A
PROJECT REPORT
ON

Prism: Graphics Accelerated Data Analysis using Deep Neural Networks

by

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Under the guidance of
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CERTIFICATE

This is to certify that project titled "Prism: Graphics Accelerated Data Analysis using Deep Neural Networks" is a bona-fide record of Project-B carried out by the following students of final year in Computer Engineering.

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This project is carried out for the partial fulfillment of requirements for the degree of Bachelor of Engineering (B.E.) in Computer from University of Mumbai, Mumbai for academic year 2016-2017.

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We have examined this report as per university requirements at SIES Graduate School of Technology, Nerul, Navi Mumbai on ________________

Signature:	Signature:
Name:	Name:
(Examiner-I)	(Examiner-II)

DECLARATION

We declare that this written submission represents our ideas in our own words and where others ideas or words have been included, we have adequately cited and referenced the original sources. We also declare that we have adhered to all principles of academic honesty and integrity and have not misrepresented or fabricated or falsified any idea/data/fact/source in my submission. We understand that any violation of the above will be cause for disciplinary action by the Institute and can also evoke penal action from the sources which have thus not been properly cited or from whom proper permission has not been taken when needed.

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Date: 22/04/2017

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Abstract

When a customer of say a corporate telecom major like Airtel decreases spending on his or her number, they tend to provide more offers to the customer. Now this logic may sound straightway outrageous but this is true based on churn models. Churning refers to customers leaving a service and switching to another provider. The standard industry practice is to generate churn models for every consumer, so that they can provide business intelligence to increase customer retention and spending. Thus this translates to greater profit for a company. Although such processes can be carried out with a GPU, the software that exists like SAP handles everything on the CPU. This leads to longer delivery period for business intelligence and analytics which in turn means less time spent doing business and more time spent waiting. GPUs can generate huge number of threads and thus introduce parallelism in this area. In addition to the above advantage the churn models have assisted learning and cannot learn on its own unlike Deep Neural Networks which apply the concept of machine learning. This project aims to create a Windows based general purpose application to try predicting churn with better analytics. The scope of the project is limited to test data sets freely available on the internet as real data can only be obtained from corporates who are rather unlikely to share sensitive data with non-employees. Thus we aim to create a churn model that uses GPU based DNNs which not only will improve execution time for large data sets, it will also prove to be a huge plus point for corporate customers who want to use this software.

Contents

List of Figures

List of Tables

Chapter 1

INTRODUCTION

The concept of our project is to build a churn model which helps in predicting whether a user may churn or not i.e the user changes or leaves the existing service provider. Project is implemented in Matlab as it allows for rapid prototyping. Churn modelling requires computing of large datasets. Our project mainly focuses on computing these large data sets with the help of GPU acceleration.

Our technique lies in the paper presented by Sane and Agrawal [8]. We convert the textual data into an image using Min-Max normalisation as described in the paper cited above. This conversion is an intermediate step which helps us feed data into the neural network. As mentioned the main highlight exists in preprocessing the data for predictive analysis [1].

1.1 Background

As we can see in [1] churn ananlysis and prediction is a big part of managing customer relationships. The idea behind this project was to fundamentally increase the efficiency of this analysis process by introducing the concept of Prism. The concept of Prism is to split the data and perform analysis on it parallely on a Graphics Processing Unit (GPU). This decreases the time spent on analysing and executing neural networks by putting them on a GPU.

1.2 Objective

Objective of the project is to demonstrate a significant speedup in execution time of analysis of data sets on Neural Networks.

1.3 Purpose, Scope and applicability

Purpose, Scope and Applicability are important parameters to be discussed to give a definite direction to the project. They are described briefly as follows:

1.3.1 Purpose

The project aims to provide a way to analyse your dataset faster than ever before by cutting down time required by graphics accerelation via GPU compute technology.

1.3.2 Scope

The scope of the project is to clean,extract and transform datasets to implement on a Neural Network.

1.3.3 Applicability

Applicabilty of done work is universal in the sense that data is independent of language. As long as the dataset under consideration is numeric, the technique is applicable.

Chapter 2

LITERATURE SURVEY

2.1 Literature Survey

The highlight of the paper is the idea of using the normalized data as an image and using the generated image as input to the neural network. This concept was inspired by the paper on churn data model viewed as periods of time [2].

