Mobile Food Recognition And Dietar Management For T2dm Patients In Malaysia

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Abstract: The population of Type 2 Diabetes Mellitus (T2DM) patients in Malaysia is growing at an alarming rate and studies have shown that improper dietary habit is one of the root causes contributing to this growth. With high smartphone penetration rate identified, a mobile application which aims to ease dietary management process by integrating artificial intelligence technologies (AI) to perform food recognition and dietary recommendation is thereby proposed. This paper presents the preliminary study to gather diabetic patients and general public opinions for the proposed system. An online survey in the form of questionnaire was conducted to collect information from T2DM patients and general public including their confidence level on AI technologies, perceived motivating factors on using mobile dietary logging solution and preferred input method for dietary logging. Also, an experienced clinical dietitian was interviewed to gain domain knowledge including commonly used dietary guideline, method of dietary analysis, and her opinions on the proposed system. This study yielded results where people are, in general , confident that AI technologies could be beneficial for aiding dietary management although the popularity of a similar system is still low in the local market. Results also showed that people would prefer image-snapping based dietary logging method as it is perceived to be more convenience than traditional text-based method. This study has justified the need for the proposed system as a technological solution in aiding dietary management process for T2DM patients as well as the general public who are concerned of developing diabetes in the future.

Index Terms: Artificial Intelligence, Dietary Management, Fuzzy Logic, Image Processing, Mobile Application

1. INTRODUCTION

The population of T2DM patient in Malaysia has a worrying and unneglectable growth rate at which is projected to rise until 21.6% of Malaysia's adult population by the year 2020 [1]. It has seriously impacted the lives of the diabetic patients for its potential complications such as stroke, amputation, blindness, heart attack and total kidney failure [2]. In Malaysia, diabetes mellitus was also listed as the top 7th cause of death and top 5th as the cause of disability with growth rate from year 2005-2016 at 41.4% and 42.1% respectively [3]. T2DM does not only burden the patients on his/ her own health condition; it also incur burdens on the country Ministry of Health (MoH) as the cost for the management of the disease is estimated at approximately RM 3,700.00 per annual for each patient [1]. Multiple studies have highlighted that improper dietary habit of individuals as one of the root causes contributing towards the growing prevalence of T2DM [4]–[6]. Improper dietary habit in this context refers mainly to diet which includes high intake of red meat, sweet and fried foods, and soft drinks which comprises high level of carbohydrate, fat and sugar [4]. Dietary management was described as one of the cornerstones of diabetes care, but the same research has also stated that only 16.4% diabetic patients are willing to adhere to dietary guideline provided by dietitians[5]. Beside the low adherence to dietary planning, it is believed that low fibre intake is another key factor that has contributed to the increasing prevalence of T2DM. Although high fibre intake was suggested as it could potentially result in a better managementand even remission of T2DM, the vegetables and fruits intake of Malaysians are still less than the recommended amount and frequency [4], [6]–[9].With the high mobile cellular especially smart phone penetration rate as per reported in [10] considered, the author proposes a mobile application which could provide a better solution on self-conducting dietary management by easing dietary recording method and dietary recommendation process.

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2. MATERIALS AND METHODS

2.1. The Proposed System

The proposed system is a mobile application aimed to replace traditional paper-based dietary logging methods. Using this solution, the process to recording a meal is reduced to a one-step process, which is to snap a picture of the current meal. The system will then provide information of the current meal and recommendation of following meals. Also, a user could revise his/ her own records of food log to construct a better dietary management plan.Table 2-1 summarizes the proposed components for developing the system.

Table 2-1: Chosen technologies for the proposed system

Component	Proposed Implementation
Operating Platform	Android 7.0 Nougat
Programming Language(s)	Java for Android application development and Python 3.7.3 for TensorFlow
Food Recognition Module	TensorFlow for developing image processing model and TensorFlow Lite for deploying model to Android application
Diet Recommendation Module	FuzzyLight'sjfuzzylite 6.0 library

Table 2-1: Chosen technologies for the proposed system (Cont'd)

Component	Proposed Implementation
Database Management System	MySQL 5.7.22

The technology stack of the proposed system is illustrated in Figure 2-1.

