Theme Article: Special Section on Machine Learning for End Consumers

Juice Recipe Recommendation System Using Machine Learning in MEC Environment

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***Abstract*—The combination of machine learning with healthcare services is emerging. However, when machine learning functions are executed on resource-constrained mobile consumer devices, the computing overhead will increase, and the user experience will deteriorate. In essence, the existing approaches delegate such tasks to a central cloud data center. However, data processing on remote cloud servers results in a long response latency. Therefore, this article proposes a machine learning-based smart recipe recommendation system that uses a local mobile edge computing server. The proposed system delegates the machine learning and recipe search tasks to the mobile edge computing server, thereby reducing the response latency for data processing and the computational burden placed on mobile user devices.**

Today, new kinds of mobile services are emerging with the appearance of various smart devices.[1] In particular, interest in artificial intelligence, machine learning, and healthcare has recently increased. Thus, in addition to services that follow the original usage pattern in which users simply consume content data, new kinds of services that provide additional useful information on the basis of either user-generated data or data processed by mean of artificial intelligence are receiving increasing attention.[2] A typical example of such a service is a healthcare service utilizing user-specific data. Such a service provides user-specific guidance, such as

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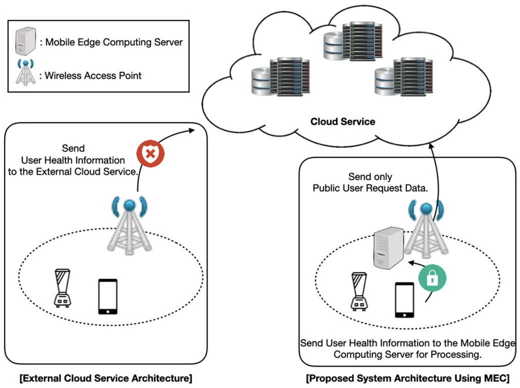

Figure 1. Illustration of the processing of users' health information with an existing cloud-based service and the proposed MEC-based system.

diet aids and blood sugar management for diabetic patients as well as healthy recipes.

However, the existing healthcare services rely on statistical information, not user-specific information, to recommend recipes and health management methods. Therefore, there is no user-specific service available. As service requests from users are delivered to the remotely located cloud server, privacy issues emerge with the possibility that users' sensitive information may be exposed while being transferred to a remote external server.

Therefore, this article proposes a smart recommendation system for providing user-specific recipe information based on mobile edge computing (MEC) and artificial intelligence processing to facilitate secure user-specific health services. The concept of MEC is defined as a new type of platform that provides IT and cloud computing capabilities within a wireless access network (RAN) in close proximity to mobile users.[3]

As shown in Figure 1, existing systems transfer users' health information to a remote cloud server for processing, while the proposed system utilizes critical user information only within the local MEC server and then, transfers basic recipe information, without any user information, to the external cloud server. The proposed smart recipe recommendation system delegates the high computational burden of the artificial intelligence processing to a MEC server. Also, the proposed recipe recommendation system protects user privacy by keeping critical user information within a localized area. In other words, the proposed system preserves the privacy of users because only a local MEC server within a user's home, not an externally located cloud server, is responsible for the processing of the user's health-related information and the recipe search operation. Thus, user privacy is maintained by having a local server perform both the inference of recipe information from user information and the recognition of ingredients in images provided by the user.

SMART RECIPE RECOMMENDATION SYSTEM

To provide users with customized juice recipes, the proposed system uses a chatbot, which can interact both with the juice recipe recommendation server and with users. The proposed recipe recommendation server is based on a MEC design that enables servers to be placed at edges close to users and provides ultralow-latency services.

Moreover, these edge servers can interact with an external cloud server to efficiently address the situation in which the recipe desired by the users cannot be retrieved from the edge server.

Recipe Recommendation Chatbot

The proposed system uses a chatbot-based user interface (UI) to avoid the need to install additional applications on user devices and to provide a usage environment that is independent of the device platform. The chatbot has two main features: searching for recipes by juice names input by users and recommending juice recipes by recognizing juice ingredients in photographs.

