A Report on End-Semester Project

Machine Learning based Spectrum Detection for Cognitive Radio

Supervised by
DR. SUNEEL YADAV

DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING

INDIAN INSTITUTE OF INFORMATION TECHNOLOGY
ALLAHABAD

Presented By
NEHA KANDPAL [IEC2015048]
AKRITI GUPTA [IEC2015043]
BHARTI SAINI [IEC2015032]

NOVEMBER 20, 2018

CANDIDATE DECLARATION

We hereby declare that the work presented in this project report entitled "**Machine Learning Based Spectrum detection For Cognitive Radio** ", end semester project of 7th Semester of B.Tech (ECE) at Indian Institute of Information Technology, Allahabad, is an authenticated record of our original work under the guidance of DR. SUNEEL YADAV. Due acknowledgment has been made in the text to all other material used.

Place:Prayagraj
Date: 20.11.2018

Akriti Gupta (IEC2015043)
Neha Kandpal (IEC2015048)
Bharti Saini (IEC2015032)

CERTIFICATE

This is to certify that the above statement made by the students is correct to the best of my knowledge.

Dr. Suneel Yadav
IIIT-Allahabad
Date: 20.11.2018

ABSTRACT

With the development of wireless technology, the most recent and upcoming project is the improvement of cognitive radios. Cognitive radio technology is a method to use the limited spectrum provided to primary users to its maximum. Cognitive radios are often referred to as secondary users, since they have no spectrum allocated of their own and simply use the spectrum which is made free by the primary user in its idle time. Cognitive radios are a part of intelligent networks and are yet to be integrated with general/communal technologies.

The recent research on cognitive radios have aimed at using novel methods to increase its efficiency as well as make the decision process accurate and faster. Keeping this objective in mind, machine learning algorithms are best suited for such technologies and can change the pace of development in this field and the face of technology as we perceive today.

This paper aims to contribute to this research by a three fold mechanism. Firstly we aim to understand the cognitive network and its methodology, the techniques that have been perfected and the Grey areas which need further improvement especially concerning machine learning. Secondly, we wish to pick up the machine learning algorithm used for cognitive radios, and understand the regression model that the data is fit into. Thirdly, we'd like to draw up a test and training dataset and fit our own regression model into each, comparing the similarities and accuracy of the model fitted through our function. Through the process we aim to find parameters which help to increase/decrease the accuracy of the model.

CONTENTS

1 Introduction **1**
1.1 Overview 1
1.2 Basic Idea of Work 1
1.3 Motivation 1

2 Objective **2**
2.1 Problem Definition 2
2.2 Solution 2

3 System Model **2**
3.1 Methodology 2
3.2 System Architecture 3

4 Implementation **4**

5 Result **4**

6 References **5**

1 | INTRODUCTION

1.1 | Overview

Wireless communication has come a long way; from 1G to 5G, and this evolution has been ubiquitous as well as continuous. Wireless technology has inevitably become an indispensable part of our day to day life and by analogy, the wireless spectrum has become a revolutionary man-made resource. With the development of mobile phone generations and the increased usage of this limited spectrum, the optimized utilization of this resource is the next big thing. The technology which answers to this problem is cognitive radios. Cognitive radios help to utilize the spectrum provided to primary users through various architectures such as
1.Overlay
2.Underlay
3.Interweave
We aim would be to propose a methodology to increase the efficiency of the system through machine learning and fit a regression model in the dataset as best as possible.

1.2 | Basic Idea of Work

Machine learning is a tool that helps to train systems according to prevalent trends and patterns observed in day to day activities, so that the future outcomes can be predicted with a high probability. Any event that occurs in our lives is usually based on a variety of parameters, for instance take the example of occurence of traffic on highways. It may be due to rush hour (depends on time), due to rain (depends on weather), due to public holiday (depends on occassion) etc. these parameters, if properly weighed and fit into a perfect regression model then the model can accurately predict how the future outcomes of the event may turn out to be. Thereby providing us a probable shape of the prediction which may be very accurate to the actual figure. We will try to fit such a model in the working of a cognitive radio so that the radio understands beforehand the routines of spectrums and may not need to waste resources over a busy spectrum everytime.

1.3 | Motivation

With the advent of wireless technology and its widespread applications, many challenges are being faced by the industry. We have picked up one such challenge that is to optimize the utilisation of the spectrum allocated to users for full efficiency. The solutions proposed are multitudinous and are constantly being being revolutionised to change the future of technology as we percieve it. With this knowledge and a will to contribute towards the future of this technology we propose to implement machine learning algorithm in the development of cognitive radios to maximise the throughput and increase the efficacy of decision making process that governs the System.

