Cost Optimized Hybrid System in Digital Advertising using Machine Learning

Avinash Sharma, Swati V. Kulkarni, Dhanajay Kalbande, Surekha Dholay

Abstract*: Digital advertising or Internet marketing is the term used to describe the process of advertising a product or brand through digital medium. It includes promotional advertisements and messages delivered through email, social media websites, search engines, mobile applications, web sites and affiliates programs. This work presents a system that solves the challenge of reaching correct people and optimizing the cost problem using various machine learning techniques. It also explains various research trends in predictive analytics, product pricing and targeting audience for digital advertising. Digital Advertising has captured wide attention from market. It is very powerful tool to reach correct people at correct time. Also it reduces the cost of broadcasting advertisement as the ad is displayed only to people who might be interested in the content. The interest prediction for audience targeting provides 89.44% accuracy using Naive Bayes classifier.

Index Terms*: Digital Advertising, Predictive Analytics, Cost Optimizing, Audience Expansion, Machine Learning, Logistic Regression, Naive Bayes.

I. INTRODUCTION

Advertising industry has seen tremendous transformation in digital era. It started from displaying an advertisement on the wall of church. It has now reached to personalize advertisements on individual's social networks. Approximately 20 years ago an advertisement used to mean displaying, promoting a product or service through broadcasting information about the same through newspapers or television. This was then the only way to attract people towards the product or service and gain probable customers. As the technology advanced, the old broadcasting way of advertisement changed to personalize digital advertisements.

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Nowadays advertisers promote their product using online social platforms such as Facebook, YouTube and many other websites. Machine Learning and Artificial intelligence is now widely used to understand the current trends and to know the characteristics of people who might be interested in the contents of their advertisement. Machine learning algorithms can be used in many ways to achieve impressive personalize experience. The three most popular ways are predictive analytics, cost optimizing and audience targeting. The use of machine learning techniques in digital advertising is beneficial for all three stakeholders namely advertiser, publisher and end users. It is very effective and cost saving option because it gets more recognition with lesser number of displays.

Predictive analytics is the process of understanding one's future behaviour depending on the past actions. In predictive analytics, machine learning algorithms can be applied to predict CTR (Click-Through-Rate: No. of Clicks per ad impressions) for an advertisement. CTR value is not only used for targeting specific audience and cost cutting but also depicts brand reputation and ranking in global competition. Hence it is now very important for companies to achieve high CTR for their advertisement. This is the reason industry and academia showing deep interest in research for digital advertising domain.

Cost optimizing is a technique for optimizing pricing for sales and profit. Profit Optimizing is the process of gaining maximum profit through minimum advertisement displays. Cost for displaying an advertisement depends on various factors such as cost per click, inventory that is space provided by publishers for advertisement display, CTR etc. This can be achieved by real time process of estimating utility (like clicks, conversions) of ad impressions, forecasting the market value of ad impression hence the cost of product. Profit Optimization can be achieved through machine learning in predictive analytics and audience expansion.

Audience Targeting Techniques is the process of predicting relevance of advertisement to individual. Machine learning algorithms perform analysis on individual's personal data that they voluntarily share with companies. The results are promising for audience targeting. The research in this area is done by the team working at LinkedIn Corporation. They deployed their audience expansion model on LinkedIn's social networking platform. This large scale experiment demonstrated effective results that helped not only advertiser, and LinkedIn as social networking platform but also end users. Companies like Google, Facebook also does audience targeting for

providing personalize ad experiences to their users.

II. RELATED WORK

Advancements in digital advertising can be divided in three parts namely, predictive analytics, cost optimization and audience targeting. Authors have proposed new neural network based approach to solve CTR prediction problem. Data available for CTR prediction problem is imbalanced data. The proposed system consists of two layer mechanism called Hierarchical Extreme Learning Machine (H-C-ELM). In the first layer, Weighted Output Extreme Learning Machine (WO-ELM) and Weighted Extreme Learning Machine (W-ELM) is used for classification of imbalanced data. The combined output of WO-ELM and W-ELM are used as input to second layer of ELM. The final output is generated at second layer. WO-ELM and W-ELM has 100 hidden neurons each whereas H-C-ELM has 50 hidden neurons in its structure when imbalanced ratio (IR) was 3:1000. Experiments also have been performed with different IR ratios. Experimental results show that H-C-ELM is significant guide for showing ads and it performs much better than existing techniques [4].

The existing methods of CTR prediction are mostly shallow layer models. These models cannot capture high-order nonlinear features in ad data, which deep neural network layers can. However training deep layer networks is very time consuming and hence cannot be directly used for online CTR predictions. Authors in this approach combined deep and shallow layers to get advantages of both methods. This novel technique is referred as Deep Shallow Layers (DSL). Factorization Machines are used as shallow layer to learn basic features from ad dataset. And deep neural networks are used as deep layer for high order non-linear feature extraction. Sigmoidal activation function is used in this network. The DSL model proposed in this work makes complete use of available information and extracts basic features, pair-wise interactions and high order non-linear features from ad data[13].