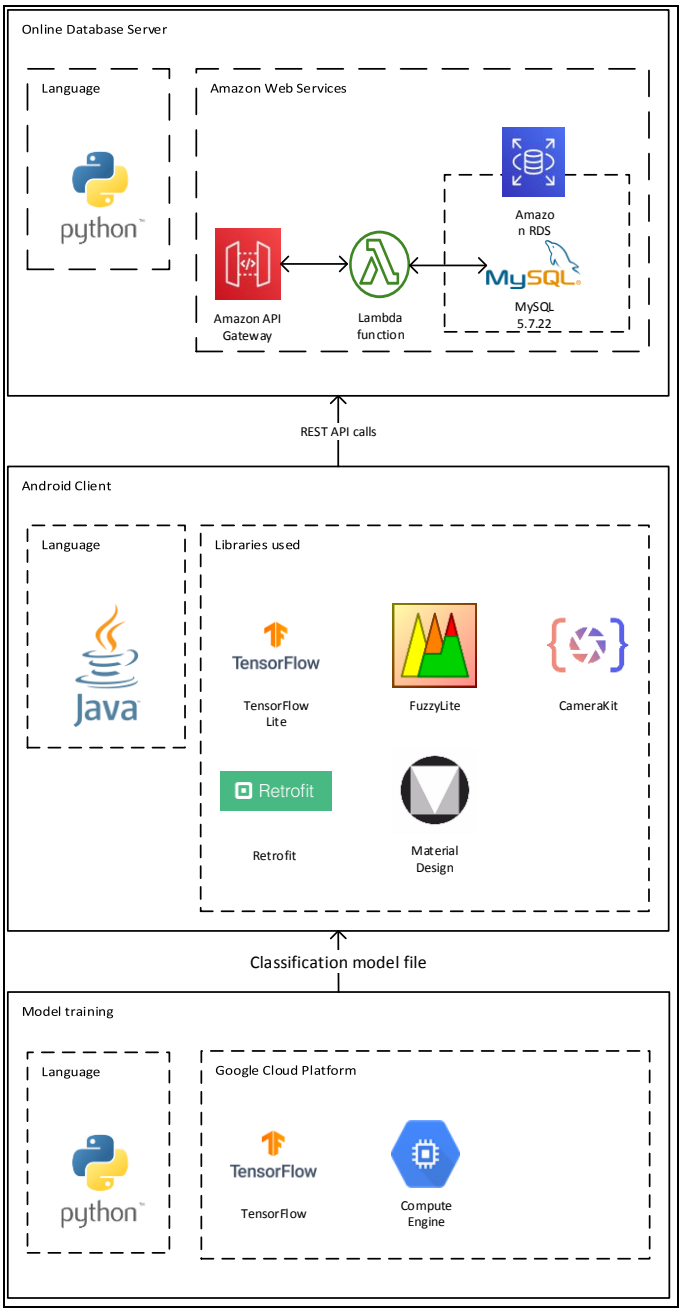

Figure 2-1: *The technology stack diagram of proposed system*

2.2. Online Questionnaire

The online questionnaire used in this study was created using Google Form and has been distributed through social media including Facebook and WhatsApp group in which the group members are from different age group and some of the groups are a form of diabetic patients' community supporting group where diabetic patients share their personal experience in controlling and managing their diet.The set of questions asked in the questionnaire was designed to obtain several sets of data including respondents' demographic profile, personal dietary management practices, personal experiences and perceived motivations of mobile dietary logging, confidence in artificial intelligence (AI) technologies and their opinions/ suggestions for the proposed system.The questionnaire in total consists of 22 questions in 4 sections. The questionnaire has 4 Likert scale questions (#12, #14, #18 and #21), 2 open-ended questions (#13 and #22) which allow respondents to describe their opinions and feedbacks, and 16 multiple-choice close ended questions.

2.3. Informal Interview with Clinical Dietitian

An informal interview session with a clinical dietitian, Assoc. Prof. Dr Chan Yoke Mun from the Faculty of Medicine and Health Sciences of Universiti Putra Malaysia (UPM) was conducted to obtain professional input as to gain more domain-specific knowledge on T2DM dietary management. Assoc. Prof. Dr Chan has excellent experience in the field of dietary management for diabetic patients and has authored/ co-authored multiple peer-reviewed scientific papers and presented works in relevant field.

