AppTree: An Intelligent Platform for Discovering the World of Plants

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***Abstract*——"AppTree" is an intelligent platform to bring researchers, visitors, and all interested people closer to the oldest and most attractive botanical garden at the University of Tehran. AppTree can scan the QR-Barcode of each plant in person by smartphone or search various plants on the website and get all the useful knowledge about them. Also, the ability of AppTree is the recognition of different plants which don't have labels. The plant recognition part is a machine learning module that can identify more than 100 different species of plants and give the user details about them. This novel platform is based on Android and Web-app and the identification of new plants type is done by machine learning approach. We utilized VGG19, a deep CNN, to classify images and to identify unlabeled plants. The classification accuracy, F1-score, recall, and precision were 98.25, 93.16%, 88.21%, and 94.85%, respectively, on the plant dataset of the University of Tehran. The proposed method was compared with other deep learning architectures such as AlexNet, AlexNetOWTBn, and GoogLeNet on the same dataset and obtained higher performance. Our AppTree platform has achieved considerable success and easily can be extended to use in other botanical gardens.**

Keywords— Mobile App; Web App; Classification; Machine Learning; Deep Learning.

1. INTRODUCTION

The use of smart applications in visitor attractions and tourist trails has received considerable attention from researchers in recent years. In recent years, botanical gardens have also started to provide science and environmental-related education to visiting botanists, students, interested people using interactive technologies such as QR (Quick Response) Barcodes technology. Early botanical gardens were considered as the places where plants are labeled, but now these are becoming the source of education [1].

The QR-Barcodes are used to design an information and electronic guide system. QR-Barcodes are urgent to smartphones and greatly utilized in various fields and the ability to connect to the Internet. This leads to many different fields to search for an enhancement in capacity storage. Moreover, they can encode various types of data. All these made the QR-Barcodes more attractive than traditional barcodes [2, 3].

We developed a novel intelligent platform for Botanical Gardens to enhance garden visiting experiences. The main objectives of this research were to explore how intelligent mobile and web applications can be used to achieve this purpose, how effective they can serve as an educational tool to share knowledge about local plants, and what opportunities and barriers arose from deploying the technology in a real-world setting. We demonstrated the usability and feasibility of the approach in a user experience study held at the Botanical Garden of the University of Tehran.

The Botanical Garden of the University of Tehran is a collection of living plant specimens that was established in 1310 Shamsi by Mr. Julin Gauthier on a plot of land with an area of less than one Hectare and gradually increased to an area of about 8 Hectares. This Garden has more than 200 plant species, most of which are trees and shrubs. A view of QR-Barcodes that we have created in the botanical garden of the University of Tehran is shown in Fig. 1.

We believe that the study is vital to understanding how to design more engaging and effective digital technologies to support informal learning in public settings based on scanning. Nowadays, agricultural IoT has become a major part of planning and design for intelligent Botanical Gardens, and how to integrate and coordinate IoT planning with industrial planning, tourism reception, landscape planning, and farm life management planning is an essential problem now. So, the research of planning and design of intelligent gardens based on the integration of agricultural IoT has the significance of enhancing industrialization [4]. The main contributions of this study are as follows:

- We developed a novel intelligent platform for Botanical Gardens to enhance garden visiting experiences in Iran.

- We integrated and coordinated intelligent Android-based and web-based applications as well as machine

Fig. 1. A View of Created QR-Barcodes in Botanical Garden of the University of Tehran.

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learning techniques to achieve industrial planning, tourism reception, landscape planning, and farm life management.

- The experimental results showed that our deep learning model can obtain higher classification accuracies in comparison to the other CNN models on the plant dataset of the University of Tehran.

2. RELATED WORK

There has been growing interest recently in exploring how the use of personal digital technologies such as smartphones can augment the visitor's engagement with their surrounding environment [5, 6].

Karasah et al. [7] investigated the functions of botanical gardens and classified 30 different botanical gardens from all around the world with the aim of ordering by priority. They studied the recreational functions of the Nezahat Gökyiğit Botanical Garden in Turkey. Several surveys on the topic of botanical gardens visitors' preferences are mentioned by the authors and they also conducted their own. The authors were interested in some aspects such as the seasons preferred by the visitors, the frequency of the visits, or the reasons people enjoy being in a botanical garden.

