A new approach of drawing airport noise contours on computer based on Surfer

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Abstract: Noise contours are used to describe the extent of airport noise pollution and to plan land use around airports. The \(L_{WECPN}\) (weighted equivalent continuous perceive noise level) recommended by ICAO (International Civil Aviation Organization) is adopted as airport noise rating parameter in this paper. With the help of various mathematical models in the software Surfer, noise contours can be drawn automatically by the completed program in Visual C\++ Code. Corrections for thrust, velocity, atmospheric temperature, humidity and lateral ground attenuation are also considered in the new method, which can improve the efficiency of drawing contours. An example of its use for drawing noise contours of an airport in Zhejiang Province of China is proposed and the predictions and the measurements show agreements well.

Keywords: airport; noise contours; weighted equivalent continuous perceive noise level \(L_{WECPN}\); Surfer

Introduction

Airports are symbols of cities’ modernization. However, the noise produced by aircraft operations represents a serious environmental problem because of the increase of the type and number of aircrafts in airports and the expansion of the city itself. How to reduce aircraft noise level is a crucial task for aviation departments, environmental protection agencies, and specialists in designing and planning airports. Compatible land use around airport is an efficient way to control airport noise, and noise contours are adopted as tools for land use planning and accessing the reactions of communities around airports.

The aircraft noise pollution has become a serious problem since 1950s in the world and scholars have been searching the rating parameters that represent the characteristics of aircraft noise since then. In 1960s, many countries had their own specific method for quantifying and assessing aircraft noise in the vicinity of airports. The standard of aircraft noise for environment in China has been customized since 1983. A great deal of measurements of aircraft noise around several airports in Beijing and Shijiazhuang and social surveys on reactions of people around Beijing airport were taken. The experiments on subjective evaluation of aircraft noise were also carried out indoors and we customized “Measurement method of aircraft noise around airport” and “Standard of aircraft noise for environment around airport”. The results indicated that \(L_{WECPN}\) concludes not only aircraft noise level, number of flight operations, flight time durations but also reactions and subjective evaluation of people around airports. So it is an effective measure of aircraft noise not only in physical but also in psychological evaluation.

The research on drawing airport noise contours in China began in late 1980s, when the reference information in this field was rarely little and the rating parameter adopted was the day-night-average sound level \(L_{dn}\) which was inconsistent with the index recommended by “Standard of aircraft noise for environment around airport”. In 1990s the program of calculating noise contours for a certain airport was available in which a single interpolation was invited to satisfy its own needs. These programs cannot be put into practice extensively because of its poor compatibility. Research on models used for assessing aircraft noise abroad began relatively early and there are corresponding applied soft wares in environment impact assessment of airport. The validity of NEF (Noise Exposure Forecasting) system adopted by Canada in forecasting aircraft noise impact and predicting communities’ reactions has been proved in practice. Because their airport noise rating systems vary greatly from ours, we cannot draw airport noise contours by means of their models and soft wares directly. It is essential to set up an effective method of drawing airport noise contours, which is practicable in China.

Surfer is a contours drawing tool that is devised to apply in the research of geography initially. There are scholars searching its application in environmental protection work because of its predominance in contours drawing. Wei Wenfei has made use of Surfer to draw noise contours of Longyan in Fujian Province of China. The ADMS (Atmospheric Dispersion Modeling System) provided by CERCC (Cambridge Environmental Research Consultants) includes a tool to call Surfer, which can express the distribution of air pollutants in contours.

This paper presents a new method to draw airport noise contours in China, which utilizes various mathematical
models in Surfer and draws noise contours automatically in Visual C++ code. Noise contours can be drawn according to the topography, scheduled flights, airport types and departure or approach flight paths and so on. The new method can improve the efficiency of drawing contours and the predictions and the measurements show agreements well.

1 The introduction of software Surfer

Surfer is a contouring and 3D surface mapping program produced by Golden Software that runs under Microsoft Windows. The gridding methods in Surfer can produce regular data from random XYZ data and convert the data into accurate contours based on its interpolation mathematical models. It provides 10 traditional gridding methods for contour drawing: Inverse Distance, Kriging, Minimum Curvature, Modified Quadratic Shepard, Natural Neighbor, Nearest Neighbor, Shepard's Method, Polynomial Regression, Radial Basis Functions, Triangulation. Choosing suitable gridding method and setting the gridding parameters appropriately in terms of the data source and the drawing requirements, we can get the contour presentation we expect exactly. Therefore, the interpolation mathematical model is the core of drawing contours.

Besides drawing contours, Surfer has other functions as follows: (1) Surfer provides an impressive three dimensional display of the 3D surface; (2) surfer includes a full-featured worksheet similar to Excel for creating, opening, editing, and saving data files, which can process the original data completely such as calculating data statistics, sorting, performing data transformations and calculating based on column etc.; (3) exporting files in various formats, of which the DXF format files can be utilized by other software.

