Conditional merging technique for the accurate estimation of ground settlement

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ABSTRACT: In urban area, surface and subsurface are crowded with existing structures. Hence the designs in geotechnical engineering projects are controlled by serviceability rather than stability requirements. Control of ground deformation is crucial. Accordingly, it is important to precisely monitor the ground deformation around the construction site. Typically, settlement beacon has been utilized to measure the ground deformation. Recently, the rapid development in electronic technology, digital image processing and computing power enables 3D image scanning to become available for measuring the ground deformation profile. Regarding obtaining the ground deformation profile, the 3D scanning work has an advantage, whereas its accuracy is somewhat limited because it does not directly measure the ground deformation. In this study, we developed a conditional merging technique to combine the traditional method and the 3D scanning method. Synthetic ground deformation profile was generated to validate the proposed technique. It is found that the ground deformation measurement error can be reduced significantly via the conditional merging technique.

Keywords: Settlement, Conditional merging, Excavation

1 INTRODUCTION

In urban area, the designs in geotechnical engineering projects are controlled by serviceability rather than stability requirements. Precise monitoring of ground deformation around construction site is very important. A settlement beacon is typically employed for the monitoring, but the beacon can only measure the ground deformation where that is installed. Accordingly, ground profile cannot be directly obtained but can be indirectly obtained by conducting kriging process with the limited number of settlement data. Recently, 3D scanning is possible due to development of electronic equipment including drones, cameras, scanners, etc. After obtaining multiple 2D digital images of objects from various viewpoints, 3D image can be constructed. If we apply this technique to geotechnical engineering projects, we can evaluate the ground settlement around the construction site. However, this technique does not directly measure the settlement, so the accuracy is not guaranteed. In this research, we introduce the technique of combining the settlement data measured by the settlement beacons and that obtained by 3D image. The used technique is the conditional merging technique that is used in hydrology (Sinclair and Pegram 2005).

2 CONDITIONAL MERGNING

Figure 1 illustrates the conditional merging process as introduced by Sinclair and Pegram (2005). Ground settlement is measured at discrete points by the settlement beacon, as shown in Fig. 1(a). In Fig.1 (b), kriging of the settlement beacon measurement is used to obtain the best linear estimates of ground settlement. In Fig.1 (c), the ground settlement profile is obtained from the image scanning equipment. In Fig.1 (d), the ground settlement profile at the settlement beacon locations are interpolated onto the scanned ground settlement profile. At each settlement beacon, the deviation between the observed and interpolated value is computed as shown in Fig.1 (e). In Fig. 1(f), the field of deviations obtained from Fig.1 (e) is applied to the interpolated ground settlement profile obtained from kriging the settlement beacon observations. As shown in Fig.1(g), the ground settlement profile that follows the mean of the interpolation of settlement beacon measurement, while preserving the deviations and the spatial structure of the scanned ground settlement is obtained. By following the conditional merging technique, one can combine the settlement data measured by the settlement beacons and that obtained by 3D image scanning equipment.

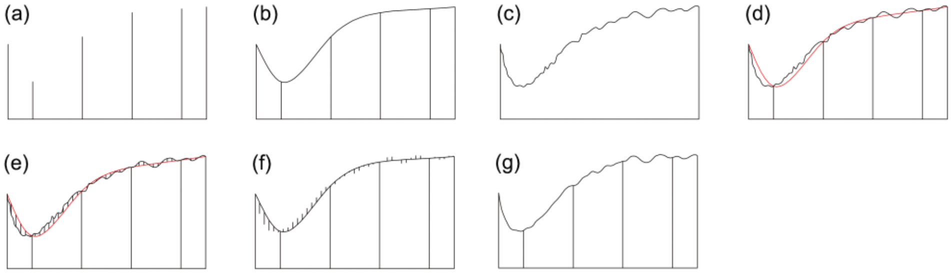

Figure 1. Conditional merging process (redrawn from Sinclair and Pegram 2005).

3 APPLICATION OF CONDITIONAL MERGING TECHNIQUE TO SETTLEMENT DATA

To apply the conditional merging technique to the ground settlement data, synthetic settlements are constructed based on the 2D ground settlement profile proposed by Hsieh and Ou (1998). To change that 2D profile into 3D profile, the error function proposed by Finno and Roboski (2005) are also used. Figure 2 shows the synthetic settlement profile and its contour. The excavation depth and the maximum ground settlement are assumed to be 20 m and 10 cm, respectively. The ground profile shown in Fig.2 is regarded as the true ground settlement at the site.

