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Digital transformation: a key to enhance project quality and improve efficiency of delivery

La transformation numérique: une clé pour améliorer la qualité des projets et améliorer l'efficacité de la livraison

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ABSTRACT: Digitalization opens the door for data analytics, facilitates data/information flow, and realizes materials archive. Digital transformation promotes the development of advancing tools aiming to increase work efficiency and enhance product quality. This paper presents the recent experience of AECOM Hong Kong Office on a few novel digital tools and discusses their roles at different stages of a project cycle. At the design stage, a 3D reality model derived from digital images obtained from camera-equipped drone and/or point cloud data collected by laser scanner not only helps provide visuals to better illustrate the sites to different stakeholders but also brings values to engineering design and construction. We have also used advanced ground modeling software to efficiently build up, and modify upon additional information, the ground model. This is particularly useful for projects developed on complex geological stratigraphy. The ground model is readily exported to other geotechnical design software to carry out further engineering analysis. This digital workflow has been shown to significantly increase the project efficiency. The merits of employing advanced digital tools are illustrated by some of our recent projects. Riding on the commonness of smartphones, we have also developed user-friendly mobile Apps for work supervision and incident reporting which have been proved as an effective tool for quality assurance and project delivery.

RÉSUMÉ : La numérisation ouvre la porte à l'analyse des données, facilite le flux de données/d'informations et réalise l'archivage des matériaux. La transformation numérique favorise le développement d'outils avancés visant à augmenter l'efficacité du travail et à améliorer la qualité des produits. Cet article présente l'expérience récente du bureau d'AECOM à Hong Kong sur quelques nouveaux outils numériques et discute de leurs rôles à différentes étapes d'un cycle de projet. Au stade de la conception, un modèle de réalité 3D dérivé d'images numériques obtenues à partir de données de drones équipés de caméras et/ou de nuages de points collectées par scanner laser permet non seulement de fournir des visuels pour mieux illustrer les sites aux différentes parties prenantes, mais apporte également une valeur à la conception technique et construction. Nous avons également utilisé un logiciel de modélisation du sol avancé pour construire efficacement et modifier le modèle au sol en fonction d'informations supplémentaires. Ceci est particulièrement utile pour les projets développés sur une stratigraphie géologique complexe. Le modèle de sol est facilement exporté vers d'autres logiciels de conception géotechnique pour effectuer une analyse d'ingénierie plus approfondie. Il a été démontré que ce flux de travail numérique augmente considérablement l'efficacité du projet. Les mérites de l'utilisation d'outils numériques avancés sont illustrés par certains de nos projets récents. Sur la base de la banalité des smartphones, nous avons également développé des applications mobiles conviviales pour la supervision du travail et le rapport d'incidents qui se sont avérées être un outil efficace pour l'assurance qualité et la réalisation de projets.

KEYWORDS: Digital transformation; laser scanner; mobile apps; photogrammetry; reality model.

1 INTRODUCTION.

Our profession is on the cusp of a new technological era. Digitization of data and information and popularization of the internet since 1990's allows knowledge to transfer at the highest pace in the history of human civilization. A successful digital transformation would change the way we design, build, operate and integrate our built structures. The adoption of Building Information Modelling (BIM) has greatly accelerated the proper use and management of digital tools at different stages throughout the life cycle of a built structure.

In this paper, we will share some recent experience of the use of various digital tools by the geotechnical team at the AECOM Hong Kong Office. These include the (i) creation of three-dimensional (3D) reality models from two different sources of raw data, i.e., two dimensional (2D) digital still images and point clouds acquired by laser scanning; (ii) construction of 3D ground models from ground investigation data in particularly borehole information, and their application in further engineering design; and (iii) development of mobile apps with project specific-objectives to streamline site operations. The paper is concluded by a few thoughts made by the authors. We hope that our experience could inspire more engineers in this profession to embrace digital transformation and to reshape our industry.

2 REALITY MODELS

2.1 *Photogrammetry*

Photogrammetry combines 2D digital images to develop a 3D model. These 2D images are overlapped such that the same point on the physical ground is captured in multiple images each being obtained from different shooting directions. The images could be taken using a drone equipped with a digital camera if the study area is large or captured simply by a smart phone if the study area is within walking distance. With georeferenced images, the constructed 3D model would represent the physical reality including geometric information such as position and dimensions, and non-geometric information such as texture and color. Figure 1 shows an example of 3D reality model constructed using digital images collected from a drone. The joint sets pattern near the shoreline can be clearly seen by a closer look at the model. This could easily facilitate a virtual site visit at any suitable time. Note that apart from a conventional digital camera, multispectral sensors, hyperspectral sensors, thermal sensors and light weight LiDAR sensors can also be mounted on a drone for different remote sensing application such as vegetation analysis, power line, and pipeline inspections.