2.4. Training Food Classification Model with Food-101 Dataset

The author trained a food classification model using the Food-101 dataset which contains 101 class of food with 1000 images for each class. The training was done utilizing TensorFlow library with Python code. The author trained two model using InceptionV3 and MobileNetV2 model respectively while using ImageNet as the weight and same hyperparameter except for the number of epochs of training. The hyperparameters used is as summarized in table below.

Table 2-2: Model Training Parameters

Weight	Model	
	InceptionV3	MobileNetV2
	ImageNet	
No. of images per class		
Training	750	
Validation		
Hyperparameters		
Learning Rate	0.0001	
Momentum	0.9	
No. of epochs	30	60

2.5. Main Flow of Proposed System

The main flow of the proposed system for saving a record is proposed as illustrated in Figure 2-2 in which consists of below steps:

1. User snaps food image using the system
2. System performs food classification on the snapped image and returns:
    a. List of food name with highest confidence
    b. The estimated percentage of fibre source
3. User verify the classification result and enters his/ her blood glucose level and click Save to save the record
4. System makes HTTP request to save the record
5. System provides diet recommendation to user

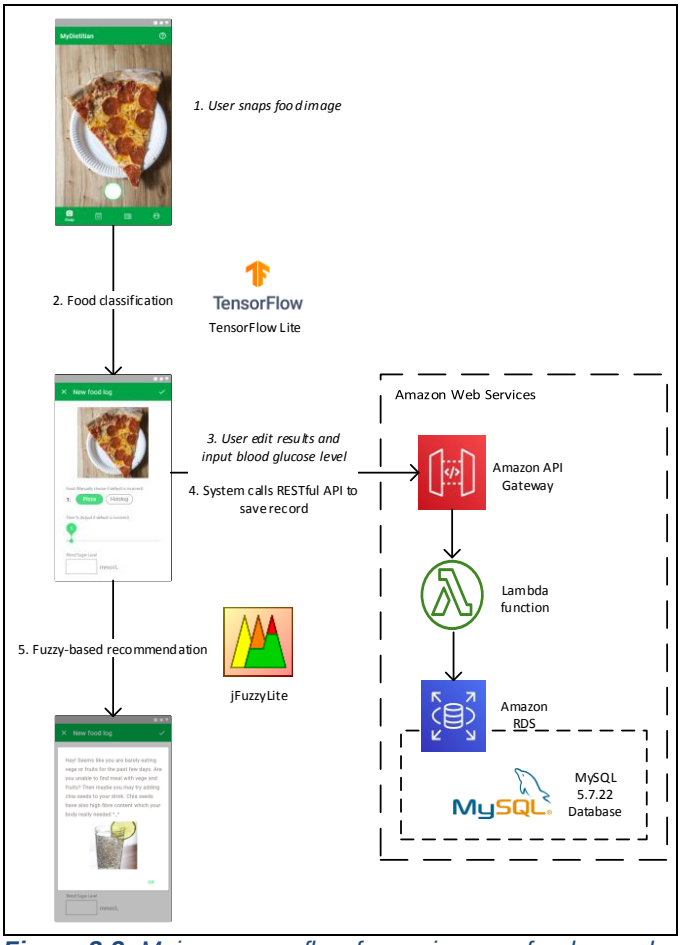

Figure 2-2: *Main program flow for saving new food record*

3. RESULTS AND DISCUSSION

3.1. Results of Online Questionnaire

The conducted online questionnaire which has, in total, received 42 responses in a 14-day period. The demographic distribution of the respondents is as shown in Table 3-1.

Table 3-1: Demographic distribution of respondents

	Number of respondents
Gender	
Male	20
Female	22
Age group	
Below 21	4
21-30	23

Table 3-2: Demographic distribution of respondents (Cont'd)

	Number of respondents
Age group	
31-40	5
41-50	4
50 and above	6
Is T2DM patient?	
Yes	4
No	38

The survey has acquired fairly even number of respondents from both gender who are from different age groups with majority of the respondents belong to 21-30 years old. The result of the survey, unfortunately, was deemed not suitable to be used for generalizing the opinions of T2DM patient population on the proposed system as nondiabetic respondents outnumbered diabetic respondents for this survey.

