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Machine Learning Based Estimation of Power Consumption through Spline Regression

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Abstract: Considering the current scenario of steady depletion of primary sources of energy, it is extremely critical to manage the consumption of power. Ensuring low wastage of power involves prediction of power consumption, which can enable generation of power according to the demand. This process is true for both micro-scale estimation and generation, for particular sectors in an urban or rural area, to macro-estimate of power requirements in terms of overall power consumed nationally, that can be further divided into sectors such as commercial and residential power consumption. The present work outlines a machine learning based linear spline regression-based approach to prediction of energy consumption which is an improvement on the standard spline regression based approach employed currently.

Keywords: Power Consumption, Estimation, Machine Learning, Linear Regression, Spline Regression

I. INTRODUCTION

The estimation of electric power required by any geopolitical entity is critical to its economic and social growth. Accurate estimation of power consumption requires the power demand to be met in a more or less exact manner, allowing power generation to be performed in a cost and resource optimized manner. Historically, power consumption estimates have been generated by utilizing regression models. Consequently, an essentially non-linear variation in power consumption has often been estimated in a linear manner, leading to significant mismatch between the expected and actual value. Spline-based piecewise linear or non-linear models offer a supervised machine learning based novel alternative to standard regression models. The essential benefits of such models are twofold. First, estimates obtained by such models are more accurate than standard regression models. Second, the models are not themselves computationally complex, so it is a relatively facile job to remodel them if and when required. The low computational complexity of linear spline models allow programmatic implementation of such models to be loaded in distributed form also, hence the models are IoT (Internet-of-Things) compatible. This is an advantage, especially for coordinated micro-generation of electric power.

Consequently, the current paper deals with development of machine learning models based on linear spline regression, for prediction of power consumption. The paper is arranged in the following manner. Section II presents a survey on the different approaches employed by researchers to estimate power consumption. Section III presents the spline regression model proposed in the current paper. The results obtained by application of the proposed model are compared against standard linear regression results and the appropriate discussions are presented, in Section IV. Section V concludes the paper.

II. LITERATURE SURVEY

The estimation of power consumption is extremely important for the growth and stability of any economy. As a result, many researchers have investigated the effectiveness of varied approaches for accurate prediction of power consumption, which can be matched to power generation. Standard forecasting techniques have been in vogue for a number of years [1], and accordingly, researchers have carried out extensive evaluations on the comparative performances of computational techniques used to this end [2]. Data mining techniques have been efficiently employed for prediction [3], as well as genetic algorithm based approaches [4]. Soft computing techniques have also been used to predict consumption with appreciable accuracy [5].

In recent years, machine learning based techniques have been shown to demonstrate appreciably higher levels of accuracy than other exact or heuristic approaches. Neural networks have emerged as a popular choice for scholars seeking to estimate energy consumption through the evaluation of specified models [6] or through nonparametric means [7]. Grey forecasting has been used in conjunction to neural networks for effective estimation [8] [9]. Deep recurrent neural network based approaches have also been employed by some scholars [10].

Spline regression methods are an effective alternative to the abovementioned techniques. This class of methods provides the benefits of generating accurate dynamic estimates with far lesser computational complexity than most other machine learning methods. One very recent work in this domain has been highlighted in [11]. The present paper also presents a spline regression based approach to power consumption estimation.

III. PROPOSED METHOD

Linear regression is a statistical technique for estimating the relationship between one or more input and output parameters of a process as a linearized statistical variation of the dependent variable(s) with the independent variable(s). In this process, a MMSE (Minimum Mean Square Error) linear approximation is used to characterize the relationship between the input and output variables. The corresponding type of equation used is shown in equation 1 below.

$$Y = mX + c \tag{1}$$

The dependent variable Y is therefore evaluated according to the value of the independent variable X, the slope m and the intercept c. Linear regression is prone to different types of estimation error since it seeks to linearize a variable that is random (and therefore nonlinear). Regression splines allow the estimation of data when they show no particular pattern of change on a micro scale. The splines may be linear or non-linear in nature, however the present work deals extensively with linear splines. Linear splines are composed of piecewise linear combinations of multiple straight lines. Each approximating regression line is constructed using MMSE principles as before and the knots (common point between regression combinations) are evaluated using cross-validation techniques. The present paper compares univariate linear regression models to corresponding linear spline regression models in terms of least erroneous prediction, measured through Root Mean Square Error (RMSE). The results and corresponding discussions are presented in the following section.

IV. RESULTS AND DISCUSSIONS

A standard dataset for electricity consumption in India from 2000 to 2011, provided by the government itself, is used to perform the simulations on the linear regression model. The coefficients for the equations for both linear regression as well as spline regression are shown in table 1.

Table 1. Slope and Intercept Data for Power Consumption Estimation Equations (for 2000-2011)

Type of Technique	Slope	Intercept	Year Range
Linear Regression	2.2657	75063	2000-2011
Linear Spline Regression	2.4271	59147.35	2000-2004
	2.2408	74881.4712	2004-2008
	2.2274	86658.2398	2008-2011

The result obtained for linear regression is highlighted in the following table 2. The table also contains the contrasting results obtained by performing linear spline regression on the same dataset.

Table 2. Average error and RMSE (for 2000-2011)

Type of Technique	Average Error	RMSE
Linear Regression	-0.09	1.09
Linear Spline Regression	0	0.74

The linear spline regression has much lower RMSE than in case of standard linear regression (around 32% less). The zero average error may indicate overfitting, making the model exact (deterministic instead of probabilistic) and prone to error for random input outside the training and testing sets. However, the spline based estimation curve actually shows zero average error since a perfectly heteroskedastic model is proposed here. The perfect distribution may have occurred due to lesser number of years being considered in the particular case.

V. CONCLUSION

The future scope of this work includes the development of simulation models for prediction of overall as well as sector-wise power consumption from the sector-wise power consumption data available for the years 2000-2011. It is also the intention of the authors to develop a weighted average based adaptive spline regression model to implement more accurate machine learning in the present context.

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