Another research presents an approach of classification of advertisements based on contents of videos viewed. The goal has been achieved using four steps namely, Frame and Audio extraction, Object Recognition, Speech Recognition, and Text Analysis. The proposed architecture specifies that the input videos are pre-processed using ffmpeg. In that last five second's video frames are extracted from video input. These extracted frames are then passed to TensorFlow for object identification and SpinxBase for speech recognition. Finally Naive Bayes algorithm is used to for text classification. Using this approach, the authors have classified videos in one of the four categories namely, 'sports', 'children', 'technology', and 'political'. This method is win-win situation for both end users as well as advertising companies [1].

One more approach to target expanded set of audience is employed at LinkedIn Inc. Authors propose hybrid technique consisting of advantages and offsetting limitations of both campaign-agnostic expansion and campaign-aware expansion. Campaign-agnostic expansion focuses on LinkedIn's Similar-X algorithm. Campaign-agnostic expansion does not require time for training. Once enabled, provides result on a per-attribute basis. On the other hand, campaign-aware framework provides fine grain expansion, even though consumes time for training process. The interaction between these two methods is achieved as they generate outputs in the same member oriented fashion. The effectiveness of proposed method is evaluated by performing large scale experiments at LinkedIn. Results indicated significant benefits for both LinkedIn and Advertisers [6].

At the point when an organization pays for advertising in a social network, it needs to get a perfect organization of the ads on the network. The perfect conduct goes for lessening the high expenses to pay, the quantity of hours to configuration advertising, the trouble in the production of ads by parts, in addition to other things. Author in this work shows an astute arrangement of administration of interpersonal organization advertising, in view of information mining methods, to consequently deliver ads. Moreover, the testing of this versatile system of computerized age of web based advertising is completed on Facebook. Genetic algorithms, SVM, Natural Language Processing are utilized to actualize this framework. The procedures utilized were very effective and have different applications in the data science and advertising area [5].

The next methodology portrays procedures to gauge the adequacy of publicizing efforts. For instance, the systems can be executed to gauge mark lift created by a publicizing effort. Ads are shown to an arrangement of clients that frame a treatment gathering and are specifically withheld from another arrangement of clients that shape a control gathering. Offers of rebates, coupons, correlative examples, and so forth are given to the two arrangements of clients. Take-up of offers by clients in the control and treatment bunches is used to quantify mark lift from the ads [7].

The hold cost is one of the key choices for distributer's offering advertisement impressions in the RTB showcase, which influences not just the promotion impression designations and the income acquisitions from the point of view of members, yet in addition supply-request balance from the viewpoint of the market. In this paper, authors think about the save cost and its effect on distributers' income both in the single-channel deals either by RTB barters or direct contracts and the multi-divert deals by both disconnected and online channels. Additionally, in light of observational Web log information, authors lead trials to make top to bottom investigations of our models. A sane online hold cost will dependably enable distributers to build incomes in the online-offers of promotion impressions [10].

Another cost optimizing strategy is real time bidding (RTB) based showcase advertising. RTB empowers promoters to purchase singular advertisement impressions through a closeout in real-time and encourages the assessment and the bidding of individual impressions over various publicists. In RTB, the publicists confront three primary difficulties while advancing their bidding procedures, specifically assessing the utility (e.g.,

transformations, clicks) of the promotion impression, estimating the market esteem (in this manner the expense) of the given advertisement impression, and choosing the ideal offer for the given closeout dependent on the initial two. Authors have proposed Bidding Machine, an exhaustive figuring out how to offer framework, which comprises of three streamlining agents managing each test above, and all in all, together enhances these three sections. The joint enhancement generally expanded the campaign adequacy and the benefit [21].

III. CLASSIFICATION OF DIGITAL ADVERTISING TECHNIQUES

Digital Advertising is now primary source of income for various publisher companies. This fact has attracted many researcher from academia and industry. The studies present various horizontal and vertical aspects of cost effective digital advertising. Below are the three major areas in which research is continuously advancing:

Predictive Analytics:
Predictive analytics in digital advertising implies predicting future actions of user from their past behavior. Machine learning algorithms can be effectively applied to achieve this goal. Authors proposed various techniques such as CTR prediction approach based on fuzzy deep neural network [2], Hierarchical extreme machine learning algorithms [4], ensemble model based on ETCF [8], Optimally connected deep belief network [9], Weighted-ELM and Adaboost Algorithm [12], Deep Shallow layers [13], Disguise Adversarial Networks [17], Logistic Regression Classifier [18], and many other deep neural network techniques [14] [15] [16] [20].

