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A feature extraction method for deformation analysis of large-scale composite structures based on TLS measurement

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A R T I C L E I N F O

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A B S T R A C T

How to obtain a three-dimensional (3D) model efficiently and extract the feature information of larger-scale composite structures, such as tunnels, accurately is a significant issue in the field of health monitoring. Therefore, an effective method based on TLS measurement is proposed and developed using surface-based non-destructive technology.

In this paper, terrestrial laser scanning (TLS) technology is adopted to investigate the tunnel structure, focusing on the extraction of the characteristic section and central curve, which could be applied in deformation monitoring. Point cloud data from TLS measurement is processed in four steps: section extraction, section projection, calculation of central points and curve approximation.

The innovation of this paper lies in the projection and iterative filtering of the ring data and rasterization of the point clouds for vertical and horizontal lines. The random sample consensus (RANSAC) algorithm is implemented to approximate the vertical and horizontal lines. The central curve, approximated from the central points, agrees with the general design model and the accuracy falls within the millimeter range.

1. Introduction

Large-scale composite structures are everywhere nowadays and new surrounding constructions are increasing rapidly, introducing complicated impacts, such as deformation, tilt and settlement, on these composite structures. The state of health of these structures could be strongly influenced by the ground surface, hard rock masses and bedrock topographies [1], which could cause invisible failures and safety problems. Therefore, it is extremely important to generate actual geometrical models with parameters of shape and evaluate the deviation of actual models of large-scale composite structures to the theoretical or temporal models which can be used to analyze the transverse, longitudinal displacement and uneven deformation of tunnel structures.

Terrestrial laser scanning (TLS) is a promising geodetic measurement technology and a range of research papers implementing TLS have appeared since the end of the last century. High-resolution TLS offers quantitative data for spatial and across-time analysis of features such as sea cliff morphology [2], forest health [3] and snow distribution [4]. The advantages of TLS are high accuracy, efficiency and lack of contact. Therefore, it is widely utilized to monitor the deformation of engineering structures [5–11]. Several authors have applied TLS in tunnel health monitoring. Traditional research has focused on error models, geo-referencing and registration of the tunnel point clouds data [12–14], while newer research has included robust methods of point clouds processing for precise tunnel geometry acquisition and change detection [15]. Tunnel point clouds discarding accessories were achieved with corrected intensity information [16]. Ref. [17] used 3D mesh to generate 2D tunnel profiles, but the metric distortion cannot currently be absolutely avoided. Local direction and profile description were realized by piecewise linear functions of approximation [18]. Ref. [19] combined a two-dimensional (2D) projection strategy and angle criterion for tunnel boundary point detection in the X-Y plane, and the projection of nearby points onto the adjusted plane orthogonal to the boundaries were filtered as the cross-section. Ref. [20] extracted tunnel central axis using a curve fitting algorithm on the 2D projection plane and fitted the blank area of points with a surficial interpolation algorithm.

Although the acquisition of actual geometric parameters and the inspection of the tunnels is currently possible using TLS, the existing works are more restricted regarding pointwise or piece-wise description of the profile and central curve, which is not conducive for promoting and storing the data. The result is judged statistically by point clouds, but lacks the comparison of theoretical or design data. Furthermore, the automation of the process is not realized completely. The aim of this

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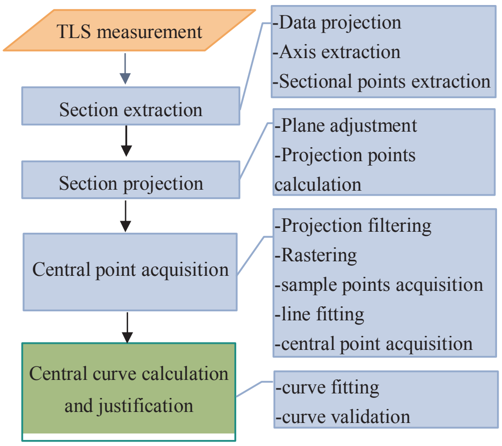

Fig. 1. Work flow of tunnel central points optimization.

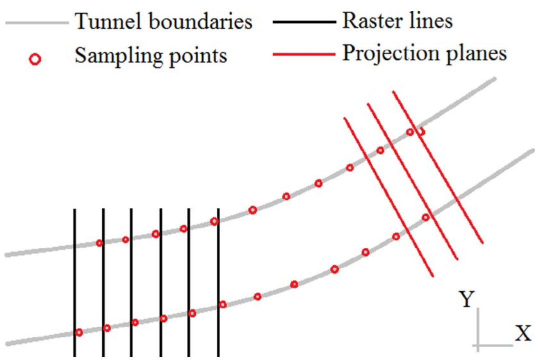

Fig. 2. Determination of section extraction plane.