Heywood et al. [8] proposed the role of Mediterranean botanical gardens in the plant life of the region. Their study helps to the introduction of new material, reintroduction of threatened species, and conservation and recovery. They mentioned an imbalanced distribution of botanical gardens; more specifically, in the eastern and southern Mediterranean countries. They noticed that the botanical gardens have a less important role in these places. Also, they investigated some botanical gardens that cannot accommodate conservation collections of growing plants because they are too old or small. Finally, they proposed some solutions to solve these problems.

Blaszak et al. [9] mentioned that botanical gardens often focus on biological aims, e.g., the necessity to preserve biodiversity, giving less importance to educational and social purposes. Educationally speaking, cognition and emotions together bring high benefits to the learning experience. They has introduced the concept of "useful botanical garden", based on three aspects: functionality (features that encourage interactions and cognitive processes), sensibility (features that lead to welcoming comfort, safety, and homeostasis), and rationality (visitors' reflection on values such as care and authority and how the values relate to the elements present in the botanical garden and the visitors' emotions). Their ideas have significance for the design of botanical garden spaces, formative processes based on garden spaces, visitor expectations, and interactive activities.

Android mobile applications are very common in plant disease recognition [10, 11, 12]. Plant disease is an important problem in plant growth. Farmers should take high care to find the diseases of the plant. But, due to the lack of knowledge for recognizing the diseases, early detection of plant disease may not be possible for farmers. Applications can help the farmer to identify the diseases of the plant.

Vesali et al. [13] implemented an app on an android phone to estimate the chlorophyll content of corn leaves. The new method of imaging, contact imaging, was used to reduce the effects of real conditions. Both linear and neural network models were developed to estimate SPAD values. In another study, they introduced a new spectral absorption photometry method to estimate the chlorophyll content of corn leaves by smartphones [14]. The first method acquires light passing through a leaf by smartphone camera, compensating for differences in illumination conditions. Smartphones would help to make this possible, due to better and faster processors and sensors which turn them into handy meters ready for field use. Since smartphones and free apps are available around the world today; this device might have applications beyond communications. For instance, by establishing simple field-based tests, farmers can now create custom reference values for adequate chlorophyll concentration by simply applying known quantities of nitrogen fertilizers and recording plant growth.

Patil et al. [15] proposed application to access plant information. Also, they integrated QR codes for accessing plant information using smartphone or tablet devices. The aim of their research was to create a system that uses QR codes to increase knowledge gained by students to the Dada Patil College Campus. Neto et al. [16] argued that applying technology and innovative methods provides a better approach to biodiversity education. They also revealed a practical web-based app with AI, which was useful to guide those supporting biodiversity projects in education. They applied deep CNN techniques for classification task through transfer learning. Pristouris et al. [17] proposed an integrated system for urban parks touring and management, based on a mobile application for the park visitors and web applications for park managers. They showed that the use of new technologies can make urban parks more attractive and optimize their management, leading to better use of green spaces in cities. In practice, it causes to have more visitors in urban parks, a better touring experience, and potential benefits for the environment.

An overview of the above-mentioned approaches is shown in Table I. In summary, most of the related researches on investigating different modern approaches by using IoT for discovering the world of plants consist of plants classification [7, 8, 13, 14], plant disease recognition [10, 11, 12], obtaining plant information for tourism reception [9, 15, 16, 17]. Although there are some studies in the literature that created Android-based or web-based apps for getting plant information in some famous Botanical Gardens in the world, there is a research gap in this area in Iran. In addition, we have proposed the identification of new plants by utilizing a machine learning approach.

3. PROPOSED METHODOLOGY

AppTree is an intelligent platform that consists of 1) an Android application that allows through a simple QR-Barcode to identify different plants and trees and provides a lot of useful information about them, 2) a web application that manages databases and knowledge as well as Botanical Garden website, 3) a machine learning model which is used to identify unseen plant data. The architecture of AppTree is illustrated in Fig. 2.