2 | OBJECTIVE

2.1 | Problem Definition

A cognitive radio (CR) is a radio that can be programmed and configured dynamically to use the best wireless channels in its vicinity to avoid user interference and congestion. Such a radio automatically detects available channels in wireless spectrum, then accordingly changes its transmission or reception parameters to allow more concurrent wireless communications in a given spectrum band at one location. The problem that this system encounters is that the model can be relatively inefficient, since the system will have to continuously scan each and every spectra for the availability, wasting time as well as resources which may be put elsewhere to more benefit.

2.2 | Solution

Once a regression model is fit for a certain training data and the past observations have given the system an idea as to which parameter should be weighed in what proportion, the system will then automatically understand the trends for users using the spectrum. This can be a big aid in making this technology more efficient, since now the radio already has a sense of which spectrum will be free in what hour and now it can save its resources by not scanning the broad spectra all the time. The features of the spectra used for analysing it are its users' energy information. The users working on different channels of the spectrum are observed and the channel is classified to be relatively free or busy according to the traffic that the spectra is handling.

3 | SYSTEM MODEL

3.1 | Methodology

To begin implementing the machine learning algorithm, we had to choose among a wide variety of algorithms for training the model. There are supervised and unsupervised learning algorithms and different equations which weigh different parameters in different ways. For our research we have chosen support vector machine algorithm (SVM) , which is supervised learning approach.

SVM

There are many ways to separate data.The Support Vector Machine theory provides a systematic method for separating data optimally. The focus is on finding the margin which gives a maximum distance between the separable classes. The solution process of Support Vector Machine (SVM) focuses on finding a hyperplane that divides a set of samples into two categories (here, benign and malign cells). To achieve this, we must find a hyperplane which keeps the samples as far away as possible. Another approach for sample that are not linearly separable is to transform them to higher dimensions. This increases the probability of the samples being linearly separable in higher dimensional space. The transformation can be achieved by using a kernel. For this classification, we use linear and polynomial kernels. Since SVM is a supervised form of machine learning, it requires an extensive dataset which should contain the parameters that the learning is based on and which need to be weighed to make future predictions.

3.2 | System Architecture

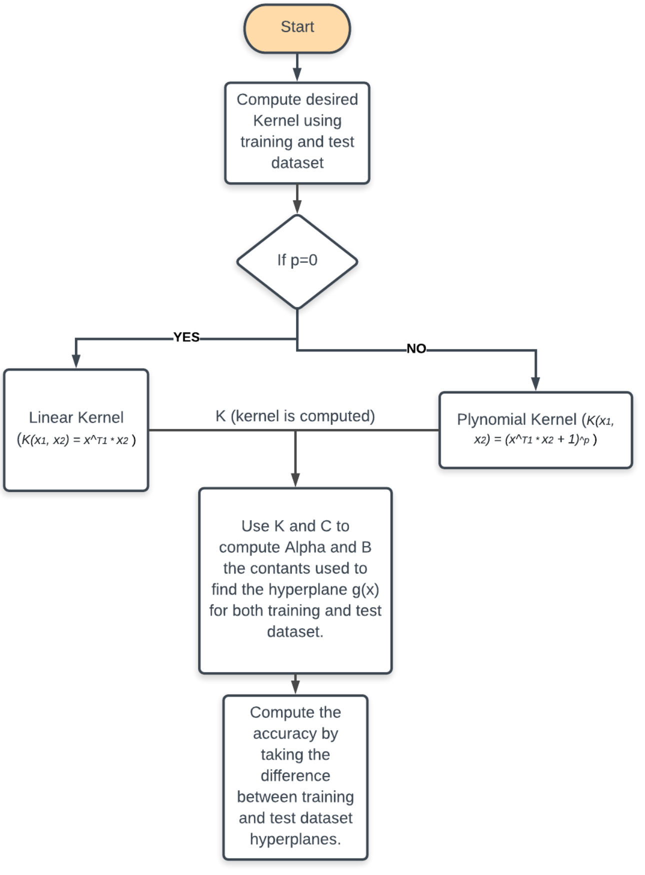

Figure 1: Block Diagram of Machine Learning based Spectrum Detection for Cognitive Radio

4 | IMPLEMENTATION

THE DATASET

The training dataset picked up by us contains a 258 hour based matrix analysing a single spectrum which has an assumed count of 30 users working over it. The matrix shows the energy levels of all the users in each hour and is being fed into the algorithm to decide whether the system is idle or busy.

The test dataset contains the 100 hour based matric analysing the same spectrum for the same number of users, which will be fed to the trained system and the spectra will be classified as busy or idle. The actual classification will also be then compared with the output of ML based machine and the accuracy will be compared.

