INFRARED THERMOGRAPHY FOR THE DETECTION AND CHARACTERIZATION OF BURIED OBJECTS

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Abstract

Infrared (IR) thermography is a technique that uses an imaging system to measure the electromagnetic energy emitted from a surface in the IR radiation band. This kind of energy is also known as thermal radiation. Applications of IR thermography have been found in various fields from science, civil and military industries to medical diagnostics, fire rescue and maintenance, etc.

Among the various applications of IR thermography, nondestructive evaluation of materials has received a special consideration of the scientific community. The idea of nondestructive evaluation is to use measurements on the surface of an object to infer its inner structure. In this work, we study the application of IR thermography in one kind of nondestructive evaluation: the detection and characterization of objects which are shallowly buried under the ground. Particularly, we consider its application in the detection of buried (non-metallic) landmines.

IR thermography for the detection and characterization of buried objects can be divided into two steps. The first step, referred to as thermal modeling for shallowly buried objects, aims at predicting the soil temperature provided thermal properties of the soil and the buried objects under investigation. In this step, a forward thermal model, which represents the physical theory of heat transfer processes inside the soil and on the soil surface, is established. In the second step, referred to as inverse problem setting for buried object detection, the forward thermal model and measured IR data (images) are used to detect the presence of possibly buried objects and characterize them based on the estimation of their thermal as well as geometrical properties.

For humanitarian landmine detection, IR techniques can help reducing the number of false alarms and therefore speeding up the clearance process. However, these techniques are still in the early stage of development and their practical applications are still limited due to limitations of data processing techniques. This motivates us to improve their applicability and performance in practical situations by developing efficient methods for processing measured IR data.

This work consists of two main parts following the two steps mentioned above. In the first part, we focus our study on the establishment of a forward thermal model for shallowly buried objects. Theoretical aspects as well as numerical methods for the forward thermal model are investigated. The validation of the forward thermal model for buried landmines is demonstrated by comparing the simulations with measured data acquired in an outdoor minefield.

In the second part, we consider the inverse problem setting for the detection and characterization of buried objects. Mathematically, it is stated as a coefficient estimation problem. Our research in this part is focused on the development of mathematical methods for solving the estimation problem. The main difficulty of this inverse problem is that it is severely ill-posed due to lack of spatial information in the measured data. Our idea in solving this inverse problem is to reduce the number of unknown parameters by parameterizing the coefficient of interest using some assumptions about the properties of the buried objects under consideration. Numerical results show the potential of the proposed approach.