Table 3-3: Respondents' portion of vegetables/ fruits in meal against awareness of high fibre intake helps in preventing/ curing diabetes

Portion of fibre source in meal	Aware of high fibre intake helps in preventing/ curing diabetes (Number of respondents)	
	Yes	No
Less than 10%	3	0
10% - 25%	16	6
More than 25%	16	1

It is seen that although most respondents (35 out of 42) knew that high fibre intake helps in preventing/ curing diabetes, majority of them are having less than 25% vegetables or fruits in a meal. 3 respondents are even having less than 10% even if they are aware of the benefits of having high fibre intake. Moreover, among the 3 respondents, 2 of them has claimed to be worried of developing diabetes in the future. Therefore, an assumption to be made is that people sometimes are aware of what makes a good diet, but they might not tend to follow the recommended practice. One proposed method to overcome this phenomenon would be constantly reminding one on the benefits of the recommended guideline and the way to practise the guideline.From the 42 responses received, only 2 respondents claimed to be practising dietary logging. Both of them record their food with text although one of them uses paper-based method and another uses digital method.

Table 3-4: Number of respondents who does or does not know/ use dietary logging application

Experience with dietary logging mobile application	Number of respondents	
	Yes	No
Knowing one	15	27
Using one	3	39

Majority of the respondents (27 out of 42) were unaware of the existence of mobile application which could be used for performing dietary logging and only 3 respondents among those who knew dietary logging mobile application were actually utilizing the technology (shown in Table 3-4). This could be an indicator that the popularity of dietary logging mobile application is still relatively low in Malaysia market.Respondents, in general, were found inclined to agree that both the listed factors: having easier logging process ($\bar{x}$ = 3.595) and easier historical record retrieval ($\bar{x}$ = 3.738), could be the motivations for them to start adopting mobile application for dietary logging. 76.2% or 32 respondents have chosen image-snapping-based method as the preferred method to perform food logging including the two respondents who are currently practising text-based food logging. It is believed that such selection is due to the perceived better convenience of image-based method as compared to the text-based method which is likely to require more user interactions while logging a food record.Most respondents (59.5% or 25 respondents) are found to be uncertain whether they will practise dietary recommendations provided by an AI, while 16 respondents (38.1%) are certain that they will practise the recommendations. Only one respondent clearly refuses to follow the recommendations given by an AI. This result indirectly depicts that respondents' confidence level on AI technologies in providing appropriate dietary recommendations are still moderate.Most respondents have expressed rather high confidence in AI technologies for performing food recognition ($\bar{x}$ = 3.310) and providing dietary recommendations ($\bar{x}$ = 3.571). There were 15 neutral response for each task while number of positive responses (agree/ strongly agree responses)

for each task are 20 and 24 respectively for food recognition AI and dietary recommendation AI (shown in). Therefore, a small discussion to be drawn for this question is that people, in general, are positive on the ability of AI technologies in performing food recognition and dietary recommendations. However, if this result is being related to the result of previous question, it is found that being confident on AI could provide appropriate dietary recommendations does not necessarily imply that recipients of the recommendations would practise them as majority are rather conservative to practise these recommendations.

3.2. Results of Informal Interview with Clinical Dietitian

Some of the key findings from the informal interview session conducted with Assoc. Prof. Dr Chan Yoke Mun could be summarized as follows:

- A generally used dietary guideline for T2DM patients in Malaysia is the Medical Nutrition Therapy (NTM) for T2DM which provides information such as nutrients prescription, lifestyle modification, medication commonly used to manage diabetes and possible nutrient-drug interactions. This guideline is applicable for everyone including T2DM patients and non-diabetes.
- Advising T2DM patients to practise dietary logging is indeed a common practise of health care professionals in Malaysia; but, the compliance to such advise are dependent on the patients' motivation and ability to carry out the activity
- Dietary analyses are normally performed based on the food diaries provided by patients and analysed using food composition tables or food exchange list in compliance to NTM.
- Text-based diet diaries logging require additional efforts from patient and thus some patients avoided it and causes the lack of proper dietary record as reference for health care practitioners in providing optimal dietary recommendations.
- A mobile application which is user friendly, has less language barrier and less recording burden among patients could be the solution for promoting self-conduct dietary management for T2DM patients. This is in turn is relatable to the findings of the conducted questionnaire which image-based logging method is preferred.

