The Social and Pedagogical Advantages of Audio Forensics and Restoration Education

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1.1 Introduction

The world in which we live is permeated with technology that assists, entertains and documents our lives. From the first wax cylinder recording of “Mary Had a Little Lamb” created by Thomas Edison in 1877, we as a society have valued the ability to create and play back audio recordings of our personal and artistic history (Cunningham 24). In order to perpetuate our recordings for future use, we devise methods to counteract the degradation of the media used during the initial recording session – specifically those that do not safely hold audio recordings for significant periods of time – by transferring, preserving and restoring our recordings as new, more stable technology is developed.

Although audio recordings frequently document personal memories or moments of artistic inspiration, they are also widely used as a means of analytical documentation of an event even if it may not, at the time of recording, seem to be historically noteworthy. At the convergence of art, history and personal documentation we find the discipline of audio preservation – a general term used to describe the fields that are the focus of this paper: forensic audio analysis and audio restoration.

Although superficially these fields might seem to differ, they are connected to such a degree by tools, methodologies and over-arching goals that they can and should be viewed collectively as audio preservation. I suggest that because of the interrelation of audio restoration and forensic audio analysis, they can and should be taught as a single discipline at the undergraduate level as part of an existing audio production program,
alongside other audio production fields such as mastering, postproduction for moving image and field recording that also share numerous similarities with the audio preservation discipline.

This thesis is structured to provide the reader reasons for investigating this topic in conjunction with the development of an undergraduate course. The history of audio preservation and its current relation to more traditional forms of audio production are central to understanding the importance of an university-level class covering audio preservation. As such, this paper covers a brief history of forensic audio, audio restoration, how they relate to one another, and to traditional audio production. In addition, parallels between audio preservation and the more well known discipline of film restoration will be shown, further underscoring the importance of this type of education. Finally an example of a forensic audio and restoration undergraduate course is provided to offer a conceptual outline that could be implemented in undergraduate audio production programs.

1.2 Scope and Motivation of this Thesis

During the course of my ongoing Honors Tutorial College tutorials with Professor Eddie Ashworth, I became aware the audio preservation discipline while researching the uses of audio in areas other than traditional music and film production. This area of study immediately peaked my interest because it was barely mentioned in my previous audio courses. Even though I had a few general notions about audio
preservation, I was not aware of the use of audio in law enforcement or intelligence. My discovery of this field while doing independent readings for a surround-sound mixing tutorial further fueled my curiosity.

Professor Ashworth encouraged me to investigate these areas of study; what we dubbed “non-traditional audio production.” We used this term to generally classify areas of audio engineering not commonly taught in collegiate audio production programs. More specifically, this term came to describe audio restoration and forensic audio analysis. At this point I started to draw the connection between these two disciplines via the tools used in both, specifically audio restoration plug-ins such as BIAS Sound Soap Pro and Digidesign's DINR (noise reduction software).

Not being content with the information I was able to find online and in the limited texts at my disposal on the subject, I sought out information directly from professionals in the field during the summer of 2007. Despite the possibility I'd likely receive limited responses, I sent emails to a number of state and federal agencies that had some form of forensic audio analysis capabilities. Fortunately, once such email I sent to the Ohio State Highway Patrol and was forwarded to Daniel S. Lee, the supervisor of the Forensic Video Analysis Unit. This unit handles all forensic audio, video and digital multimedia analysis needs of the Patrol itself as well as any outside requesting agencies; however, it primarily serves those found within the state of Ohio. Mr. Lee not only responded to my email with a significant amount of information, he also facilitated a tour and ultimately my employment with the unit, which began in
October of 2007, and continues to the time of this writing.

Early on, I learned that the forensic audio and video analysis responsibilities had only recently been put under the charge of Mr. Lee, a civilian. Originally this work would have been conducted by a sworn member of the force. In an organization structured like the Ohio State Highway Patrol, sworn members are normally promoted out of their original department or unit as they move up in the organization. Civilian members of this and similar organizations, however, tend to be promoted within the same unit, department and field. In these situations, fewer funds would be spent on training non-sworn support staff than a revolving door of sworn members. This allows the organization to not only save money but to more easily adhere to the best practices set forth by the Law Enforcement and Emergency Services Video Association (LEVA), which places emphasis on the importance of formal training (“Law Enforcement and Emergency Video Association” 10). LEVA is the primary non-profit organization that trains and establishes guidelines for forensic audio and video analysts in some type of law enforcement or related position.

In addition to numerous law enforcement agencies that conduct forensic audio analysis, I discovered there were many non-governmental organizations that perform similar work. Such non-governmental institutions include law offices, corporations and private investigators. This realization not only confirmed the potential career possibilities in this field, it also caused me to realize this is a largely untapped area of collegiate audio production education. It seemed logical that a course covering
forensic audio analysis would work well with an audio program such as that offered by Ohio University's School of Media Arts and Studies. I already had an existing interest in pedagogy so I began conducting research and formulating a general concept for an undergraduate course.

After a few months at the Highway Patrol I began to establish a solid understanding of the forensic audio analysis field because of the thorough on the job training I received. Thanks to my courses in audio production at Ohio University, I began to notice areas in which forensic audio was similar to traditional audio production (including but not limited to music production and sound for moving image). It became apparent to me that these fields shared many overlapping practices and techniques. I began to wonder: could a background in traditional, entertainment-based audio production lead directly to expertise in audio forensics? I suspected that the answer was “yes,” but to bridge the two fields I knew that specialized training was also necessary.

After discussing the possibility of devising a forensics course with Professor Ashworth he suggested I also investigate audio restoration because this discipline utilized many of the same tools and methodologies I was using in forensic audio analysis (with some key differences discussed later). After much research (during which I was able to identify the strong connections between restoration, forensic and entertainment audio) I set about to create a course geared towards undergraduates who were already majoring in audio production. Consequently, I devoted three HTC
tutorials to the creation of such a class, resulting in a ten-week experimental presentation of the course and all pertinent materials to Professor Ashworth and MDIA Facilities and Technology Manager, Ricky Chilcott.

This thesis represents the culmination of nearly three years of concentrated research and work in audio forensics and restoration and my effort to fill a void in current audio pedagogy within the American university system.

2.1 Forensic Audio Analysis Definition, History and Implementation

Audio forensics, as defined by the Audio Engineering Society's Technical Committee on Audio Forensics, is “engineering and scientific analysis, evaluation and presentation of audio and acoustic evidence in a judicial inquiry normally leading towards a presentation in court,” (AES Technical Committee on Audio Forensics).

Forensic audio analysis work is usually undertaken for local, state or federal governments (specifically police forces and prosecutors' offices). In addition to law enforcement, respected audio expert Tom Owen of Owl Investigations in New York notes that audio forensics is used by private businesses as a means of enforcing accountability and preventing corporate espionage (Blades 18). Furthermore, audio surveillance (a sub-discipline of forensic audio analysis) is becoming more widely used by organizations outside of the intelligence community as police forces worldwide embrace technological advances as a key to more effective law enforcement.
In order to understand the origins of audio forensics, it must first be established that audio forensics evolved from signals intelligence (SIGINT) but is strongly rooted in traditional audio production. According to the National Security Agency, the U.S. agency responsible for SIGINT, signals intelligence “is a category of intelligence that includes transmissions associated with communications, radars, and weapons systems used by our adversaries,” (“Signals Intelligence”). As early as World War II, the interception of radio/audio transmissions by intelligence operatives necessitated the use of specially trained engineers to enhance the quality and clarity of the communications.

Throughout WWII and subsequent decades, the use of audio recordings became more prevalent in both the intelligence and law enforcement communities. SIGINT includes a variety of operations including domestic spying programs like Project MINARET during the Cold War and the controversial NSA program undertaken during the George W. Bush administration. This discipline of intelligence also includes foreign counter-intelligence programs like that undertaken by the well known Navajo Code Talkers and Welsh-speaking British code talkers. Signals intelligence is, as the definition indicates, a rather broad area of intelligence that now encompasses a large amount of gathered data.

