Discrimination of reflected sound signals

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*Abstract*—Machine learning (ML) in acoustics and signal processing domain has experienced rapid advancements and developments with persuasive outcomes over a course of years. The statistical techniques of Machine Learning offer detection of data patterns, which helps in identification of convoluted relationship between features and further discrimination, or classification based on these features. One of the ML technique, called Binary classification is usually used to discriminate between two class labels. This paper provides ML-based solution for the discrimination of reflected sound signals, which are reflected from two different objects. Firstly, data pre-processing is performed on the reflected time signals to render the dataset. Secondly, Quadratic Time Frequency representation (QTFR) of the reflected sound signal is generated and features extraction is performed on it. Afterwards, four different Machine Learning classification models; namely, K-Nearest Neighbors, Random Forest, Logistic Regression and Decision Trees are utilized for data training and prediction for the realization of binary classifier or discriminator. Finally, an assessment of classification results based on accuracy and various other measures are presented and discussed.

Keywords—Machine Learning, Quadratic Time Frequency Representation, Binary Classification, Discriminator, K-Nearest Neighbors, Random Forest, Logistic Regression, Decision Trees

# Introduction

The recent inventions of smart and intelligent systems and devices have increased the utilization of Machine Learning and computational intelligence-based algorithms. A wide range of research on the popular topic of Machine Learning (ML) algorithms and techniques are available, which have brought considerable progress and ease to routine activities in this digital era. Machines are being trained to perform the task that humans do. The innovative algorithms and techniques of Machine learning (ML) have empowered advancements in automatic-data processing and pattern recognition across many science and engineering fields. ML offers intelligence-based solutions to complex engineering challenges, in same manner as the processing of human’s brain. Additionally, ML deals with a variety of diverse big dataset such as image, video, audio, time series signals, 1D signals, text, etc, which are vastly produced and stored by intelligent systems [1]. ML techniques in the domain of sound signals and acoustics have gained much attention for its persuasive solutions towards crucial tasks such as identification and validation of different sound signals. These ML algorithm detects data patterns by extracting useful attributes and features from the given dataset. Data labeling is performed afterwards by utilizing these patterns. ML based statistical methods enables the system or machine to learn and predict on the basis of pattern recognition [2].

ML classification technique works through estimating the mapping pattern that logs the training dataset to the target class or label [3]. One of the ML classification techniques which acquire only two class labels is referred as Binary classification technique. The input dataset samples are classified into two states by computing specific classification measurements. There are 2 disjoint classes available for binary classification [4]. Some of the popular ML algorithms that can be used to realize binary classifier are Logistic Regression, k-Nearest Neighbors (k-NN), Decision Trees, Support Vector Machine (SVM), Naive Bayes, etc.

The inspiration behind this study is to deliver a classification-based solution to discriminate between the reflected sound signals coming from different objects. The considered use-case scenario is the acoustic signals that incident on the surface of some objects and reflect back. The time signal is formed after recording those reflected sound signals. The resultant time signal is the convolution of the incident sound waveform along with the reflecting object’s surface properties. By analyzing the properties of reflected time signal, the knowledge about the reflecting object can be achieved, on the basis of which the discrimination between reflected time signals is possible.

The ML-based solution for the aforementioned challenge is the main goal of this study. The aim is to realize a Binary Classifier or discriminator by applying different ML algorithms on the labelled dataset. The employed ML algorithms include Logistic Regression, k-Nearest Neighbors (k-NN), Decision Trees, and Random Forest (RF). This Binary classifier or discriminator is used to classify or distinguish the reflected sound signals, which belong to two different objects, named as Object#1 and Object#2. Before implementing the binary classification algorithm, the Quadratic time frequency representation is created for given sound signals, based on which the associated features are extracted to perform classification.

This paper presents a ML-powered solution for the discrimination of reflected sound signals by using binary classification technique. The framework of this paper is as follows: Section II provides the brief description about the utilized techniques for the realization of Binary classification or Discriminator model. Section III illustrates the workflow and step by step approach and methodology to achieve the discriminator of reflected signal. Section IV explains the python-based code implementation for the binary classification model. In Section V, the result analysis and assessment for the implemented binary classification model based on some evaluation metrics will be discussed. Finally, the paper is concluded in Section IV.

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# Results

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1. G. Papakostas, K. Diamantaras and F. Palmieri, “Emerging Trends in Machine Learning for Signal Processing”, Computational Intelligence and Neuroscience, vol 2017, pp. 1-2, November 2017, Article ID 6521367, DOI: [10.1155/2017/6521367](https://www.researchgate.net/deref/http%3A%2F%2Fdx.doi.org%2F10.1155%2F2017%2F6521367?_sg%5B0%5D=XWGBoldQewsJBnvG7YxetYkUFg7uR1V_B2pA9ndw1fmCp5l9hf_N_L2AHjlGfLtWdy2andutwgqn1ROjRCw9Vl3FKQ.iq11NVTyIfEmKHmDS6lxbaTc2yhelQsJoEkQ_XFhShVW0TLLugDF7CPeRBu3IGgHjj2L01xBrET0e0a1g2SvAQ)
2. M. J. Bianco, P. Gerstoft, J. Traer, E. Ozanich, M. A. Roch, S. Gannot, and C. A. Deledalle, "Machine learning in acoustics: Theory and applications", The Journal of the Acoustical Society of America 146 , pp. 3590-3628, 2019, DOI: 0.1121/1.5133944
3. A. C. de Carvalho and A. A. Freitas, "A tutorial on multi-label classification techniques," in Foundations of Computational Intelligence, vol. 5, , ed: Springer, pp. 177-195, 2009
4. M. Er, R. Venkatesan, & N. Wang, “An Online Universal Classifier for Binary, Multi-class and Multi-label Classification”, September 2016.
5. J. Clerk Maxwell, A Treatise on Electricity and Magnetism, 3rd ed., vol. 2. Oxford: Clarendon, 1892, pp.68–73.
6. I. S. Jacobs and C. P. Bean, “Fine particles, thin films and exchange anisotropy,” in Magnetism, vol. III, G. T. Rado and H. Suhl, Eds. New York: Academic, 1963, pp. 271–350.
7. K. Elissa, “Title of paper if known,” unpublished.
8. R. Nicole, “Title of paper with only first word capitalized,” J. Name Stand. Abbrev., in press.
9. Y. Yorozu, M. Hirano, K. Oka, and Y. Tagawa, “Electron spectroscopy studies on magneto-optical media and plastic substrate interface,” IEEE Transl. J. Magn. Japan, vol. 2, pp. 740–741, August 1987 [Digests 9th Annual Conf. Magnetics Japan, p. 301, 1982].
10. M. Young, The Technical Writer’s Handbook. Mill Valley, CA: University Science, 1989.

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