Poster Abstract: Shallowly Buried Trash Detection in Sandy Land Based on IR-UWB Radar

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ABSTRACT

Fast and accurate sand trash detection and localization is extremely important for trash cleaning, and at present, it still mainly depends on sanitation workers to carry out manual detection. Existing computer vision-based methods cannot detect the shallowly-buried trash. Besides, it is difficult and costly to use ground penetrating radar to detect. To overcome these limitations, we design and implement a novel detection system for shallowly buried trash in sandy land, which integrates the commercial IR-UWB radar into the intelligent unmanned vehicle. By controlling the movement of the vehicle, the radar scans the targeted sandy land and synthesizes the signal into the radar heat-map to detect and locate the shallowly buried trash. Experimental results show that the detection accuracy of the system reaches 92.3% with the radar is 75cm from the ground and the angle perpendicular to the ground is 20°. In the direction parallel to the ground, the farthest trash can be detected is 4.2m away from the radar. Within the range of 4.5m^2, it can detect and locate up to 9 trash at the same time.

KEYWORDS

Trash detection, Sandy land, Radar Sensing

1 INTRODUCTION

Sand trash pollution such as beach trash pollution is increasingly serious. Fast and accurate trash detection and localization is extremely important for trash cleaning and environmental protection. Thus far, a series of techniques have been proposed for trash detection, which can be categorized into the camera-based and radar-based ones. Camera-based techniques [1–5] capture pictures or videos of the trash and apply the latest deep learning model to detect and localize trash, which have low work cost, low deployment difficulty, and can detect medium and irregular shapes of objects. However, they cannot detect occluded and buried objects. For the radar-based techniques, most of the works only focus on objects with large reflection area and regular shape, and are not suitable for trash with usually irregular and small shape.

Motivated by the above facts, we propose a radar-based shallowly buried trash detection and localization system that overcomes the above limitations. Specifically, the system utilize a COTS IR-UWB radar mounted on an intelligent vehicle to scan the sand land along a certain direction at a certain speed, and we use the data collected from the radar to do the follow-up analysis. An adaptive Multi-Edge Detection algorithm is proposed to detect the edges corresponding to trash as much as possible. After that, we extract and construct the relevant feature vector and input it into SVM for classification. We choose a COTS IR-UWB radar with a frequency of 7.29GHz because that it has a compact size, lower cost compared with ground penetrating radars (GPR), and high soil penetrating capability validated by a series of experiments we carefully conducted.

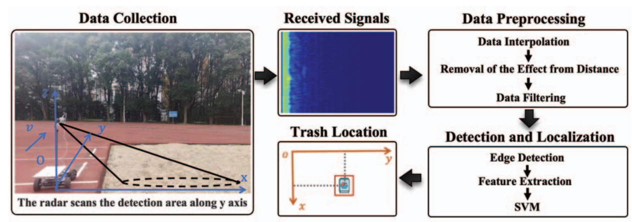

Figure 1: System and Methodology Overview.

2 SYSTEM OVERVIEW

In this poster, we propose a radar-based shallowly buried trash detection and localization system for sandy land protection. Figure 1 shows an overview of our proposed system, which contains three major components:(1) data collection, (2) data preprocessing, (3) trash detection and localization via edge detection and SVM.

Data Collection. The function of this component is to collect the IR-UWB radar signals that can be used to detect and localize the trash. The IR-UWB radar is attached on a intelligent vehicle and we can communicate with the vehicle via wireless way. We control the vehicle to move in a given direction, and the IR-UWB radar scans the target area and collects the received radar signals and stores as 2D matrixs continuously.

Data Preprocessing. In this component, we first enhance the high energy area in the raw radar data by data interpolation method. Then, we perform the removal of the effect from distance and data filtering, which improve the quality of the data and lay the foundation for subsequent trash detection and localization.

Trash Detection. We utilize edge detection and SVM methods to achieve our goal. Specifically, we propose an improved adaptive multi-edge detection algorithm to detect the shape of the trash, which overcomes the shortcoming of traditional edge detection that requires manual threshold settings. Besides, we also extract features from the detected areas and input them into SVM for better detection, which further overcomes the interference of noise.

3 EXPERIMENTS

Experimental Setup. As shown in Figure 2a, we select the sandpit used for training in the school stadium as the experimental site, and select 23 kinds of common household trash with different shapes and materials as experimental objects. The system consists of three components, i.e., the intelligent vehicle powered by Raspberry PI,

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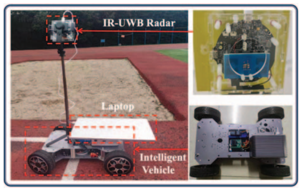


(a) Shallowly buried trash detection and localization system.