As communications technologies became more sophisticated, a sub-category of signals intelligence was created – known as communications intelligence (COMINT) – as a way to increase organization and indicate necessary specialization.
Communications intelligence [COMINT] is gleaned from foreign communications that are intercepted by other than the intended recipients. Such intelligence can be of the greatest value to a nation’s fighting forces because it allows them to be privy to the strategies, weaknesses, and attitudes of the enemy. For example, before and during World War II, the U.S. Navy’s breaking of the Japanese PURPLE code allowed the United States to know of Japanese moves in advance ("SIGINT").

This definition places special emphasis on the role of COMINT in cryptanalysis and international conflicts but also provides the backdrop for audio forensics in the modern criminal justice system – leading to its use in the private sector. Additionally, this definition makes note of the interception of communications, a process included as part of surveillance work that may be undertaken or assisted by the forensic audio analyst. Furthermore this definition omits (but can be logically expanded to include) enhancing the intelligibility of the intercepted communications – one of the primary challenges overcome in audio forensics.

Specific historical examples of this type of analysis include the breaking of Japan's PURPLE code during World War II, the Nixon Tapes which date back to 1971 (Doyle 1), the previously mentioned Project MINARET and the Julio Iglesias case, in which Tom Owen of Owl Investigations was tasked to verify that the artist had in fact wrote and recorded a song before he heard an unknown's demo (Prentice 2). Predating these well-known applications of audio for non-entertainment purposes are two legally significant cases that not only set precedent for the admission of “voice identification evidence” but also further cemented the acceptance of recorded evidence as a whole (McDermott Owen 5). The two cases of special importance
mentioned by the McDermott and Owens paper are United States v. Wright and New Jersey v. Cary (McDermott Owen 5). The Wright trial was a court marshal so it did not set the legal precedent for the use of voice print identification in the civil criminal justice system however it indicated that the system as a whole had begun to look at experienced and trained audio engineers as expert witnesses. The Cary trial, however, was the first case where voice print analysis evidence was accepted and set the legal precedent necessary for its use in other cases. It is from this foundation that audio forensics has evolved into the intricate and pervasive public and private field it is today.

2.2 Forensic Audio Challenges

One of the primary challenges, and usually the first step in any forensic audio case, is shared with most other fields that focus on meeting the customers' needs: the analyst must identify what exactly the customer is hoping to gain by having their recording analyzed and/or enhanced. To do so, the customer and the analyst must discuss the major technical issues of the recording, a likely timetable for project completion and the analyst's expected quality of the end product.

Another challenge is mitigating less than optimal recording practices one frequently encounters in forensic situations. In addition to the low recording bit rates\(^1\) commonly (and unfortunately) utilized in day-to-day forensic work, the analyst also

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\(^1\) Bit Rate: A way to indicate the resolution of the audio recording that directly relates to the accuracy with which it represents the analog signal (Huber 272)
must counter poor initial recording techniques. Frequently microphones or digital
recorders with built in microphones are not placed in an optimal position, or are even
positioned in a fashion that renders audio unintelligible. Furthermore, recording levels
are often not set correctly, if at all, even when the conditions are controlled such as
those found during an interrogation.

This was the situation on an important case in which I was involved that
occurred about one year prior to the time of this writing. A suspect was detained and
then interviewed in connection with a felonious crime by local law enforcement
officials. This interview took place inside of a county building where public meetings
took place, rather than a proper interrogation room. Instead of a professionally
installed and maintained recording system (designed to clearly pick up details of
conversation) the interview was recorded using the facility's installed surveillance
system, with microphones positioned too far from the subject and too near ventilation
ducts to clearly capture the conversation. As a result, the suspect was not properly
recorded and his confession was unintelligible due to room noise and unchecked
recording levels, two problems that are avoidable in most cases. The room noise that
was most obscuring was a low ventilation rumble that masked the voices. In this
situation the customer felt that all he needed was for the recording to be made louder –
but after I examined the recording and discussed the matter with him, he realized that
the process was actually more complex. The voices had to first be isolated from the
room noise before they were made louder or the resulting recording would be equally
unintelligible. Fortunately the court date was approximately two weeks after I received the recording, allowing enough time for it to be successfully enhanced.

Although I had a little over two weeks to process this recording, the prosecutor's office had the recording for over two years prior to my receiving it. It wasn't until the court date was in sight did they have the recording enhanced. In my experience, this is quite common and generally means that recordings have been stored for some period of time. This can cause issues with improperly archived media such as discs that can become scratched, audiocassettes that become damaged through multiple duplication iterations, and source materials degraded in many other ways.

Short timetables pose another common challenge analysts must overcome not directly related to audio engineering: prioritizing. A common problem with prioritizing one's work is that every customer feels his or her project is of the utmost importance. Although the project is quite important to them, it may not be the case when compared to others with more restrictive deadlines. Thus, it is vital for the analyst to be advised if and when the case is going to trial, and other pertinent details such as the seriousness of the event recorded and the length of the recording. This will allow the analyst to work most efficiently and offer the quickest turnaround possible for cases that require the most immediate attention. Prioritization, in some form, must occur as soon as the analyst has more than one case to process at a time. There have been times that I have been given simultaneous cases that have a significant difference in the severity of the crime. It is typically wise to prioritize felonious cases (terrorism,
violent crimes, arsons etc.) over less severe cases (vandalism, vending machine theft etc.) If it is explained to a client why another case will be prioritized above their case, the client will normally be both understanding and accommodating. Although many cases undergo a similar process, I find the degree of difficulty involved in each case is unique. As such, prioritizing must be taken seriously by the analyst to offer the best service possible to one’s customers.

The most common type of audio enhancement that takes place in forensic audio is much like the example case mentioned above: voice isolation and increased conversation intelligibility. There are various reasons the voice of a subject might be obscured. Typically the cause of this is use of low-quality (but space-efficient) recording formats, poorly placed microphones (obscured by clothing, too far from the source of the sound, etc.), environmental noise (such as wind, traffic noise, etc.) and poor quality recording systems. Although there can be other recording conditions present that make the voice of the subject(s) difficult to hear, nearly every case contains at least one of the four aforementioned problems.

In order to combat these audio issues, analysts commonly use equalizers (frequently band-limiting\(^2\) to include only vocal frequencies), compressors\(^3\) and selectively applied gain\(^4\). Other tools used include adaptive noise filters\(^5\), limiters\(^6\) and

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2 Band-limiting: A type of equalization that allows only selected frequencies to pass (Huber 227)  
3 Compressor: A piece of equipment that functions as an “automatic fader” that is used to control the volume of a sound relative to the rest of volumes present in the recording (Huber 460)  
4 Gain: An increase in the power of a sound signal, can also be reduced (Huber 408)  
5 Adaptive Noise Filter: A filter that uses a noise sample to then subtract that noise from the rest of the signal (Huber 492)  
6 Limiter: A special form of a compressor used to keep sounds from exceeding a preset level in order to prevent overloading (Huber 465)
multiband compressors also called multipressors.7

Although voice isolation is the most common type of audio enhancement conducted by forensic audio analysts, there are other situations that require clarity improvement using interactive combinations of the aforementioned tools, along with careful analysis. These include noise identification and authentication, stereo splitting and balancing, cover noise removal, transcription and voice print analysis, all of which are next examined.

Noise identification and authentication is a process in which an analyst attempts to distinguish the source of a sound in a recording, or even the original location of the recording itself. This is typically not a process that is undertaken when conditions are controlled. Frequently this type of analysis is only conducted on recordings that are not accompanied with video or those whose origins are in question. Although accurately pinpointing the source of a sound without video is quite challenging, there can be contextual clues such as when and where the recording were made that can help the analyst identify the source. These details, coupled with careful listening, analytical thinking and deductive reasoning can result in the engineer providing the client with a likely source of the sound. If the situation warrants, the engineer can then attempt to recreate the sound under controlled recording conditions to verify the validity of his or her previous deduction. Similarly, if the source of a recording is unclear, the analyst can use the recorder in question and compare noise

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7 Multipressor: A piece of equipment that isolates frequencies by band-limiting and then applies differing degrees of compression to those isolated frequencies (Huber 464)
signatures present in the recording. Noise signatures include the unique waveforms created by a recording device when it begins and ends recording as well as other low volume noise introduced in to the signal.