Figure 1. An example of 3D reality model.

2.2 *Point clouds from handheld laser scanning*

Handheld laser scanning (HLS) is an excellent alternative to photogrammetry or terrestrial laser scanning (TLS) when the site is congested with scattered objects for instance a wooded hillside which is typical to Hong Kong's natural terrain. 3D point clouds containing geometric positions and color are generated from the scanning. With appropriate format conversion, the data can be opened in most BIM software for further processing.

2.3 *Applications of reality models*

Two examples are presented to illustrate how a reality model could assist engineering study, design, and construction. In the first example, a 3D reality model derived from photogrammetry is used to assist hazard inspections at a hard-to-reach hillside. Conducting hazard inspections on a natural hillside involves significant efforts including for instance the provision of temporary access, clearance of densely vegetated ground cover and mobilization of equipment. These would inevitably require additional time and cost due to safety and statutory requirements. In this example, images were taken as close as 10 m from the slope surface with the aid of a drone and the 3D reality model was created using the software ContextCapture by Bentley Systems (see Figure 2).

Figure 2. Slope surface exposed after a landslide.

Using the technique of Virtual Reality (VR), stakeholders can have a better appraisal of the interaction between the landslide and the adjacent environment (see Figure 3).

Figure 3. VR model for landslide details.

Many commercially available CAD/BIM software allows a quick estimation of the size and volume once the reality model is georeferenced. This could be useful for landslide studies to evaluate the volume of landslide and site formation analyses to estimate the volume of cuts and fills.

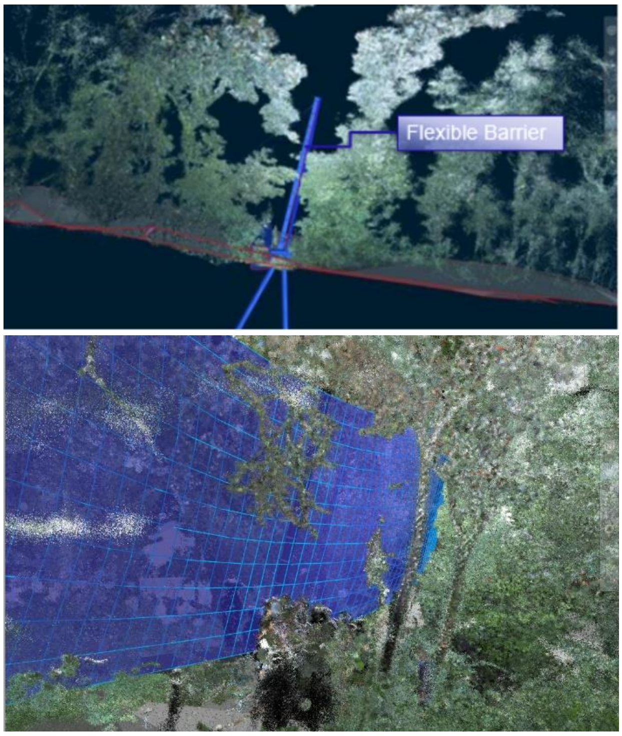


Figure 4. Design flexible barrier and the environment.

In the second example, a 3D model constructed using point clouds is used to improve the efficiency and quality of an engineering design and to facilitate construction at the later stage. A flexible barrier placed at the toe of a catchment, often densely vegetated with trees and shrubs, is one of the common engineering measures to mitigate natural terrain hazards. In the past, the alignment of the flexible barrier was determined based on land surveying during the design stage where a tree is simply represented by a point on the 2D topographic map. The 3D architecture of trees including spread of branches and tilt of tree stem is missed. Design review is a must before construction to ensure that the design meets with the site constraints, e.g., no clashing of the barrier with the tree trunks and branches. In many cases, frequent on-site design adjustments/modifications are often needed which lead to delays in construction and extra costs. HLS offer an excellent solution to resolve this problem.

Point clouds collected using HLS help to create a digital replica of the site to a high degree of accuracy. Engineering design using the BIM approach can avoid potential clashing between the flexible barrier and the environment at the early stage of the design phase. Figure 4 shows how the design barrier can be incorporated into the environment without the need of tree felling or significant pruning. Furthermore, superimposing the design flexible barrier onto the 3D ground terrain helps to identify any excessive basal gaps at the early design stage (see Figure 5). Note a large basal gap could significantly affect the performance of a flexible barrier as a landslide mitigation measures. In this project, it only took one staff member to scan the area which was finished in 20 mins as compared to many hours spent by a survey team comprising at least two members. In this example, post-processing of the cloud data took about three days with most of the time spent on the removal of noisy data and conversion of file format.

