Modulation Classification Techniques Using Deep Learning

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Abstract: Classification of the modulation techniques of the signal at the receiver's end is one of the important key features in this world with advanced technologies. This classification of modulation techniques is also one of the key applications for military purposes and during the time of war. The new progressions in the field of Machine Learning and Deep learning have flooded the interest of the scientist in the area of wireless communications which made the development of Automatic Modulation Classification(AMC) easy. So in this work, we develop an automatic modulation classification using neural networks and also we use other regular methods like the Likelihood approach and predict the accuracy of the developed model. We consider datasets and divide the datasets for training and testing, the data is considered as 80% for training and the remaining 20% for testing. We finish up by comparing all the results we obtain with the developed models and propose future work for additional exploration and developments in the area of wireless communications.

Keywords: Modulation, Modulation Techniques, Convolutional Neural Network, Deep Learning, Applications of Deep Learning.

I. INTRODUCTION:

Wireless communication in this world is becoming gradually complicated as communication of signals with different forms of modulation techniques becomes more dynamic and complex as communication technology advances [1]. In modern wireless communication, automatic classification for modulation techniques(AMC) is critical [2]. Only when it is present can signal analysis and processing be carried out.

A CNN-based modulation classification method has been suggested, and it can be used to explicitly sample the intermediate frequency signal's sampling series [19]. Rajendran et al. suggested that the recurrent neural network (RNN) be used for the classification of modulating signals having intermediate frequency signal sampling series.

Modulation: - Modulation is the process of transforming the data into radio signals by adding additional information to the electronics or optical carrier signal. Carrier signal is one having a steady waveform constant height, amplitude, and frequency.

Modulation Techniques: - Modulation is the process of transforming the data into Electrical signals which are optimized for transmission.

Modulation techniques are basically classified into four different types

1) Analogue Modulation
2) Digital Modulation
3) Pulse Modulation
4) Spread spectrum Method

Classification: -

1) Analogue Modulation: - Analogue Modulation is the process of converting the Analogue signal having low frequency signals like audio or video signal upon the higher frequency signal.

   There are three types of Analogue Modulation

   A) Amplitude Modulation
2) Digital Modulation: - Digital Modulation is the process of encrypting a digital signal having information into amplitude, phase, and frequency of the carrier signal. In general form Modulation technique encrypt several bits into one symbol

The most common types of Digital Modulation Techniques are

A) Phase - shift keying (PSK)
B) Frequency – shift keying (FSK)
C) Amplitude – shift keying (ASK)

3) Pulse Modulation: - Pulse Modulation is basically a device that transforms the Analog data signal to a pulse form. A pulse modulator is used to encode the amplitude information at a specific time by a set of short or long duration pulses. Those approaches are acknowledged as pulse – amplitude, pulse – width, pulse – position, pulse – density, pulse – code modulation.

Types of Pulse Modulation: - There are many ways of pulse modulation

A) Pulse amplitude modulation
B) Pulse position modulation
C) Pulse number modulation
D) Pulse width modulation
E) Pulse density modulation

4) Spread spectrum method: - Spread spectrum method is a process that refers to a system initially it was developed for military applications, to provide secure communications by extending the signal over a large frequency band.

Types of Spread spectrum method: - There are mostly four categories of Spread spectrum signals

A) Direct Sequence
B) Pseudo noise
C) Frequency Hopping
D) Linear frequency modulation

II. RELATED WORK :

Convolutional neural network: -Convolutional neural networks are part of deep learning. A convolutional neural network is a class of deep neural network which is most commonly used are applied to many survey models visual imagery. A convolutional neural network is basically inspired by biological processes in that the connectivity design between neurons resembles the organization of the animal visual cortex.

Convolutional neural network is a model which allows user to encrypt higher representation for the image content. Disparate the classical image recognition where you explain the image features yourself. Convolutional neural network takes raw images pixel data, extract the data, train the model data, and then excerpt the features automatically for greater classification.

Uses of Convolutional neural network: - Convolutional neural network is basically a neural network that has one or more convolutional layers that are used primarily for the purpose of image classification, segmentation but also
for other autocorrelated data. Convolutional is essentially able to move smoothly along a surface of a filter upon the input.

Working of a neural network:

The neural network has a large number of processors. These large processors are operated parallelly but they are arranged in the format of tires. The first tire collects the raw input data which is similar to how the optic nerve receives the raw information in human beings.

In each and every successive tire format they collect input from the tire before it and then it passes on its output tire after it. The final output was processed by the last tire.

Neural networks are alienated into small nodes and small nodes are made up as each tire. The small nodes are vastly unified with the nodes in the tire after and before. Each and every node in the neural network has its individual sphere of knowledge, including the rules that were programmed with and the rules that it has learned by itself.

In neural networks, the key to efficiency is that they are extremely adaptive and learn very hastily. Each node weighs the equal importance of the input data that it obtains from the nodes before that attains. The inputs that contribute the greatest towards the right output are given as the highest weight.

