EXTRACTION OF SPATIAL PARAMETERS FROM CLASSIFIED LIDAR DATA AND AERIAL PHOTOGRAPH FOR SOUND MODELING

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Commission IV, WG IV/3

KEY WORDS: LIDAR, Aerial Photograph, Sound Modelling, Noise Maps, Principal Path Identification

ABSTRACT:

Prediction of outdoor sound levels in 3D space is important for noise management, soundscaping etc. Sound levels at outdoor can be predicted using sound propagation models which need terrain parameters. The existing practices of incorporating terrain parameters into models are often limited due to inadequate data or inability to determine accurate sound transmission paths through a terrain. This leads to poor accuracy in modelling. LIDAR data and Aerial Photograph (or Satellite Images) provide opportunity to incorporate high resolution data into sound models. To realize this, identification of building and other objects and their use for extraction of terrain parameters are fundamental. However, development of a suitable technique, to incorporate terrain parameters from classified LIDAR data and Aerial Photograph, for sound modelling is a challenge. Determination of terrain parameters along various transmission paths of sound from sound source to a receiver becomes very complex in an urban environment due to the presence of varied and complex urban features. This paper presents a technique to identify the principal paths through which sound transmits from source to receiver. Further, the identified principal paths are incorporated inside the sound model for sound prediction. Techniques based on plane cutting and line tracing are developed for determining principal paths and terrain parameters, which use various information, e.g., building corner and edges, triangulated ground, tree points and locations of source and receiver. The techniques developed are validated through a field experiment. Finally efficacy of the proposed technique is demonstrated by developing a noise map for a test site.

1. INTRODUCTION

Prediction of sound level is important for managing noise pollution, urban planning, sound barrier design, 3D virtual realization of sound, etc. Generation of noise map has received special importance after the Environmental Noise Directive in 2002 by European Parliament and Council (END). Sound level in real world environment is generally predicted using semi-empirical sound propagation models (Maekawa, 1968). A sound model needs various terrain parameters related to different paths of transmission of sound, viz. distance between source (from where sound is originating) and the receiver (to which sound is propagating), the length of path difference in case sound reaches the receiver after diffraction, angle and coefficient of reflection for the sound reflecting from ground or walls, and the length of transmission through trees. A sound model enables prediction of sound level at the receiver location using primarily the above terrain parameters and sound information specific to the sound source. However, the technique to incorporate terrain parameters is often found inadequate (David et al., 2002; Kurze, 1973; RTA, 1989). There are limitations in using accurate and dense terrain information for sound modelling. The difficulty in determining detailed and accurate transmission paths is among the most significant limitations. It often forces modellers to adopt approximation or ignore important parameters (Rossing, 2007). On account of these weaknesses the existing approaches result in average sound prediction. The shortfalls of modelling can be overcome by the input of accurate terrain parameters corresponding to detailed transmission paths after extracting these from high resolution 3D terrain data e.g., LIDAR data and Aerial Photograph.

LIDAR survey and Aerial Photography can produce accurate digital terrain data of wide area in quick time. LIDAR provides point cloud information whereas Aerial Photograph supplies accurate spectral information of terrain. Generally LIDAR sensors are accompanied with Aerial camera. However, in the absence of aerial photographs, comparable spectral data can also be obtained from satellite images.

Data collected using the said technologies require to be processed to yield terrain parameters that are fed to a sound model. The initial processing aims at classifying the collected data i.e., identification of building, trees and other land features in LiDAR data. The procedure for classification of LiDAR data is well established in literatures (Ibrahim S., 2003; Lohani et. al., 2007; Tse et. al., 2004). However, there is no reported technique to extract terrain parameters from classified high resolution remotely sensed data. The determination of these terrain parameters becomes very difficult for urban environment due to the complexities of building and other over ground objects. The difficulties can be understood considering the possible paths for transmission of sound from a source to receiver location. In an urban environment having large number

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of buildings of different heights and orientations along with variation of ground types, it becomes complex to determine possible paths for transmission of sounds. Among all paths the shortest path termed as principal path make important contribution for prediction of sound at the receiver location (Bies, et. al., 2003). However these paths are required to be determined to find related terrain parameters that are needed for prediction of sound at different locations.

