sensors

Article

Machine Learning Based Object Classification and Identification Scheme Using an Embedded Millimeter-Wave Radar Sensor

Homa Arab [1,*], Iman Ghaffari [1], Lydia Chioukh [1], Serioja Tatu [2] and Steven Dufour [1]

[1] École Polytechnique de Montréal, Montréal, QC H3T 1J4, Canada; i_ghafari@ymail.com (I.G.); lydia.chioukh.1@ens.etsmtl.ca (L.C.); steven.dufour@polymtl.ca (S.D.)
[2] Institut National de la Recherche Scientifique (INRS), Montréal, QC H2X 1E3, Canada; Serioja.Ovidiu.Tatu@inrs.ca
* Correspondence: homa.arab@polymtl.ca; Tel.: +1-514-340-4711

Abstract: A target's movements and radar cross sections are the key parameters to consider when designing a radar sensor for a given application. This paper shows the feasibility and effectiveness of using 24 GHz radar built-in low-noise microwave amplifiers for detecting an object. For this purpose a supervised machine learning model (SVM) is trained using the recorded data to classify the targets based on their cross sections into four categories. The trained classifiers were used to classify the objects with varying distances from the receiver. The SVM classification is also compared with three methods based on binary classification: a one-against-all classification, a one-against-one classification, and a directed acyclic graph SVM. The level of accuracy is approximately 96.6%, and an F1-score of 96.5% is achieved using the one-against-one SVM method with an RFB kernel. The proposed contactless radar in combination with an SVM algorithm can be used to detect and categorize a target in real time without a signal processing toolbox.

Keywords: doppler frequency; in-phase/quadrature demodulator; machine learning; millimeter-wave; multi-class SVMs; metronome; radar cross section (RCS); wavelet scalogram

check for updates

Citation: Arab, H.; Ghaffari, I.; Chioukh, L.; Tatu, S.; Dufour, S. Machine Learning Based Object Classification and Identification Scheme Using an Embedded Millimeter-Wave Radar Sensor. *Sensors* **2021**, *21*, 4291. https://doi.org/10.3390/s21134291

Academic Editor: Petros Daras

Received: 14 May 2021
Accepted: 18 June 2021
Published: 23 June 2021

1. Introduction

The analyses of the received electromagnetic signal from different targets have been of great importance in many research and engineering topics. Accurate computational methods in classification and identification of targets are very much desired. Autonomous self-driving car [1], intelligent robots [2], smart home devices [3], and diagnosing disease [4] are just some of the domains that usually target detection and target classification play an important role. Wireless radar sensing using millimeter wave signals is proven as an effective tool for various purposes [5–7]. For instance, in [8], a millimeter wave radar sensor is presented for early-stage detection of melanoma skin cancer. The proposed sensor has ability to detect melanomas in its early and most treatable stages with the accuracy on the order of tens of microns. In [9,10], a 77-GHz six-port sensor is designed for accurate near-field displacement and Doppler measurements with high accuracy, at a reasonable cost. In [11], a millimeter wave radar sensor is studied for medical signal detection. In [12], they developed fully coherent, solid state, FMCW radar systems operating at 94 and 340 GHz, which is suitable for micro-Doppler and vibrometry studies with the sensitivity of 1 micron in range measurements. In [13], they proposed to use of Ultra Wideband (UWB) radars and audio processing techniques for eavesdropping applications in various environments.

The millimeter-wave radar sensor can measure phase, frequency and relative amplitude variations of the reflected signal from the target, with respect to a reference signal derived from the transmitted continuous wave (CW) signal. Various parameters, such as object dimensions, shapes, material properties, positions, and speeds of movement could be extracted from the received signal. However, the effect of many static and dynamic