Different Types of Neural Networks:

Neural networks are of different types so that they use different principles in control their own rules. There are many types of Neural networks, each with their unique strength and weakness. Here are some of the important neural networks and the applications where these neural networks are used.

1) Feedforward Neural network
2) Radial basis function Neural network
3) Multilayer Perceptron
4) Convolutional Neural Network
5) Recurrent neural network
6) Modular neural network
7) sequence-to-sequence model

1) Feed-forward neural network: In a neural network, the feedforward is the modest type. In a feedforward neural network, the data goes through different input nodes until it reaches the output node.

The added implication of a feedforward neural network is, data moves in only one direction from the first tire onwards until it reaches the output node. This type of method is known as a front propagated wave which is usually achieved by using a classifying activation function.

In a feed-forward neural network, the sum of the products of the information sources and their loads are calculated. This is then fed to the output. Here is an example of a single-layer feed-forward neural network.
A feed-forward neural network is equipped to deal with data that contains a lot of noise. Feedforward neural networks are also relatively simple to learn.

2) Radial basis function neural network: - Radial basis function considers the distance of any point relative to the center. Radial basis function neural network having two layers internal layer and the external layer. And in the internal layer, the features are pooled with the radial basis function. Then the output of these features is taken into consideration when calculating the yield in the following time step. Below is the illustration which shows a radial basis function neural network.

The function of radial basis neural networks is extensively applied in power restoration systems. In recent or present decades, power systems have become larger and more complex.

This particular method increases the risk of blackout. This radial basis functions neural network is used in the power restoration system to restore power in the shortest possible time.

3) Multilayer Perceptron: - Multilayer perceptron has basically three or more layers. It is basically used to classify the data that cannot be separated linearly. It is a category of ANN (Artificial Neural Network) that is fully connected. This is because every single node in a layer is associated with every node in the following after layer.

Multilayer perceptron uses a nonlinear activation function mainly uses hyperbolic tangent or logistic function. Here is the diagram of what a multi-layer perceptron looks like.

Eventually, This type of neural network is extensively applied in speech recognition and machine translation technologies.
4) Convolutional Neural Network: - Convolutional neural network is a variation of the multi-layer perceptron model. The convolutional neural network model is having at least one or more than one convolutional layer. The layers of the convolutional neural network can be either be completely interconnected are else pooled.

The result passing in the convolutional neural network to the following next layer the neural network uses an operation on the input named as Convolutional Operation. Because of this convolutional operation, the neural network can be much deeper with fewer parameters.

Because of this ability, the CNN shows exceptionally viable outcomes in picture acknowledgment and signal or speech identification, and NLP (Natural Language Processing), and also in the recommender systems as well.

The Convolutional neural network shows fabulous results in semantic praising and also in paraphrase detection as well. This is also applied in the processing of signals and classification and processing of real-world images.

III. METHOD:

HISTORY OF DEEP LEARNING:

The concept of Artificial Intelligence is not new, it was first coined in 1956, but it is a theoretical concept, then in the '80s and 90's we talked about Neural Networks. So we are not having enough computational power. We couldn't use it properly. But in the late '90s & 2000s. We started using Neural Networks for Machine Learning. In 2006 Deep Learning was brought into being for the first time that overcomes the limitations of Machine Learning and from 2010 Deep Learning was used commercially as well. Limitation in Machine Learning had given birth to Deep Learning. One of the big challenges with traditional ML models is a process called feature extraction. For example problems such as object recognition or handwriting recognition, this is a huge challenge.

What is Deep Learning:

Deep learning is a branch in Machine learning that which teach computers to do things naturally as a human, like recognizing speech, translating language and make decisions by own. It is a subset of machine learning, which stimulates human-like decision-making.

To achieve Artificial Intelligence, there were few technologies that came. First came Machine learning, there were certain limitations in Machine Learning. In order to overcome those limitations then came deep learning.
How Deep Learning Works:

Deep Learning models are proficient in the center on the right features by themselves own self, requiring little guidance from the programmer. These models also partially solve the dimensionality problem. The idea behind Deep Learning is to build learning algorithms that imitate the brain. The concept is completely to imitate the human brain.

Deep Learning is implemented through Neural Networks. The main theme behind Neural Networks is the biological neuron. They are nothing but brain cells.

Neurons will have dendrites which act as inputs, and the nucleus in the cell body of neuron perform some functions, from there output travel through axon terminals and one neuron fire the output to the next neuron.

The study tells us two neurons are not connected to each other, there is a gap between them and that is termed as a synapse and this is the process of how completely neuron works like.

Why We Need Artificial Neurons:

In the same way artificial neuron works, Here also there are several inputs and these inputs are provided to processing element. Here in processing element summation takes place which includes inputs and weights and that summation generates transfer function f(s).

Then here comes the concept of activation function, we can use step function or sigmoid function as an activation function. The activation function is nothing but, to provide a threshold, if your output is about the threshold then only the neuron will fire otherwise it’ll not. Once it exceeds the threshold it fires and there hereafter we check the output with the desired output.