Stereo splitting and balancing is a process that I have conducted on a number of cases for the Ohio State Highway Patrol. This technique is commonly utilized because police car camera systems usually record a microphone placed inside the car on one channel and a belt microphone that the officer wears on the other. Which microphone is assigned to which channel can vary from model to model but the common characteristic across all in-car camera systems is that these channels are not balanced in volume. This makes it difficult to understand all dialog recorded unless these two channels are isolated (“stereo-splitting”) and then independently enhanced and examined.

Cover noise removal is primarily an issue in cases that involve an undercover informant secretly fitted with a microphone in order to covertly record their surroundings, colloquially called “bugging.” This informant (or the person being recorded) then attempts to deliberately mask a conversation with loud music or a similar obstructing noise. Although this may seem illogical for the informant to do, they typically agree to be an informant in order to lessen a sentence for a crime they have committed. They then may try to do as little as possible to assist law enforcement officials but still fulfill the terms of their agreement. This type of case is not a common occurrence for an agency such as the Ohio State Highway Patrol; I am aware
of only one case of this nature in the past three years. It is, however, a more prevalent issue for agencies such as the FBI or the Ohio Bureau of Criminal Investigation that handle this type of evidence and investigation more frequently. Typically music cover is counteracted using specialty automated noise filters that can remove predictable rhythmic patterns, such as the “Improved Adaptive Filter” found in Diamond Cut's DC Live Forensics software suite (“Features of DC LIVE/Forensics”). In addition to automated filters, the analyst isolates only the vocal frequencies (approximately 300 to 3 kHz) with a bandpass filter, a process that is used in most vocal enhancements. Although very useful in forensics, this method would not be used in a music restoration setting as it negatively impacts the timbre of the recording. This type of bandpass filtering is also used to a less severe degree in sound for moving image for dialog enhancement.

Another frequently requested service is written transcription of a conversation. Personally, I find it best to avoid offering this service. Unless the engineer has significant training and experience in the field, it is easy to draw incorrect conclusions regarding what is being said. If a conversation was initially obscured and the engineer then made it audible, it is sensible to alert the customer of this but not to assist the customer in drawing potentially inaccurate conclusions regarding what was said via transcription. Typically, it is best to advise the customer seek out someone in their own or another governmental agency that is trained to transcribe recordings for use in court.
A service very rarely requested during my time at the Ohio State Highway Patrol's Forensic Video Analysis Unit is voice print analysis. Voice print analysis is the process by which a person is identified exclusively by a graphical analysis of their vocal patterns. This is done through careful comparative listening and visual renderings of the voice by specialized software. At least two recordings are required for this process to be undertaken: the source or unknown recording and at least one reference or control recording. The source recording contains the voice of a speaker whose identity is not known. The control recording contains a known individual repeating a section of dialog in various ways. The analyst must then compare the known and unknown recordings to determine the probability they are the same speaker. On the surface this seems to be a simple process but the intricacies of human speech patterns makes this the most difficult and specialized form of audio forensics. Blades' article includes a step-by-step breakdown of the voice identification process used by Tom Owen:

Voice Identification: The Aural Spectrographic Method
Steps for Voice ID Case Procedure
1. Receive, mark and photograph evidence tapes, recorders and containers.
2. Physical inspection, tape inspection, lot number, condition.
3. Track configuration Mono or Stereo, 1 or 2, control track, etc.
4. Azimuth and Zenith alignment on lab recorder.
5. Playback speed analysis and adjustment.
7. Critical listening and notes.
8. Create "unknown" word and phrase list.
9. Take verbatim exemplar and create known "best" word list and phrases.
10. Create an audio unknown/known short-term memory tape for aural
comparison.
11. Do the Visual comparison of the spectrograms of the unknown/known ST phrases.
12. Analyze the results and form conclusions, offer an opinion. Write report.
13. Write to an archive file, make copies and send report to client with original materials (FedEx or Certified Mail). Include all Rule 26 requirements (Blades 22).

Typically, the customer won't request voice print analysis directly, but will instead ask the analyst if two voices sound like the same person. According to a paper written by Jeff M. Smith published by the AES, on average, 45% of the time trained but inexperienced voice print analysts incorrectly identified a subject in his study. Although these engineers had been taught this process in a graduate level course, voice print analysis is highly specialized aspect of forensic audio analysis that should only be conducted by specially trained and experienced professionals (Smith 1). By incorrectly identifying a voice in a recording, an analyst not only undermines his or her own credibility but that of all the professionals in the field, specifically those qualified to conduct voice print analysis. This is one requested service that the analyst should, in all situations, politely decline to offer their opinion unless they are trained and certified to do so. By explaining the intricacies of voice print analysis to the customer, they will usually understand the analyst's reticence and appreciate their candid honesty.
2.3 Audio Restoration Definition, History and Implementation

Audio restoration (a term typically used interchangeably with audio preservation) can be defined as the transfer of audio recordings from volatile mediums while, according to the Oxford English Dictionary, “return(ing them) to a former condition,” (“Restoration”). When audio engineers and non-engineers alike discuss audio restoration they are typically referring to the improvement in quality of audio recordings that were recorded many years earlier as well as the transfer of that recording to an archive-quality medium. These audio recordings could be of an influential music performance, a historically significant speech or even something as personal as a family member recounting a memorable experience. Audio restoration, like that conducted at the Library of Congress' Packard Campus, aims to preserve audio recordings that are historically noteworthy whether it be for artistic or documentation purposes.

The owner of the largest collection of sound and film recordings, and one of the most widely recognized restorers of audio, is the United States Library of Congress. The Recorded Sound Division can trace its roots to a 1926 donation of more than 400 discs by Victor Records (“Recorded Sound Reference Center”). Although the main Library of Congress complex is in Washington D.C., the Library's Recorded Sound Division actually resides in nearby Culpepper, VA on what is known as the Packard Campus – named for its primary donor David Woodley Packard, whose “$115 million gift is the largest in the Library's 207-year history,” (Trescott). This complex is
on 45 acres and has “415,000 square feet, more than 90 miles of shelving for collections storage, 35 climate controlled vaults... 124 individual vaults for more flammable nitrate film,” (“The Packard Campus”).

Another well-known sound recording restoration operation in the U.S. is the Smithsonian Folkways record label. This label and musicology research center, owned and operated by the Smithsonian Institute, has a unique history that requires its entire back catalog remain accessible to the public.

...in 1987 the Smithsonian Institution Center for Folklife and Cultural Heritage in Washing D.C. acquired Folkways Recordings and the label's business papers and files to ensure that the sounds and genius of its artists would continue to be available to future generations. As a condition of the acquisition, the Smithsonian agreed that virtually all of the firm's 2,168 titles would remain 'in print' forever – a condition that Smithsonian Folkways continues to honor through its custom order service. Whether it sells 8,000 each year or only one copy every five years, every Folkways title remains available for purchase (“Smithsonian Folkways”).

The Folkways label not only helps to distribute American folk recordings from decades past, it is perpetually performing preservation on its catalog to keep it in commercial quality condition. Although the Library of Congress and Smithsonian Institute are owned and operated by the U.S. Federal Government, not all audio restoration operations reside in the public sector.

The famous art-film distributor Janus Films promotes itself with the statement that it has been “…for fifty years, the preeminent U.S. Distributor of foreign and classic films that have collectively shaped the art of contemporary cinema.” (Janus
Films) The fifty-year period during which Janus has been releasing and re-releasing films covers the entire history of popular U.S. motion pictures with sound, films that have gained popularity in the United States shortly before World War II (“Motion Pictures”). An important film being re-released by Janus at the time of this writing is Kurosawa's *Rashomon*.