The Kernels

A hard-margin SVM with a linear kernel - K(x1, x2) = xT1x2 A hard-margin SVM with a polynomial kernel - K(x1, x2) = (xT1x2 + 1)p where the values of p are listed in the following table. A soft-margin SVM with a polynomial kernel, and with the values for p and C as listed in following table. The Kernel is implemented in getkernel.m file. The Kernel is linear when p is 0 and polynomial otherwise. The categorization of hard and soft margin is done by the variable c; if c is 1000000, the kernel will be hard margin, otherwise it will be a soft margin. Since hard margin does not allow for any room of deviation, so there is no threshold required there. However, when the soft margin is taken into consideration a certain threshold is required to set the limit till which deviations are allowed. Usually the value of threshold is closer to 1, to allow minimum deviations possible (around 0.9-0.95). The algorithm for calculating the values of alpha and b0 is implemented in solvealpha.m and solveb0.m Matlab functions. Alpha is calculated using quadprog function in Matlab. B0 is calculated by its characteristic SVM equation. Alpha and b0 are used in the equation to create a hyperplane through the bessel function which has other parameters like kernel, c, p etc.

WORKING The training dataset is fed into the code and the machine is said to have been trained by creating a hyperplane that fits the dataset accurately. The test dataset is then inputted into the machine in order to test our learning. A new hyperplane is generated, along with a new matrix that shows if the spectra is available (-1) and busy (1). This matrix is ten compared with the actual scenario, whether the spectra was actually available or busy and the accuracy of our prediction is observed. The observations are plotted in MATLAB.

The same procedure is repeated with changing parameters such as c and p, for polynomial/ linear kernel or hard/soft margin. The values of p are increased to observe a peak in accuracy by making the polynomial more and more complex. The comparison of all the different scenarios is fed in a table and compared.

5 | RESULT

Following are the results:
1.The Accuracy of hard margin with linear kernel is .91
2.The Accuracy of hard margin with polynomial kernel is .97
3.The Accuracy of soft margin with polynomial kernel is .94
4. The Accuracy of soft margin is increasing with p until value of p is less than equal to 7 after that it is decreasing .

Accuracy Results :

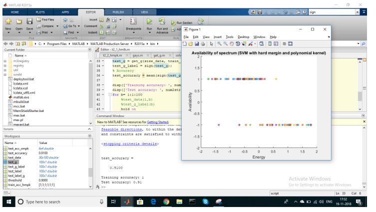

Figure 2: Accuracy of SVM with hard margin and linear kernel

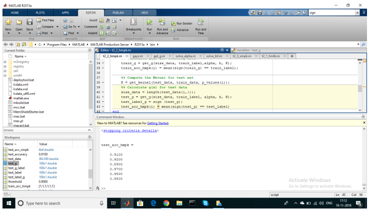

Figure 3: SVM with hard margin and polynomial kernel

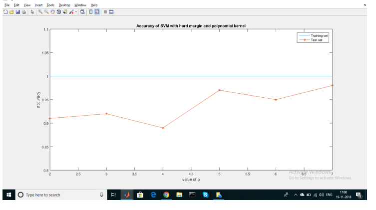

Figure 4: Acurracy plot for SVM with hard margin and polynomial kernel

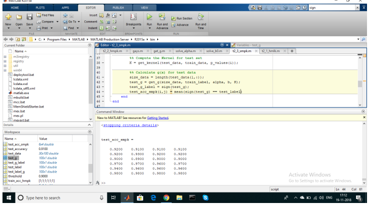

Figure 5: SVM with soft margin and polynomial kernel

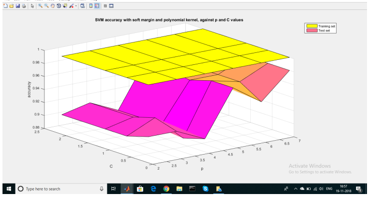

Figure 6: Accuracy plot for SVM with soft margin and polynomial kernel

6 | REFERENCES

[1] https://medium.com/machine-learning-101/chapter-2-svm-support-vector-machine-theory-f0812effc72

[2] https://machinelearningmastery.com

[3] Patil, Sandeep. (2017). A Comparative Analysis of Optimization Techniques in Cognitive Radio(QoS). International Journal of Engineering and Advanced Technology (IJEAT). 6. 97-102.

[4] Jan, Sana Vu Van, Hiep Koo, Insoo. (2018). Throughput Maximization Using an SVM for Multi-Class Hypothesis-Based Spectrum Sensing in Cognitive Radio. Applied Sciences. 8. 10.3390/app8030421.
[5] Z. Lin, X. Jiang, L. Huang and Y. Yao, "A Energy Prediction Based Spectrum Sensing Approach for Cognitive Radio Networks," 2009 5th International Conference on Wireless Communications, Networking and Mobile Computing, Beijing, 2009, pp. 1-4.
[6] https://machinelearningmastery.com
[8] https://arxiv.org/

Comments and Suggestions