If the output or the result we got is not equal to the desired output, centered on that difference we again update the weights, in such a way process will keep on repeating until the output we get matches the desired result or outcome and the way of updating the weights is known as backpropagation.

Like this, data transfer from one neuron to another neuron, and the connection of one neuron to another neuron is known as artificial neural networks.

Basically deep learning is comprised of deep networks, Deep networks are nothing but neural networks with multiple hidden layers. In this type of learning deep network is an advantage. It is having multiple hidden layers, which undergo a keen process to get desired output.

Some Deep Learning Frameworks:

TENSOR FLOW: Tensor flow is the topmost deep learning framework that is widely used by top most companies like Google, Airbus, Mozilla, etc. It is an advanced deep learning framework. The most known use of tensor flow is Google translator id, it is a natural language processing text classification, image recognizer, forecasting, and tagging.

PyTorch: It is a scientific computation package created by all the talented people at Facebook, it is mainly used by industrial giants such as Facebook Amazon, and Google to a certain extent.

KERAS: It supports both convolutional and recurrence networks that are capable of running on top of either theano or tensor flow.

In terms of deep library, it is a high-level neural network API and runs on top of the tensor flow. It is high performing API used to indicate and perform differentiable programs. It targets user experience and it is easy to group all the concepts.

MXNET: The talent of Mxnet is, it provides the user the ability to code in any programming language. That means we can train our deep learning models in the language that we are comfortable with. It is known for its capability in speech recognition, forecasting, natural language processing as well as imaging. It is the official deep learning reference library for amazon.
CAFFE: It is also one of the deep learning frameworks that are supported with an interface like C C++ Python Matlab and also a command-line interface. It is mainly used for visual recognition.

**Deep Learning Applications:**
- Automatic Machine Translation.
- Automatic Image Caption Generation.
- Voice Controlled Assistance
- Natural Language Processing
- Virtual Assistants
- News Aggregation and Fraud News Detection
- Visual Recognition.
- Colorization of Black and White Images.
- Automatic Machine Translation.
- Object Classification in Photographs.
- Automatic Handwriting Generation.
- Character Text Generation
- Image Caption Generation.
- Automatic Game Playing.

**IV. RESULTS:**

The first major outcomes we observe when we run the final simulation, we get to see a basic dashboard where we are given chance to see the simulated outputs of different plots. So all these are done within Matlab with the help of a neural network toolbox which provides us with a different handful of options to analyze our developed model. Fig 5 below shows us the dashboard of the developed model where it represents different sections for the developed model.
In the next step, we are shown the basic block diagram. **Fig 6** below represents the basic block diagram of the developed neural network model.

![Basic Block Diagram](image)

**Fig 6: Block Diagram**

The next result, **Fig 7** below represents the plot for the performance test of the model which was developed for automatic modulation classification with the help of neural networks. The plot is drawn between Mean Squared Error and Epochs. And this graph is considered or taken at four different stages like training, testing, validation, and final we get the best performance which is shown as a green circle dot in the graph. This best validation performance is 3.5583e-07 at epoch 82.

![Plot for Best Validation Performance](image)

**Fig 7: Plot for Best Validation Performance**
The next plot Fig 8 below represents the plot of the Error histogram for the developed model at the training, validation, testing stages. It is plotted between Errors vs Instances. And errors values on the x-axis are resultant of outputs subtracted from total targets. The histogram was considered with 20 bins. The y-axis represents the number of samples at that particular point represented for testing, validation, and training.

![Error Histogram with 20 Bins](image)

**Fig 8: Plot represents the error histogram for the developed model.**

When we run the simulation part we also get a plot for the confusion matrix. Fig 9 below shows us a confusion matrix at each stage that is testing, training, validation, and overall or final confusion matrix. We tested the developed model using testing datasets and also calculated the overall accuracy of the model. The equation or formula which we used to calculate accuracy is given as follows

\[
\text{Accuracy} = \frac{\text{True Positive} + \text{True Negative}}{\text{True Positive} + \text{True Negative} + \text{False Positive} + \text{False Negative}}
\]
Next, we used regular algorithms to check the accuracy of the automatic modulation classification so in this we used regular methods like the Likelihood-based approach. Fig 10 below shows the plot between Accuracy and SNR values using the Likelihood-based approach.
Now we add Additive white gaussian noise (AWGN) and then plot the graph between accuracy and SNR values for the modulation techniques. Fig 11 below shows a graph in which we considered SNR values of -10 to 10 dB with a gap of 2dB along the x-axis and accuracy from 0 to 1 along the y-axis.

CONCLUSION:

The main idea for us as a team to choose this particular project is it involves a wide area of knowledge and models that can be used for the development of signals and the better classification of signals with different modulation techniques. This project can be used in real-world applications like during military warfare, where we can automatically classify different modulation techniques. This project is just a prototype and it cannot be directly used for real-world applications, but based on this prototype we can build a real-world working model for different military and government uses. And there are other advanced methods developed in the present world that can be implemented with this project.

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