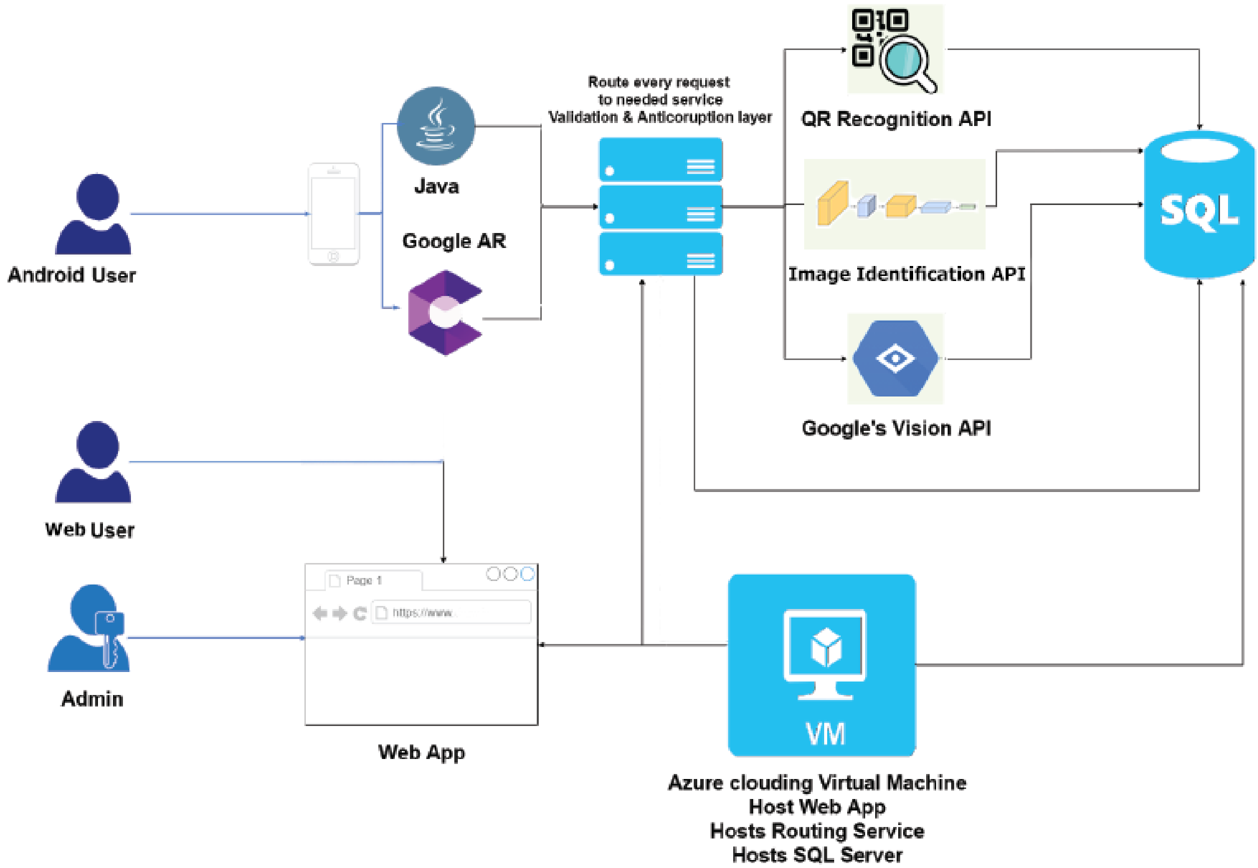

Fig. 2. "AppTree" Intelligent Platform Architecture

TABLE I. RELATED RESEARCH ON INVESTIGATING BOTANICAL GARDENS TO ENHANCE VISITING EXPERIENCES.

Ref	***Year***	***Description***
[7]	2013	Classified the 30 different botanical gardens
[8]	2015	Investigating Mediterranean botanical gardens
[13]	2015	Android app for extracting some major features of the leaves
[14]	2017	Android app for extracting some major features of the leaves
[9]	2019	Neuro-cognitive perspective for tourist attraction
[10]	2020	Android app for plant disease recognition
[15]	2020	Android app for increasing gained knowledge
[11]	2021	Android app for plant disease recognition
[12]	2021	Android app for plant disease recognition
[16]	2021	Web-based app with AI for biodiversity education
[17]	2021	Android and web-based app for touring and management

3-1. Android application

This module is the Android part of our platform. It is written in Java and built for smartphones that run Android 5 or higher (see Fig. 3). When the app is opened the user gets a prompt asking for camera permission. If users deny, the app closes itself, else the app starts. After the app opens, the user has a camera view right in front of his/her eyes and with this; he/she can explore the surroundings.