2.1.1 Dataset Used for the Experiment

Our experiment required data to be processed and used as an input. This was obtained online from bigml [12]. We, thus, obtained a labelled dataset, which enables us to use supervised learning approach for our neural network. Here, our sample dataset appears to be monthly rather than weekly as compared to the dataset used by Wangperpong et al. [4]. Our sample dataset consists of rows - customers and columns as attributes associated with customers. The attributes, which are significant, are not identified in our dataset, but we only consider numeric values while trying to predict the churn rate.

2.1.2 Pattern Matching and Clustering Neural Networks Using Supervised Learning

Furthermore, there has been a lot of work done in pattern matching via supervised learning. Schwenker et al. [3] describe this concept very clearly in their detailed analysis of the topic. This approach to supervised learning is heavily applied to neural networks. Neural networks thus find far and wide reaching applications that can have major impacts on society like the traffic camera system [5].

2.2 Problem Definition

Customer retention is a huge requirement for any service based business. This is especially more emphasised in the Telecommunications industry where cellular carriers must retain customers to remain profitable or risk losing money. Churn analysis aims to predict the churn which is the act of a consumer leaving or switching service. Thus these predictions offer a chance to act on potential loss of subscribers. But this deep analysis of data using Neural Networks requires immense computing power and time both of which are critical in a subscription model of business. The problem is to create a technique to demonstrate speedup in the analysis process of churn data and then provide predictions with accuracy over 90% reliably.

Chapter 3

IMPLEMENTATION

3.1 Hardware

The main system has i7, 6700k processor with 16gb DDR4 RAM clocked at 2133MHz. Graphics Processing Unit (GPU) which is Nvidia Titan X (Maxwell Gen.) 12gb GDDR5 VRAM. This particular system was running Windows 10 Pro x64 build 1607. For the sake of comparison we implemented the project on MacBook Air 13 inch early 2015 edition with specs of intel core i5 at 1.6kHz and 4gb DDR 3 1600MHz. This particular system did not possess a discrete GPU. Therefore it provided a good benchmark analysis of a graphics enabled version vs CPU only version of the project. MacBook Air was running MacOS sierra as the operating system.

3.2 Software

Matlab was chosen as the software to build the project. Dealing with large amounts of data meant that we needed a quick way to evaluate results and import and export data conveniently. All these features were readily made available by Matlab and hence it was the ideal software for completing the project.The GPU acceleration provided by Matlab is through the CUDA runtime which is transparently available to the programs with only slight modifications required for GPU based code.
The following steps are taken in software to execute the project:

1. Import data from the data source.

2. Run transformation of the dataset to an image.

Table 3.1: SYSTEM CONFIGURATION FOR EXPERMIENTAL SYSTEMS

Processor	Physical RAM	CUDA GPU name	MATLAB GPU support	Operating system and build
Intel Core i7 6700k @ 4 GHz	2 8 GB Kingston DDR4 Non ECC @ 2133 MHz	NVIDIA Titan X Maxwell Architecture 12 GB GDDR5	Yes	Windows 10 64 bit Build 1607, Custom PC Build
Intel Core i5 @ 1.6 GHz	4 GB DDR3 Non ECC @ 1600 MHz	N/A	No	MacOS Sierra 10.12.2 Build 16C67 on MacBook Air Early 2015, 13 inch

3. Feed generated image into the neural network generated by Matlab.

3.3 Algorithm

Raw numeric data is first transformed into the grey scale color domain via min-max normalization. Min-max normalization preserves the integrity of data via scaling. Various methods exist for normalization [10], but the proposed method requires scaling to an interval between [0, 255] hence, we use min-max normalization. Eq. 1 describes min-max normalization, which is a step in the proposed method.

$$X' = a + \frac{(X - X_{min})(b - a)}{X_{max} - X_{min}} \tag{3.1}$$

.

Here, X is the normalized pixel. X is the current pixel in consideration. X_{max} and X_{min} is the maximum and minimum value of the dataset respectively, a and b are the minimum and maximum values of the color space. Since, the color space is 8 bit we scale the dataset to the interval [0, 255] where a is 0 and b is 255. Hence, we get the following equation:-

