MACHINE LEARNING BASED NONLINEARITY DETERMINATION FOR OPTICAL FIBER COMMUNICATION-REVIEW

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Abstract: The technological growth in our day to day life and its integration advancements in the communication network to activate a seamless communication have led to digital transformation in almost all applications. This causes a huge set of digital information conveyance via email, audio and video calls connecting people at all times. These data that are presently conveyed with the aid of the optic fiber communication technology would become outdated in the future years due to the growing demands of the digital information due to its intrinsic nonlinear effects. The machine learning appears as the promising technology to handle the complexities to be faced in the future systems by identify novel methodologies and utilizing available resources. The paper is to present the review on the nonlinearities experienced in the optical fiber and the promising solution provided by the machine learning techniques to enhance the capabilities of the optical fiber communication.

Keywords: Machine learning, Optic Fiber Communication, Digital Information, Nonlinearities

1. INTRODUCTION

The growing interdependence of the world's economies contributes much to the development of the information and the communication technology [1-7]. The world strives to have a seamless communication and utilizes the modern technology such as the laptops, smart phones, etc. and the communication methods such as the audio, video calls and the emails to connect with people all around the world anywhere and anytime [21-26]. The information is communicated over the internet with the infrastructure based on the optical fiber communication. The internet is highly relied to convey information across various countries and the continents. This internet circulation is anticipated to reach Exabyte's per month. The transmitting data at today's data rates and the delay is only possible with the bandwidth and low loss provided by the optical fibers as transmission medium.

To start with the construction, the optical fiber is made of pliable, translucent strand of very pure glass that behaves like a light pipe to convey the light between the two ends of the fiber. It is made of a core surrounded by a cladding layer that is made of dielectric material. The signals in the core of the optical fiber are confined by launching a refractive index that is greater than the cladding. It is used as the standard for telecommunication and networking. The light travelling through the optic fiber bounces constantly via core form the cladding. The optic fiber operates based on the principle of the total internal reflection i.e. the cladding does not absorb the any light form the core.

The first fiber was developed in the year 1966; this caused the creation of the standard single mode fiber that had a low loss and a larger transmission distance. , The communication process with the help of fibers replaced the electronic repeaters with erbium doped fiber amplifier that made possible the cost effective optical amplification, as well as the

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coherent transceivers. The rapid development in communication technology and devices causes an exponential growth in the data that would exceed triple times the world population in the coming years. The swift data growth would overtake the capability of the prevailing optical communication due to the nonlinearities present in them. The machine learning appears as the promising technology to handle the complexities to be faced in the future systems by identify novel methodologies and utilizing available resources.

. So the paper is to present the review on the nonlinearities experienced in the optical fiber and the promising solution provided by the machine learning (ML) techniques to enhance the capabilities of the optical fiber communication and improvise the currently accessible data rates of the optical fiber system.

The paper is organized with the non-linearity in the optic fiber in the section 2 and overview of the machine learning techniques in section 3, mitigating of the nonlinear effects using the machine learning in section 4 and conclusion in section 5.

2. LITERATURE SURVEY

The paper put forth by Wang, et al [1] "utilizes the support vector machine in the transmission system that is optical to bring down the nonlinear phase noise experienced in it. The Support vector machine develops a boundary for the nonlinear distortion to distinguish the nonlinear noises. The SVM learns using the small amount of training data and ensures a lower bit error rate compared to the maximum likelihood estimation algorithm".

The impairments found in the optical system is overcome utilizing the "powerful machine learning detector based on the k-nearest neighbor algorithm" is done in the paper. Wang et al [2] the methods considers the ZDL the zero dispersion link and the DML the dispersion managed link and includes the distance weight KNN to subside the different impairments in the optical system.

The author presents the Khan, et al [3] "novel method applying the deep neural networks for the identifying the formats of the modulation in the optical fiber system. The DNN based pattern recognition is applied over the amplitude histograms that were obtained from the constant modulus algorithm equalization. The method was found to be more compatible for the modulation format identification as it avoided the usage of the additional hardware's and the top of the standard digital coherent receiver and was found to be simple and cost effective for the heterogeneous optical networks"

Danshi, et al [4] provides a "bio inspired detector that fully relies on the artificial neural networks and the genetic algorithm in the coherent optical system , to continuously overcome the impairments in the system and provide an enhanced line-width tolerance , nonlinear tolerance and longer transmission distance. This method was found to be more effective than the maximum likelihood estimation algorithm and the k-means algorithm".