The audio from the 1962 print of *Rashomon* was first captured and transferred to digital tape by DJ Audio in Studio City, CA. It was then restored by Audio Mechanics in Burbank, CA. Due to signal degradation of the original media, and the comparatively primitive equipment used for the initial recordings, undesirable noise as well as other sonic artifacts such as pitch fluctuation were introduced (“*Rashomon: The Restoration Story*”).

Not only has Audio Mechanics restored the soundtrack of *Rashomon*, they were chosen by Twentieth Century Fox to restore *The King and I*, by CBS to restore all of the *I Love Lucy* episodes, as well as many other major release projects including the sound restoration of *Alien* and *Jaws* for DVD release (Polito).

In addition to these noteworthy entertainment audio restoration projects, the company's founder, John Polito, “was hired by the Eagle County District Attorney to enhance and authenticate the police interview tape recording of Kobe Bryant,” (Polito). This underscores the practical connection between restoration, forensic and entertainment audio that discussed in this thesis.
2.4 Audio Restoration Challenges

Audio restoration engineers are faced with many of the issues we traditionally associate with old vinyl and tape recordings – scratches, clicks, pops, hiss, etc. Although they do deal with these types of obvious audio “speed bumps,” they also overcome the more perplexing problems such as the best way to preserve deteriorating audio tape that is half a century old, dealing with improper azimuth (record/playback head alignment) during the recording process, low rumble introduced during filming and subtle phase and pitch variations that are caused by the recording playing back at slightly varying speeds. These more delicate and difficult audio problems force restoration specialists to frequently wear the hat of an audio analyst while focusing on the aesthetic quality of the end product.

Like audio forensics, one of the first steps is meeting with the client, correctly identifying their needs, and offering a timetable and projected final product quality. This can be difficult on some projects that have unforeseen problems such as gaps in audio that were missed on an initial listening or projects that are spread over multiple reels and have differing problems per reel. As with evidential audio, proper storage and transfer to the digital realm is often a primary concern. There are situations when the engineer will transfer the audio from a film or studio session that took place decades earlier. In many of these cases there is only one copy of the recording left in the world. Because of this, there is no room for mistakes regarding the handling and care of the recording. This also occurs in forensics cases in which audio recordings
haven't been duplicated prior to storage.

### 3.1 Connecting Forensics and Restoration – Forensic Audio Perspective

Since all recordings handled by forensic audio analysts must be treated as if they were evidence in a criminal trial, special attention is paid to preservation. Preserving the recordings on a safe medium is essential because trials, appeals and acquittals can take place months and even years after the incident was initially recorded. Enhancement, colloquially called “cleaning up,” is undertaken in nearly every forensic audio analysis case. After enhancement and overcoming the aforementioned challenges occurs the most important step of the process: the presentation of the analyst's work to the client and when necessary to a court of law.

Although no two audio forensic cases are exactly the same, there is a relatively consistent workflow from project to project. In most cases undertaken by a forensic analyst, the process begins with a recording in which the voice cannot clearly be heard. Before the analyst hears the audio, it normally has been played numerous times (an issue with analog tapes, or CDs/DVDs that have been handled roughly). Immediately upon reception of the media, the analyst must make a duplicate that “accurately reproduces the original” so as to not unnecessarily overplay the original which may cause irreversible damage (“Federal Rule of Evidence 1001”). The client will sometimes have what they feel is an accurate idea of what is being said and then will ask the analyst to “clean up” the relevant area of the recording. The analyst must
be careful not to “over-enhance” small sections of the recording since doing so has the potential to obscure vital contextual details if a conversation was recorded. After the enhancement is complete, the analyst will then review the work performed with the client. During this step the engineer must explain the stages of the analysis and enhancement process in the same manner they would if the evidence was presented in court. Since the analyst may then present the work they have completed in court at a much later date, it is important for the analysis to keep careful notes regarding the enhancement process.

3.2 Connecting Forensics and Restoration – Audio Restoration Perspective

As with forensics, in audio restoration the engineer must preserve the recording, restore the piece to its original quality, enhance clarity as requested and then present the work to their client or supervisor. One of the primary differences between audio forensics and audio preservation is the restorer may be requested to only bring the recording back to its original quality and not to enhance it to a modern standard. The restorer also has to retain an aesthetically pleasing tone for the recording. The engineers in both situations must conduct the same general steps, including submission of the finished work to the customer. Typically the presentation is accompanied by supporting written documents that chronicle the engineer's methods and, if requested in forensics cases, any conclusions drawn regarding the authenticity of the recording.
The procedures forensic audio analysts and audio restorers undertake are largely the same, as are the high-end tools they use. Choosing precision equipment and software that does not introduce any uncontrolled sonic coloration is of utmost importance for the restoration engineer and the forensic audio analyst. Special consideration is given to the type of audio monitors, digital audio workstations and outboard gear selected. Companies such as CEDAR Audio, Wave, BIAS and DC Live have specialty tools, in digital and analog form, that are designed for both audio restoration and forensic audio analysis. In addition, many tools such as compressors, multipressors, preamplifiers and equalizers are used in traditional production, forensic audio analysis and audio restoration.

3.3 Forensics and Restoration Relationship Conclusions

Due to the numerous similarities in work flow, tools and written supporting documents found in forensic audio analysis and restoration, I contend these fields should be recognized to be part of the same discipline for pedagogical and professional purposes and can be effectively taught simultaneously in a collegiate setting. Since universities are typically on the leading edge of trends in audio production, it is logical for undergraduate level audio programs to include a course devoted to these emerging areas of study. Despite this seemingly obvious conclusion, no American institutions with popular audio production programs currently have such an undergraduate course on the books.
This gap in audio engineering education, discussed in depth below, can be bridged quite thoroughly while remaining financially feasible. If an institution is already teaching traditional audio production using Pro Tools or a similar modern digital audio workstation, it can invest in a plug-in such as Sound Soap Pro without making significant or costly changes to the digital audio workstation used. It goes without saying that the university must include faculty members that have either worked in this field or are willing to include this new area of expertise.

4. Preservation's Relation to Traditional Audio Production

Not only are restoration and audio forensics related to one another, they are both closely related to entertainment-based audio production. The same tools, methods and skill-sets that connect forensics and restoration connect their parent discipline (audio preservation) to the same type audio production that is currently taught at a collegiate level across the country.

Some of the tools used in forensics and restoration have been previously mentioned in previous sections and are the subject of the fourth week of the sample course outlined under the heading *The Course of Study*. Of the equipment used in both fields I've found equalizers, compressors and adaptive noise filters to be the most universal. Although the general type of tool employed is the same, the specific models used can vary depending on the application. Traditional audio production, specifically music production, is focused on the end product being aurally pleasing. Quite simply,
music is typically recorded and restored to be sonorous to the ear whereas forensics and speech restoration are conducted to make recordings intelligible. As such, the primary focus of music production aligns well with the aesthetic focus of audio restoration – specifically with music and soundtrack restoration – but less so than with the intelligibility focus of forensic audio analysis. It is logical then, that the compressors and equalizers that work well in music production work better in music restoration than audio forensics. Conversely the equipment used for dialog production, specifically those used on field-audio, lend better to forensic enhancement and dialog restoration than music restoration.

There are, however, specialty filters that are designed for use in forensic audio analysis and restoration that are not used as frequently in traditional audio production. One of the most notable manufacturers of these devices is CEDAR Audio that produces the Cambridge Forensic Systems. This device is a hybrid hardware/software forensics and restoration suite that is used in professional settings. In the “Expanded” version of this suite is CEDAR's award winning “Dialogue Noise Suppressor,” a type of adaptive noise filter. Adaptive noise filters are software tools that analyze the recordings and selectively remove noise present. The engineer must carefully set the parameters of these filters or they will remove more than just the unwanted signals (“DNS One Dialogue Noise Supressor”).