$$X' = a + \frac{(X - X_{min})255}{X_{max} - X_{min}} \tag{3.2}$$

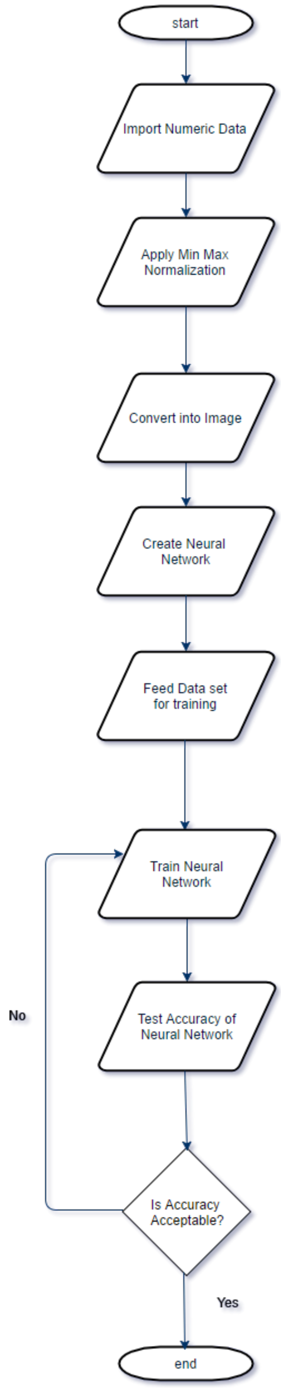

Figure 3.1: Flowchart.

. Thus, we get the dataset normalized into the greyscale color space. We, then convert the processed data set into images depending on the time scale. Eq. 3.2 provides us with a direct formula for converting textual data into a grayscale image. The results of the above described process is given in the next section.

Chapter 4

RESULT AND DISCUSSION

The implementation described in the previous section leads to a lot of results and requires explanation.

- The project is mainly to improve execution speed of analysis of datasets. It deals with converting the datasets from its numerical form to the 8 bit grayscale colour domain

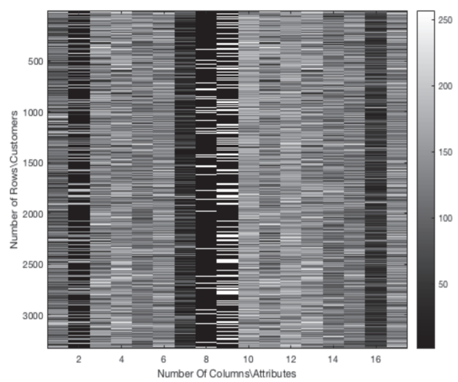

Figure 4.1: Customer records and attributes as an image.

The neural network is implemented with the Neural Network Toolkit (NNT) [11] in MATLAB [10]. The NNT contains predefined types of neural networks for clustering, fitting, pattern recognition, and time series. These types make it possible to instantly deploy the neural networks, which otherwise would take considerable time to set up. The NNT handles all initializing of weights and other trivial processes. We use the pattern recognition pre-set for the

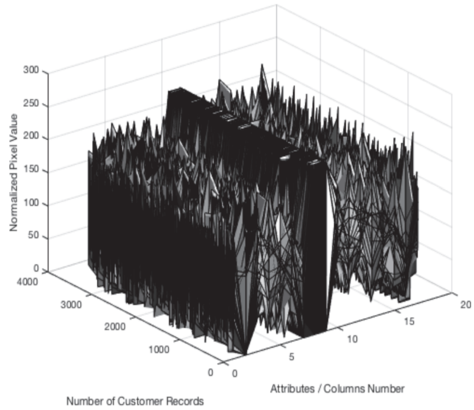

Figure 4.2: 3D surface plot of customer records and attributes.

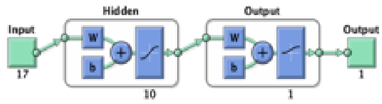

Figure 4.3: Structure of neural network.

neural network so that we can detect trends and patterns via neural networks. As we mentioned earlier, we are using the supervised learning approach since we have a labelled dataset for churn analysis. For creating the neural network, we have to select certain parameters such as $<$ parameter x, parameter y $>$. We have to select the number of hidden layers. This can have an impact on the accuracy of prediction that is obtained. We use 10 hidden layers, which is the default number of layers. The selected pre-set pattern recognition neural network in the neural network is implemented with the Neural Network Toolkit (NNT) [11] in MATLAB [10]. The NNT contains predefined types of neural networks for clustering, fitting, pattern recognition, and time series. These templates make it possible to instantly deploy neural networks, which otherwise would take considerable time to set up. The [11] handles all initialization of weights and other trivial processes. are handled by the NNT[11]. NNT[11] has to be trained like any other network for creating a model. We use Scaled conjugate gradient back propagation for supervised training [6]. This is the default algorithm for the pattern recognition neural network in the NNT. The neural network as illustrated in Fig. 3 has 17 inputs, since the input customer attributes are 17. It gives a binary output as evident in 4.3. We observed varying accuracies since the weights are all initialized randomly. Anybody wishing to recreate the experiment may not get exact matching results due to this randomness. But, the accuracy of

Table 4.1: EXECUTION TIME ON EXPERIMENTAL SYSTEMS

Computer description	CPU execution time (seconds)	GPU execution time (seconds)
High End Custom PC	0.001553	0.001051
MacBook Air Early 2015	0.004755	N/A

prediction should be nearby in the neighbourhood of 12% or more [8].

