# Evaluation of Physical Walkability using High-Definition Topographic Measurement: Toward Barrier-Optimized Road Environments

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**Abstract**: The high roughness of road surface works as barriers for pedestrians who have difficulties in walking or with wheeled baggage like heavy suitcases and strollers, whereas the roughness would also work as a preferable environment for kids and adults to develop their physical health. High-definition topographic measurements by photogrammetry and laser scanning are applied on a test site to extract detailed road surface morphology, and the physical walkability is evaluated in relation to the surface roughness and pedestrian behaviors.

**Keywords**: walkability, road surface, roughness, laser scanning, SfM-MVS photogrammetry

## 1. Introduction

Evaluation of physical environmental factors for walking in residential areas is a fundamental issue in the improvement of urban design. In particular, residential areas originally developed in decades ago often comprise problems in the presence of barriers, including steps and blocks, for walking of residents who are becoming elder and physically weaker. Such barriers can be a factor for the decrease in physical activities of the aged residents. On the other hand, physical barriers can also be necessary components in the city environment, because they can contribute to the health maintenance and development for young persons including small kids. Appropriate evaluation of such the physical road properties is therefore important.

Among else, "walkability" is an index showing the urban environment which affects the health of residents, and it is composed of three major factors (three Ds) including population Density, pedestrian-friendly Design, and land use Diversity (Cervero and Kockelman, 1997). Based mainly on the analysis of land use data, the walkability index has been widely applied to evaluate the effects of urban design on the residents' health problems (Yamada et al., 2012). However, regarding the design of roads, the physical evaluation of micro-scale morphological features, such as small steps and slopes along the pedestrian pathway that are responsible for the physical movement of walking persons, has been relatively limited. Traditional datasets of pedestrian ways have not been applicable to evaluate such small-scale morphological features on the road, and the acquisition and development of such microscale feature data are becoming crucial in the future urban design.

In this study, we propose a practical method to analyze the road surface morphology by means of photogrammetry and laser scanning (Hayakawa and Oguchi, 2016; Hayakawa et al., 2016). The efficiency of each method is compared. Preliminary analyses and visualizations, including the extraction of barrier features and evaluation of physical walkability at a micro scale, are then performed.

## 2. Materials and methods

The test site is a part of the university campus

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of The University of Tokyo at Hongo, extending flat and sloping areas, and having smooth paved surface and rough rocky blocks. The site area is constrained by the ability to move equipment for the laser scanning, as noted later.

Two different approaches for the acquisition of high-definition data of the road surface morphology are applied: laser scanning and photogrammetry. For laser scanning, we use mobile laser scanning (MLS) equipment Trimble TiMMS, and terrestrial laser scanning (TLS) equipment FARO Focus3D 330X. Because the MLS equipment is originally developed for the indoor measurement, such the outdoor measurement was partially restricted by the roughness of the road surface. For photogrammetry, we carried out interval shooting of photographs using a pole-mounted camera (RICOH GR), and Structure-from-Motion Multi-View Stereo (SfM-MVS) photogrammetry was applied to the obtained hundreds of photos.

The point clouds obtained by MLS, TLS and SfM-photogrammetry are converted to digital elevation models (DEMs), and the morphological analyses of the road surface for pedestrians are carried out using GIS.

## 3. Results and discussion

The spatial resolutions of the road surface topography obtained by the methods were on the order of millimeters to centimeters (Fig. 1). These are fine enough to extract the detailed morphological features on the ground surface. Some morphological parameters including slope angle, surface roughness, topographic profiles were obtained, and the micro-scale physical walkability was estimated.

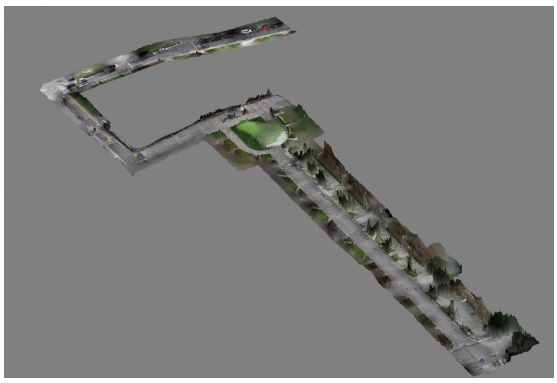

Figure 1. A bird-eye view of the 3D road surface data obtained by the close-range SfM-MVS photogrammetry of pole-mounted cameras. The spatial resolution of the data is 4 mm.

Some advantages and disadvantages in the practical measurements were assessed for each method. MLS would be suitable for the accurate measurement by the laser with high-precision inertial measurement unit (IMU), although some errors were found in the point cloud due likely to the vibration of the equipment over the rough road surface that is not supposed for indoor measurements. TLS gives better results than MLS in terms of the accuracy, although the coverage area by TLS is constrained by the number of scan position. SfM is the most practical and affordable in terms of the financial cost, although the data processing takes much time and some technical knowledge is required to obtain the appropriate results.

The results of this study will be utilized in the actual residential areas to perform extensive, quantitative evaluation of the physical walkability therein.


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