Surfer supplies six function modules: GRID (the gridding of original data), TOPO (drawing contours), SURF (drawing the 3D surface), VIEW (displaying on monitor), PLOT (drawing) and UTIL (utility functions). A brief introduction of GRID and TOPO that involved in this paper is given here. First of all, the original data (the coordinate value X, Y and the corresponding property value Z) cannot be used to draw the contours directly unless they have been interpolated with the GRID module. Gridding can convert random original data into regular data within the area the original data is dispersed according to one of its gridding methods (interpolation mathematical models). Then the TOPO module converts the data provided by GRID into accurate contours.

2 The basis of drawing airport noise contours

The study provides a method to draw airport noise contours automatically through calling Surfer in Visual C++ . Combining Surfer in Visual C++ to draw contours can avoid the poor compatibility caused by a single interpolation method. In practice, the method given in this paper can draw contours of not only noise levels but also distribution of pollutants in water and in air as long as the boundary conditions are defined.

2.1 Model of airport noise prediction

2.1.1 Principal descriptors of $L_{WECPN}$ and prediction formula

$L_{WECPN}$ is based on formula of the following form:

$$L_{WECPN} = L_{EPN} + 10 \log \left(N_1 + 3 N_2 + 10 N_3 \right) - 39.4.$$  \hspace{1cm} (1)

Where $N_1$ is the number of flight operations for aircraft from 7:00 to 19:00 hours on a given day; $N_2$ is the number of flight operations for aircraft from 19:00 to 22:00 hours on a given day; $N_3$ is the number of flight operations from 22:00 to the next 7:00 am; $L_{EPN}$ is the mean effective perceived noise level of a prediction point for $N$ aircraft operations on a given day, which is defined by

$$L_{EPN} = 10 \log \left( \frac{1}{N} \sum_{i=1}^{N} n_i \cdot 10^{0.1 \cdot p_{ij}} \right).$$  \hspace{1cm} (2)

Where $L_{EPN}$ represents single event effective perceived noise level for aircraft category $i$ in flight route $j$ of a prediction point; $n_i$ is the total number of aircrafts per 24-h day for aircraft category $i$ in flight route $j$; $N$ is the total number of aircrafts per 24-h day, namely $N = N_1 + N_2 + N_3$.

2.1.2 The calculation model of $L_{EPN}$

Single flight event effective perceived noise level is defined as follows:

$$L_{EPN} = L_{Amax} + 10 \log T_d/20 + 13.$$  \hspace{1cm} (3)

Where $L_{Amax}$ is the maximum A-frequency weighted sound level of a single event; $T_d$ is the time integration durations (the interval between the first and the last time that the A-weighted sound level is 10 dB less than the maximum A-weighted sound level). The meaning of $t_1$, $t_2$ shown in Fig.1.

![Fig. 1 The time integration durations and sound level $L_A$ of a flight event](image)

Meanwhile, the magnitude of $L_{EPN}$ correlates well with the bias distance $D$ between the prediction point and the flight route, so the conventional noise-power-distance relationship curve can be obtained from a great deal of experimental data for any type of aircraft and its function expression can also be derived from multinomial simulation recurring to computer. Consulting relevant information
When the aircraft is in air:
\[
\Delta(\beta) = 3.96 - 0.066\beta + 9.9e^{-0.13\beta},
\]
\[
L > 914 \text{ m}, 0^\circ \leq \beta \leq 60^\circ,
\]
\[
\Delta(\beta) = 0, \beta > 60^\circ.
\]
Where, \( \beta = \cos^{-1}\left(\frac{L}{D}\right) \), \( \beta \) is the angle between the bias distance \( D \) and \( L \); \( \Delta(\beta) \) is the lateral ground attenuation; \( D \) is the bias distance between the prediction point and the flight route.
\[
\Delta(\beta, L) = (\Delta L) \cdot (\Delta\beta)^{13.86}, 0 < L \leq 914 \text{ m}.
\]
Where \( \Delta(\beta, L) \) is the lateral ground attenuation.

2.1.4 The definition of the bias distance \( D \)
(1) When the aircraft is in air: The Descartes reference frame is set up with the definition that the take-off or landing point is the origin, the central line of runway is coincident with \( x \)-axis. If the ordinate value of the prediction point is \((x, y)\) and the take-off or landing line is \( \theta \), then
\[
D = \sqrt{y^2 + (x \cdot \tan\theta \cdot \cos\theta)^2}.
\]
If the flight track deflects or the flying angle varies after taking off, we should calculate \( D \) according to the actual conditions.
(2) When the aircraft is running in the runway, \( D = 1.1y \).