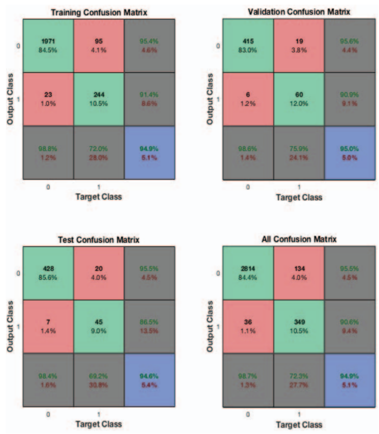

Figure 4.4: Confusion plot for neural network.

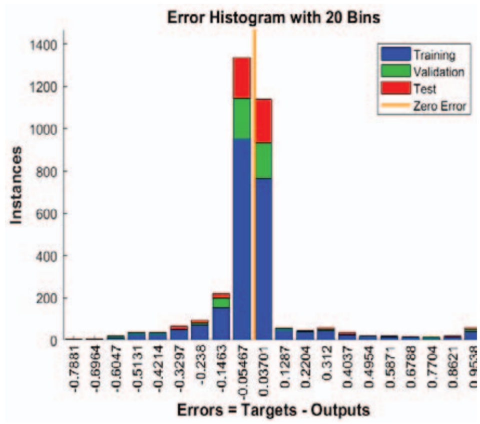

Figure 4.5: Error histogram for the neural network

Hence we obtained 94.9% accuracy which can be seen in the confusion plot in 4.4.

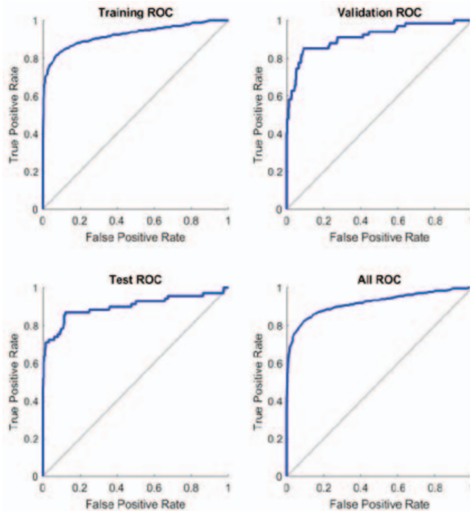

Figure 4.6: Receiver operating characteristic (ROC) curves.

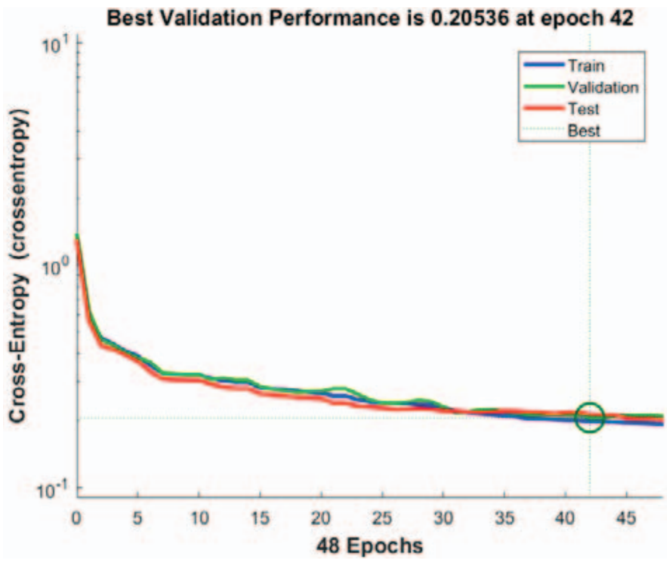

Figure 4.7: Performance plot for the neural network.

