Advances in Audio Restoration

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INTRODUCTION

Almost every audio recording that takes place today is done in the digital domain (Peitz & Waelbroeck, 2004). Audio content and its associated postproduction tools are much more complex than many people want to consider, and therefore settle for a simplified relationship with audio in their projects. Second, since the late 1980's high quality, well-produced audio has become decreasingly important, even in 'audio only' products. Digital MP3 files and other forms of converting sound into audio files, that can be easily copied and transported, were considered to be of greater importance than sound quality. This article will consist of two sections, first – what steps can be taken to maximize the likelihood that sound is recorded as clean or as accurately as possible. Secondly, the article will discuss tools that can be used to repair or remove imperfections (e.g., hiss, hum, noise, and buzz) from existing audio recordings.

BACKGROUND

The need for audio forensics is deeply related to the need to find the meaning in sound. Without meaning, there is no need for audio forensics. Audio restoration has been defined as a post-production task that edits and processes audio (Godsill & Rayner, 1998). The purpose of the editing and processing can vary. Audio restoration, or 'cleaning up the audio' is performed in countless ways using a variety of tools (Godsill, Rayner, & Cappe, 1996).

Audio forensics does not imply the preparation of sound for legal proceedings. While that may be one of the many purposes of audio forensics, the term is actually much broader and more inclusive. Audio forensics have been used in a number of high profile, public examples including the Watergate tapes, the Zapruder recording of the Kennedy assassination, homeland security (Owen, 2003), terrorism (Dickey, 2007), and in listening to black box recordings associated with airline malfunctions. However audio engineers and even non-professionals are increasingly using the technology in many endeavors including for example, the remastering of audio recordings, creating podcasts and even cleaning up the sound of a personal, home movie (Farid, 2009). These advances have occurred so rapidly that the field of forensic comparison sciences is currently undergoing a paradigm shift (Morrison, 2009) much like is occurring with DNA comparisons. In an attempt to standardize these listening experiences the International Telecommunications Union created a standard for audio quality assessment: PEAQ. Additionally, a 12 Step Methodology for Audiotape Authenticity (Owen, 2003) and Methodology Procedures for Audio Authenticity, are available through the Audio Engineering Society; an outline of steps to identify edits, alterations, and duplication in the audio portion of recordings. Relatedly, the Scientific Working Group on Digital Evidence (2012) is creating standards for the forensic examination of audio recordings that may serve to improve standards across the whole field of forensic audio examination.

Examples of Audio Forensics in Products

The first instances of audio forensics can be traced to WWII, when acoustic scientists attempted to identify enemy voices on radios or telephones. Their efforts were made possible by the newly invented sound spectrograph, a tool for graphing the frequency and amplitude of voice patterns. More currently, old record-

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ings are frequently uncovered that is the only piece of media connecting us to a time that may only be viewed through some photographs.

Audio restoration is important in any transfer of physical media into the digital domain. Cylinders, vinyl disks, magnetic tape, magnetic wire, etc. all contain substantial noise and artifacts that reduce the ratio of intended content to unwanted content (Mee & Daniel, 1990). The goal of audio restoration is to substantially alter the pre- and post-ratio of signal to noise (Schueller, 1991), usually due to decay in recordings over time or to restore speech or audio signals that have been distorted during transmission (Paulikas & Navakauskas, 2005).

Audio Dimensions and Word Length

Many people discuss audio sampling rates today but fail to recognize the often more important word length value. Word Length is also referred to Bit Depth but should not be confused with Bit Rate. Word length plays two critical roles in an audio files. First, word length contains the resolution of the quantized values. Digital audio file amplitudes can be quantized using integer values, such as 8 bits, 16, bits, or 24 bits. The number of bits in the word length represents the relative amplitude of each sample. The more bits in the value of relative amplitude, then the more distinction between each value in the sample (Chi-Min, Han-Wen, & Wen-Chieh, 2009). The more distinction between each value, then the greater the resolution of the range of dynamics. The range of dynamics is the critical 'energy distance' between the loudest and softest sound in the audio file. When an audio file has a great range of dynamics, then faithful reproduction of the delicate aspects of a sound and it's associated harmonics is possible. So, while the sample rate is handling frequencies, the word length is busy controlling the relative amplitudes of those frequencies.

Digital Headroom

Before sound waves were digitized, recording equipment made analogous representations of the waveform on physical media. Those analogous representations known as 'analog' recordings typically had a very convenient characteristic as the waveform amplitude (energy) increased. Analog recorders would typically 'compress' or naturally soften the energy peaks and created an artificial representation of a wave higher than the physical capacity of the equipment. This characteristic is known as 'headroom'. There is no equivalent in digital audio. When recording in the audio domain it is important to keep the signal level somewhere well above the noise floor but comfortably below the clipping point, the point at which distortion begins to occur.

The Importance of using 24 bit files in Audio Forensics

Consider that the sound of a baby crying can be digitized in an 8 bit, 16 bit, or 24 bit digital audio file. All other things being equal, the 24 bit audio file will contain more resolution and range of dynamics compared to the other files. Essentially this process describes the ratio of intended versus unintended sound. Audio engineers sometimes refer to this as the signal to noise ratio. It is important to note that 24 bit audio files give the audio 'Forencian' more granular information with which to perform delicate algorithms designed to separate the noise from the wanted signal (Hu & Loizou, 2007). For example, data algorithms often used MP3 encoding are designed to eliminate low-level information, but in audio forensics this low-level information is often exactly what audio forensic users are interested in – the quiet sound or the whispered conversation.

Host Digital Audio Tools

DAW Host Software

There are currently dozens of digital audio workstation (DAW) software products available for diverse hardware and operating system environments. These tools include; Cakewalk Sonar, Cubase Nuendo, Avid Pro Tools, Apple Logic, Propellerhead Record, Cuckoos Reaper, among others. The purpose of DAW software is to aggregate multiple disparate recordings and blend them into a consumable format. While DAW software gets the lion share of attention in audio production and post-production, only certain specific audio restoration tasks can be performed in DAW software.

Audio Forensic Host Software

Receiving somewhat less attention than DAWs, audio forensic hosts have grown in popularity due to decreases