(b) Different trash used in the experiment.

Figure 2: System composition and pictures of trash.

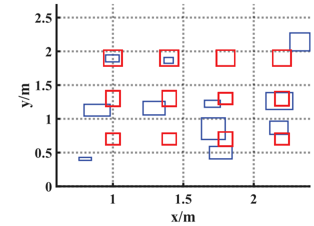
the laptop and IR-UWB radar. The vehicle is controlled to move along y direction at v speed through bluetooth communication, and a laptop is used to control the IR-UWB radar to scan the sand and collect the data. The IR-UWB radar is powered and controlled by the laptop through a serial port, and transmits the baseband signal with a bandwidth of 1.5 GHz modulated onto a 7.29GHz carrier with the low-cost Novelda X4M05 IR-UWB transceiver.

We use *Intersection over Union* (IOU) to evaluate our system, which evaluates the overlap of the ground truth and prediction region in object detection and segmentation as a metric. For the ground truth, we record the shape information of each test trash and the position of each trash center point in the experiment. According to the length and width of the trash, we can calculate the four boundary points and the corresponding bounding box in the top left corner, top right corner, bottom left corner, and bottom right corner. Given a trash buried in the sand, it is detected successfully if the IOU between the bounding box calculated by our algorithm and the actual one is greater than 0.

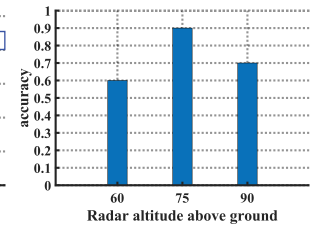
Results. (1) Performance of SVM and Overall Accuracy: We collected 124 groups of data, which are extracted from the feature vectors of the heat map region, including 69 groups of noise data and 55 groups of trash data. The data set was divided into training set and test set. We randomly split the dataset 100 times and calculate the average accuracy of SVM classification for 100 times. The accuracy of the trained model on the test set can reach 93.5%. We select lays bucket, coke can, lays bag, plastic bottle, cystosepiment as the experimental test objects, which are buried below the sand surface from 1cm-3cm. Experiments show that the overall detection accuracy can reach 92%. As shown in Figure 2b, we selected common types of trash in our daily life, such as lays bucket, coke can, and so on. The experiment use 23 different kinds of trash and the results show that our system performs well and has robustness on trash's shape in the detection of a variety of different trash.

(2) Number of Detection: As shown in Figure 3a, we placed 12 trash in a rectangular range of 0.6-2.4m in the x axis direction and 0-2.5m in the y axis direction, totaling 4.5m^2. Among them, 9 trash are effectively detected and located. Therefore, the results show that our system has a good effect in multiple trash detection. Besides, as shown in Figure 3b, when h is 75cm, the system can reach 90% detection accuracy. When the height is 60cm and 90cm, it can be seen that the accuracy relatively decreases.

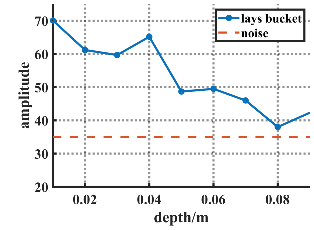
(3) Depth of Detection: We choose five kinds of trash, i.e., lays bucket, coke cans, food packaging bags , plastic bottles and glass bottles. The height of the radar is 75cm, the angle β is 30°, and the



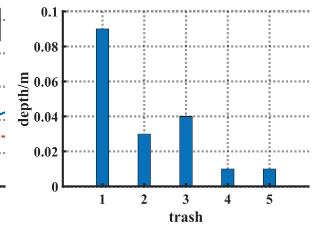
(a) Number of trash.



(b) Results at different height.



(c) Received signal's amplitude.



(d) Maximum depth of trash.

Figure 3: Experiments on the impact of the system's settings.

car moves at a speed of 0.15m/s. Figure 3c shows the amplitude of the received signal corresponding to the lay bucket varies as the depth changes. When the depth continues to increase, the received signal corresponding to the trash becomes smaller, hence the noise and the signal corresponding to the trash are difficult to distinguish and hard to be detected. Figure 3d shows the maximum depth that can be detected for different trash. With the increase of the depth of trash buried, the propagation loss of electromagnetic wave in the sand becomes larger, resulting in the low power of the received signal reflected from trash and difficult to be detected.

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