2.2 The procedure of drawing airport noise contours
The procedure of drawing airport noise contours mainly consists two parts: (1) calculate the \( L_{RECP} \) of each prediction point and generate the result file in visual C++ code; (2) grid the result data with the GRID module and draw noise contours in Surfer. The whole procedure of the prediction program is shown in Fig.2.

2.3 The design of the procedure on drawing airport noise contours
(1) The Descartes reference frame is set up with the definition that one endpoint of the runway is the origin, the central line of runway is coincident with \( x \)-axis. Prediction points are fixed up with the gridding method in which the steps of \( x, y \) directions are 200 m and 100 m.
(2) Calculate the \( L_{RECP} \) of each prediction point according to the prediction model of \( L_{RECP} \) and generate the result file in visual C++ code.
(3) Choose the interpolation model through calling Surfer in the program and grid the result data with the GRID module.
(4) Control the smoothing parameters of contours in Surfer and generate the noise contours including 70 dB, 75 dB, 80 dB, 85 dB and 90 dB with the TOPO module.
(5) Combine the local map around the airport with the contours in Surfer.
(6) With synthetically processing get the final airport noise contour map.

3 Case study
The automation level and efficiency in environmental
The scheduled flights of various aircraft types and flight routes during the three periods

The aircraft types of the airport

The take-off and landing procedure of various aircraft types

The laying-out of the prediction point

The noise-power-distance relationship curves

Calculating \( D \)

Calculating \( L_{eq} \) for a single event of each prediction point

Corrections for \( L_{eq} \)

Calculating the mean value of \( L_{eq} \)

Calculating \( L_{1000} \) and generating the result data file

Gridding the result data through the GRID module

Setting the parameters and drawing contours through the TOPO module

Programming in Visual C++ Code

Calling surfer in the programme

Fig. 2 The procedure of drawing airport noise contours

research and management can be improved if airport noise contours drawing and analysis are carried out on a computer. In this paper a soft for drawing airport noise contours based on the method referred above is established. The example of its use for drawing noise contours of a certain airport in Zhejiang Province is proposed.

3.1 The prediction of airport noise

The prediction model referred above is adopted to calculate the \( L_{1000} \) of the airport. Suppose the aircraft category in the certain airport consists of B737, A320, B757 and DHC-8, the east-west runway is 3600 m long and the flight operations on a given day are given in Table 1 and Table 2.

### Table 1 The flight operations on the measurement day

<table>
<thead>
<tr>
<th>Item</th>
<th>Total number of aircraft operations on the day</th>
<th>Taking-off eastward</th>
<th>Landing eastward</th>
<th>( N_1 )</th>
<th>( N_2 )</th>
<th>( N_3 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flights</td>
<td>86</td>
<td>43</td>
<td>43</td>
<td>70</td>
<td>13</td>
<td>3</td>
</tr>
</tbody>
</table>

### Table 2 The directions of flight operations on the measurement day

<table>
<thead>
<tr>
<th>Aircraft type</th>
<th>B737</th>
<th>B757</th>
<th>A320</th>
<th>DHC-8</th>
<th>A300</th>
<th>B767</th>
<th>B777</th>
<th>MD82</th>
</tr>
</thead>
<tbody>
<tr>
<td>Taking-off eastward</td>
<td>12</td>
<td>7</td>
<td>11</td>
<td>6</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Landing eastward</td>
<td>2</td>
<td>7</td>
<td>11</td>
<td>6</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>

3.2 Drawing noise contours through calling Surfer

Firstly, set the parameters of the airport and aircrafts appropriately in the program according to the flight schedules of the airport in 2010. Then draw noise contours through calling Surfer after the result file is generated. The calculating parameters are set as Fig. 3 shows before drawing contours.

![Fig. 3 The window of setting contours drawing parameters](image)

The mathematical models supplied by Surfer have their
own parameters setting. We can get the contours presentation we expect exactly if choosing the suitable interpolation method and setting the parameters flexibly. Various effects can be expressed according to various mathematical models. The noise contours can fit the actual conditions well if a good gridding method is chosen. In respect that the interpolation models' requirements to the data source and actual conditions, authors think the “Nearest Neighbor” interpolation method can reflect the distribution of noise level around airport appropriately after repetitive practice. The reason is “Nearest Neighbor” interpolation method is preferred when the data is dispersed regularly. Therefore we choose “Nearest Neighbor” in the option of “Gridding Method” in the window of parameters setting which shown in Fig.3

The final noise contours is shown in Fig.4.

Fig.4 The noise contours around a certain airport in Zhejiang Province in 2010(dB)

4 Conclusions

This paper presents a new method to draw airport noise contours automatically through calling Surfer in Visual C++ and a practical case is proposed. In result, the predicted value agrees with measured value well and the approach improves the efficiency of drawing contours. It will have broad applied prospects in the research of pollutants dispersion and environmental measurements where contours need to be drawn.

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