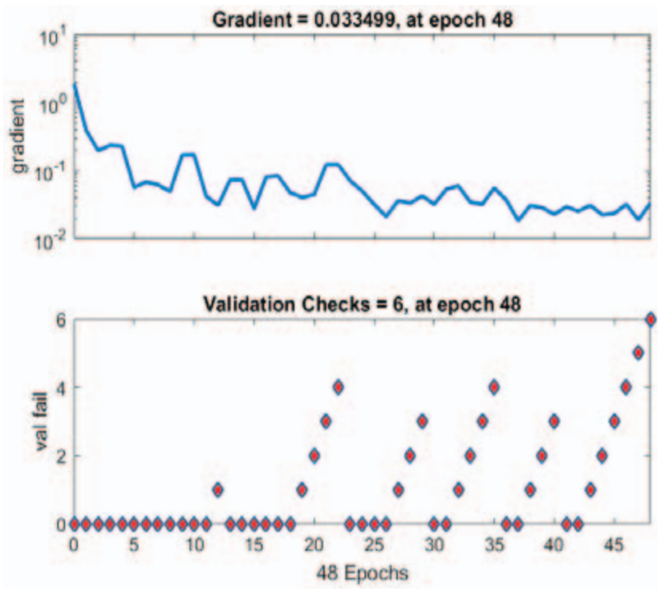

Figure 4.8: Training state for the neural network.

Chapter 5

CONCLUSION AND FUTURE SCOPE

5.1 Conclusion

The project's concept mainly includes the prediction of churn in telecom industry. To acheive the main goal of this project, we had planned to use GPU acceleration on large datasets and convert the textual data into an image format data. The idea of this project is implemented in MATLAB.The converted dataset is then fed into the Neural Network which is built using the feature of MATLAB's Neural Network Toolkit.
We effectively developed a better way to pre-process data so as to improve performance of processing data for the GPU.

5.2 Future Scope

This definitely will give better results as compared to execution on a CPU. Training is many times faster on a GPU as compared to a CPU. This is evidenced in many papers published earlier. Future scope and work can be expanded to actually implementing the Neural Network on the GPU.

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Chapter 6

IEEE PRESENTED PAPER

An IEEE paper was presented in the International Conference WiSPNET 2017 at SSN college of engineering in Chennai . The paper is attached in the following pages.

This full-text paper was peer-reviewed and accepted to be presented at the IEEE WiSPNET 2017 conference.

Pixel Normalization from Numeric Data as Input to Neural Networks

For Machine Learning and Image Processing

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***Abstract*—Text to image transformation for input to neural networks requires intermediate steps. This paper attempts to present a new approach to pixel normalization so as to convert textual data into image, suitable as input for neural networks. This method can be further improved by its Graphics Processing Unit (GPU) implementation to provide significant speedup in computational time.**

***Index Terms*—Data science, image processing, neural networks, pixel normalization.**

I. Introduction

Text to image transformation is nothing new as it is known that images can be represented with matrices having numeric elements. But, where our method differs in implementation is representing any numeric data into images. This is achieved by performing statistical normalization on entire dataset to be fed into destination process. Neural networks use databases as data source like Imagenet [1] to use images for classifying images into target classes. This inspired us to think of the churn problem visually. Churn rate (sometimes called attrition rate), in its broadest sense, is a measure of the number of individuals or items moving out of a collective group over a specific period. It is one of two primary factors that determine the steady-state level of customers a business will support [2].

Thus, to solve this complicated business problem we decided to make use of neural networks. The fastest implementation from idea to code was through MATLAB [3] and its Neural Network Toolkit. The neural network toolkit provides a pattern matching neural network for which parameters can be specified.

II. Literature Survey

The highlight of the paper is the idea of using the normalized data as an image and using the generated image as input to the neural network. This concept was inspired by the paper on churn data model viewed as periods of time [4].

A. Dataset Used for the Experiment

Our experiment required data to be processed and used as an input. This was obtained online from bigml [5]. We, thus, obtained a labelled dataset, which enables us to use supervised learning approach for our neural network. Here, our sample dataset appears to be monthly rather than weekly as compared to the dataset used by Wangperpong et al. [4]. Our sample dataset consists of rows - customers and columns as attributes associated with customers. The attributes, which are significant, are not identified in our dataset, but we only consider numeric values while trying to predict the churn rate.

B. Pattern Matching and Clustering Neural Networks Using Supervised Learning

Furthermore, there has been a lot of work done in pattern matching via supervised learning. Schwenker et al. [6] describe this concept very clearly in their detailed analysis of the topic. This approach to supervised learning is heavily applied to neural networks [7], [8]. Neural networks thus find far and wide reaching applications that can have major impacts on society like the traffic camera system in the reference [9].