Karanov, Boris et al [5] explains the "implementation of the optical fiber communication system as end to end deep neural networks, by providing the optimization of the transceiver in a single end-to end process. The method put forward in the paper models components of the transceiver and the fiber channel and utilizes the deep learning

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approached to identify the transmitter and the receiver configurations; this enables the minimization of the symbol error rate. The solutions achieved out performs the conventional IM/DD solutions"

Aladin, Sandra, et al [6] the paper presents the "non-linearity QOT determination, utilizing the Gaussians noise model the estimation model includes the nonlinear impairments in the analytical OSNR formula. The method applies the RF, SVM and the KNN to predict the QOT of the light paths as a function of link and the total signal parameters such as the total link length, channel launch power, modulation format, span length and data rate. The validation results show that the SVM is superior to the other two methods".

David, C. Ô. T. É. et al [7] the technology put forth in the paper utilizes the deep learning architectures for the parametric identification of the optical communications network. The method utilizes the trained ANN comprised with the deep residual learning and the Convolutional neural network to estimate the parameters.

Lu, et al [8] "The clustering algorithm based perception decision in the paper mitigates the nonlinearities introduced by the electrical amplifiers and the optoelectronics in the VLS system. The author has experimentally described the VLS system based on 5-band CAP16 modulation using the single RGB LED. The nonlinear compensation is achieved using the KNN clustering".

ZHUGE et al [9] "the author describes the optic fiber parameter identification in the paper" Thrane, Jakob et al [10] the paper employs the machine learning algorithms in the optical communication system to identify the parameters, determine the signal to noise ration and detect the modulation format etc.

Nguyen, Tu et al [11] "the support vector machine based- classification nonlinear –equalizer for the coherent optical orthogonal frequency-division multiplexing is developed to reduce the fiber induced non-linearity". Ahmad, Syed et al [12] the paper develops a "nonlinear equalizer for the 16 QAM-coherent optical OFDM utilizing the radial basis functional neural network (RBFNN)"

Amirabadi, et al [13] introduces the "novel sub optimal approaches for the hyper-parameter tuning of deep neural network under the shelf of the optical communication". Li, Minliang et al [14] the paper puts forth the "Non-parameter nonlinear phase noise mitigation by using M-ary support vector machine for coherent optical systems."

Shen et al [15] presents the "Fiber nonlinearity compensation using extreme learning machine for DSP-based coherent communication systems." Khan et al [16] provides the "Optical performance monitoring using artificial neural networks trained with empirical moments of asynchronously sampled signal amplitudes."

Tanimura, et al [17] details the "OSNR monitoring by deep neural networks trained with asynchronously sampled data." Skoog, Ronald A., et al [18] presents the "Automatic identification of impairments using support vector machine pattern classification on eye diagrams." Tan, Ming Chieng et al [19] provides the "Simultaneous optical performance monitoring and modulation format/bit-rate identification using principal component analysis." Zhang, et al [20] details the "Modulation format identification in heterogeneous fiber-optic networks using artificial neural networks and genetic algorithms."

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3. OVER VIEW OF ML TECHNIQUES

The section presents the over view of the machine learning techniques that are available, there are different styles in the machine learning algorithms they are supervised learning , unsupervised and the semi supervised learning. The table.1 below presents the over view of the machine learning techniques.