During the course of my research with Professor Ashworth, I have found and tested, with funding from a Provost's Undergraduate Research Fund Grant, a cost
effective software plug-in suite that fills the adaptive noise filter role. I was pleased to
discover that Sound Soap Pro, made by BIAS, works effectively in both audio
production and audio preservation environments. This plug-in is quite useful in both
traditional audio production for entertainment as well as all types of audio
preservation. Although quite useful alone, this plug-in, like most others, works most
effectively when used in conjunction with complimentary tools. I personally found it
functions best when production workstations are already outfitted with quality
hardware and software tools, specifically audio monitors and control rooms with a flat
frequency response as well as quality digital to analog converters with accurate word
clocks.

In addition to the hardware and software shared by audio production and
preservation, there are also numerous similarities found in their engineering methods.
As with all forms of audio production, the primary method on which all engineers rely
is critical listening. In addition to careful listening, engineers use various forms of
visual clues and metering such as waveform displays, spectrum analysis and volume
meters to fully understand all of the details present in the recordings on which they are
working. Verifying the frequencies and amplitudes of noises present in the recording
are two specialized uses of these common forms of visually representing audio.

Previously mentioned in the Forensic Challenges section, stereo balancing is a
method extensively used in forensics that is also heavily used in music and most

8 Word Clock: A device used to synchronize audio data at a sample level across multiple pieces of
equipment and sources (Huber 237)
production. This includes numerous specific processes including mixing instruments and vocalists in music, panning dialogue relative to a moving image and properly balancing volumes of more than one recording of the same source. All of these specific process are rooted in the same core concept that is to properly orient the listener to his or her audio surroundings.

5. Advantages of Audio Preservation Education

The pedagogical advantages I have discovered during my research include offering students a more complete view of the careers present in audio production as well as reinforcing valuable engineering skills that enhance the full spectrum of audio production. Before coming across audio restoration and subsequently forensic audio analysis, I was unaware careers in these specialty fields existed. If a course that covered audio preservation, including both restoration and forensics, existed in the undergraduate course catalog at an institution like Ohio University, students would be able to not only learn of the existence of these fields, but also have the opportunity to gain some experience within them. Furthermore, students that enroll in this type of course would learn to listen to their own recordings with an increased attention to detail as well as to properly backup and preserve their work.

The problem solving and increased attention to detail that would be central to this type of course would help the student become a better audio engineer no matter the type of audio project. These skills enhance the student’s ability to notice small
flaws in their work that they may have otherwise overlooked; small flaws that if present in their work would differentiate them from professionals in the field. Some of the specific processes that would directly increase the student’s ability as an engineer are vocal isolation and enhancement, stereo (leading to surround sound) mixing and balancing and noise identification and removal. These processes and adaptations of them are commonly used in music production, live sound production, and field recording and sound for moving image.

6. A Gap in Undergraduate Education

While very few universities offer courses that include audio restoration, even fewer have classes or programs of study that include forensic audio analysis; of note, however, are two grants received by the University of Colorado Denver professor Richard Sanders in 2008 for the express purpose of setting up a “National Center for Audio/Video Forensics,” (“National Center for Media Forensics”). Unfortunately, the program's director, a pioneer in forensic audio, passed away in August 2009 – but not before he saw the National Center for Media Forensics come to life on the Downtown Campus of the University of Colorado, Denver. This unique program was dedicated to media forensics as a whole, including “Audio/Video Enhancement and Authentication,” (“National Center for Media Forensics”). During the 2009-2010 academic year the University of Colorado Denver's MSRA 6530 Graduate Audio Forensics course was taught as part of the Master of Science in Recording Arts
program. This course is exclusively focused on forensic audio and its uses in law enforcement and society. At the time of this writing, however, there was no other dedicated forensic audio analysis and restoration course to be found in the undergraduate course catalog of any university with a well-known undergraduate audio production program.

Due to the lack of collegiate undergraduate courses and programs that include forensic audio analysis and restoration in their curricula, and even fewer with it as their main focus, there is a relatively large field of audio engineering that many budding engineers may not know exists, let alone get the chance to personally investigate. As such, an effective solution to bridge this gap in audio education would be a course dedicated to forensic audio analysis and restoration. This type of class would ideally be taught as part of a complete audio production course of study, such as that found at Ohio University's School of Media Arts and Studies.

7. Filling a Void in Audio Education

During the academic year 2008-2009, as part of three independent study tutorials with Professor Eddie Ashworth, I created a course prospectus that covers forensic audio analysis and restoration as if it were to be taught as an upper level recording class in the School of Media Arts and Studies. During Spring Quarter 2009, this course was presented to Professor Ashworth and MDIA Technology and Facilities Manager Ricky Chilcott in a prototype classroom setting. Both Ashworth and Chilcott
offered constructive criticism for specific lecture details, lecture styles, projects assigned and even proper weighting of course elements (including participation, paper and project grades). Through the implementation of the feedback provided from both a seasoned professor as well as a technically accomplished media engineer who majored in audio production during his undergraduate years, the course presented in the following section offers a potential solution to the lack of forensic audio analysis and restoration education found in undergraduate audio production programs.

7.2 Program Structure

The course discussed below is designed to work in an audio production program like one found at Ohio University. The School of Media Arts in Studies in the Scripps College of Communications current uses a quarter system and is comprised of five different major sequences. These major sequences include digital media, media studies, media management, video production and the sequence for which this type of course would be used, audio production.

The audio production sequence, like the video production sequence, is designed to introduce students to core concepts, history and production methods. These lessons are the bases for upper-level courses that become more specific and significantly more challenging in their respective subjects. Audio production is comprised of two specialization course tracks: Music Production and Audio Post Production. The following courses are required of all students in the audio production
sequence. Course descriptions and sequence structure outlines come directly from the Ohio University Undergraduate Course Catalog (“Ohio University”).

**MDIA 220 – Introduction to Audio Production**

Introduction to basic audio theory and production skills, including desktop audio production, commercial production, mixing, microphone theory and techniques, sound design, and digital audio basics.

**MDIA 308 – Technical Basis for Telecommunications**

“Electronic principles of reproduction and transmission of sounds and images; functions of audio and video equipment.”

Students choosing the Music Production major track must take the following courses:

**MDIA 320 – Recording Industry Survey**

An examination of the history, aesthetics, business practices and cultural impact of the recording industry with an emphasis on popular music creation, consumption and commoditization. Topics include major and independent label structure, songwriting & music publishing, copyright issues, music placement in media, alternate distribution models, music production, artist management, the DIY phenomenon, among others. Special emphasis is placed on ongoing developments in the industry.

**MDIA 413 – Commercial Music Recording and Production**

Advanced studio production techniques in music production with introduction to digital multitrack recording, recording studio procedures and business practices, typical equipment set-ups, ancillary equipment, advanced microphone techniques and advanced digital audio workstation applications. Aesthetic topics as they relate to music recording and production and current commercial music industry trends.
**MDIA 414 – Advance Projects in Music Production**

Advanced music recording and product development. Album production from artist development to CD mastering and replication will be covered.

**MDIA 497 – Independent Music Production Projects**

Students propose a music production project to their professor and upon approval, are allotted 30 hours of studio time to complete the project. Typically students record a short album as their project for this course. Students are not directly supervised, but their work is critiqued by the instructor.

Audio Post Production students are required to take the following courses:

**MDIA 240 – Introduction to Video Production**

“Introduction to basic video production skills and aesthetics.”

**MDIA 415 – Audio Post Production for Moving Image**

Audio post-production for moving picture. The course will explore the technical and aesthetic aspects of sound as it relates to the moving image. Mixing to picture, SMPTE synchronization to video, Foley sound effects, dialogue replacement, and music for picture will all be covered.

Students in the Audio Post Production major track are then able to pick from the following courses to fulfill the remainder of their major requirements under the supervision of their academic advisor.

**MDIA 322 – Digital Video Post Production**

This course is no longer in the course catalog but is typically substituted with a similar 300 level advanced video editing course. Students are required to take this type
of course so they fully understand how audio for moving image fits into professional video production. By better understanding the roles of all parties involved, students are being trained to be more effective and productive engineers that will make for a faster and smoother production process. MDIA 474 – Advanced Digital Video Postproduction is described as, “Deep exploration of the processes and tools of digital nonlinear editing of video material.”