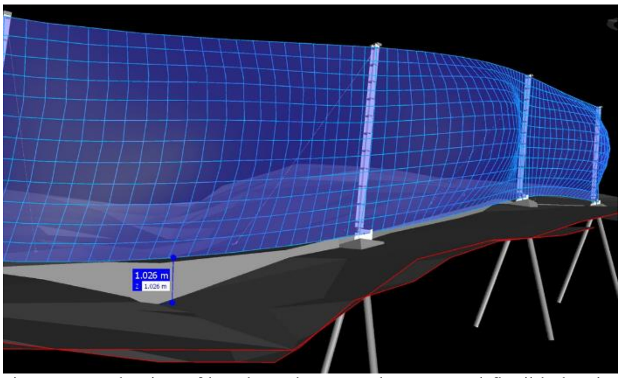


Figure 5. Evaluation of basal gap between the proposed flexible barrier and the ground in the virtual environment.

3 GROUND MODEL

For infrastructure projects of significant scale, it is anticipated that large amount of ground investigation works would be undertaken. Besides, ground investigations are often carried out in stages and therefore the investigation findings such as borehole logs and soil testing results are obtained in phases. Proper data management is not a trivial task and could greatly facilitate data interpretation. We have been using a 3D ground modeling software package called the Leapfrog Works (a product of Seequent Limited). The program allows input of borehole logs in spreadsheet or AGS format. Subsurface ground modeling can be done easily with the help of pre-defined interpretative tools. Besides, the 3D geological model and outputs such as section views are dynamically updated once new data are input to the program without the needs of recreating the entire model. This is particularly beneficial to projects with complex geological setting and additional ground investigation records coming in continuously as the projects proceed. Figure 6 shows an example of a 3D ground model created using the Leapfrog Works. The complex geological setting which is interpreted from ground investigation can be readily seen.

The 3D model does more than provide visualization of the geological features. It also facilitates the study of engineering options. For instance, with the help of suitable CAD tools, proposed engineering structures could be appended onto the model to offer a quick understanding of how the structures interact with the ground (Figure 7).

We have also developed program scripts to extract ground profile information from the 3D ground model to the engineering analysis tool PLAXIS. By doing so, any changes of the ground model can be automatically updated in the PLAXIS numerical model which significantly streamlines the design workflow.

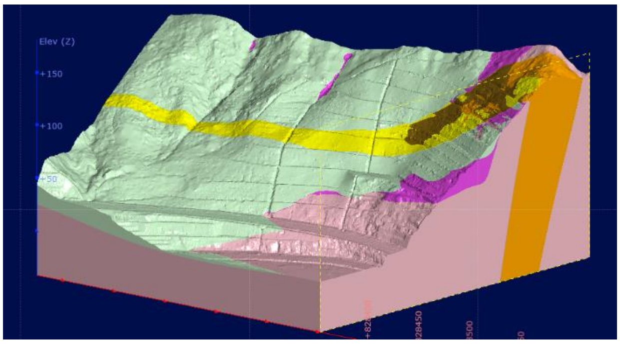


Figure 6. An example of a 3D ground model.

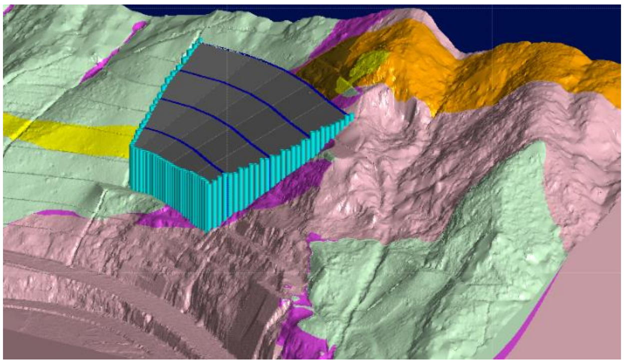


Figure 7. Superposing the proposed structure onto the ground model.

4 MOBILE APPS

In this section, three mobile apps developed to handle different site operations are briefly presented. The apps clearly show how digital transformation could improve work quality and efficiency.