2. OBJECTIVE

The objective of this paper is to develop algorithms for identification of principal paths, using classified LIDAR data and Aerial Photograph, so detail terrain parameters for sound propagation modelling along these paths can be computed. Satellite Images can also be used for this purpose. However, this paper will use the term Aerial Photograph to represent these images containing spectral information of terrain. The identification of principal paths requires understanding of involved phenomena of sound propagation between two points (i.e., source and receiver). Based on this understanding the principal paths for direct transmission, or diffraction, or reflection, or absorption through trees etc. can be determined using classified LIDAR data and Aerial Photograph. The detailed objectives of this paper are thus to (i) develop algorithms for determining principal paths under various conditions using LiDAR data and Aerial Photograph, (ii) develop methodology to extract terrain parameters along the principal paths, (iii) input the determined parameters in a sound propagation model, (iv) validate the developed technique, and, finally (v) demonstrate the technique for a test site.

3. METHODOLOGY

Considering the physics of sound four possible components can form a principal path (Bies, et. al., 2003), (Rossing, 2007). These components are (i) path for direct transmission (through air), (ii) path for transmission after diffraction, (iii) path for transmission after reflection, and (iv) path through trees resulting in absorption. The path for transmission after diffraction can further be of two types i.e., diffraction over or around a building. Similarly two reflective paths can be possible i.e., reflection from ground or building wall.

To determine various principal paths, LIDAR data are used to provide positional information of building, ground, and trees. Source and receiver are considered to have unique positions inside the terrain in 3D and are incorporated separately. Attempt is made to determine all possible principal paths between source and receiver. This process becomes complex in the case of multiple sources and multiple receivers, as is frequently encountered in urban environment (i.e. many sources such as road, factory etc transmit sounds to many receivers i.e., locations at their surroundings.) In these cases, principal paths between every possible pair of source and receiver are identified.

In principal path identification technique, first the algorithm tries to determine whether sound can directly transmit to receiver without any obstruction (i.e., building, ground, other object or tree). In case of direct transmission the reflected (from ground or walls) paths are also considered. In the absence of an un-obstructed path the diffraction, reflection and trees absorption paths are identified.

The flow chart shown in Figure 1 demonstrates the steps employed for determination of terrain parameters and their consequent use for sound modelling. LIDAR data points are classified to building, ground and tree points. Building corner and edges of roof are extracted from building class manually and are used subsequently to determine the possible diffracting paths for a combination of source and receiver using cutting plane technique. The ground and tree points are triangulated separately and processed further to derive reflective paths or through-tree paths for the source and receiver pair. Aerial Photograph is used to associate ground points with the ground type information for determining reflection coefficient for the ground. Different terrain parameters required for sound modelling such as distance between source and receiver, length of path difference for diffraction, reflection coefficient, tree absorption length etc are determined, using simple geometric relationships, along different principal paths identified above. Detail terrain parameters, derived for a source and receiver pair, are incorporated inside the sound propagation model to calculate the sound level for receiver location due to the sound source. The prediction technique for a pair of points, as mentioned above, is required to be scaled up for various scenarios as is needed in noise mapping, i.e., single source multiple receivers or multiple sources multiple receivers cases.

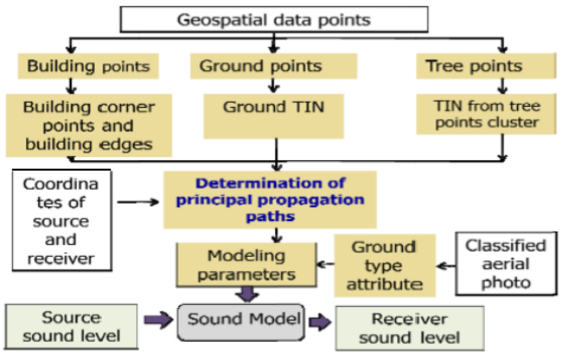

Figure 1. Flow chart showing extraction of terrain parameters and sound modelling

3.1 Data preparation:

LIDAR data employed in this work were collected over IIT Kanpur, India with an approximate density of 1 point/m^2. LIDAR data are classified as building, ground and tree classes using commercial software Terrascan. Classified point clusters of different classes are used to extract principal paths and terrain parameters. Ground and tree point clusters are triangulated and used to generate reflective or through-tree paths. Satellite image with 5 m resolution is used as spectral information, in place of Aerial Photograph. Satellite imagery is registered with LIDAR data and classified to provide ground type information to LIDAR points. Details of each step in algorithm are described below.

3.2 Determination of direct transmission path and decision on possibilities of other paths:

In order to determine various principal paths a plane perpendicular to X-Y plane (ground plane) is considered which contains source and receiver locations (Figure 2). It is ascertained first whether this plane (referred as cutting plane) intersects any of the building walls or obstructions in between the source and receiver locations. Points of intersection are