like cell phones, tablets and laptops is more than ever shifting the focus of musical activities from consumption to composition and production. Our contribution lies in bringing the world of real instruments, analog processes and high quality closer to these devices by means of ease of access and low cost, effectively making these process ubiquitous.

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