Osprey Demo: A mmWave Approach to Tire Wear Sensing

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ABSTRACT

In this paper, we demonstrate Osprey, a tire wear sensor presented in [4]. Osprey makes use of commodity, automotive, mmWave RADAR, places it in the tire well of automobiles to image the tire and then measures the tire wear. Osprey measures accurate tire wear continuously while being resilient to road debris and without embedding any electronics in tires. Osprey achieves this by building a super resolution algorithm based on Inverse Synthetic Aperture RADAR imaging and by embedding thin metallic strips along coded patterns in the grooves to combat debris. Here, we implement Osprey on a tire rotation rig and demonstrate the ability to measure tire wear (with and without debris) accurately and detect potentially harmful foreign objects.

CCS CONCEPTS

• **Hardware** → **Sensor applications and deployments**; **Sensors and actuators**; **Wireless devices**; **Signal processing systems**; • **Computer systems organization** → **Embedded and cyber-physical systems**; • **Applied computing** → Computers in other domains.

KEYWORDS

Millimeter Wave, Wireless Sensing, Tire Wear, Tread Depth, RADAR, Automotive, 77 GHz, FMCW, Super Resolution, Inverse Synthetic Aperture RADAR Imaging, Debris, Spatial Coding, Orthogonal Codes, Free of Electronics, Foreign Object

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1 INTRODUCTION

This paper describes our proposed demonstration of Osprey [4], a novel solution to sense tire wear continuously even in the presence of debris. Today's solutions are either crude [2], don't measure continuously, are expensive to setup [1], or are susceptible to the accumulation of debris [3].

Osprey overcomes these problems by leveraging commodity, automotive mmWave RADAR and placing it in the tire well, thus allowing for easy, continuous measuring and monitoring of tire wear. Osprey measures the tire wear by analyzing RADAR signals reflected from the tire, estimating the range of the surface and the groove and subtracting the two. Through this demonstration, we will show how Osprey addresses the following two challenges. First, the distance between surface and groove is so small (2 mm - 20 mm) that mmWave RADARs can't resolve reflections from them. Second, even if the surface and groove's reflections are resolved, in the presence of debris, distinguishing the groove from the debris is challenging. Our demonstration of Osprey overcomes these challenges through a super-resolution Inverse Synthetic Aperture RADAR (ISAR) imaging algorithm using the natural rotation of the tire. This ISAR image is used to estimate the surface range. Osprey embeds thin metallic strips in the grooves to emulate a certain spatial code. Using this code, Osprey declutters the reflections from the groove and debris, and estimates the groove range. Osprey then subtracts the surface and groove range to obtain tire wear / tread depth. In addition, Osprey also uses the ISAR image to detect and localize harmful foreign objects such as nails.

We demonstrate the working of Osprey on a tire rotation rig. We show the measurement of tire wear with and without debris, and the detection of foreign metallic objects.

Demo URL: https://www.witechlab.com/osprey.html

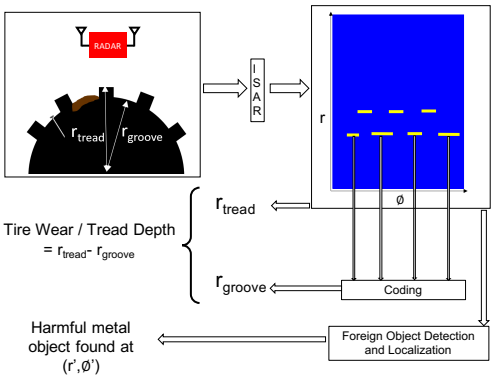

Figure 1: Osprey's Overview: (1) Generate a super-resolution Inverse Synthetic Aperture RADAR (ISAR) image. Obtain r_{tread} from the image (2) Isolate groove from debris using coding to obtain r_{groove}. Subtract r_{tread} and r_{groove} to obtain tire wear / tread depth (3) Detect and locate foreign objects using ISAR image.

2 SYSTEM OVERVIEW

Osprey's sensing system consists of 3 main parts (see Fig. 1):

Super-resolution algorithm and tire surface ranging: In order to separate the reflections from the surface and the groove of the tire tread, we design a super-resolution ISAR algorithm which overcomes the limited range and azimuth resolution of the RADAR.

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