Future Generation Computer Systems 88 (2018) 333–341

Contents lists available at ScienceDirect

Future Generation Computer Systems

journal homepage: www.elsevier.com/locate/fgcs

Improving consumer satisfaction in smart cities using edge computing and caching: A case study of date fruits classification

M. Shamim Hossain [a,*], Ghulam Muhammad [b], Syed Umar Amin [b]

[a] Department of Software Engineering, College of Computer and Information Sciences, King Saud University, Riyadh 11543, Saudi Arabia
[b] Department of Computer Engineering, College of Computer and Information Sciences, King Saud University, Riyadh 11543, Saudi Arabia

HIGHLIGHTS

- Use of 5G technology and deep learning for consumer satisfaction in smart cities.
- A novel framework to classify mobile data in real-time using 5G technology.
- Deep learning used for automatic date fruits classification.
- Edge computing & caching provide low latency real-time transmission of date images.

ARTICLE INFO

Article history:
Received 31 December 2017
Received in revised form 10 May 2018
Accepted 22 May 2018

Keywords:
Smart cities
Cloud technology
Edge caching
Deep learning
Date fruit classification

ABSTRACT

The emergence of 5G technology has enabled a fast development of the wireless communication based on Big Data, Internet of Things (IoT), cloud computing, edge and fog computing. The development has contributed to enhance the lifestyle of the citizens in smart cities. Different applications are provided with 5G technologies to solve problems of the citizens. In this article, we take advantage of the 5G technology to develop a framework of images' classification to satisfy consumers in smart cities. As a case, study, we develop an automatic date fruits classification system in the framework to satisfy date fruits consumers interest. In the proposed system, a deep learning approach is utilized with fine-tuning pre-trained models. The edge computing and caching are used to provide a low latency and real-time transmission of the date fruits' images. The experimental results show the viability of the proposed framework.

1. Introduction

With the emergence of 5G, there is an unprecedented development in wireless technologies based on Big data, cloud computing, edge computing, IoT. There is a sharp rise in the development of mobile internet, resulting in a great demand for fast and high-quality data, video streaming, and machine-to-machine communications. In future mobile users would be able to access Big data processing and high-speed emerging services and applications over clouds and other networks [1]. With this growth in technology, the number of mobile users is also growing exponentially according to CISCO, by 2020, there can be approximately 50 billion Internet-connected smart devices. We need to facilitate so many users, with personalized and interactive services like real-time monitoring services, which include smart home, emotion recognition, health monitoring or other IoT services and that too at high data rates. In order to provide these computing-intensive and massive multi-dimensional data processing services and applications, 5G technology will use the services of mobile cloud computing and big data analytics [2–5].

The wireless big data generated from connected smart devices poses challenges to handle it due to its massive size, complexity, and multi-dimensionality. The 5G wireless technology connected with IoT together with the capabilities of big data analytics and cloud processing has a tremendous potential to address the challenges with high resource utilization and response time, and high accuracy. With these facilities in 5G, mobile networks can be used for intelligent real-time decision-making in a wide range of applications. Hence, we need a framework to enhance mobile user experience in 5G and to make use of a massive shared pool of computing and storage resources from the cloud and provide real-time data analytics capability. In this respect, we propose a novel framework to classify mobile data in real-time using 5G technology, a mobile edge computing, and the cloud computing. With this proposed framework, a system of big data image classification is proposed. The results show that the proposed

* Correspondence to: Department of Software Engineering, College of Computer and Information Sciences, King Saud University, Riyadh, Saudi Arabia.
E-mail address: mshossain@ksu.edu.sa (M.S. Hossain).

https://doi.org/10.1016/j.future.2018.05.050
0167-739X/

methodology accomplishes 99.2% image classification accuracy. To show the suitability and validity of the proposed approach, Deep Convolution Neural Networks are used to speed up the processing and classification accuracy. As far as our study of the literature is concerned, there is no existing framework for 5G that is developed to classify images over the cloud which uses big data processing facility and provides a real-time result with such high accuracy. As a case study, we choose date fruit classification from real-time images captured using mobile devices. The Middle-East and the North African countries account for the biggest share in production of date fruits among all the countries in the world [6]. The Arab world has a huge economy based on date fruits. The date fruits are not only full of nutrition but also significant to Muslim populations. There are many types of date fruits, and these types differ from one region to another region. Therefore, if there was an automatic date fruit classification system using smart phones, it would benefit the consumers of date fruits. Besides, most of the major Arab cities are turning into smart cities, where this type of systems would greatly improve the quality of the lifestyle of the citizens.

