DISORDER SOUNDS IN ORDER
Theory and Practice in Instrument Simulation
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ABSTRACT: The role of disorder as a constituent of musical sound is investigated, and its importance is evaluated. The paper identifies different types of disorder in musical sound, including disorder in the onset of partials, random changes in amplitude and frequency during sustain, differential decay of partials, and tuning disorder. The effects of these disorder types upon the perception of musical instrument sounds, played individually and in ensemble, are discussed. The paper includes consideration of the implications of disorder for simulation, and some synthesis compromises used by the authors are described.

Introduction

This paper explores the concept, occurrence and simulation of disorder in musical instrument sound. It asks what are the elements of this disorder, what are their perceptual effects, and what are the contributions of various types of disorder to the creation of satisfying musical instrument tone.

The sounds of all acoustic musical instruments are characterised by varying degrees of disorder. The presence of disorder makes a musical sound perceptually unpredictable, since the quality of the parent instant does not follow in orderly progression from that of the moment before. The disordered development and progression of the sound continually confounds expectation and therefore attracts and holds the listener’s attention. Provided disorder is limited in extent, it is not only an inevitable but a welcome characteristic of acoustic sound.

In simulated sounds, it is possible to produce effects from which disorder is absent, although the novelty of such sounds quickly renders them boring. However, it is the perceptual role of the disorder which is important for the simulation. Not necessarily the inclusion of exactly the same disorder patterns as in the original. Thus the theory of “disorder substitution” has evolved, whereby in some instances the unpredictability role of the original disorder pattern can be musically satisfactorily fulfilled by alternative, generally easier-to-generate disorder patterns in the simulation. Simulation experiments have been carried out using the Bradford Musical Instrument Simulator (BMIS) (1), and examples of the practical application of disorder substitution appear in the paper.

Disorder also makes a major contribution to the perception of ensemble, because the individualistic behaviour of each sound within the complex whole identifies the totality of sound as the product of many different sound sources.

Some examples of the occurrence and simulation of disorder in musical sound

a. disordered onset of partials

Waveform characteristics during the attack period of a musical instrument tone have long been known to have an importance out of all proportion to the relatively short duration of that attack period in determining the way in which the note is perceived. Disorder may be seen as a significant contributory factor to this importance, with development of partials during the attack period being non-uniform both in amplitude and in frequency. Partial’s amplitude envelopes can vary widely both in attack shape and in total attack time. A good example is the behaviour of a gemshorn organ pipe (fundamental frequency 623): the second partial attack is 28ms to the peak of a large overshoot, and takes a further 160ms to “settle” into sustain state,

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while the fundamental takes 60% - much longer than any of the other partials - to reach its maximum amplitude. This order of differential development is typical of the diapason family of stops of which the gemshorn is a member, and must be preserved in imitation in order to produce a perceptually acceptable example of a tone within that timbre group. However, so long as the attack characteristics of the most prominent partials are retained, a simplified treatment can be applied to the attack disorder of the lower amplitude partials, without musically unacceptable detriment to the sound.

Differences in partials' amplitude onset rates and total attack times occur not only between timbres but across the pitch range of individual organ stops and instruments. Such variation in temporal differentials contributes to the perception of ensemble, as can be demonstrated experimentally.

Wild fluctuations in frequency can occur during onset of partials, before resonance is established. The thrilling nature perceived of organ reed stops owes much to the erratic frequency behaviour of the reedpipe combination during initiation (2). Sounds with similarly arresting perceptual effects can be created by starting some partials sharp and others flat, so that they clash against each other during attack and both contaminate the pitch of the sustained note. An approximation to the bow-scrape effect on a violin may be simulated experimentally by wildly varying frequencies during the attack period.

In many instruments, sound dynamic can be varied under player control (by blowing harder or more slowly, or pressing more gently, and so on). This alters the number of partials an sound and also overall attack times, which tend to shorten as the intensity of the initiative event increases. It also changes the patterns of disorder between partials, particularly at the start of the note. A simulation must therefore match a range of disorder patterns to the different dynamic levels under player control.

Unpitched noise elements, consisting of many unrelated partials, feature in many instrument sounds, and are particularly noticeable as part of imitation sound. The familiar and characteristic thumps of the piano hammer is, like the sound it initiates, modified by the rate of key depression. The burst of wind noise at the start of an organ noise is of surprising prominence for such a relatively quiet sound element. This is partly due to the disordered nature of noise components and partly because it is heard before true resonance begins to develop (3).

b. disorder in frequency and amplitude envelopes during sustain

The sound of wind and bowed instruments can be sustained by the player by continued application of the energy source - air from the lungs, air from a wind-sack or wind chest, or movement of a bow. It is inevitable that the application of energy from such sources will not be completely uniform. These variations cause random differential changes in both amplitude and frequency envelopes of partials during sustain. Frequency movements cause mutual phase changes between partials, and amplitude fluctuations are often discernible not only as variations in loudness but also in slight but continuous changes to the tonal spectrum. The rate and range of such instability vary with timbre and with pitch, throughout the duration of the note. Although ideally each partial should be individually affected by instability, simulation data and resources can be reduced by randomising partials on a group basis. Noise components of sustained sound are also subject to the same influences of instability, which cause fluctuations in both the spectral content and the loudness of the noise.

c. disorder during decay

Disorder during decay has in many ways a "mirror image" similarity to the elements of disorder which occur during attack, although amplitude envelopes do tend to be less disordered in decay than during attack because they are the product of successive degradation and not of an initial complex excitation event. For instruments which sustain sound, all partials will begin their decay from the same time point, that is, when the sound-sustaining energy source - such as the air supply - is removed. These decays are generally quite short. In instruments which do not sustain sound, for example in attack and plucked instruments, the relationship between the partials' amplitude envelopes during decay - the product of the instrument's resonant structure - is of primary importance in timbre perception.
d. tuning disorder

Polyphonic instruments are in practice seldom precisely in tune across the frequency scale, which becomes apparent when chords rather than single notes are played. Tuning is similarly imprecise when many acoustic instruments or many organ pipes sound together, and there are inevitable small deviations between unisons and octaves. Such tuning disorder makes a significant contribution to the perception of ensemble, as can be readily demonstrated by removing disordered tuning from a simulation. The effect of tuning upon the perception of timbre is also of interest - an organ reed chorus can be rendered perceptually "grittier" or "softer" by an increase in the de-tuning within and between its component stops.

Effect of acoustic upon the perception of disorder

In a reverberant acoustic, the listener hears not just the direct sound but also delayed indirect sound bouncing back from many points in the building. Besides amplifying the perceived sound, and altering its timbral balance and lengthening its decay, this effect will elongate the length of time for which the disordered attack transient characteristics are apparent. Where there is a clash of frequencies at the start of a note, the off-tuned elements will overlap the sustain period of the note so that the sounds are heard not only in successive contrast but in concurrent conflict. A related effect has been encountered in experiments with the organ wind chest frequency sag effect (3); whereas in a dead acoustic the frequency drop and recovery can be fairly fast, in a reverberant acoustic the successive pitch changes run one into another, so very slow rates of frequency drift must be employed to avoid unacceptable frequency clash.

Conclusion

Disorder is an important and characteristic element of musical instrument sound. Its perceptual role of unpredictability can often be fulfilled successfully in simulation by alternative simpler patterns of disorder.

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References