4.1 *Supervision of soil nail construction*

Soil nailing is probably the most adopted slope stabilization measures in Hong Kong. In the current practice, at least one full time resident site staff (RSS) is required for each slope upgrading project to undertake the site supervision work which includes for instance the measurement of drill bit, nail size, grout volume, etc, and photo record of the construction at different stages. For a typical slope upgrading works in which about 100 soil nails are installed, there could be up to 1,000 photos. Handling these records, in particularly the hardcopy measurement records, is time-consuming and prone to human errors. A mobile app was developed to streamline the process.

The app contains details of each nail tallying the approved design (see Figure 8). The RSS could easily update the nail construction progress, record the measurements, and document the construction using the built-in texting and photo taking function. All these records would be systematically stored for future auditing. A dashboard view helps to provide an overall picture of the project progress.

4.2 *Monitoring of site cleanliness*

The Hong Kong government slope and capital works contracts require the contractors to undertake a daily cleaning and weekly site tidying of the public areas of the project sites and submit the inspection records timely. As one could expect, the volume of records is substantial, and their storage and search remain a big challenge. A mobile app was therefore developed to facilitate the communication between the contractor and the RSS for the preparation of the inspection records. Figure 9 shows some captures along the workflow of this mobile app. After the site cleaning, the contractor would complete the inspection checklist and upload the site record photos, which are already geo-referenced with the built-in GPS function of the mobile phone. The RSS would then be notified via an automatically generated email to review, comment, and sign off to complete the process.

(a) (b)

Figure 8. Mobile app for soil nail construction (a) details of the soil nail schedule; (b) overall progress of the project.

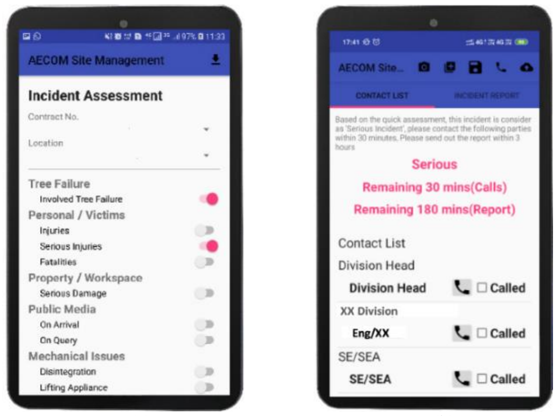
(a) (b) (c)

(d) (e) (f)

Figure 9. Mobile app for site cleanliness (a) dashboard; (b) site location; (c) checklist; (d) site photos; (e) contractor's signature; (f) comment by RSS.

4.3 *Reporting site incidents*

There are well-established reporting procedures to follow if a site incident happens for government projects. In particular, for serious incidents the engineer is required to submit a verbal and written report to all relevant parties within 30 minutes and 3 hours, respectively (CEDD 2020). The mobile app was developed to assist the engineering to make decision of incident seriousness, and to report the incident in a timely manner following the protocol. The verbal report could be readily submitted using the call and record function of the smart phone and the written report could be easily completed using the built-in template of the mobile app (Figure 10). The reports are automatically sent via email to the relevant parties.



(a) (b)

Figure 10. Mobile app for site incident reporting (a) incident assessment; (b) dashboard for reporting.

5 CONCLUSIONS AND THOUGHTS

This paper shares some recent experience of how digital solutions are adopted in the AECOM Hong Kong Office to help our engineers and geologists to enhance the work quality and to improve the project delivery efficiency. Examples of digital solution employed at different stages of a project cycle are presented and discussed. The key findings are summarized below:

- Reality models created using photogrammetry or point cloud data collected from laser scanning are useful not only from the perspective of visualization but also design facilitation. The models could assist engineers to understand how the proposed engineering solutions interact with the environment. More economic and efficient engineering solutions can then be proposed.
- Ground investigation at discrete locations can be efficiently managed and interpreted using appropriate 3D ground modeler. By customizing workflows using tailor-made program scripting, program interoperability can be enhanced and therefore increases work efficiency.
- Mobile apps are developed to greatly improve the quality of site supervision, monitoring and management.

Development of Machine Learning (ML), Artificial Intelligence (AI) and construction robotics could further change the way now civil engineering is doing. The use of intelligent algorithms and robots for engineering design, construction, monitoring and management could be something happened faster than what we think. Embrace changes is the key for our profession to sustain and develop.

5 ACKNOWLEDGEMENTS

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6 REFERENCES

CEDD. 2020. Reporting of incidents on CEDD works sites. Civil Engineering and Development Department Technical Circular No. 6/2020. Hong Kong SAR Government.