**MDIA 422 – Narrative Production II**

This course, like MDIA 322, is no longer offered in the course catalog. It was an advanced production course with a focus on narrative projects. Students typically take one of the other many video production courses in place of this or other courses if they have been removed since the sequence outline was last updated.

**MDIA 485 – AVW Productions**

This course is also no longer offered but is instead replaced by MDIA 486Y – Athens Video Works, as well as students doing on campus internships for credit. Athens Video Works is a student ran video production company that produces content for WOUB, the Athens PBS station, as well as numerous other outlets.

**MDIA 497 – Independent Production Projects**

As previously noted, students register for this course when they are conducting an independent study project like those mentioned under the Music Production major track. Many Audio Post students take on projects such as mixing, Foley and automatic dialog replacement (ADR) for various films.
Music production students also must complete a music minor as a graduation requirement. Audio post students are required to select a corollary that totals thirty five credit hours outside of the School of Media Arts and Studies from at most two different areas of study. Of these thirty five hours, students must take at least twenty credit hours (approximately 5 courses) at the 300 to 400 level.

8.1 The Course of Study

The following sections include a syllabus, week-by-week outline of the lectures and labs as well as a more in depth discussion of each week's subject matter. Specific details of the course are in the follow sections but the general course composition should be considered two two-hour meetings per week. Although this course is designed for a 10-week quarter system, it could be expanded to cover a 15-week semester. One of these meetings is of a traditional lecture style and the other is a lab section to be held in a computer lab equipped with Pro Tools (or a similar profession digital audio workstation) and Sound Soap Pro.
MDIA 486: Audio Restoration and Forensic Analysis
Syllabus

MDIA 486
Audio Restoration and Forensic Analysis
4 Credit Hours
Spring 2010, RTV 188, 12:10-2:00 M/W

Course Description: This class offers advanced instruction and practice in audio restoration and forensic audio analysis. This course is presented as two hours lecture, two hours lab each week. Not only will this course work as an introduction to the technical skills needed to work in the aforementioned fields, it will also cover the moral and ethical duties that are intrinsically connected to these professions. Furthermore, this course will cover methods audio engineers can use to interface with law enforcement and those not familiar with the technical aspects of the field.

Required Text: No required textbooks. Handouts will be given out no less than once weekly. All handouts are kept until the end of the quarter; all material on the handouts is subject to be on the final.

Prerequisites: MDIA 220

Meeting Location: Lecture is Monday 12:10-2:00 in RTV ###; Lab is Wed 12:10-2:00 in MDIA lab on 2nd floor RTV

Attendance: Students are expected to attend every class meeting, although allowances are made for absence. Each student is allowed to miss 1 lab and 1 class during the quarter without an excuse. Students are responsible for all information/assignments missed. Any missed classes beyond those allowed will result in a reduction of the attendance grade.

Grading: 20% Attendance
30% Exercises/Quizzes
15% Midterm Exam
5% Ethics Paper
12.5% Forensic and Restoration Project 1
12.5% Forensic and Restoration Project 2
15% Final Exam
**Weekly Outline:**

<table>
<thead>
<tr>
<th>Week</th>
<th>Lecture Topic</th>
<th>Lab Topic</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Intro/administrative. What is audio forensics? What is audio restoration? What is audio surveillance?</td>
<td>Introduction to using Sound Soap with Pro Tools, Hum &amp; Rumble/Click &amp; Crackle, Exercise 1</td>
</tr>
<tr>
<td>2</td>
<td>Differences and similarities between forensic analysis and restoration methodologies.</td>
<td>Sound Soap Cont. Broadband Noise/Noise Gate, Exercise 1 Due, Exercise 2</td>
</tr>
<tr>
<td>3</td>
<td>Interfacing with law enforcement and those not familiar with audio engineering. Expressing effectively what the “customer” can expect, written and verbally.</td>
<td>Exercise 2 Due, Quiz 1</td>
</tr>
<tr>
<td>4</td>
<td>Advanced audio analysis/restoration: spectrograms, multipressors, broadband noise reduction and steganography.</td>
<td>Advanced audio forensics, Project 1 Presented</td>
</tr>
<tr>
<td>5</td>
<td>Guest lecture via teleconference*.</td>
<td>Advanced cont. Exercise 3</td>
</tr>
<tr>
<td>6</td>
<td>Midterm</td>
<td>Exercise 3 due, The Conversation</td>
</tr>
<tr>
<td>7</td>
<td>The Conversation Discussed Ethics of audio forensics</td>
<td>Project 1 Version 1 Due, Quiz 2</td>
</tr>
<tr>
<td>8</td>
<td>Audio restoration: when preservation becomes remastering; when remastering becomes remixing. Final projects presented.</td>
<td>Project 1 Due, Project 2 Presented, Begin work on Project 2</td>
</tr>
<tr>
<td>9</td>
<td>Types of careers available with a background in forensics/restoration.</td>
<td>Project 2 Version 1 Due, Project 2 Cont.</td>
</tr>
<tr>
<td>10</td>
<td>Summary of course, review for exam.</td>
<td>Project 2 Due, Presentations Begin</td>
</tr>
<tr>
<td></td>
<td>FINAL EXAM, Finish Presentations</td>
<td>DATE TBD</td>
</tr>
</tbody>
</table>

*Ethics paper assignment presented; if no guest teleconference, the class will be used for research for the paper as well as a short in class project.
MDIA 486: Audio Restoration and Forensic Analysis Weekly Lecture Outline

1. **Week 1**
   1. Go over syllabus
   2. What is audio forensics?
   3. Clarification and Analysis
   4. What is audio restoration/preservation?
   5. Preservation/Archiving
      1. Restoration
   6. What is audio surveillance?
      1. “Bugging”
      2. Why it’s done
      3. Who does it
   7. How entertainment production applies to these fields
      1. Music production and mastering
      2. Post-production mixing

2. **Week 2**
   1. Purpose of forensics:
      1. Clarifying voice, words etc
         1. Methods
      2. Authenticating
         1. Methods
      3. Detection of steganography
   4. Voice Print Analysis
      1. Examples
   2. Purpose of restoration:
      1. Preserving audio
         1. To what degree sound is modified
         2. Improving sound quality and longevity
         3. Priority of quality/intelligibility
      4. Why is it used?
         1. Preserve art
         2. Preserve famous speeches
         3. Wax cylinders
         4. Reels, records, tape etc
      5. Examples

3. **Week 3**
   1. Interfacing with Law Enforcement
      1. Military-like structure
      2. Explaining in non-technical terms
      3. Keeping respectability
1. Having technical knowledge to act as an expert
2. Not drawing conclusions
3. Preventing fallacies of logic due to lack of technical knowledge
4. Prepared to face equipment issues
5. Confidentiality

2. Restoration environments
   1. Typically better knowledge of the field
   2. Prepared to justify why decisions were made
   3. Confident to have name permanently attached to work

4. **Week 4**
   1. Advanced audio forensics
      1. Broadband noise reduction
      2. Finite noise reduction
      3. Voice isolation
      4. Removal of cover sounds
      5. Detection of phase anomalies
      6. Steganography
   2. Advanced audio restoration
      1. Extremely noisy recordings
      2. Damaged media
   3. Tools used
      1. Equalizers
      2. Multipressors
      3. Broadband noise filters
      4. Spectrum Analyzers
      5. Spectrograms
      6. Appropriate monitors and AD/DA converters

5. **Week 5**
   1. Guest Teleconference and discussion regarding the importance of networking for professional development and reliability

6. **Week 6**
   1. Midterm and begin *The Conversation*

7. **Week 7**
   1. Ethics of Audio Forensics
      1. Nature of the work
         1. For law enforcement
         2. Typically confidential
         3. Clear background checks
         4. Act as an expert witness
         5. Disallow false conclusions
         6. Nanny cam Case (poor analysis resulting in innocent conviction)
      2. Technical limitations
1. Technical advice regarding purchases
3. Divorce self from work
4. Committed to solving problems
5. Shut out harsh material
6. Does not draw conclusions
7. Refuses to let bias influence work

