BASIC CONSIDERATIONS IN THE DESIGN OF ROBOTIC SYSTEMS

FOR ENVIRONMENTAL GEOTECHNOLOGY

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ABSTRACT

The intent of this paper is to identify the basic factors involved in the successful application of robotic systems to the preliminary site investigations of ground conditions in hazardous waste areas. Specific attention is directed to the human-robot-environment interations in hazardous landfill.

INTRODUCTION

Considerable emphasis has been rightfully given to the use of robotics in the advancement of construction. Both the quality of construction and the associated productivity can be significantly enhanced through the practical application of robotics to a wide variety of situations. Due to the complex nature of these applications, a multi-disciplinary approach is required for successful implementation.

Among the various potential applications in Civil Engineering related areas, the use of robotics in environmental geotechnology appears to be both urgent and significant. Environmental geotechnology deals with a variety of hazardous conditions including the following:

a) Disposal and transport of liquid and solid waste,
b) Construction operations in landfill areas, and
c) Damage assessment of natural and man-made hazards.

In these areas, the conventional approaches which involve human operators may not be suitable for preliminary investigations and/or any in-situ testing.

The use of robotic systems as a substitute for human labor, in general, may cause labor problems. The deployment of robots under adverse hazardous conditions as mentioned above, however, should be welcomed by a labor force.

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BASIC NEEDS

In order for robotic systems to be successfully implemented in the advancement of construction, and rehabilitation or repair, several basic needs must be satisfied. These needs may be conveniently grouped together under the heading "human-robot-environment" interactions.

The basic requirements for mobile robots to be used in environmental geotechnology include the following automated data acquisition and, possibly, processing functions: diagnosis for preliminary investigations; process planning and control for monitoring and tactical planning; and decision-making for future actions and strategic planning.

Certainly the application of robotics to these types of functions involves complex interrelationships among numerous disciplines. The resultant product, the robotized system, of separate yet interrelated components suggests "adaptive" hard and soft interfaces between the human-robot-environment components. Attention here is first directed to the soft interface development. Then discussion will focus on the hard, environmental, factors influencing the development of the machine.

With the use of some of the known concepts of Artificial Intelligence, it appears highly probable to be able to aid the engineer in his decision-making process and to enhance his inherent creativity by "maximizing" the computer's ability to process data (1). The knowledge base and the interface mechanism determine, in great measure, the effectiveness and usefulness of a given system.

As Fenves and Rehak (2) have aptly pointed out, the development of EXPERT systems can play a significant role in the diagnosis, interpretation, and prediction of geotechnical behavior under varied conditions. The use of EXPERT systems should be effective in the development of a world model for field data interpretation.

In designing the hardware for robotic systems, one must carefully investigate, as well, the robotic-environmental factors which affect the robot itself. For robots that are used in hazardous waste conditions, for example, the more important factors that must be considered are described below.

(a) Corrosion. In many areas of the U.S. where waste-water temperatures are high, detention times in landfill are long and sulfate concentrations are appreciable.

(b) Bacteria Attack. Bacteria capable of oxidizing hydrogen sulfide to sulfuric acid are always present in hazardous landfill areas.

(c) Heat. In many areas, protection against thermal pollution must be provided.

(d) Electric Shocks. These can occur in areas where least expected due to powerlines being interrupted by natural hazards.

(e) Dynamic Effects. Suitable protection must be provided against impact or other dynamic forces such as those caused by irregular terrain.

In order to protect the robotic system under adverse conditions, it must be built of select materials. Conventional metal that is commonly used is not suitable. Special coatings such as polymers, or other materials must be used. Joints and other specialized parts must be carefully protected.

A POTENTIAL APPLICATION

As a representative project, consider the application of robotic systems to proposed construction sites in hazardous landfill areas. The overall objective is to use a land-based, mobile robot to estimate the soil properties governing the bearing capacity. A determination of the soil profile and the water table is required.

A brief outline of the major steps required of the robot to achieve this goal is as follows. First, the robot traverses the terrain to a predetermined or random set of locations. Second, a sampling device such as a pentrometer is inserted into a particular location in the hazardous area. Next, through remotely controlled sampling, pentrometer resistance data is acquired and transmitted for analysis at a laboratory. One should note that in applications such as this, other data may be useful. For example, measurement of ground temperature and ground pH can be useful in determining soil properties and soil stability in hazardous landfill areas. This cycle of measurements is then repeated until the desired number of locations have been remotely sampled.

As Fenves has suggested, on-site interpretation of data can become a distinct possibility with the advent and implementation of EXPERT systems for these purposes. This promises to become a very exciting and productive area in robotics. Especially when hazardous materials or other dangerous conditions are involved.

In relation to ground improvement of hazardous landfill areas, work is presently underway at Lehigh University to develop undisturbed sampling techniques and instrumentation to measure in-situ stability (3,4). Research is also being conducted on conceptual models of integrated information systems as applied to decision-making. These present efforts are planned to be incorporated into geo-robotic systems as discussed herein.

SUMMARY AND CONCLUSION

For hazardous waste areas, the conventional approaches which involve human operators may not be suitable for preliminary investigations and in-situ testing. The use of robotics coupled with EXPERT systems offers significant promise in these situations.

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