Recognition for User Text Input A step for extracting the meanings of sentences input by users is required for the recommendation of juice recipes based on user text input. The proposed system is designed to interpret English and Korean input by analyzing its meaning through the separation of morphemes. For morphological analysis, we use the Stanford Part-of-Speech Tagger for English natural language processing and the Python dataset for Korean natural language processing.[4, 5]

Morphological analysis is applied to the user input in order to perceive the desired meaning by comparing only verbs, without creating a separate rule. By means of morphological analysis, it is possible to simultaneously recognize both the root of a verb and diverse variants, thereby enabling quick recognition. After recognizing the meaning in the manner described above, we send the input to the proposed MEC server. When it receives user input, the MEC server performs a recipe search and then sends the retrieved recipe to the chatbot server. Subsequently, the chatbot presents the juice recipe to the user.

Recognition for the ML-Based Image Detection Image-based recognition method is implemented to provide juice recipe recommendations based on photographs that users have sent to the chatbot. The image-based recognition scheme is based on a convolutional neural network (CNN)-based machine learning model. With this model, the proposed system can recognize ingredients in photographs, allowing the user to request a recommendation of a juice recipe simply by sending a photograph to the chatbot. Because the proposed system is required to distinguish between cases of text and photo requests, a tag is utilized to identify the type of data that the chatbot server transmits to the MEC server when a user sends input to the chatbot. When a user takes a picture and sends it to the chatbot, the local MEC server analyzes the user's picture and then informs the chatbot of juice recipes containing the ingredient in the picture sent by the user.

MEC-Based Recipe Recommendation Server

To offer the juice recipe recommendation service to users with a short response latency, the proposed system uses a server based on the MEC technology. The proposed server system performs two main functions: The first is to provide juice recipes on the basis of text input, and the second is to recommend juice recipes based on the recognition of ingredients in pictures taken by users.

Operation for User Text Input A user can employ the chatbot to retrieve a desired juice recipe. When a user inputs a juice name into the chatbot to search for a recipe, the user input is transmitted to the chatbot server. The chatbot server that receives the message delivers the contents to the MEC server located near the user. The data sent to the MEC server are presented in the JavaScript object notation (JSON) format. The MEC server performs a tag check operation on the received contents to distinguish text searches from photo requests. The MEC server performs a juice recipe search operation using a database. The contents of the internal database are based on recipes provided by a juice manufacturer. If a suitable juice recipe is found in the database, that juice recipe will be converted into the JSON format and sent to the chatbot server. After receiving JSON data containing a juice recipe, the chatbot server generates a recipe message and delivers it to the user.

Unlike existing recipe recommendation services, the proposed system does not require recipes to be stored on the user's device to enable a local search. Instead, the computational operations required for the recipe search are transferred to the local MEC server for processing, thus greatly reducing the computational burden on the user device and improving the energy consumption efficiency.

Because the MEC server is located within the user's home, personal information such as individual health data and eating habits is not delivered outside the local area of the consumer, facilitating the protection of user privacy.

Operation for the Ingredient Image The proposed system can handle photo-based multimedia input through the use of machine learning technology. First, a user takes a picture of a fruit and sends it to the chatbot server. After receiving the image, the chatbot server transfers the photograph to the local MEC server. Then, the MEC server performs the operation to recognize the juice ingredient contained in the photograph. Once the juice ingredient has been recognized, juice recipes related to the recognized ingredient are retrieved from the database in the MEC server. If it finds a suitable juice recipe in its database, the MEC server sends that recipe to the chatbot server in JSON format. When the user selects the desired recipe, the

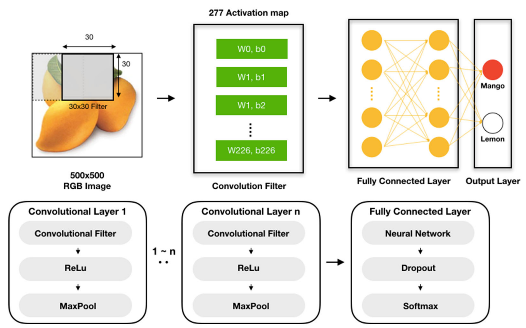

Figure 2. CNN model used in the proposed system and an example of feature extraction by applying a filter.

chatbot server creates a juice recipe message based on the received JSON data and delivers it to the user.