III. Method

Raw numeric data is first transformed into the grey scale color domain via min-max normalization. Min-max normalization preserves the integrity of data via scaling. Various methods exist for normalization [10], but the proposed method requires scaling to an interval between [0, 255] hence, we use min-max normalization. Eq. 1 describes min-max normalization, which is a step in the proposed method.

$$X' = a + \frac{(X - X_{\min})(b-a)}{X_{\max} - X_{\min}}. \tag{1}$$

Here, X' is the normalized pixel. X is the current pixel in consideration. $X_{\max}$ and $X_{\min}$ is the maximum and minimum value of the dataset respectively, a and b are the minimum and maximum values of the color space. Since, the color space is 8 bit we scale the dataset to the interval $[0, 255]$ where a is 0 and b is 255. Hence, we get the following equation:-

$$X' = \frac{(X - X_{\min})255}{X_{\max} - X_{\min}}. \tag{2}$$

Thus, we get the dataset normalized into the greyscale color space. We, then convert the processed data set into images depending on the time scale. Eq. 2 provides us with a direct formula for converting textual data into a grayscale image.

The time scales are very important to consider along with churn prediction. As mentioned earlier, the dataset is monthly rather than weekly, so a rolling 7-day analysis cannot be made in this case. We can prepare individual images for a customer where a pixel intensity is given by the processed normalized value from the dataset. We generate an image for the entire dataset as evident in Fig. 1. All processing is performed in

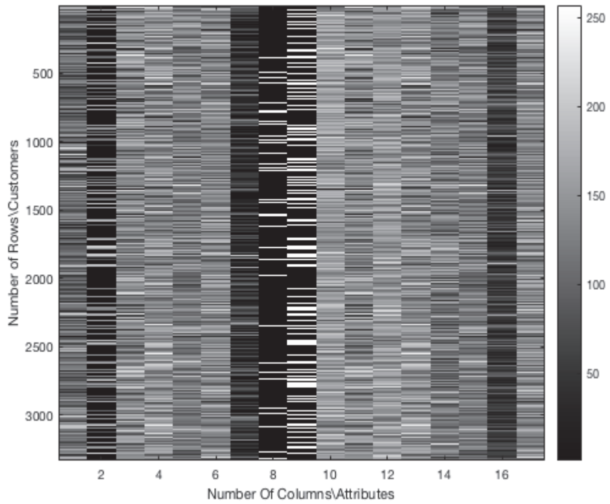

Fig. 1. Customer records and attributes as an image.

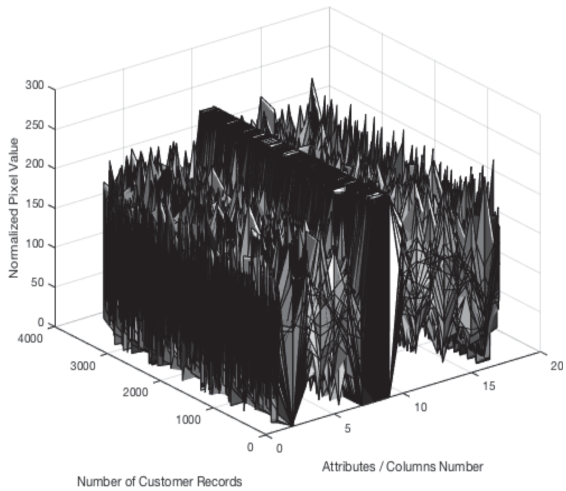

Fig. 2. 3D surface plot of customer records and attributes.

MATLAB [3]. We also generate a 3D surface plot to describe the entire dataset in three dimensions for greater visualization as shown in Fig. 2.

Fig. 1 describes the processed customer data as an image in grayscale. Here, there is no information loss as long as we have access to the fixed constants $X_{\min}$ and $X_{\max}$ for the dataset under consideration. We can easily calculate the original data by solving the Eq. 2. We use this image for further processing. Fig. 1 represents the image that is generated and used for input to the neural network.

The 3D surface plot shown in Fig. 2 brings to light the pixel intensities across columns for every customer. The sample dataset consists of 3334 customer records with 17 numeric columns. This data excludes the *churn* label column, which

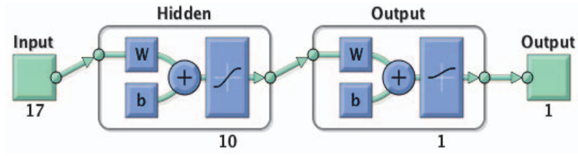

Fig. 3. Structure of neural network.

describes whether the customer in question has churned. The classification is a binary one where a churn is recorded as 1 and 0 is a retention. We try to predict churn via the neural networks.