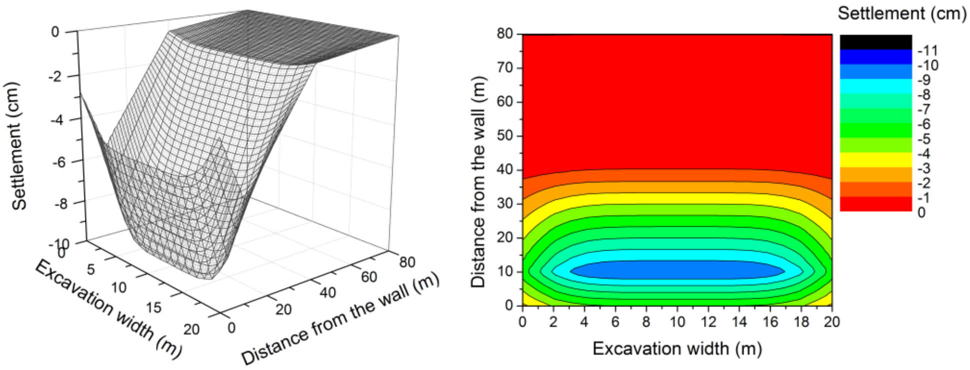

Figure 2. Synthetic settlement profile and its contour.

The ground settlement profile obtaining by the 3D scanning is also synthetically constructed by adding 20% of errors to the contour shown in Fig. 2. Figure 3 shows the scanned ground settlement profile that is synthetically made.

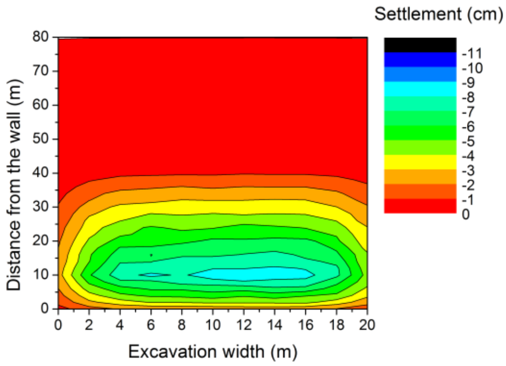

Figure 3. Contour of synthetic scanned settlement profile.

The contour shown in Fig.2 is made with the data from 451 points. Among these points, only 10 points are randomly selected and these points are regarded as the measurement data from settlement beacons. Figure 4 shows the interpolated settlement contour by kriging from 10 settlement beacons.

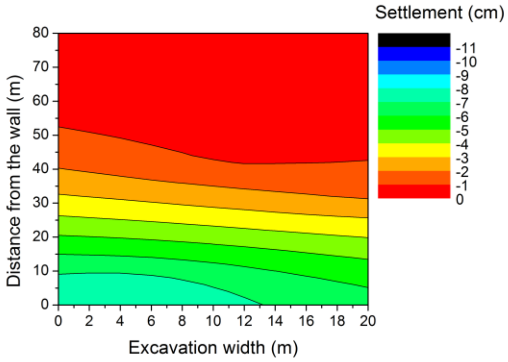

Figure 4. Interpolated settlement contour by kriging from 10 settlement beacons.

The settlement values of the scanned image at the location of settlement beacon are extracted and interpolated by kriging method. The contour is shown in Fig. 5.

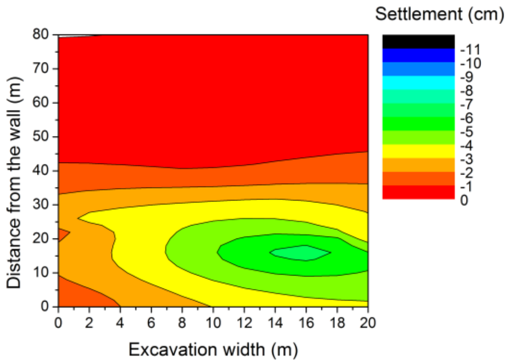

Figure 5. Kriged scanned settlement contour from the locations of 10 settlement beacons.

The difference between the settlements shown in Figs. 3 and 5 is calculated. Using that, conditional merging is conducted. Figure 6 shows the results of the conditional merging and that contour is very similar to the true settlement contour shown in Fig. 2.

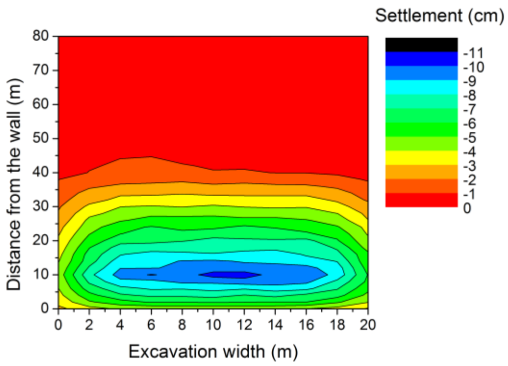

Figure 6. Settlement contour of conditional merging results.

4 SUMMARY

The conditional merging technique to combine the ground settlement data from the settlement beacon and the scanned image has been presented. This technique can be used to obtain the 3D ground settlement profile at the construction site including deep excavation. The ground settlement from conditional merging technique is improved while maintaining the mean settlement values obtained from the settlement beacon and reflecting the spatial structure of the ground settlement profile from the 3D scanned image.

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