Cost Optimizing:
As stated before, cost optimizing is a process of optimizing pricing for sales and profit. Profit Optimizing means gaining maximum profit through minimum advertisement displays. Researchers are working on various techniques to achieve better results. Some of them are An Adaptive Intelligent Management System of Advertising for Social Networks: A Case Study of Facebook [5], Digital advertising effectiveness measurement [7], The Reserve Price of Ad Impressions in Multi-Channel Real-Time Bidding Markets [10], Simple and Scalable Response Prediction for Display Advertising [19], Bidding Machine: Learning to Bid for Directly Optimizing Profits in Display Advertising [21].

Audience Expansion:
Audience Targeting Techniques is the process of predicting relevance of advertisement to individual. Many industry giants such as Facebook, LinkedIn are deploying interesting models to create target audience groups for various advertisements. The research work in this area include Ad Analysis using Machine Learning [1], Audience Expansion for Online Social Network Advertising [6], Facebook's Advertising Platform: New Attack Vectors and the Need for Interventions [22], Modeling users for online advertising [23].

IV. OPTIMIZED HYBRID SOLUTION FOR COST EFFECTIVE DIGITAL ADVERTISING

Requirements & Assumptions

Digital Advertising has become one of the primary source of income for many companies such as Google, Facebook etc. There are three famous models which are mostly used in cost management of digital advertising namely, Cost-Per-Impression (CPM), Cost-per-Click (CPC), Cost-per-Conversion (CVR). The hybrid solution resented here considers Cost-per-Click (CPC) model.

Display space available for advertisement on publisher's site is called as 'inventory'. The inventory is classified as Prime Inventory (space available on home page) and Personalize Inventory (space available after login).

System Design

Below is the process that describes the system shown in Figure 1.

1. The process starts with data collection. In this step system allows all advertisers competing for inventory at publisher's site to display their respective ads in Round Robin fashion. These ads are allowed to be displayed at primary inventory. Each advertisement gets equal opportunity to gain high CTR in this step.
2. After a period of time the system collects data for each advertisement. CTR rate is predicted for each advertisement using simple logistic regression classifier.
3. System selects top x% advertisements which gets high CTR. The value of x can be determined by industry standards.
4. Then audience categorization is performed to classify users in x categories namely, c1, c2, c3…cx. Data is sorted based on ad displayed and clicked for x advertisers in c1, c2, c3…cx classes. For example, c1 is the class for all users who clicked on advertisement x1 and similarly for others. This data is used as training data for classifying users in 'x' no. of classes. Naïve Bayes multiclass classifier is used for same.
5. Whenever a new user visits publisher's site, a user profile is created. Class of new user is predicted based on trained machine learning model.
6. Personalize ad for that class is displayed to the particular user at personalize inventory on publisher's site.

Outcome

'Cost per click' is most common model for cost management in digital advertising industry. In this method, ads having high CTR are being displayed to their most suitable audience group. There is high probability of getting large no. of clicks and thus increasing profit for publishers.

Since audience is interested in contents being displayed in advertisement, there is high probability that they will buy the respective

product. Thus, the goal of advertising the product can be achieved. Advertiser will be then satisfied with conversion rate.

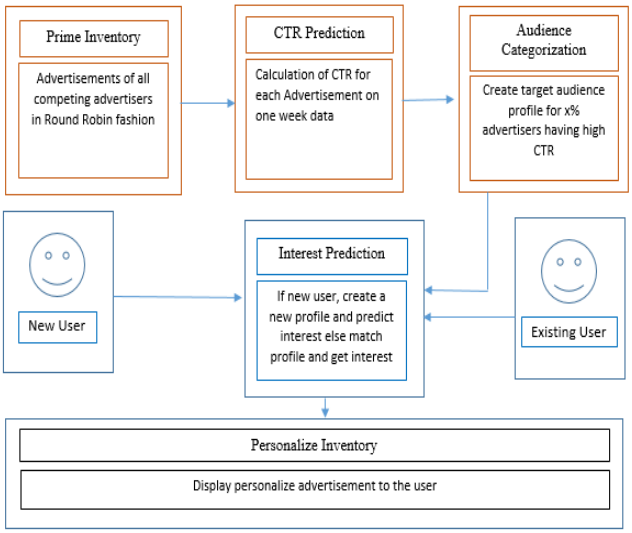

Figure 1: Hybrid System for cost effective Digital Advertising

End users get most relevant products with least efforts and may be with exiting personalized offers. Hence they will also be satisfied. This will also reduce the annoyance for irrelevant ads.