Most of the previous research studies on date fruits are regarding inspection and grading of date fruits and not classification. In two such studies by an author, two methods are proposed for date fruit inspection and grading, one is based on co-occurrence matrix [7] and the other is based on color machine vision technique [8]. In one study [9] the author proposed a method to sort dates into defected or good quality by using image analysis techniques. In [10] a method was proposed for date maturity inspection using near-infrared spectrometry. There are also some methods, which use shape and size features for date grading. One such study [11] used neural network classifier, and another approach [12] used probabilistic neural networks. In another research [13] on dates grading, size, shape and intensity features were extracted, and they used neural network to classify the date fruit images according to the predefined grades. To the best of our knowledge, there is very limited research for date recognition or classification. Most of the previous studies aim to classify the dates based on the grades. We found one study [14] for date fruit classification, which used features like mean, standard deviation, the entropy of RGB color components and shapes, size features to classify dates. Using neural networks, they achieved an accuracy of 98.6% and using linear discriminant analysis, they got an accuracy of 96%. In another study for date fruit classification [15], G. Muhammad developed a date fruit classification technique which was based on shape, size features and local texture descriptors. He used SVM with RBF kernel as classifiers. He used four classes of dates to give an overall best accuracy of 98.1%. IN both these approaches, the date fruit images were taken from a close distance and had single fruit under specific light conditions. Hence these approaches are unsuitable for multi-fruit images and are not robust enough to work in different environments. Therefore, we develop a robust and real-time automatic date fruit classification approach suitable for different environments and scenarios.

If a user who is shopping, wants to recognize the type of date fruit, he simply captures images at a real-time using his smart phone to the get result instantaneously. The proposed framework has an image classification engine which makes use of convolutional features for the captured image and a softmax classifier. The main contributions of the paper are (i) embedding a new image classification component in the 5G framework, (ii) using fine-tuned convolution neural network, to extract features from the captured images and to classify them.

Automatic Fruit classification is a challenging computer vision task due to a different shape, size and color properties of numerous types of fruits. Classification of date fruits make it more complicated due to its many varieties with a lot of similarities. All previous date fruit classification approaches focused on designing handcrafted features, and all of them used segregated date images as classifying images in the bunch is more difficult. As most of the date fruits are available after packaging, and there is no work to classify multi background images. Hence in this work, we explore how Convolutional Neural Network (CNN), can be applied to the task of robust date fruit classification, which is not only independent of the handcrafted shape, size, color features but also of the background which including different environments and packaging. To add robustness, we build our own database extracting images from Google search engine, for each of the four dates classes used. Unlike previous deep learning based techniques employed for fruit classification, we employ transfer learning using pre-trained models, namely AlexNet [7] and fine-tune them to classify images. This enables us to achieve very good accuracy with relatively small database and with minimum training time.

2. Proposed image classification framework

The proposed image classification framework is shown in Fig. 1. The framework has three layers namely infrastructure, resource engine, and the data engine layer. The infrastructure layer is decomposed into: (1) devices layer and local cloudlet, (2) infrastructure and network for communication, which includes radio access network (RAN), and (3) infrastructure for processing and storage, which has cloud processing capability. Optimization of the network resources and efficient communication is performed by the resource engine layer. The framework and the communication network should be highly flexible and scalable hence optimization is essential. In order to accomplish optimization, the resource engine layer can use services from technologies like self-organizing network (SON), Software-defined networking (SDN) and network function virtualization (NFV) etc. The data engine layer has the responsibility to Artificial Intelligence (AI) and Machine Learning (ML) techniques to preprocess the data, feature extraction and pattern recognition. It may also use recent automated techniques like Deep Learning (DL) to accomplish these data processing tasks. The final objective of the data engine layer is to process and classify the data into predefined classes. In our case study, the data engine layer classifies the date fruit images into predefined classes.

The device layer has mobile devices, which may consist of mobile, smart, or connected devices, with cameras to collect the images and video frames which need to be classified. Deep Learning based on convolution neural networks is the learning classification algorithm to classify images. There is also local cloudlet within the device layer. It uses short-range radio communication technologies; devices like PCs, smartphones, home appliances, and robots are connected to each other in order form a local cloudlet. The local cloudlet provides more information about the images to be classified. The images collected by the devices can be noisy due to the mobile device environment so the local cloudlet also pre-processes captured image data to improve its quality and to compress it to reduce its size. The local cloudlet can also be used for effective feedback.

Communication Infrastructure transmits the data which is collected from different types of applications and services in the mobile device, to the data centers on the cloud service layer. The Communication Infrastructure consists of a range of communication technologies such as RAN (radio access networks).

Storage and computing infrastructure includes edge cloud and remote cloud. The remote cloud provides resources to support computing, by providing more data sources. The edge cloud is realized by a mobile edge computing (MEC) server, which administers the mobile edge cloud. The MEC platform is designed to work within the RAN.