The user has the option to scan the QR-Barcodes to gain any information about plants in Botanical Garden. Also, the app can give the user directions to the Botanical Garden for an interesting virtual tour experience.

The interaction between the garden's environment and the visitors is made through a mobile application. This will be done as follow:

- The user should install, firstly, the application from the Botanical Garden of University of Tehran website;
- The user opens the application, selects from the menu "Scan QR-Barcode" and points the phone's camera to a QR-Barcode of each plant;
- After the image is processed, the user can see much information consists of the scientific plant's name, the Persian plant's name, origin, and description.

3-2. Web application

This module is utilized to create the Admin part of our application as well as the Botanical Garden website. It is a web app written in Angular 8. The Admin part of the application will be available for the admin who will create an account based on which they will be authenticated. The admin will have the option to add, edit and delete different types of plants that can be found in the Botanical Garden. The other part of this web application is accessible to anyone who is not an admin to view and search all plants information. The main page of the application has a simple interface that makes interaction as simple and pleasant as possible.

The admin part of web app task is as follow:

- An employee from Botanical Garden will be delegated to insert data about the garden's plants;
- The employee will log in using an administrative account in the web application;
- In the application the user can add a new plant using the following properties: scientific plant's name, the Persian plant's name, origin, and description;
- After all the mandatory fields have been completed the user can save the record;
- The user can use the application to display a list with all of the records, to edit and delete them.

3-3. Machine Learning

In the machine learning module, features are extracted from the plant's image files and saved in a format that allows us to do the classification task. This module of the AppTree platform can help to identify unlabeled plants even in other Botanical Gardens.

We utilized VGG19 [18] as a machine learning model which is used to identify unlabeled plants. It is shown in Fig. 4.

For the dataset, we used a combination of images from a general plant database[1] and the collected images from the Botanical Garden of the University of Tehran which are 1,584 images, containing 99 different classes in totally. The model training phase and testing phase were performed with the use of 80% and 20% of images in this dataset, respectively.

We illustrated the contribution of the proposed strategy in Fig. 5.

4. EXPERIMENTAL RESULTS

The VGG19 was used for the prediction model of the machine learning section in the AppTree. We compared the VGG19 with five basic CNN architectures that were tested in the classification task to identify plants type from images of their leaves. These CNN architectures are AlexNet [19], AlexNetOWTBn [20], GoogLeNet [21], and VGG19 [18]. All models and their training and testing processes were implemented using the Torch7 machine learning computational framework.

