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Product image classification using Eigen Colour feature with ensemble machine learning

S.A. Oyewole, O.O. Olugbara *

ICT and Society Research Group, Durban University of Technology, P.O. Box 1334, Durban 4000, South Africa

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ABSTRACT

The plethora of e-commerce products within the last few years has become a serious challenge for shoppers when searching for relevant product information. This has consequently led to the emergence of a recommendation assistant technology that has the capability to discover relevant shopping products that meet the preferences of a user. Classification is a machine learning technique that could assist in creating dynamic user profiles, increase scalability and ultimately improve recommendation accuracy. However, heterogeneity, limited content analysis and high dimensionality of available e-commerce datasets make product classification a difficult problem. In this present study, we propose an enhanced product image classification architecture which has data acquisition pre-processing, feature extraction, dimensionality reduction and ensemble of machine learning methods as components. Core amongst these components is the Eigenvector based fusion algorithm that is meant to obtain dimensionality reduced Eigen Colour feature from the histogram of oriented gradient based colour image representative features. The ensembles of Artificial neural network and Support vector machine were trained with the Eigen Colour feature to classify product images acquired from the PI100 corpus into 100 classes and their classification accuracies were compared. We have obtained a state-of-the-art classification accuracy of 87.2% with the artificial neural network ensemble which is an impressive result when compared to existing results reported by other authors who have utilised the PI100 corpus.

1. Introduction

The adoption of e-commerce in modern times has led to higher profitability for merchants and brought more satisfaction to consumers [1–4]. This has also impacted positively on the economy of countries worldwide by improving Gross Domestic Product (GDP). The PricewaterhouseCoopers (PwC) in South Africa has reported that user online retail shopping sales surpassed a trillion Rand (South Africa currency) for the first time in history, which has increased to 1.46 trillion Rand in 2016 [5]. In addition, the same source reported that because of the global surge in e-commerce, the collective GDP of Africa continent is expected to rise by US $1trillion by the year 2020, which is up from US$1.6 trillion in 2010. Moreover, the Economist Intelligence Unit (EIU) has forecasted a real GDP growth of 4.9% from 2012 to 2016 for the African continent, which is well above the average global growth [5,6]. E-commerce is playing a key role in the global economic growth and the need to keep satisfying customers cannot be over emphasized. However, abundance of e-commerce information in recent years has become a serious challenge for shoppers, because of the inherent difficulty in information discovery. This has led to the emergence of recommendation systems to assist a user in the information discovery. A content-based image recommendation system is an application that uses image features to filter information from all the available sources and displays the appropriate information based on personal preferences that are kept in the user profile [7,8]. The origin of recommendation systems can be traced to methods in cognitive science, management science, approximation theory and information retrieval, which have since been applied in various human endeavours.

* Corresponding author.
E-mail addresses: 21242711@DUT4life.ac.za (S.A. Oyewole), oludayoo@dut.ac.za (O.O. Olugbara).

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In the e-commerce application domain, many methods and principles have been applied to implement recommendation systems of which classification methods have been identified as an important component. Product classification, which involves the association of classes with related products from a large number of merchants, is one of the most important processing tasks of content-based recommendation systems. Apart from user profiling [9,10], classification methods have been found useful in many recommendation applications such as product image retrieval [11–13], product taxonomy browsing [14], increase scalability [15] and improve overall recommendation accuracy.

Meanwhile, most of the accuracies reported on product classification studies rely heavily on text tagging, which is a traditional product data representation method [16–18]. However, product classification based on text tagging is plagued with several hiccups such as overlapping text across product classes [19,20], labour intensiveness [21], discrepancy in vocabulary usage [22], spelling error [23] and undescriptive nature of texts [20,24]. While incremental improvement can be achieved by trying new methods that exploit textual features [19,21], current research efforts have shifted focus to image based product classification models with diverse applications in various fields of life [24–26]. According to the pattern recognition theory, feature extraction and feature recognition methods play major roles in the classification process. As accuracy is one of the common assessments of performances, several researchers in the recommendation domain have carried out interesting studies to enhance the performance of product classification.