The neural network is implemented with the Neural Network Toolkit (NNT) [11] in MATLAB [3]. The NNT contains predefined types of neural networks for clustering, fitting, pattern recognition, and time series. These types make it possible to instantly deploy the neural networks, which otherwise would take considerable time to set up. The NNT handles all initializing of weights and other trivial processes. We use the pattern recognition pre-set for the neural network so that we can detect trends and patterns via neural networks.

As we mentioned earlier, we are using the supervised learning approach since we have a labelled dataset for churn analysis. For creating the neural network, we have to select certain parameters such as $<$ parameter x, parameter $y >$. We have to select the number of hidden layers. This can have an impact on the accuracy of prediction that is obtained. We use 10 hidden layers, which is the default number of layers.

The selected pre-set pattern recognition neural network in the neural network is implemented with the Neural Network Toolkit (NNT) [11] in MATLAB [3]. The NNT contains predefined types of neural networks for clustering, fitting, pattern recognition, and time series. These templates make it possible to instantly deploy neural networks, which otherwise would take considerable time to set up. The NNT handles all initialization of weights and other trivial processes. are handled by the NNT.

NNT has to be trained like any other network for creating a model. We use Scaled conjugate gradient back propagation for supervised training [12]. This is the default algorithm for the pattern recognition neural network in the NNT. The neural network as illustrated in Fig. 3 has 17 inputs, since the input customer attributes are 17. It gives a binary output as evident in Fig. 3.

We observed varying accuracies since the weights are all initialized randomly. Anybody wishing to recreate the experiment may not get exact matching results due to this randomness. But, the accuracy of prediction should be nearby in the neighbourhood of 1–2% or more.

IV. Discussion of Results

We obtained an overall accuracy of 94.9% in predicting churn. Furthermore, a comparison of CPU vs. GPU execution is given for the image transformation. All time mentioned is in seconds. The MacBook Air does not have a NVIDIA GPU

Fig. 4. Confusion plot for neural network.

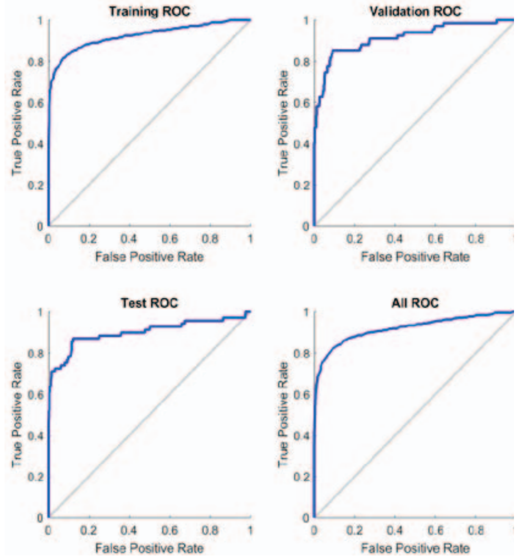

Fig. 6. Receiver operating characteristic (ROC) curves.

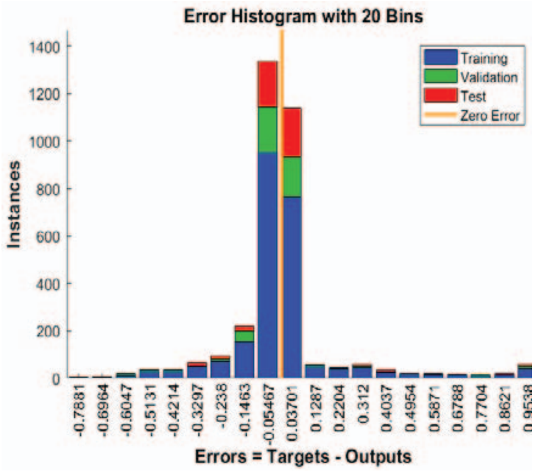

Fig. 5. Error histogram for the neural network.

