

A Novel Surface Recognition System Using an Artificial Finger

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Summary:

This paper presents a method for an interactive surface recognition system using a robot and a vibrotactile sensor. The robot was equipped with an artificial finger made of metal to which a three-axis accelerometer was attached. The robot interacted with 10 different surfaces by performing scratching movements on each of them. Random Forest is used as the surface classification algorithm by extracting statistical features of the vibrations detected by the accelerometer. By using only one accelerometer as the main measurement feedback, the results show that it has acceptable classification accuracy.

Keywords: Surface Recognition, Vibrotactile Sensing, Robot Perception, Accelerometer, Random Forest Classification

Background, Motivation and Objective

The sense of touch is important for humans to recognize and experience the properties of everyday objects. For instance, when we run our finger over an unfamiliar object, we can detect the texture. Therefore, there is a growing interest in the development of algorithms and sensors that allow robots to use and interpret tactile feedback while manipulating objects [1].

There are several approaches to surface detection and identification systems [2]. Previous research has differed in terms of the sensors used and the surface texture information extracted from the objects. Acoustic signals generated by friction have been used for material identification [3]. In [4], an artificial finger equipped with a microphone (i.e., a dynamic touch sensor) is used to detect friction noise, which is mapped into the frequency domain using the Fast Fourier Transform (FFT) to detect different textures.

Compared to previous studies, this work proposes a simpler and more efficient approach to material classification by capturing the vibrotactile feedback generated during interaction with each material surface using just a 3-axis accelerometer. In addition, a classification algorithm was presented. There have been some studies involving tactile texture recognition with the use of deep learning methods, such as [6]. However, in contrast to these studies, this work uses only a single modality and a less costly tactile sensor, showing that similar results can be achieved with a simpler setup and data processing methods.

Experimental Setup

The robot used in the experiments and the entire experimental setup is shown in Fig. 1. The robot model is a universal robot (UR10e) developed by Universal Robotics. A metal rod simulating a finger is attached as the end effector of the robot, to which a 3-axis accelerometer is mounted. The robot was controlled by a series of commands to perform a scratching behavior.

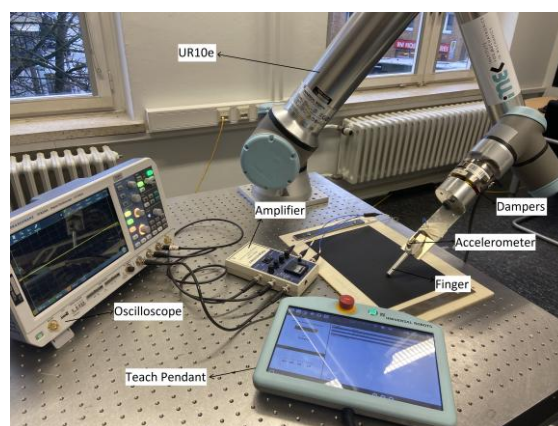


Fig. 1. Experimental setup

The measurement data is recorded during the sliding motion of the robot finger over the material surface at a rate of about 8.33 KHz in a time window of 1.2s. An example of the measurement is shown in Fig. 2.

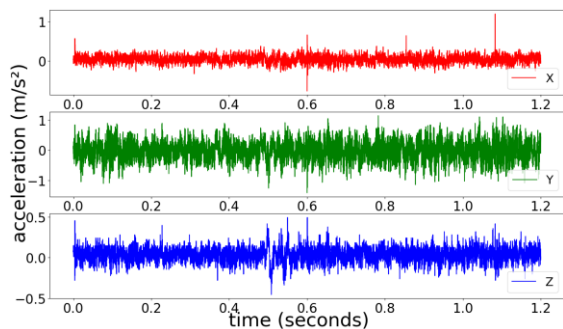


Fig. 2. Sample of a measurement recording

The scratching behavior was performed by sliding the robotic fingertip at a speed of 20 mm/s over a distance of 200 mm over the respective material surface in x direction. For this study, ten surfaces are used for classification and are shown in Fig. 3. The scratching behavior was performed 25 times on each surface resulting in 250 trials.



Fig. 3. Ten surfaces examined by the system

Results

The main objective of this study was to achieve high surface recognition rate by a random forest classification model and check this possibility. Fig. 4 shows the confusion matrix of this random forest classification model and it gives us predictions in 7.83 MS and an accuracy of 91.5%.

Conclusion and Further Improvements

Surface recognition systems play a crucial role in many fields such as biometrics, robotics, and security. The ability to accurately identify and distinguish between different materials based on their physical properties provides a reliable and efficient method for identifying and authenticating objects and their surroundings. One of the main results of this study is to investigate how combination of robotics and machine learning can improve the surface recognition task in industry. In this work, results have shown that this combination can give us good result and for

future using more materials and testing other machine learning algorithms can give us a better vision.

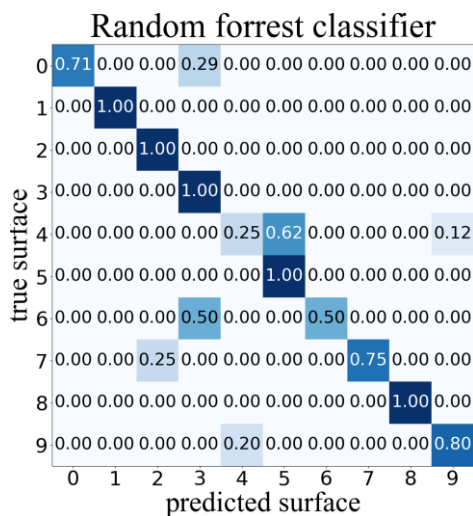


Fig. 4. Confusion matrix of the classifier

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