In contrast to text tagging, image based product classification involves the use of images for product representation and classification model. The high dimensionality of extracting image features, limited content analysis, artefacts, inhomogeneity and other nuance factors often inhibit image-based classification performance [10,16,27]. A significant volume of researches have been channelled towards this direction, nevertheless, the number of image-classes investigated and accuracies reported still leave much to be desired for real-time applications. In acknowledging the complexity of these problems, an initial attempt is made to solve a simpler sub-problem of image content-based recommendation by proposing enhanced product image classification architecture. Among the core algorithms used in the proposed architecture is the ensembles of artificial neural network trained with the Eigen-based colour features. The propose architecture is used to classify product images into 100 classes.

Specifically, effort in this work is channelled toward actualising an effective image-based classification model that majorly relies on an ensemble of Artificial neural network (ANN) and potential of efficient Eigen-based image feature representation. The extraction of colour product features from a product image is performed using the Histogram of Oriented Gradient (HOG) and Uniform Linear Binary Pattern (ULBP) feature extraction methods. The Eigen-based algorithm is then applied to extract a dimensionality reduced product image features. We applied data partitioning (cross validation) scheme that splits the initial data into training, validation and testing subsets in the proportion of 70%:15%: 15% (70% of the dataset is used for training the network, while 15% each of the remaining datasets is used for validation and testing), were experimentally explored on the PI100 categorization data set [28]. We chose this database because it has been widely used in e-commerce research for product image classification [25,26,29,30] and it is freely available for research purpose.

The overarching objective of the study at hand is to generate an efficient image-based classification model that can be used to deliver an effective user-centric categorical preferences or be integrated with any conventional recommendation system to improve its quality. In realising this singular objective, four different experiments were performed to establish the appropriateness of the product image classification models for the proposed architecture. This paper makes three major contributions enunciated as follows:

(1). Propose an Eigen-based product image feature extraction algorithm that delivers an effective product image representation for large product classes. The results of this method can serve as an image segmentation approach in e-commerce applications such as recommender systems to resolve inherent limited content analysis problem.
(2). The final classification model obtained from this work can be easily integrated with any other decision supporting applications in e-commerce domain to improve its quality.
(3). The proposed Eigen-based product image feature extraction algorithm is evaluated quantitatively on experimental images acquired from publicly available product images using the standard accuracy and mean squared error metrics.

This work further stresses the fact that an ensemble of machine learning classifiers gives better results than any classifier used in isolation. The rest of this paper is structured as follows. In Section 2, relevant literature is discussed. Section 3 describes in detail our proposed architecture as well as materials and methods. Then we describe the experiments carried out to validate the performance of the various methods for the tasks of product image classification in Section 4. In section 5 discussions of results are presented. The paper is finally concluded in section 6 by giving a brief discussion about the future directions.

2. Literature review

Image feature extraction and classification methods are two important tasks in the recognition process. Artificial neural network (ANN) and Support vector machine (SVM) are two popular classifiers that have been applied to e-commerce product image classification and decision supporting tasks with some degree of success. Specifically, ANNs have the ability to model nonlinear relationships between a set of input variables in the user profile and corresponding preferences of the user. Large number of product data often caused overfitting when an ANN is integrated with any e-commerce applications [31,32] such as recommendation systems. To overcome this overfitting problem, cross-validation is considered to be one of the most effective methods to ensure overfitting does not occur [31,32]. Here, available data is usually partitioned into three sets which are training, testing and validation. The training set is used to adjust the connection weights, the testing set is used to check the performance of the network at various stages of learning and training is stopped once the error in the testing set increases. The validation set is used to evaluate the performance of the model once training has been successfully accomplished [32]. This partitioning-based cross validation can be accomplished in recommendation systems using time, item rating (which can come in the form of user preferences expressed in numeral or product-item feature), categorization and user-stratification [31,33].

Many authors have integrated ANN-classifier with image content-based approaches to improve product image recognition. In Bonnet [34], an object recognition pipeline for e-commerce products was developed using a combination of convolutional neural nets (Deep Learning) and natural language processing (NLP). In his work 85%, 86% and 86% classification accuracy was realised

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