Fig. 3. View of Our Android Application

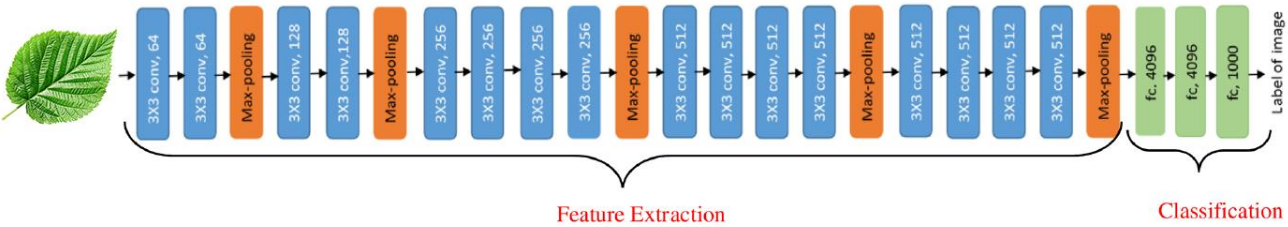

Fig. 4. Architecture of VGG19 model

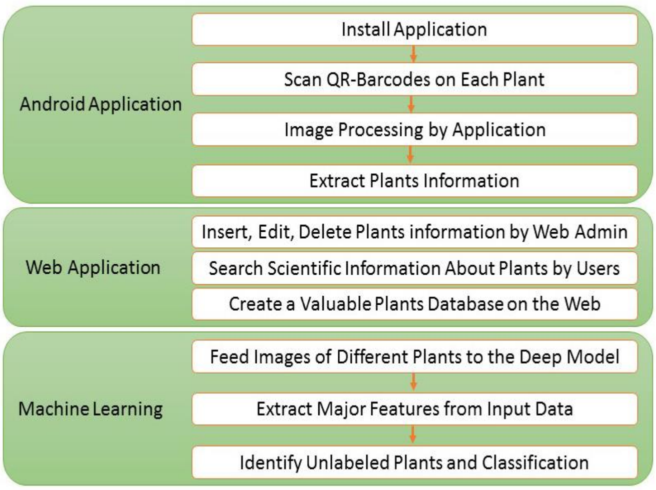

Fig. 5. Diagram to Represent the Contribution of the Proposed Strategy

[1] https://www.kaggle.com/c/leaf-classification/data

4-1. Implementation Details

We have implemented our codes in Python and Pytorch. A Python script was developed for the creation of the training and testing datasets, producing uniformly distributed pseudo-random numbers for the random selection of the images.

All different CNN models presented in Table II were trained using the following training parameters. The optimization approach was mini-batch stochastic gradient descent (SGD) with a momentum of 0.9 and a learning rate of 0.01. The classifiers were trained based on back-propagation with a batch size 32 (minibatch) and the accuracy was obtained for a maximum of 30 epochs.

4-2. Results and Discussion

Table III and Fig. 6 present successful classification percentages during training and testing of the various models, for the two basic training/testing approaches of the 99 classes. We can see that VGG19 deep learning model achieved the best classification accuracy in comparison to the other CNN models. So, we decided to use it for the machine learning module of our AppTree platform. In addition to accuracy, we used F1-score, recall, and precision to evaluate the performance of the classifier. These indices are defined as (1) to (4):

$$\text{Accuracy}= (TP+N)/ (TP+FP+TN+FN) \quad (1)$$

$$\text{Precision}= (TP)/ (TP+FP) \quad (2)$$

$$\text{Recall}= (TP)/ (TP+FN) \quad (3)$$

$$\text{F1-score}= 2. (\text{Precision}.\text{Recall})/ (\text{Precision}+\text{Recall}) \quad (4)$$

where accuracy measurement is the result of dividing the number of correctly classified cases by the total number of cases (Eq. 1). Precision measurement for a class is equal to the number of correctly classified cases divided by the sum of true or false classified cases (Eq. 2). Recall measurement is the fraction of correctly classified cases to the total number of cases classified in a class (Eq. 3). F1-score is a useful measurement to evaluate the classification performance and define the weighted average of recall and precision values (Eq. 4).

In Table III, we assessed the accuracy of different CNN model architectures based on F1-score, recall, and precision. Fig. 7 Shows ROC curves and AUC scores on each CNN model.

TABLE II. CLASSIFICATION ACCURACY OF DIFFERENT CNN MODEL ARCHITECTURES FOR THE IDENTIFICATION OF PLANT TYPES ON THE TESTING DATASET.

Model	***Classification Accuracy***	
	Validation	***Training***
AlexNet	95.35%	97.83%
AlexNetOWTBn	96.46%	98.50%
GoogLeNet	94.21%	98.68%
VGG19	**98.25%**	**99.30%**

TABLE III. ASSESS THE ACCURACY OF DIFFERENT CNN MODEL ARCHITECTURES BASED ON FI-SCORE, RECALL, AND PRECISION.

Model	***F1-score***	***Recall***	***Precision***
AlexNet	89.14%	88.95%	93.47%
AlexNetOWTBn	90.18%	77.28%	90.54%
GoogLeNet	77.80%	77.85%	92.16%
VGG19	93.16%	88.21%	94.85%

