4 DIGITAL AUDIO RESTORATION

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Abstract: This chapter is concerned with the application of modern signal processing techniques to the restoration of degraded audio signals. Although attention is focussed on gramophone recordings, film sound tracks and tape recordings, many of the techniques discussed have applications in other areas where degraded audio signals occur, such as speech transmission, telephony and hearing aids.

We aim to provide a wide coverage of existing methodology while giving insight into current areas of research and future trends.

4.1 INTRODUCTION

The introduction of high quality digital audio media such as Compact Disk (CD) and Digital Audio Tape (DAT) has dramatically raised general awareness and expectations about sound quality in all types of recordings. This, combined with an upsurge in interest in historical and nostalgic material, has led to a growing requirement for restoration of degraded sources ranging from the earliest recordings made on wax cylinders in the nineteenth century, through disc recordings (78 rpm, LP, etc.) and finally magnetic tape recording technology, which has been available since the 1950's. Noise reduction may occasionally be required even in a contemporary digital recording if background noise is judged to be intrusive.

Degradation of an audio source will be considered as any undesirable modification to the audio signal which occurs as a result of (or subsequent to) the recording process. For example, in a recording made direct-to-disc from a microphone, degradations could include noise in the microphone and amplifier as well as noise in the disc cutting process. Further noise may be introduced by imperfections in the pressing material, transcription to other media or wear and tear of the medium itself. We do not strictly consider any noise present in the recording environment such as audience noise at a musical performance to be degradation, since this is part of the 'performance'. Removal of such performance interference is a related topic which is considered in other applications, such as speaker separation for hearing aid design. An ideal restoration would then reconstruct the original sound source exactly as received by the transducing equipment (microphone, acoustic horn, etc.). Of course, this ideal can never be achieved perfectly in practice, and methods can only be devised which come close according to some suitable error criterion. This should ideally be based on the perceptual characteristics of the human listener.

Analogue restoration techniques have been available for at least as long as magnetic tape, in the form of manual cut-and-splice editing for clicks and frequency domain equalization for background noise (early mechanical disk playback equipment will also have this effect by virtue of its poor response at high frequencies). More sophisticated electronic click reducers were based upon high pass filtering for detection of clicks, and low pass filtering to mask their effect [Carrey and Buckner, 1976, Kinzie, Jr, and Gravereaux, 1973].[1] None of these methods was sophisticated enough to perform a significant degree of noise reduction without interfering with the underlying signal quality. Digital methods allow for a much greater degree of flexibility in processing, and hence greater potential for noise removal, although indiscriminate application of inappropriate digital methods can be more disastrous than analogue processing!

Some of the earliest digital signal processing work for audio restoration involved deconvolution for enhancement of a solo voice (Caruso) from an acoustically recorded source (see Miller [Miller, 1973] and Stockham *et al.* [Stockham et al., 1975]). Since then, research groups at Cambridge, Le Mans, Paris and elsewhere have worked in the