Abstract

This study aims at defining reliable acoustic cues for the measure, characterization and prediction of the acoustic comfort of air-treatment systems (ATS). To meet customers’ expectations, industrial products tend increasingly to follow a process of “sound design”. In this process, the perceptual evaluation of sound quality is a necessary step to define acoustic specifications. In this context, this study aims at defining the main perceptual attributes of the sound of air-treatment systems in order to predict users’ preferences. The timbre space of a sound dataset extracted from a large recording database was thus identified through a similarity experiment where participants were asked to rate the resemblance between each pair of sounds. The results of this experiment were analyzed with a Multidimensional Scaling (MDS) method in order to extract the main perceptual attributes. Finally, these attributes were linked to relevant audio features through a regression method in order to define a reliable computable metric of acoustic comfort. This study was conducted through the Vauteur Air² project supported by OSEO.

Similarity scaling experiment

Goal: Whereas it is difficult for a listener to identify a sound’s most relevant acoustic features, it is much easier to rate how much 2 sounds of the same kind are different from one another

Stimuli:
16 loudness-equalized monophonic sounds = 16 different ATSs

Apparatus:
– GUI Labview 2010
– Interface audio RME Fireface 800
– Casque audio Sennheiser HD650

Procedure:
Each possible pair of sounds (120 pairs) is presented to the listener who has to rate its similarity with a slider on a continuous scale

MultiDimensional Scaling analysis [1]

Context:
– Similarity matrix: distances between the sounds = perceptual similarities
– N element in a common geometrical space ⇒ N − 1 dimensions required

Goal:
Model all distances with a space of much lower dimensionality, (2 or 3)

Models:
– MDSCAL - single model
⇒ Rotationally invariant space
– INDSCAL - weighted model [2]: applies weightings to the dimensions
⇒ The space is no longer rotationally invariant
⇒ The dimensions are perceptually meaningful

MDSCAL model

\[ d_{ij} = \sqrt{\sum_{r=1}^{R} (x_{ir} - x_{jr})^2} \]

INDSCAL model

\[ d_{ijn} = \sqrt{\sum_{r=1}^{R} w_{nr} \cdot (x_{ir} - x_{jr})^2} \]

Results

Psychoacoustic descriptors [3]

<table>
<thead>
<tr>
<th>Dim. 1</th>
<th>Dim. 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spectral centroid (perceptual modeling)</td>
<td>r(df=14) = -0.36</td>
</tr>
<tr>
<td>Spectral Spread (perceptual modeling)</td>
<td>-0.61</td>
</tr>
<tr>
<td>Sharpness</td>
<td>-0.28</td>
</tr>
<tr>
<td>N(1)</td>
<td>0.84</td>
</tr>
<tr>
<td>N(2)</td>
<td>0.89</td>
</tr>
<tr>
<td>N(1) + N(2)</td>
<td>0.91</td>
</tr>
</tbody>
</table>

Conclusions & further work

Conclusions:
– The MDS analysis of perceptual distances measured through a similarity scaling experiment raised a 2-dimensional timbre space
– Correlation calculations indicate that these 2 dimensions correspond respectively to the loudness in the two first Bark bands (i.e. between 0 and 200 Hz), and to sharpness

Further work:
– The perceptual dimensions identified here and their associated psychoacoustic descriptors need to be included into ATS acoustic comfort modeling
⇒ Perceptual experiments aiming to measure hedonic preferences among the sounds.

Références