In existing service schemes, the recognition of objects in a photograph, which is a task with high computational complexity, is performed on the user device. Therefore, these schemes have low energy consumption efficiency and long result extraction times. By contrast, the proposed system can conserve the resources of the user device because it delegates the high computational burden of this task to the local MEC server. Moreover, because the machine learning results are stored in the local MEC server, the proposed system has a short response latency.

External Cloud Server

In the proposed system, external cloud servers may be utilized to increase the accuracy of juice recipe search results. Specifically, the proposed system performs juice ingredient detection using external cloud server if the detection operation at the local MEC server cannot recognize the juice ingredient in a photograph from the machine learned data. If the local MEC server fails to find a suitable result in its internal search, it delegates the processing to an external cloud server. Then, it delivers juice recipes to the user based on the results of the external search.

Juice Ingredient Recognition Method

To recommend juice recipes based on photographs, recognition processing for the identification of the ingredients in the photographs is required. The proposed system uses a machine learning based object recognition scheme. It utilizes a CNN model consisting of convolutional layers and a fully connected layer.

The proposed system requires a large volume of image data for accurate image recognition. However, there is no fruit image dataset available that is as large as the Modified National Institute of Standards and Technology database.[6]

Therefore, for the proposed system, this constraint was overcome by collecting fruit pictures through web crawling and by modifying properties such as the resolution and image orientation. The collected ingredient images were resized to 500×500 pixels to be utilized as input data. Because these input data are color images, each image can be represented as a $500 \times 500 \times 3$ matrix. To extract the characteristics of each input image, a convolution filter is applied to the input data in each convolutional layer. Figure 2 shows an example of 277 feature extractions performed by applying a 30×30 filter to the input image data.

To prevent the loss of features during the feature extraction process, the filter is applied in a sliding manner from the upper left corner of the image in regular intervals with padding. After the filter is applied, each convolutional layer applies the rectified linear unit (ReLu) activation function, which is commonly used in CNNs, to the filtered values. In addition, a subsampling method called max pooling is utilized, which uses only a subset of features for rapid determination. In the max-pooling method, the input data are divided by a pooling size, and only the largest value among the representative data is extracted. This process reduces the data size, saves computing power, and enables quick judgment. The features extracted by the convolution filters are classified by the neural network in the fully connected layer, and the fruit is determined by means of the softmax function. To train the model defined above, the cross-entropy function is used as a cost function, and batch training is conducted.

Implementation of the Proposed System

To provide a user-friendly interface, the KakaoTalk messenger platform is used as the chatbot platform. The Samsung ARTIK Platform is utilized to implement the MEC server. The chatbot and the MEC server can communicate