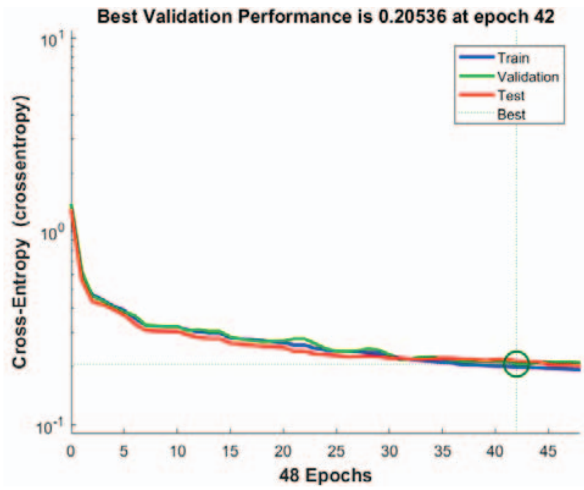

Fig. 7. Performance plot for the neural network.

and MATLAB [3] does not support non – NVIDIA GPUs for graphics acceleration. Hence, the performance numbers for that machine for the GPU domain is not considered. Consider the following figures to explain and further elucidate the results.

The confusion plot in Fig. 4 describes the various results obtained for the different case scenarios including training, validation, and testing. We, thus, observe an overall accuracy of 94.9% in predicting churn. Figs. 5 and 6 provide the error histogram and ROC curves of the Neural Network respectively.

Figs. 7 and 8 describe the performance and training parameters of the neural network. The best validation performance is obtained at epoch 42. The performance can be contrasted with machines having two different Operating Systems and Hardware. The Table I presents numbers that explain very clearly the performance difference between systems that can be appreciably measured.

V. Experimental Computer Configuration

Compute Unified Device Architecture (CUDA) support in graphics cards or processors, popularly known as Graphics Processing Unit (GPUs). CUDA accelerates computational tasks and require less time to execute [12]. The above discussed image transformation is executed on two systems of different configuration.

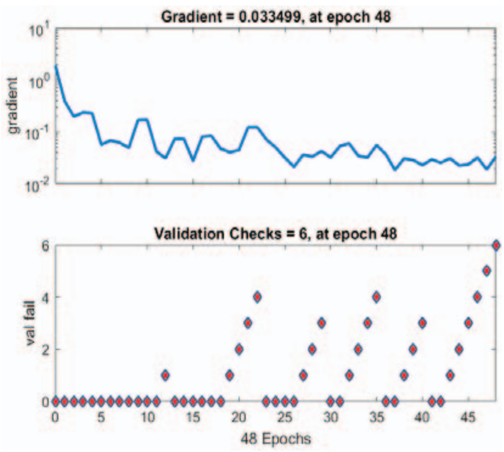

Fig. 8. Training state for the neural network.

TABLE I
EXECUTION TIME ON EXPERMENTAL SYSTEMS.

Computer description	CPU execution time (seconds)	GPU execution time (seconds)
High End Custom PC	0.001553	0.001051
MacBook Air Early 2015	0.004755	N/A[a]

a. Does not have CUDA GPU.

TABLE II
SYSTEM CONFIGURATION FOR EXPERMIENTAL SYSTEMS.

Processor	Physical RAM	CUDA GPU name	MATLAB GPU support	Operating system and build
Intel Core i7 6700k @ 4 GHz	2 × 8 GB Kingston DDR4 Non ECC @ 2133 MHz	NVIDIA Titan X Maxwell Architecture 12 GB GDDR5	Yes	Windows 10 64 bit Build 1607, Custom PC Build
Intel Core i5 @ 1.6 GHz	4 GB DDR3 Non ECC @ 1600 MHz	N/A[a]	No	MacOS Sierra 10.12.2 Build 16C67 on MacBook Air Early 2015, 13 inch

a. Does not have CUDA GPU.

As evidenced in Tables I and II different computer configurations lead to varying performance numbers and lead to interesting comparisons between possible hardware and software choices. A mobile machine like a MacBook Air that although manages to perform the necessary task, it is clearly not made for heavy and intensive scientific work. The numbers in the Table II clearly highlight this fact.

VI. CONCLUSIONS

We obtained a method for processing numeric data as image input to a pattern matching the neural network. This provides a new strategy of analysing entire numeric datasets as images.

This opens up a whole new perspective at data which can be visually conceptualised as an image viewable on a display or screen. Visual strategies to data become a possibility if this method is considered. Further the colour domain may be expanded to color spaces other than grayscale. after scaling to the required interval [15].

VII. FURTHER POSSIBLE WORK

MATLAB was particularly helpful for implementing this experiment. Hence, anyone attempting to replicate the same experiment would be advised to follow a similar approach via MATLAB or any other similar software or framework. To be clear, the actual neural network was not run on the GPU at the moment. A GPU implementation makes the neural networks run faster as compared to CPU implementations, as evidenced in many earlier implementations. Hence, it would be interesting to see how results pan out on the GPU when the neural network is implemented. A larger dataset would have been helpful to evaluate this experiment on a larger scale.

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