PREDICTION OF SPEECH INTELLIGIBILITY ALONG UNDERGROUND PLATFORMS USING A WEB BASED MODEL

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Dance, Stephen
Acoustics Group, FESBE, London South Bank University, London SE1 0AA.dances@lsbu.ac.uk

ABSTRACT

Over the last 5 years a computer prediction model based on a web browser has been developed, www.whyverne.co.uk; first to predict sound levels in rooms, followed by early decay time and reverberation time. Now Speech Transmission Index (STI) can be calculated for many identical sound sources in any type of room with or without noise control. Comparisons of sound propagation and early decay time in a hypothetical and a scale model of an underground station were undertaken for one and many sound sources. Next, the web model predicted actual STI measurements taken on a London Underground platform. Finally CATT-Acoustic was used to predict the speech intelligibility on the station platform. The predictions by both models were within 0.05 STI, or 1 limen of the measured STI values along the length of the platform, although the CATT-Acoustic model was more accurate, the web model was significantly quicker at predicting the results.

INTRODUCTION

The aim of this research was to develop the web model, CISM, so that it was capable of predicting speech intelligibility on Underground platforms from multiple identical sound sources. CISM is freely available on-line and capable of predicting 9 receiver positions, in a room with fittings or various noise control methods [1] from up to 18 sound sources. It should be noted that source directivity of the speaker was not considered, although this is to be simulated in the next version of the model, based on the Windows model [2]. To give a comparison the commercial software CATT-Acoustic v8.0 was used to predict SPL, RT, STI and RASTI in the rooms [3].

The benefit of the CISM model is that it predicts each receiver in a few seconds, rather than a few minutes as in the case of CATT [1]. The accuracy of the models was assessed against predictions from CATT-Acoustics, and measurement taken using the MLSSA system in real spaces.

CISM MODEL

CISM is an image source based model, capable of modeling multiple directional sound sources in rooms with fittings near the floor and/or ceiling, with rectangular absorptive patches on any of the six walls and total absorptive rectangular barriers in the room. CISM can predict sound pressure level and reverberation time in each octave band, each band being processed separately. This model can be learnt in 5 minutes without any prompting, assuming an undergraduate level of understanding of acoustics, as established by the MSc Architectural Acoustics students. The noise control aspects of the web model take approximately 10 minutes to master, based on a sample of six students [4], see Figure 1.

To predict STI it was necessary to make various amendments. To wit, simultaneous processing of all 6 octave bands, associated changes in the reflection order, introduction of background noise levels, the STI/RASTI calculation itself and the necessary room description [5]. The model uses EDT to calculate reverberation in the room.

The reflection orders, one per octave band, were based on a 99% energy discontinuity [6]. The largest of these was used as the reflection order, contributions beyond each octave’s reflection order were ignored. This aspect of the web model had to be reduced to a fixed 14 reflections, as Javascript code is limited compared to native executable code.
HYPOTHETICAL INVESTIGATION

A typical tunnel was predicted, 120m long, 6.5m wide and 4m high, with hard reflecting surfaces, $\alpha = 0.05$. The tunnel entrances were considered to be completely absorbing and 3m by 3m in dimension. The model was run for 1 sound source, half way down the platform positioned against the wall at a height of 3m, (50,0.3,3). The model was rerun assuming multiple identical omni-directional sources at 10m intervals along the platform. One receiver was positioned near the tunnel entrance, (5,4,1.5) and three were positioned near the middle of the space (50,4,1.5), (55, 4,1.5) and (60,4,1.5), see Figure 2. Parameters predicted were RT15 and STI.

Figure 1. The Web Model CISM, available at www.whyverne.co.uk/acoustics

Figure 2. CATT-Acoustic model of a hypothetical underground platform
With one sound source the CATT-Acoustics model predicted a significantly higher RT than CISM, see Figure 3. However, when all 10 sources the difference became marginal, 18% across the frequency range. This shows the limit of web modelling, as not enough reflection could be considered in this reverberant space to model the sound field fully for one sound source. This is reflected in the comparative run-times of the models: 6 minutes for CATT and 6 seconds for CISM for 1 source. When all ten sources were considered: 1 hour 40 minutes verses 57 seconds.

When considering STI the predictions were in agreement for the receiver near the tunnel entrance, far from the single sound source, see Figure 4. The STI improving near to the source, however there was a 0.10 difference in STI between CISM and CATT for the single source. When 10 sources were predicted CISM predicted a general reduction in STI, 0.04. Near the tunnel entrance the STI predicted by CISM improved. However, for CATT large differences in predicted STI were seen, the highest values, 0.72, occurring directly opposite a loudspeaker compared to 0.32 near the tunnel entrance.

SCALE MODEL INVESTIGATION
Based on measurements taken by Yang [7] in a 1:16 scale model, see Figure 5. CISM was used to predict the sound propagation and Early Decay Time along the length of the platform, see Figure 6.
It can be seen from Figure 6 that sound propagation was accurately predicted by CISM at all distances from the single sound source. EDT was less accurately predicted, although the trend and absolute final times were representative.

Figure 5 shows the source and 5 receiver positions in a scale model of an underground station.

Figure 6 Sound Propagation and Early Decay Time along the platform in Full Scale, 1kHz

**LONDON UNDERGROUND STATION**

Measurements were taken along the length of a London Underground station using MLSSA with 19 loudspeakers operating, see Figure 7. The measurements were taken when the station was closed to the general public. The platform is 120m long and circular in cross section, although modelled using a rectangular cross-section, with an equivalent cross section area by both models and using omni-directional sound sources, see Figure 8.

Figure 7 London Underground station with 5 microphone and 19 loudspeaker positions.
It can be seen, from Figure 9, that CISM predicted a marginally too high a STI, the STI limen is 0.05. The discrepancy in the STI predicted by CISM may be due to the use of RT_{sabine} in the STI calc, rather than RT calculated. The run-times were 4 minutes for CISM and 12 hours for CATT-Acoustic v8.
CONCLUSIONS
The Web model has shown that it is possible to quickly calculate the standard acoustical parameters in long enclosures with single or multiple sound sources. The model was shown to be between 60 and 100 times faster in terms of mathematical calculations than commercial models. Unfortunately, the limiting characteristic of Internet browsers, interpreted Javascript, reduced the number of reflections traced to 14 reflections. This effected the accuracy of RT predictions to a greater extend than sound propagation or early decay time. However, accurate RTs are essential for accurate Speech Transmission calculations. The Web model will be rewritten to exploit the Java system which can be loaded on top of the web browser. The accuracy achieved varies, with SPL and EDT relatively accurately predicted, but RT and STI require further work.

References