8. **Week 8**
   1. Ethics of Audio Restoration
      1. Identify needs of the customer
      2. Work to meet personal goals
      3. Clearly identify duty
      4. Express limitations if any exist
      5. Work to meet needs of customer
   6. Self-control
      1. Do not allow preservation become restoration
      2. Do not allow restoration become remastering
      3. Do not allow remastering become remixing

9. **Week 9**
   1. Careers with a background in Forensics/Restoration
      1. Audio analyst
         1. local police
         2. state police
         3. federal government
         4. law firms/independent
      2. Audio preservation/restoration
         1. libraries
         2. archives
         3. record label
         4. Intelligence analyst
            1. SIGINT/COMINT
   10. **Week 10**
      1. Students begin presentation of final project with a limited amount of “cross examination” by their peers and the professor. This exercise is meant to challenge the student and allow them to explain their process and justify
Finally, an outline of the lab section will be provided to the class. Allowing students to see a general outline of the lab sections and all related practical exercises, they will be able to begin formulating questions in regards to later material early on in the quarter. Furthermore they will be able to decide if this course is one they feel they are both prepared for and interested in pursuing.

**MDIA 486: Audio Restoration and Forensic Analysis**

**Weekly Lab Outline**

1. **Week 1**
   1. Go over topics of lab sections
   2. Using Pro Tools to make your work repeatable/organized
   3. Intro to basic tools
      1. SoundSoap Pro
      2. Spectrogram
   4. Demonstration
      1. Analyze the noise as a group
      2. Careful Listening
      3. Students express what they hear as the problem
      4. Spectrogram
         1. What does hum look like
         2. What does a crackle look like
   5. SoundSoap tools to solve the noise
      1. SoundSoap Spectrogram
      2. Hum & Rumble
         1. Example
      3. Click & Crackle
         1. Example
   6. Exercise 1
      1. Hum & Rumble/Click & Pop exercise
      2. Due by start of next lab meeting

2. **Week 2**
   1. Listen to Exercise 1 as a group
      1. Each student tells their process
      2. Expresses issue that was easiest/hardest to resolve
2. Demonstration
   1. Analyze the noise as a group
      1. Careful Listening
      2. Students express what they hear as the problem
      3. Spectrograms Revisited
   3. What does broadband noise look like
   4. What does noise that a noise gate would help look like
   5. SoundSoap Cont.
      1. SoundSoap Spectrogram
      2. Broadband Noise
         1. Example
      3. Noise Gate
         1. Example
   6. Exercise 2
      1. Broadband noise/Noise gate curable
      2. Due by start of next lab

3. **Week 3**
   1. Listen to Exercise 2 as a group
      1. Each student tells their process
      2. Expresses issue that was easiest/hardest to resolve
      3. Offer tips regarding any over-arching problems noticed
   2. Issue in-class Quiz-exercise that is due by the end of class (no more than 1 hour)

4. **Week 4**
   1. Advanced audio forensics and restoration
      1. Finite noise reduction
         1. Example
      2. Voice isolation
         1. Example
      3. Removal of cover sounds
         1. Example
   2. Tools used
      1. SoundSoap
      2. Wave Surfer and other spectrograms
   3. Equalizers
      1. Notch
      2. Bandpass
      3. Lowpass/Highpass
      4. Importance of Butterworth filters in especially bad cases
   4. Compressors/Multipressors
   5. Spectrum Analysis
3. **Project 1 Presented**  
   1. Students assigned partner  
   2. Assets given to students, either forensics or restoration  
   3. No partners have both forensics or restoration  
      1. At least 2 assets for each discipline  
      2. Told about the importance of peer review  
      3. Expected to write 1 page review of partners work  
         1. Covers what was done best  
         2. What might the student change if it was his/her work  
         3. Expected to provide short list of suggestions given to partner

5. **Week 5**  
   1. Demonstration  
      1. Quick demonstration of severe analysis/restoration example from top to bottom  
      2. Illustrates proper presentation of a very complicated session  
   2. Discuss importance of being able to repeat work  
   3. Discuss importance of others being able to repeat work in forensics  
   4. Exercise 3  
      1. Multi-problem recordings (perhaps wax cylinder exercise)  
      2. Reviewed by project partner during last 15 minutes of class

6. **Week 6**  
   1. Exercise 3 due  
   2. Written partner review of Exercise 3 due  
   3. The Conversation

7. **Week 7**  
   1. Students expected to have first version of project done  
      1. Submitted to prof  
      2. Reviewed during class by partner  
   2. Quiz-exercise 2 “Exercise 3 Redux”  
      1. Express importance of working on a short time table  
      2. Students only gain full credit for Exercise 3 by enhancing their recordings by following prof notes which will be handed to students, must be finished within final hour of class

8. **Week 8**  
   1. Project 1 Due  
   2. Project 2 Presented  
      1. Students use same partner  
   3. Assets given to students  
   4. Student is given different forensics or restoration example than that their
partner used for Project 1

5. Project expectations
   1. Expected to write 1 page review of partner's work
      1. Covers what was done best
      2. What might the student change if it was his/her own work
      3. Expected to provide short list of suggestions given to partner

6. Students begin work on Project 2

9. **Week 9**
   1. Students expected to have first version of project done
      1. Submitted to prof
      2. Reviewed during class by partner
   2. Continue work on Project 2 after receiving verbal feedback from partner; professor introduces other plug-ins that may be useful such as the Wave's Restoration Bundle

10. **Week 10**
    1. Project 2 Due
       1. Each person presents what they feel is their strongest Project (1 or 2) with a before and after, and quickly discusses problems noticed/methods used to cure the problems


8.2 In-depth Weekly Breakdown

As briefly discussed earlier, each week this class will consist of one two-hour lecture and one two-hour lab section. These two sections help to provide students equal parts theory and practice, furthermore consecutive lectures and labs allow students to not only achieve short-term educational goals within the week but also learn major themes of the course over multiple weeks. Found in the appendix section of this work, as well as on www.JSteinhour.com, are example Power Point slides like those used during the lecture portion of each week as well as a few example audio files like those to be used in the lab section. These clips are only examples and should be viewed as such for professors when selecting and creating clips for their class.

8.2.1 Week 1 – Introduction and Administrative

During the first class meeting of the quarter students will be handed the two previously mentioned documents: a syllabus and a weekly outline of the course. As is normal in most undergraduate courses, the syllabus will be discussed as will the course outline during the start of the class. Also, all questions the students have regarding administration portion of this course (attendance, grading etc) will be addressed at this time.

Instead of dismissing class after addressing all the students' questions, an introduction to audio forensics and restoration will begin immediately. In doing so, students will be able to begin thinking about the core concepts and methodologies that
will be later discussed in this course. The reasoning behind this decision is the students will be able to come to the second-class meeting, a lab section, with questions about the basic audio principles used in the course. These questions will likely be answered during the first lab section but those that aren't will be addressed during the class. This lab section will also review the basic tools to be used throughout the quarter, offer a short reintroduction to Pro Tools (specifically session organization), introduce the first two modules of SoundSoap Pro as well as provide the students their first practical exercise which is due at the beginning of the following lab section.

8.2.2 Week 2 – Differences and Similarities

During the second week of this ten week quarter system course, students will be presented with in depth material regarding one of the core concepts of this course: the interconnectivity between forensic audio analysis and audio restoration. These two fields will be analyzed side by side allowing students to examine the similarities and differences between the two. This lecture, like those of many other weeks, will have a heavy focus on discussion within the class.

