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Automated identification of partially exposed metal object

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Abstract

This paper describes a method for automated shape and pose (position and orientation) identification of partially exposed metal objects that enables safe and efficient excavation of hazardous materials. The method estimates the object pose by matching a model of the object with the area that is extracted from the range image using the characteristics of metal objects. The paper introduces a method for an initial search area for object matching in order to obtain the accurate shape and pose of the partially exposed objects with reasonable calculation time. The experimental results show feasibility of the shape and pose identification of partially exposed objects.

Keywords: Automated excavation; Range image; Pose identification; Genetic algorithm; Object recognition; Abandoned munitions

1. Introduction

It is desirable that hazardous materials, such as abandoned chemical weapons in burial pits, be safely removed within a short span of time [9]. The metal objects are unevenly and densely distributed in burial pits, for example, hundred of thousands of such metal objects are buried in a single burial pit. In addition, metal objects get damaged because of long-term corrosion. Therefore, automated excavation for the removal of such metal objects from burial pits is desirable.

Several automated systems have been proposed for the excavation of hazardous metal objects from burial pits [1,2,4,9]. These systems identify the shape and pose (position and orientation) of the metal object. Then, the robot arm excavates the metal object upon identification. One of the challenges in realizing these systems is the identification of the shape and pose of these objects with good accuracy. However, identification systems for these excavation purposes hardly have been reported.

In this paper, a method for the automated shape and pose identification of partially exposed metal objects has been described. The method uses three-dimensional range data for the identification of such partially exposed objects. Several automated excavation systems that use ground-penetrating radars (GPRs) and metal finders have been proposed [5,6,8]. These systems identify the objects before or during the removal of the soil around them. In addition, the metal objects are buried in the soil and they are not exposed during the identification part of the excavation task. On the other hand, the proposed identification method is developed for the excavation of already detected and exposed metal objects in the burial pit because of the excavation task procedure used in this study. Therefore, the configuration of the identification part of the system is different from that of searching objects such as unexplored metal objects or landmines under the ground.

The study focuses on the pose estimation algorithm based on three-dimensional pattern matching in the system. The pose accuracy of the identified object influences the safety and efficiency of the excavation task. In addition, the identification

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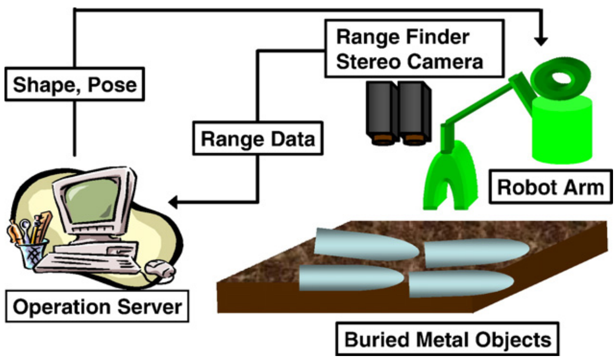

Fig. 1. Overview of automated excavation system.

method must rapidly determine the object shape and pose. In this paper, we introduce a method for setting an initial search area for object matching in order to obtain an accurate shape and pose of the partially exposed objects with a reasonable calculation time.

The experiment for the identification of the object shape and pose was performed under several target object conditions. The experimental results reveal the feasibility of the shape and pose identification of the partially exposed object.

2. Automated excavation system

This section provides an overview of the automated excavation and recovery system and describes its feasibility. An overview of this system and the setup of the prototype identification part of the system have been described. In addition, the characteristics of the metal objects to be identified have been discussed to elaborate on the feasibility of this system.

2.1. System overview

Fig. 1 shows an overview of the automated excavation system. The data capture system, for example, a three-lens camera or a laser range finder, is used to obtain the three-dimensional range data of the buried pit. The robot arm removes the soil around the objects and handles them. The data capture system, robot arm, and operation server are interconnected using the Internet [3].

The system excavates the metal object according to the following procedure: First, the soil around the object is removed using an air jet and then the data about the surroundings of the metal objects are captured using sensors. The system then identifies the object pose and shape. If the identification result is sufficiently accurate to warrant an excavation, the robot arm excavates the object. Otherwise, the system continues with the soil removal from the object surroundings.

The identification of metal objects in the burial pits is the crucial issue for the realization of the automated excavation system. The identification part of the system is required to estimate the shape and pose of the metal object with good accuracy and within a reasonable calculation time. If the identification result is inaccurate, the robot arm will be unable to efficiently and safely handle the object. Further, the metal objects need to be identified within reasonable calculation costs due to the presence of several metal objects in the burial pits.

The characteristics of the metal objects have been discussed to elaborate on the feasibility of automated identification. A prototype of the identification system will then be introduced in order to discuss an identification algorithm.

2.2. Characteristics of buried metal objects

We introduce the conditions of buried metal objects in this study. According to the survey on the abandoned metal object in the burial pit [10], there are hundreds of metal objects in one burial pit. The size of one burial pit is, According to the survey on the abandoned metal objects in the burial pit, there are hundreds of metal objects in a single burial pit. The dimensions of one burial pit are, for example, 25 [m] (length) × 12 [m] (width) × 6.5 [m] (height) [10]. Typically, four types of abandoned metal objects exist in a burial pit.

Table 1 lists the categorization of metal objects according to size and weight abandoned in a burial pit according to the survey on abandoned objects in the burial pit [10]. According to this table, more than 90 [%] of the metal objects are small and light; therefore, the size and weight of these objects can be handled by an industrial robot arm.

The characteristics of the buried metal objects in the burial pit have been enumerated as follows in order to discuss the feasibility of the automated identification part of the excavation system.

(1) Limited types of metal objects exist in the burial pit since they are mass-produced materials.
(2) Metal objects have rotary-symmetrical shapes. These objects have long and slender shapes.
(3) Their colors gel altered as a result of long-term corrosion and rust formation.
(4) They are deformed due to corrosion and rust formation on their surfaces.
(5) In the identification part of the excavation task, a part of the metal object is exposed. In the excavation procedure, the excavation system blows the soil around the metal objects until the metal objects are exposed.
(6) Several metal objects are unevenly and densely distributed in the burial pits.

Characteristics (1) and (2) show the feasibility of the automated identification system required for a safe excavation. On the basis of characteristic (1), it may be concluded that an automated pattern matching method is useful for identification

Table 1
Sizes and weights of the metal objects buried in the pits [9]

Type (diameter) [mm]	Length [mm]	Weight per one object [kg]	Percentage distribution [%]
75	302.5	5–6	22.4
90	392	5–6	70.9
105	485.5	16	4.9
150	556	32	1.8