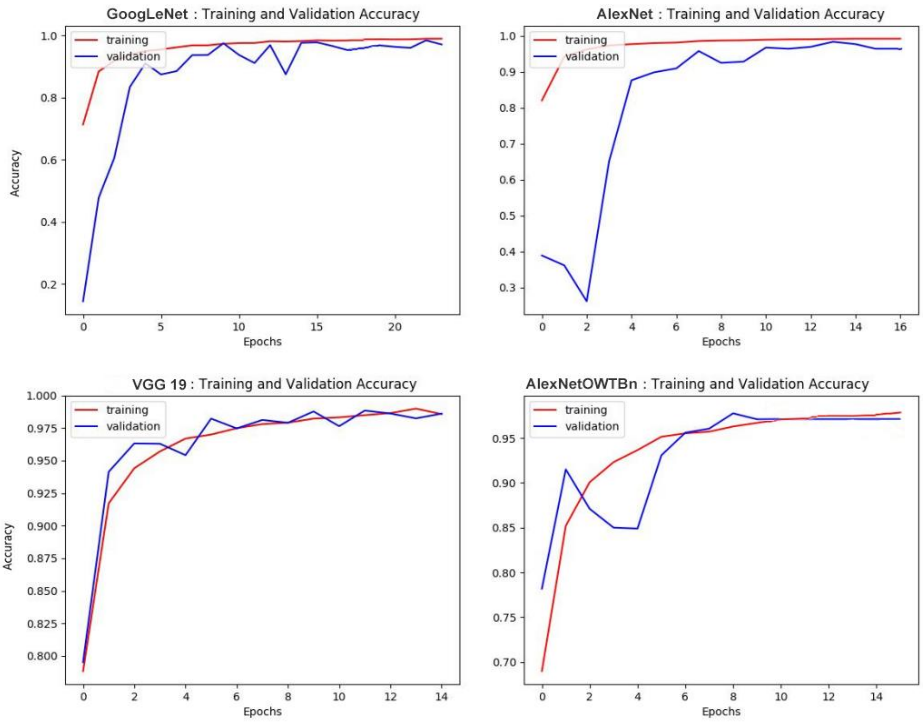

Fig. 6. Accuracy Performance on Each Model

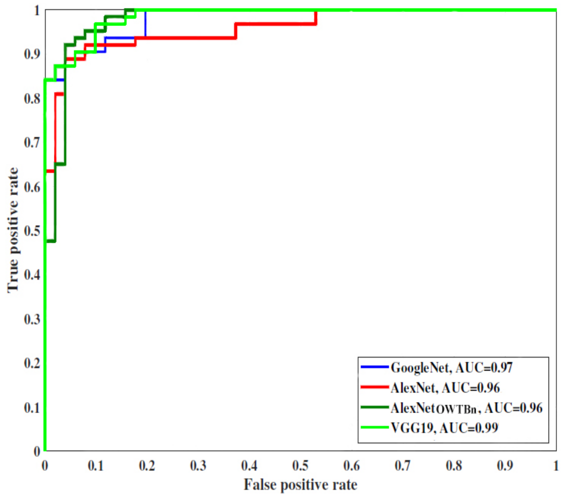

Fig. 7. ROC Curves on Each Model

Our intelligent framework is built in such a way that it may be used to classify not just plants. The module is currently “work in progress”, as getting a good training dataset is a challenging task. So far, the work (the API and the ML-related processes) has been done on several sample files, downloaded from the Kaggle website, and provided by the Botanical Garden of the University of Tehran. We intend to get more files, ideally from the Botanical Gardens, in order to create a proper dataset and perform the actual training, for a model that can be deployed.

5. CONCLUSION AND FUTURE WORK

In this paper, we presented how augmented reality can be used in the Botanical Garden. We introduced a novel intelligent platform, named "AppTree", which was implemented and operated in the Botanical Garden of the University of Tehran. We showed details about AppTree and its applications. The platform is complex and has multiple modules.

The Web App is the admin part of the application, and it is responsible for adding new plants information, managing all the existing information, and indexing them all in a simple and user-friendly way. The web part of also consists of the Botanical Garden website. The Android app is responsible for end-user interaction. Thus, users can scan plants, can search for them, find more information and photos about anything in the garden, and can scan various QR-Barcode to receive more information about different plants, a map of the garden and all its sections, and the plant recognition module embedded inside it. The plant recognition module is a machine learning module that can identify over 99 different species of plants and give the user details about them. The classification accuracy, F1-score, recall, and precision results of machine learning module are obtained 98.25, 93.16%, 88.21%, and 94.85%, respectively. The results of our machine learning module outperformed the results of other compared CNN models. All this considered, we think our intelligent platform represents a new way to think and to understand better the existing information from the Botanical Garden of the University of Tehran.

In the future, we intend to improve the existing modules and to increase the resources of the image recognition module.

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