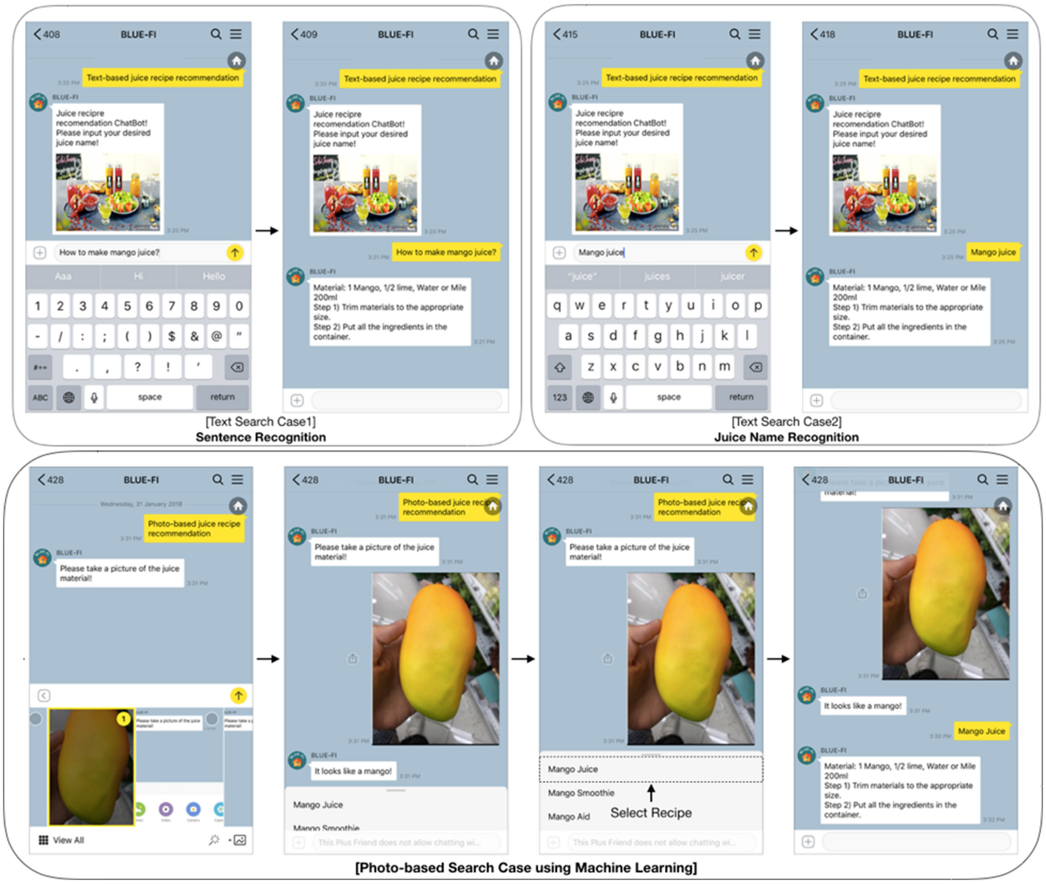

Figure 3. Implementation and overall operation of the proposed system.

with each other by using a representational state transfer API. Tensorflow, a machine learning library, is used for juice ingredient learning.

The learned data are stored in the MEC server to reduce computational complexity and to enable rapid distribution. It is possible to quickly search for the juice recipes among the learned data stored in the MEC server database. To use the chatbot service, users search for the name of our system, BLUE-FI, in the user search window of the messenger platform. When a user registers for the proposed chatbot service, the proposed system performs an authentication process between the user and the chatbot service. Only authorized users both obtain access to the chatbot service and request the juice recipe recommendation service. The system also protects user privacy because only a registered user can access his or her own information. In addition, to enhance the security between the user and the MEC server, the proposed system uses an access control list, which allows only authorized users to access the local MEC server. After the registration process, the chatbot sends a greeting message to the users in the chat window. The user's joining process is complete at this time.

Text-Based Recipe Recommendation

When a user inputs a juice name or sentence in the chat window of the KakaoTalk messenger platform to initiate a search, the KakaoTalk messenger server delivers a JSON-format message to the proposed MEC server. The tag included in the received message is confirmed by the MEC server.

After verifying the text tag, the MEC server extracts the meaning of the message through morphological analysis. The morphological analysis function of the MEC server extracts the meaning and retrieves a recipe from the database.

The retrieved recipe is sent to the chatbot server in the JSON format. Then, the chatbot server transmits the juice recipe in text form to the user.

Image-Based Recipe Recommendation

When a user sends a picture to the chat window, the KakaoTalk messenger server sends a message containing the URL of the image to the proposed MEC server in JSON format. Upon receiving the message, the MEC server stores the image file. The stored image file is used not only to recognize the ingredient but also as future training data.

The server detects the ingredient in the picture from the prelearned data and then searches its internal database to recommend juice recipes containing that ingredient. Figure 3 shows the UI for an example in which the system recommends mango juice by recognizing a mango in a picture sent by a user. Unlike in a text-based juice recipe search, if a recipe is recommended through a photo search, several juice recipes containing the ingredient in the picture are shown. When the user selects a juice recipe from the list, the corresponding recipes is sent to the chatbot server in the form of JSON data, and the chatbot server transmits the selected juice recipe to the user.

Moreover, the MEC server may delegate the juice ingredient recognition task to the external Google Vision cloud service when the juice ingredient search process fails because the ingredient in the photograph has not been learned before. If the external cloud recognizes the ingredient and responds to the MEC server, the proposed system executes the recipe recommendation function following the process described above.

CONCLUSION

In this article, we propose a system that recommends juice recipes using a chatbot and a MEC-based server. The proposed system not only provides juice recipes in response to text-based input, but also recommends juice recipes by recognizing the ingredients in photographs by means of CNN-based machine learning model.

Generally, the CNN-based recognition of ingredients in images would impose an excessive burden on resource-constrained user devices. The proposed system overcomes this problem by delegating the recognition task to the local MEC server, resulting in a short response latency and reduced computational overhead on the user device.

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