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# Geographical and Equipment Modeling for 3D Excavation Simulation

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**Abstract:**

Excavation for construction is implemented in natural geographical terrain using a variety of construction equipment. Therefore, 3D excavation simulation requires integration of geographical and equipment modeling. This paper proposes a technique that integrates geographical and equipment modeling for 3D simulations of construction excavation. The geographical model uses a digital map to show ground surface changes during excavation and the equipment model shows equipment movement and placement. This combination produced a state of the art 3D simulation environment that can be used for machine guidance. An equipment operator can use the 3D excavation simulation to help construction equipment operators with decisions during excavation work and consequently improve productivity.

**Keywords:** 3D excavation simulation, geographical modeling, equipment configuration modeling, machine guidance

## 1. INTRODUCTION

Excavation for construction is implemented in natural geographical terrain using a variety of construction equipment such as excavators, dozers and motor graders. Therefore, 3D excavation simulation requires integration of geographical and equipment modeling. Gharti et al. (2012) studied a 3D simulation of multistage excavation and Huang and Han (2013) developed a 3D simulation for foundation pit excavation based on a vector graphics technique. Azar et al. (2015) applied computer vision technology to provide construction equipment configurations when developing a 3D simulation environment.

The effort of 3D excavation simulation can provide visual information for construction equipment operators. The 3D simulation is the first step toward providing machine guidance. DiMaio and Reboulet (2001) applied an excavator simulator to assist human equipment operators make better decisions regarding construction equipment control. Park and Lim (2004) developed a 3D simulation modeling the mechanical dynamics of construction equipment. Previous research suggests that a combined geographical and equipment configuration model could provide a state of the art simulation environment suitable for machine guidance applications.

This paper proposes an integrated geographical and equipment model for 3D excavation simulation. The geographical model incorporates a digital map to show ground surface changes during excavation, and the equipment configuration model shows equipment movement and placement. The integration of these two models creates the 3D graphical simulation of excavation at the construction site. The final goal of this 3D excavation simulation is to help construction equipment operators with decisions during excavation work and consequently improve productivity. This paper mainly focuses on the technique of integrating geographical and equipment models for 3D excavation simulation.

## 2. GEOGRAPHICAL MODELING

Geographical modeling describes the graphical simulation of ground surfaces within a construction site. The ground surface is represented as a digital map that stores spatial data from discrete points on the ground surface in a digital format. Three types of digital maps are used for geographical modeling: 1) original, 2) planned; and 3) current maps. For example, Fig. 1 shows the original and planned maps in geographical modeling. In the figure, the original map shows the existing ground surface before excavation commences (Fig. 1(a)), and the planned map shows the intended final ground surface after excavation (Fig. 1(b)), whereas the current map shows the ground surface during excavation. The spatial data is stored in a database and constantly updated to be used in 3D excavation simulation.

a) Original map b) Planned map

Fig. 1. Typical original and planned digital maps

## 3. EQUIPMENT CONFIGURATION MODELING

Equipment configuration modeling simulates equipment configurations during excavation. The sectional elements of construction equipment, e.g. an excavator, were modeled using the Unity Technologies (2017) modeling tool, as shown in Fig. 1(b). The various sections are assembled to represent the specific equipment configuration, and used in the 3D simulation. For practical application, the equipment model should be integrated with sensor data to confirm accurate equipment configuration.

Usually, inertial measurement unit (IMU) and position sensors provide location data. A kinematic solution model is required to accurately calculate equipment configuration. The sensor modules detect the equipment section deployment in XYZ coordinates in real-time and transmit the data for calculation in the kinematic model. The transformation of XYZ coordinates provides the information on the end tip bucket position of an excavator.

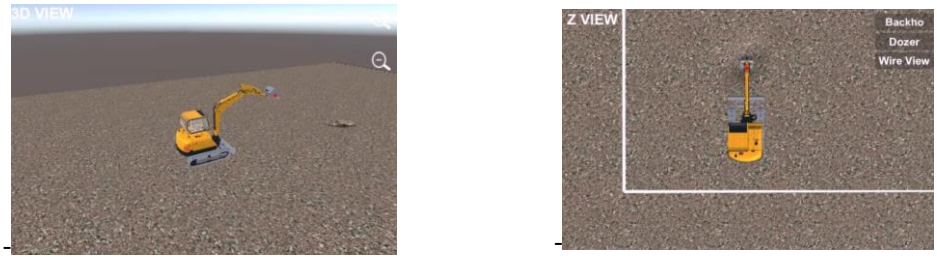
a) Equipment sections b) Assembled unit

Fig. 2. Typical equipment modeling for an excavator

## 4. THREE DIMENSIONAL EXCAVATION SIMULATION

Once geographical and equipment configuration models are complete, they can be integrated into the 3D excvation simulation. A prototype 3D simulation environment was developed to implement the excavation simulation. The prototype is unique in that the simulation provides the building information model (BIM) technique for excavation. Combined with the sensor modules, the integrated model provided a state of the art 3D simulation environment that can be used for machine guidance. An equipment operator can use the 3D simulation to assist decisions during excavation work and consequently improve productivity.

For example, Fig. 2 shows the actual graphic simulation of an excavator. In the figure, Fig. 2(a) shows the movement of the excavator in a 3D view point. Meanwhile, Fig. 2(b) shows the movement of the excavator in a top view. This visual information can be extended to include numerical information for providing a machine guidance functions. This visual and numerical information can help construction operators understand the requirement of width and depth for digging ground surfaces.




a) 3D view b) Top view

Fig. 2. Three dimensional 3D excavation simulation in virtual space

## 5. CONCLUSION

This study applied 3D simulation techniques to model excavation at a construction site. A prototype 3D excavation simulation was developed integrating geographical and equipment configuration models. Since the geographical and equipment configuration models are developed in a 3D objects, the final product of the 3D excavation simulation functions as a 3D BIM environment. This implication suggests that the 3D excavation simulation can be further expanded to be used as a managerial tool for the earthwork operation.

Since earthwork excavation uses a significant portion of construction budgets, state of the art technologies should be developed to improve excavation effectiveness. The 3D excavation simulation environment will be suitable for machine guidance, and, when fully developed, provide visual and numerical information to assist construction equipment operators in decision making and help improve productivity during excavation.

## ACKNOWLEGEMENTS

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## REFERENCES

1. Azhar S, 2011. Building information modeling (BIM): Trends, benefits, risks, and challenges for the AEC industry. Leadership and Management in Engineering, 11(3): 241–252.
2. DiMaio SP, Reboulet C, 2001. A virtual environment for the simulation and programming of excavation trajectories. Presence, 10(5): 465–476.
3. Gharti HN, Oye V, Komatitsch D, Tromp J, 2012. Simulation of multistage excavation based on a 3D spectral-element method. Computers and Structures, 100-101: 54–69.
4. Huang M, Han X, 2013. A 3D simulation method of foundation pit excavation based on vector graphics. International Journal of Computer Science, 10(3): 44–47.
5. Park CG, Lim KH, 2004. A simulation environment for excavator dynamics. Proceedings of Americas Virtual Product Development Conference, Huntington Beach, CA, 1–12.
6. Unity Technologies (2017). Unity user manual, https://docs.unity3d.com/Manual/OptimizingGraphicsPerformance.html