Machine Learning Algorithms	Prominent Algorithms
Regression Algorithms	Ordinary Least Squares Regression (OLSR) ,Linear Regression,Logistic Regression ,Stepwise Regression Multivariate Adaptive Regression Splines (MARS) Locally Estimated Scatterplot Smoothing (LOESS
Instance-based Algorithms	k-Nearest Neighbor (kNN) ,Learning Vector Quantization (LVQ),Self-Organizing Map (SOM) Locally Weighted Learning (LWL),Support Vector Machines (SVM)
Regularization Algorithms	Ridge Regression,Least Absolute Shrinkage and Selection Operator (LASSO),Elastic Net Least-Angle Regression (LARS)
Decision Tree Algorithms	Classification and Regression Tree (CART) Iterative Dichotomiser 3 (ID3),C4.5 and C5.0 (different versions of a powerful approach) Chi-squared Automatic Interaction Detection (CHAID),Decision StumpM5 Conditional Decision Trees
Bayesian Algorithms	Naive Bayes, Gaussian Naive Bayes Multinomial Naive Bayes, Averaged One-Dependence Estimators (AODE),Bayesian Belief Network (BBN) Bayesian Network (BN)
Clustering Algorithms	k-Means, k-Medians ,Expectation Maximization (EM) ,Hierarchical Clustering
Association Rule Learning Algorithms	Apriori algorithm ,Eclat algorithm
Artificial Neural Network Algorithms	Perceptron, Multilayer Perceptron (MLP) Back-Propagation, Stochastic Gradient Descent Hopfield Network, Radial Basis Function Network (RBFN)
Deep Learning Algorithms	Convolutional Neural Network (CNN), Recurrent Neural Networks (RNNs), Long Short-Term Memory Networks (LSTMs), Stacked Auto-Encoders Deep Boltzmann Machine (DBM),Deep Belief Networks (DBN)
Dimensionality Reduction Algorithms	Principal Component Analysis (PCA), Principal Component Regression (PCR), Partial Least Squares Regression (PLSR), Sammon Mapping, Multidimensional Scaling (MDS), Projection Pursuit Linear Discriminant Analysis (LDA), Mixture Discriminant Analysis (MDA), Quadratic Discriminant Analysis (QDA), Flexible Discriminant Analysis (FDA)
Ensemble Algorithms	Boosting, Bootstrapped Aggregation (Bagging) AdaBoost, Weighted Average (Blending) Stacked Generalization (Stacking) Gradient Boosting Machines (GBM) Gradient Boosted Regression Trees (GBRT) Random Forest
Other Machine Learning Algorithms	Computational intelligence (evolutionary algorithms, etc.), Computer Vision (CV), Natural Language Processing (NLP), Recommender Systems, Reinforcement Learning, Graphical Models

Table.1 Overview of Machine Learning Techniques [21]

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4. NON-LINEARITY EFFECTS MITIGATION IN OPTICAL SYSTEM USING ML

The idea of ML is utilized in the optical communication for the nonlinearity mitigation [2], optical performance monitoring [16], modulation format and data rate identification [3], carrier synchronization [10] , line width effect mitigation and phase noise characterization [6], parameter identification [7], non-linearity compensation [8][15],

The machine learning techniques such as the SVM, KNN, DNN, ANN, GA, RF and RBFNN are employed in the optical fiber cables to reduce the non-linearity in it causing impairments to the operation. The ML techniques learns the attributes of the various non-linear impairments from the observed data and then blends the mathematical models of the impairments so that they can be engaged later in either recompensing the damages found in the optical fibers and enumerating the number of distortions introduced. The ML seems to be more promising as well as a cost-effective technology for the multiple-impairment monitoring in the optical networks. Methods such as the regression model, decision tree, association rule learning, dimensionality reduction, ensemble algorithms and the other machine learning algorithms such as the Computational intelligence, computer vision, natural language processing, recommender system, reinforcement learning and the graphical models for the optical medium based dispersion management in the heterogeneous optical networks assisting the channels that have multiple data rates, various modulation formats with the bandwidths. More over the machine learning employs the Bayesian algorithm in the carrier synchronization and laser line width effects mitigation.

5. CONCLUSION

The paper presents the review on the application of the machine-learning techniques to mitigate the nonlinear effects in the optical fiber communication. it continues with the literature survey detailing the idea of the ML being employed in the optical fiber for various purposes, followed by the over view of the various machine learning techniques available and providing the summary on the mitigation of the nonlinear effects on the optical fiber system. In future the it is to concentrate on the effective use of the machine learning in the managing the noise deviations caused in the optical fiber cable.

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