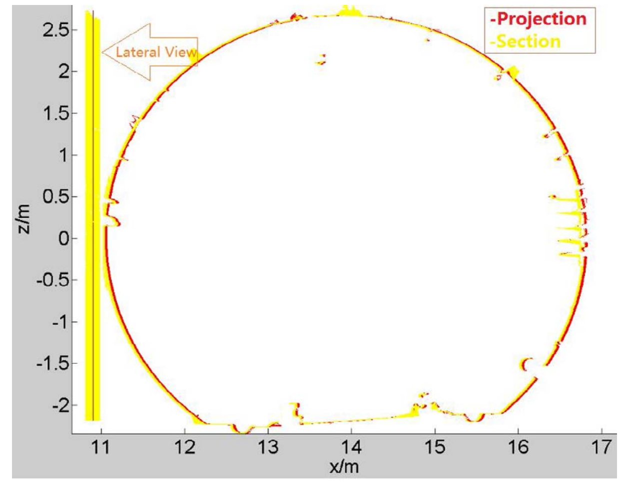

Fig. 4. Projection of extracted section.

paper is to remove non-lining points of cross-sections automatically and propose an integral description for the profiles and the central curve, based on which, the deflection with the theoretical or design model could be acquired.

2. Methods

Checking actual tunnel geometry is primary method for deformation monitoring and clearance inspection [19]. A measurement is carried out for tunnel inspection using TLS technology, and the actual geometry represented by dense profiles and central curve is obtained with the TLS point clouds data.

2.1. Work flow

The work flow of the acquisition of tunnel profile and central curve

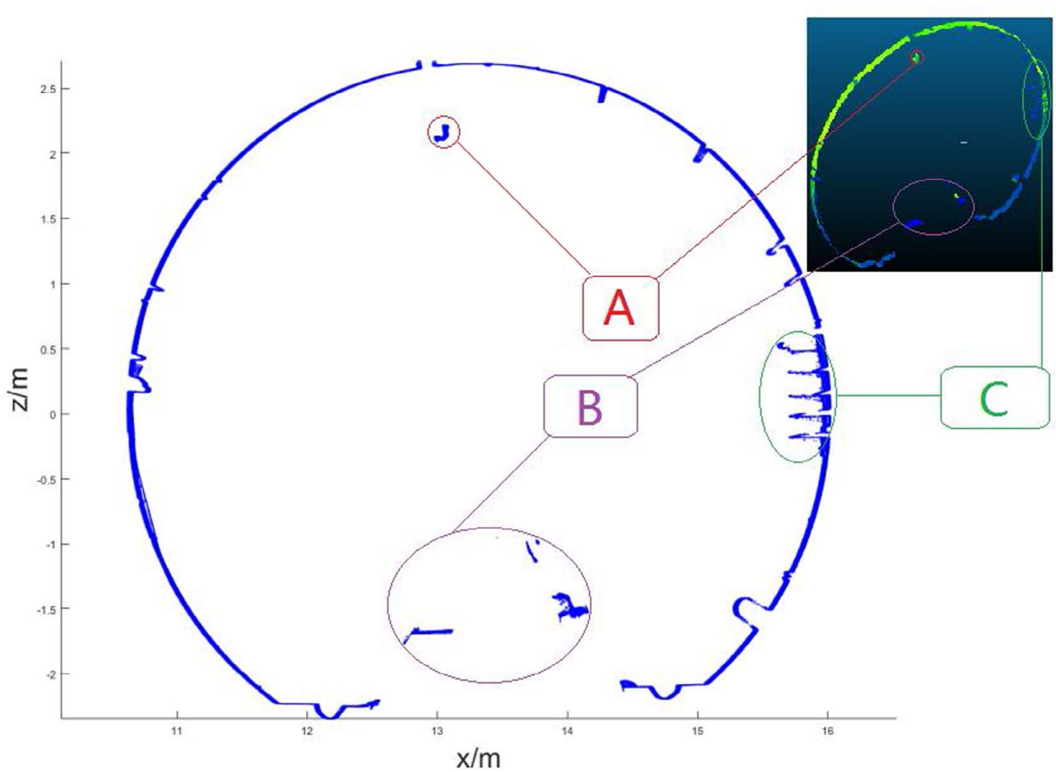

Fig. 3. Section extraction.