V. METHODOLOGY

Logistic Regression Classifier:

Logistic regression utilizes a condition as the representation, particularly like linear regression. Input esteems (x) are consolidated linearly utilizing weights or coefficient esteems (w) to anticipate an output esteem (y). A key contrast from linear regression is that the output esteem being displayed is a twofold qualities (0 or 1) as opposed to a numeric esteem. Below equation represents net output

$y1 = x*w + b$

where, b is bias or intercept term. Every section in your input information has a related w coefficient (a consistent genuine esteem) that must be learned from your training data. The following is a precedent logistic regression equation:

$y = [ey1] / [1 + ey1]$

Naive Bayes:

Naive Bayes is a sort of classifier which utilizes the Bayes Theorem. It predicts participation probabilities for each class, for example, the probability that given record or information point has a place with a specific class. The class with the most elevated probability is considered as the in all likelihood class.

The following is the recipe for ascertaining the contingent probability,

P (A/B) = [P (B/A) * P (A)] / [P (B)]

P (A) is probability that A being true regardless of B.

P (B) is the probability that B being true regardless of A.

P (A/B) is probability of A given that B is true.

P (B/A) is probability of B given that A is true.

Naive Bayes classifier accept that every one of the highlights are disconnected to one another. Nearness or nonattendance of an element does not impact the nearness or nonappearance of some other component.

VI. IMPLEMENTATION

Naive Bayes classifier is used for Interest Prediction mechanism. Below are the details of the dataset used:

Table 1 Dataset Description for User Interest Prediction

Category	Description	Datatype
Age	Age of user ranging from 17 to 90	Number
Work-class	Type of employment	String
Final-weight	numerical values ranging from 12285 to 1455435	Number
Education	Highest qualification of user	String
Education-years	No. of years spent in education ranging from 1 to 16	Number
Marital-status	Relationship status of user	String
Occupation	Job status	String
Advertisement	Advertisements of all participating advertisers	String
Race	Race of individual	String
Sex	Gender	String
Capital-gain	Amount ranging from 0 to 99999	Number
Capital-loss	Amount ranging from 0 to 9999	Number
Hours-per-week	No. of working hours per week ranging from 1 to 99	Number
Native-country	Base country of user	String
Class	Clicked, Non-clicked	String

Weka is an open source classifier tool. Figure 2 shows the details of the experimental results using Weka tool. The accuracy achieved is 89.44%.

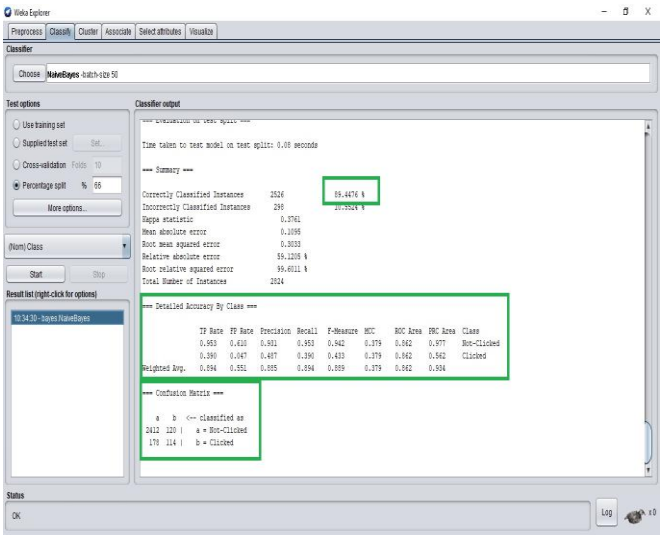

Figure 2: Implementation Accuracy using Weka Tool

VII. CONCLUSION

This work presents cost effective solution for displaying advertisements to users on digital media. This is beneficial for all three stakeholders namely, advertiser, publisher and end users. The presented system combines predictive analytics for CTR prediction, audience targeting and cost optimization. The interest prediction for audience targeting provides 89.44% accuracy using Naive Bayes classier. 'Cost per click' is most common model for cost management in digital advertising industry. In this method, ads having high CTR are being displayed to their most suitable audience group. There is high probability of getting large no. of clicks and thus increasing profit for publishers. Since audience is interested in contents being displayed in advertisement, there is high probability that they will buy the respective product. Thus, the goal of advertising the product can be achieved. Advertiser will be then satisfied with conversion rate. End users get most relevant products with least efforts and may be with exiting personalized offers. Hence they will also be satisfied. This will also reduce the annoyance for irrelevant ads. There are numerous impressive advancements coming up in the field of digital advertising. For example, dynamic interactive ads, which are displayed for same product differently for different people. Such ads interact with user and provide customize response. This interactions can generate a lot of useful data which can be analyzed as future work.

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