Task planner design for an automated excavation system

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An automated excavation system, which is a robotic excavator with site modeling capability, is being developed by a Korean research consortium in order to improve the productivity, quality, and safety of conventional earthwork. This paper presents the excavation task planner devised to incorporate the intelligence of a construction planner and a skillful operator into the robotic control mechanism of the automated excavation system. The excavation task planner aims to generate an optimal excavation plan based on 3D models of the work environment and the excavator updated by various cognitive technologies. The structure of the task planner was designed in harmony with the sensing and the control schemes of the automated excavation system. The algorithms used to partition the work area and to generate the excavator path were developed as the critical components of the task planner. The suggested design of the excavation task planner focused on the functions required to utilize the automated excavator at actual construction sites. Case studies showed that the task planner was able to generate effective work plans that could be fed into the automated excavation system.

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1. Introduction

Production lines in most industries are now automated, providing many benefits such as improvements in productivity, industrial safety, and work quality. However, the construction industry still largely depends on the labor even with the use of construction equipment. Earthwork has not been an exception. The performance of an excavator and other earthmoving equipment still heavily relies on operator skill [14], which can create quality control issues which impact the overall project management. In addition, these problems have been increasing due to the decreasing number of skilled equipment operators.

Due to the need for construction automation and the rapid development of supporting technologies such as sensing, IT, and control technologies, the development of construction robots and semi-automated construction equipment had increased. In the case of earthwork, Global Positioning System (GPS)-based machine guidance systems have been developed, and their use at construction sites is increasing. Typically, these systems utilize and on-board Man–Machine Interface (MMI) that displays real-time information on the position and configuration of the earthwork equipment in relation to the earthwork design information in order to provide guidance to the equipment operator [18]. These GPS-based on-board machine guidance systems are well-suited for dozer-type earthmoving equipment because the visualization of the equipment’s blade with respect to the design can provide guidance for intuitive operation.

There have been various research efforts focused on excavator automation. Lancaster University’s Computerized Intelligent Excavator [2] and Carnegie Mellon University’s robotic excavator for autonomous truck loading [17] are both good examples of automation efforts at the autonomous level. Makkonen et al. [12] examined the possibility of controlling an excavator with 6 degrees of freedom; the final goal was to control the movements of the excavator bucket using a positioning system in conjunction with a CAD model of the road surface. Recently, Kim et al. [6] attached three sensors to detect the motions of a human body and to create operational commands for controlling an excavator. Using Bluetooth wireless communication, the operational commands could be transmitted to an excavator robot. Various R&D efforts have been initiated in Japan, from the virtual operator interface for the remote-control of a single excavator for embankment construction [13] to the remote operation of a fleet of earthwork equipment in risky environments such as construction after a volcanic eruption [4].

The work related to the task planning of earthwork equipment can be classified into two categories. The first category covers the object-level task planning. This category considers pieces and/or portions of an earthwork site as objects, and the work orders for these objects are created as the result of planning. The level of detail involved in this type of task planning varies, but primarily focuses on job scheduling based on large work areas and/or sections for construction management purposes [8,19]. The further detailed task planning in this category includes the task plans specifying the movement of soil and equipment when soil needs to be moved within the site for cut-and-