The lab portion of this week's classes will address the final two modules of SoundSoap Pro: broadband noise reducer and noise gate. These two features were left to be covered last because not only are they the most sophisticated and difficult to use correctly, their uses in forensic audio analysis can differ slightly from their uses in audio restoration. The settings used for these two tools relies on their specific use;
although similar, the exact process and finished product differ at times between forensic audio analysis and restoration as noted above. The difference in the use of these last two features of SoundSoap Pro offer students an example of this separations between audio restoration and forensics thus allowing them to experience firsthand the adaptations to their work they must make depending on the situation.

8.2.3 Week 3 – Interfacing with the Customer

An important and previously mentioned aspect of audio preservation is interfacing with the customer. This is true whether this customer is the agency for which the analyst is employed or a record label requesting the restoration of a song to its former glory. The engineer must be able to clearly communicate with their client. Important points of discussion are the expectations of the customer (and how realistic those expectations actually are), a timeline for the project and typically a final report including the general process undertaken and any conclusions drawn if necessary. This type of communication is used in both forensic audio analysis and audio restoration with unique differences that will be explored fully through this week's lecture section.

The lab section of the third week will begin with the submission of the second exercise at the start of class. Also, students will be given general suggestions regarding the first exercise turned in during the previous lab section. This advice will cover any general issues that are present with a large portion of the class or anything that is particularly troublesome for an individual. During this class meeting, students will be
given their first quiz. This is not a traditional pencil and paper quiz but rather a practical exercise similar to the two previous lab assignments. Students will have the remainder of the class period, approximately an hour and a half, to complete the quiz.

This relatively short timetable within which the students must work replicates a very common real-world occurrence: the “rush job.” Students must work quickly but not sacrifice the quality of their work. In order to best facilitate their success on this matter, students will be presented with audio problems that should be relatively easy for them to identify as well as correct if they have applied themselves during the previous weeks. Students should be graded on a curve for this quiz, as this is likely one of the first times in an in audio production course they will be forced to adhere to a very short time table.

8.2.4 Week 4 – Advanced Issues

At this point in the quarter students will begin to understand and practice the use of tools other than Sound Soap Pro for their forensic audio analysis and restoration needs. Some of tools that will be covered and used include: equalizers, compressors, multipressors, broadband noise filters, automated noise filters, spectrum analyzers and spectrograms. All of the aforementioned tools will be used by the students in the form of software (either plug-ins or standalone programs). Some tools like equalizers, compressors and spectrum analyzers will also be demonstrated and used in their analog form. Not only will the tools used to enhance sound be discussed during this
week, those that are used to monitor, capture and store recordings will also be covered. Specifically we will discuss what to do when working on a limited budget like many forensic analysts are forced to do as well as how to make purchases that will be beneficial in the distant future not just for the immediate case at hand. Budget constraints will perpetually plague the forensic audio analysis and restoration engineers that work for the government. Students will learn that it's the creative use of the tools on hand and effective justification regarding a purchase (when necessary) that will allow them to overcome these obstacles.

The lecture section of the fourth week will focus on presenting the tools to students with examples of their use whereas the lab will focus on the students using these tools themselves. Included in this lab section will be 3 examples/practice sounds of challenging forensic audio analysis and restoration tasks. These audio recordings will be presented to students who will then work independently with their only resource being a partner (assigned alphabetically or in some random fashion) after the initial introduction of each exercise. This randomly assigned partner will also be the person with whom they work on the two major projects of the quarter. The specifics of this project can be found on the webpage that corresponds to this week, found on www.JSteinhour.com. In general, the two projects are actually each one part of a large final project that is undertaken over the last few weeks of the course by a team of students that work together to provide one another written notes and reviews so as to better one another through peer review. Peer review is an integral part of forensic
audio analysis and restoration undertaken professionally, as such it is key for students to work under similar conditions on this particularly difficult task.

8.2.5 Week 5 – Guest Teleconference

Hearing from one or more professionals about their field is an aspect of media arts and studies education that assists students in better knowing what to expect from the professional world. A guest lecturer (or if a physical presence is out of the question, a teleconference from a professional) in both forensics and restoration will be very important for students. The fifth week of the quarter was chosen so students will have enough time to familiarize themselves with these fields but early enough students will still benefit academically from the lecture.

The lab portion of this course will continue in the same vein as the previous week and offer additional examples to students of advanced problems they may encounter in the field. Also a third exercise will be assigned to students that will be due at the start of the following lab section. This exercise will be particularly challenging and will act as the practical side of the students' midterm examination. Students will not be allowed to ask the professor for advice but they will, however, be able to use their previously assigned partner for assistance for a short time.
8.2.6 Week 6, 7 and 8 – Midterm, The Conversation and Ethics

This first meeting of week 6 includes the more traditional midterm examination that students will complete during the first one and a half hours of class. During the final half hour of the lecture meeting students will begin viewing The Conversation, Francis Ford Coppola's critically acclaimed thriller, as a way to begin our discussion of ethics involved in forensic audio analysis and restoration.

Because of this film's length it will continue in to the following lab meeting, at the start of which Exercise 3 will be due. The reason this film was chosen for viewing is because it deals specifically with audio enhancement like that done in forensic audio analysis. Crucially, the protagonist of The Conversation falls in to many of the ethical pitfalls that will be outlined in the coming weeks. The film also allows for discussion regarding the tools used in the film and how they are similar or different from real tools used today and those that would have been used at the time of filming.

Week 7 will focus on the discussion of the ethics of audio forensics. Students will be encouraged to offer their opinion on scenarios and provide scenarios of their own for everyone to discuss. Topics during this discussion will include when to avoid catering to superiors, dealing with personal bias and knowingly allowing false conclusions to be drawn. Many additional ethical topics are up for discussion and should be tackled as the professor sees fit.

Week 8 somewhat mirrors Week 7's discussion of the ethics of forensics but is geared toward the ethics of restoration. This week will also include some of the
academic and professional research that has been undertaken regarding the degree to which recordings should be restored. There are different schools of thought that were originally put forth by William Storm in 1980: should recordings be restored to their original quality or brought to a modern commercial standard (Orcalli 2). Another topic to be examined is how we as a society decide which recordings should be preserved and which should not. Professors could also discuss the effects budgets have on recordings that are not viable for commercial re-release.

8.2.7 Week 9 – Careers

This week’s discussion is primarily focused on the types of careers in forensic audio and restoration. It may be difficult for students to initially identify all of the different organizations and companies that undertake this type of work – for me personally this was one of the most difficult areas to research. Students should also be presented with some anecdotal experience from the professor as well as suggestions regarding writing cover letters and resumes for these jobs.

In addition, students should be informed about the practical experience gained through internships. This is one of the most important ways to learn the intricacies of forensic audio analysis and directly contributed to my career in this field.

8.2.8 Week 10 – Final Exam and Final Project

The final week of the course will be dedicated to students presenting one of
their two final projects (either the forensics or restoration challenge). After students present their project they will then submit to the professor the written supplementary report that outlines their process and any conclusions they have drawn. At that point the student will then be “cross examined” by their fellow students and professor regarding the choices they made. This is to act as a type of mock trial for the student and offer them a chance to express their knowledge while under a bit of pressure. Before the first trial in which I testified, my coworkers and I conducted this type of exercise. By doing so, I feel I was much more well prepared for the questions I was asked during cross examination, the testimony process and came in to the trial with more confidence than I would have otherwise.

9. Final Thoughts

Throughout my research and work in forensic audio analysis and audio restoration I have learned many audio engineering tricks and tools that I do not believe I would have otherwise learned. More importantly, however, I learned that audio production work is never one dimensional. Even if an engineer is recording what seems to be simple demo session, it could later prove to be an influential recording (like those of early blues legends Robert Johnson or Son House). My own study in this field has lead me to persue a career in forensic audio and video analysis at the Ohio State Highway Patrol.

This field of study is constantly evolving as new technologies and
methodologies are adopted. It is key for any university that wishes to adopt this type of course to keep themselves current and relevant with changes in the industry; this is also true in traditional audio production. Most importantly, universities should impart to their students a personal reverence for the impact sound recordings have on our society. I was given this chance at Ohio University, under the guidance of Professor Ashworth, and would like all student engineers to have this same opportunity.
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