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SIMULATING MACRO AND MICRO PATH PLANNING OF EXCAVATION OPERATIONS USING GAME ENGINE

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ABSTRACT

The planning of large excavation operations requires careful consideration of the conditions of the site, the soil to be excavated, and the equipment to be used. Previous research in this area addressed the macro-level or micro-level path planning of excavation operations. However, this research is integrating both macro and micro path planning issues and considering safety at the level of equipment fleet. This paper aims to: (1) synthesize a new approach for integrating macro and micro path planning methods considering the safety of excavation operations, and (2) simulate these methods using a game engine. The Unity3D game engine was used to develop a simulation environment for earthmoving operations using A* algorithm for macro path planning, and a parametric rule-based approach and RRT algorithm for micro path planning.

1 INTRODUCTION

The planning of large excavation operations requires careful consideration of the conditions of the site, the soil to be excavated, and the equipment to be used. The topography of the land usually dictates the decomposition of the excavation work into masses. The site layout and equipment dimensions impose additional constraints on the optimal sequence of the digging areas and the path planning of equipment in order to improve the efficiency and safety of the operations. Planning excavation operations has benefitted from the research in the area of automated excavation with many contributions from robotics, computer science, and civil engineering. The previous research separately addressed the macro and micro levels path planning of excavation. However, this research is integrating both macro and micro path planning and considering safety at the level of equipment fleet. The objectives of the paper are: (1) to synthesize a new approach for integrating macro and micro path planning methods considering the safety of excavation operations, and (2) to simulate these methods using a game engine.

2 PROPOSED SIMULATION MODEL

Our previous research introduced the concept of agents that can support the excavator and truck operators (Hammad et al. 2013). Figures 1 and 2 show the flowcharts of the excavator and the truck operator agents, respectively. The excavation site is divided into work areas (WAs) where the excavator is supposed to dig the earth. The WA should be excavated based on several strips. When excavation is done in one WA, the excavator moves to the next area using the A* algorithm to ensure avoiding dynamic and static obstacles. At each WP, the excavator regularly utilizes a parametric script for digging the earth and dumping it into a truck. However, in case of any potential collisions with other equipment or obstacles, the parametric script is not reliable. Therefore, the path planning is done using a more sophisticated algorithm such as RRT (LaValle 1998). Figure 2 illustrates how a truck works to achieve its duty in the fleet. When there is more than one fleet of equipment, a truck has to select the excavator that has the shortest queue. The truck can also uses A* to avoid its obstacles when hauling to dump and returning. The truck will wait until it is completely loaded; then it will find its optimal way to the dumping area using A*.

3 IMPLEMENTATION AND CASE STUDY

The proposed model is implemented in Unity3D game engine (2014). It has an initial default scenario with two excavators and four trucks, which is loaded from an XML file. However, the user can modify the scenario by adding more equipment with different attributes, including the ability to specify the speed of movement of each component. Furthermore, the path-planning of excavators is implemented using a modified version of the RRT-BiasedLimCon algorithm (ALBahnassi and Hammad 2012). A simplified model of the excavator is used to define the robotic structure including the DoFs and the range of motion for each DoF. This model is used as the input to the path planner to generate a feasible path. Engineering constraints are also considered, e.g., the movement of the loaded bucket should be constrained to keep the soil in the bucket. Figure 3 shows an excavator working safely in a narrow space using the new RRT algorithm.

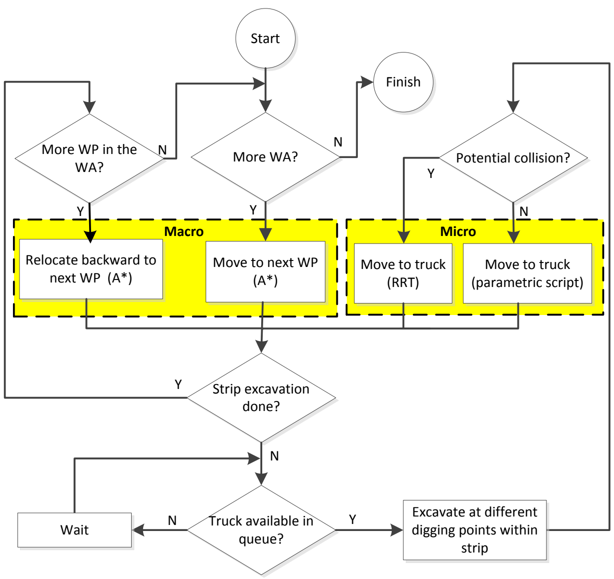

Figure 1: Excavator operator agent flowchart

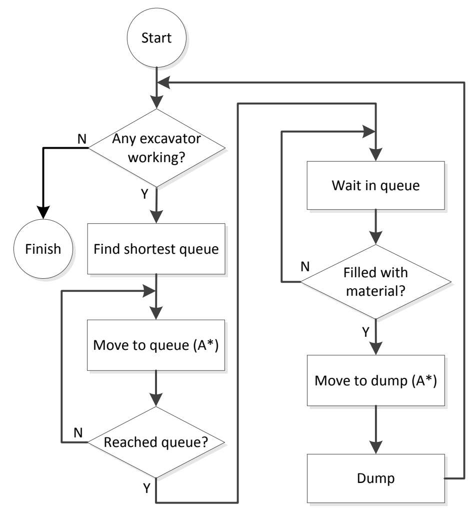

Figure 2: Truck operator agent flowchart

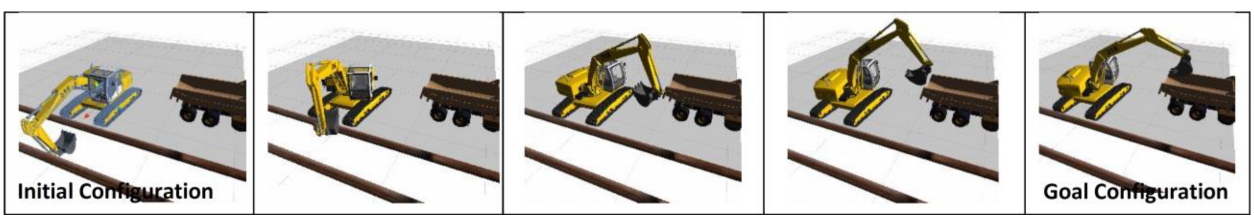

Figure 3: Excavator working safely in a narrow space using RRT algorithm

4 SUMMARY AND CONCLUSIONS

This research developed an agent based simulation for excavation operations in the Unity 3D game engine which consists of a synthesized approach at macro and micro path planning. A* was used for the macro path planning, while a rule-based script and an RRT-based algorithm were used for the micro path planning.

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