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# CONTINUOUSLY DEFORMATION MONITORING OF SUBWAY TUNNEL BASED ON TERRESTRIAL POINT CLOUDS

Zhizhong Kang [a, *], Lei Tuo[a], Sisi Zlatanova[b]

[a] School of Land Science and Technology, China University of Geosciences, 29 Xueyuan Road, Haidian District, Beijing 100083, China - zzkang@cugb.edu.cn, tinytony.f@gmail.com
[b] OTB Research Institute for Housing, Urban and Mobility Studies, Delft University of Technology, Jaffalaan 9, 2628 BX Delft, The Netherlands - s.zlatanova@tudelft.nl

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**ABSTRACT:**

The deformation monitoring of subway tunnel is of extraordinary necessity. Therefore, a method for deformation monitoring based on terrestrial point clouds is proposed in this paper. First, the traditional adjacent stations registration is replaced by section-controlled registration, so that the common control points can be used by each station and thus the error accumulation avoided within a section. Afterwards, the central axis of the subway tunnel is determined through RANSAC (Random Sample Consensus) algorithm and curve fitting. Although with very high resolution, laser points are still discrete and thus the vertical section is computed via the quadric fitting of the vicinity of interest, instead of the fitting of the whole model of a subway tunnel, which is determined by the intersection line rotated about the central axis of tunnel within a vertical plane. The extraction of the vertical section is then optimized using RANSAC for the purpose of filtering out noises. Based on the extracted vertical sections, the volume of tunnel deformation is estimated by the comparison between vertical sections extracted at the same position from different epochs of point clouds. Furthermore, the continuously extracted vertical sections are deployed to evaluate the convergent tendency of the tunnel. The proposed algorithms are verified using real datasets in terms of accuracy and computation efficiency. The experimental result of fitting accuracy analysis shows the maximum deviation between interpolated point and real point is 1.5mm, and the minimum one is 0.1mm; the convergent tendency of the tunnel was detected by the comparison of adjacent fitting radius. The maximum error is 6mm, while the minimum one is 1mm. The computation cost of vertical section abstraction is within 3 seconds/section, which proves high efficiency..

## 1. INTRODUCTION

In order to alleviate the pressure of the ground transportation, subway has been the main component of public transport system with high carrying capacity, in consideration of its advantages of high efficiency, safety and low consumption. However, the deformation of subway tunnel and surrounding building which is unavoidable would make a negative impact to each other and then endanger the whole urban transportation system. Thus, the deformation monitoring of subway tunnel is of extraordinary necessity. The main approaches of deformation monitoring applied on subway tunnel can be divided into two types, i.e. contact and non-contact. The contact measurement obtains the slope and deformation of tunnel by the inclinometer in different position, such as convergence ruler, BASSETT CONVERGENCE SYSTEM（BCS）(LI and FANG, 2004), etc. The main way of non-contact measurement is intelligent total station, such as Topcon GPT-9000A and Leica TCRA1201. A method of deformation monitoring based on phase shift laser ranging device is proposed by Zhou et al. (2010). The intelligent total station can determine the vertical section through control software or PDA, such as the TM tunnel section measurement system (Tao and He, 2008). The software EasyScan applied on GPT-9000A is developed based on WinCE (Huang and Xie, 2009). Leica TCRA1101 integrated with the TPSPRO section measurement system is applied on abstracting section in reference (Liu and Qin, 2009). However, the disadvantages of monitoring methods mentioned above include limited monitoring points, low efficiency, and the accuracy is prone to be impacted by environmental factors, which can be tackled by applying 3D laser scanning technology.

As a new approach of measurement, TLS (Terrestrial laser scanner) is more appropriate for monitoring of subway tunnel by comparison, which can acquire mass 3D point clouds with high density and high resolution, meanwhile, no reflection prism and low requirement for light and temperature. Tsakiri et al. (2006) discussed methods of surface modelling implemented for deformation monitoring and approaches used to measure the deformation from surfaces. By using a weighted-constraint, least-squares curve-fitting approach, Gordon and Lichti (2007) developed a modeling strategy from fundamental beam-deflection equations to permit coarse-precision terrestrial laser scanner observations to be used to accurately measure vertical deflections of deforming beams. Gosliga et al. (2006) described a work flow for the use of terrestrial laser scanning for detecting deformation by gaining benefit from both data redundancy and individual point quality. Schneider (2006) applied the analysis of highly redundant unstructured point clouds which represent the surface of objects the determination monitoring of the

* Corresponding author. *E-mail address*: zzkang@cugb.edu.cn.