3.3. Results of Initial Attempt to Train the Classification Model using InceptionV3 and MobileNetV2

The model trained using InceptionV3 yielded a considerably good initial result where the validation accuracy reached up to ~0.83. However, when the model file is converted to TensorFlow Lite file and tested on Android device, the time needed for performing a single classification consume 3000-4000 milliseconds. With this performance issue considered, the author retrained a model using the MobileNetV2 model which claimed to have better performance on mobile devices in terms of its inference speed. This training also used ImageNet as the pretrained weight with the similar hyperparameters, except the number of epochs is doubled to 60. Figure 3-1and Figure 3-2shows the training log of accuracy against epochof the classification models using Food-101 dataset using InceptionV3 and MobileNetV2 model respectively.

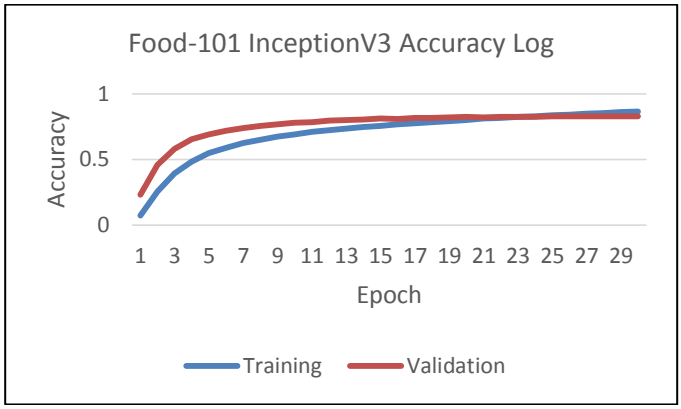

***Figure 3-1**: Training log (accuracy) using Food-101 InceptionV3 model*

Using MobileNetV2 as the model resulted in a minor decrease in the validation accuracy, from ~0.83 to ~0.80. However, after being converted to TensorFlow Lite file and tested on Android device, the inference time decreased significantly to ~330 milliseconds.

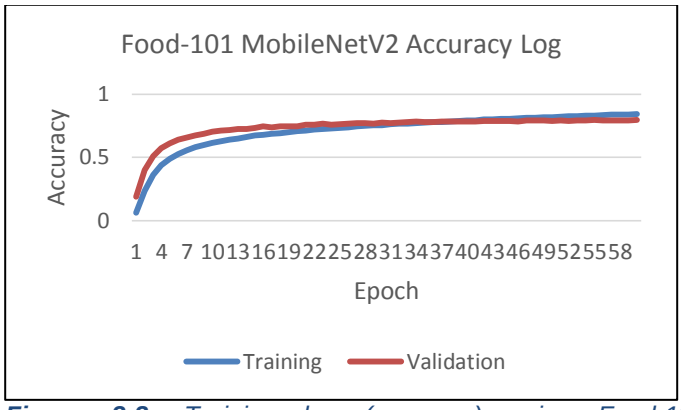

***Figure 3-2:** Training log (accuracy) using Food-101 MobileNetV2 model*

3.4. Discussion

The findings from the conducted questionnaire, although does not meet its expectation on collecting data from more T2DM patients, have provided great insights for non-diabetes who have worries on developing the disease. Some of the findings have direct relation to the specification of the proposed system such as the choice of Android as the targeted deployment OS which is found to be suitable as it is identified as the most widely used mobile OS. The findings also suggested that image-based food logging of the proposed system is preferred over the traditional text-based logging. Besides, the overall high confidence level of respondents justified the appropriateness of using AI technologies in the proposed system. The suggestion received for having an alternative approach for the image-based food logging mechanism is considered thoroughly and is included as a special feature for the proposed system specification as it could overcome the limitation of loss dimensionality as per mentioned in the feedback. The findings from the informal interview session has also validated the need for an easier dietary logging method and consistent support from health care practitioners could be the factor for better dietary management. These factors are among the main concern of the proposed system which provide image-based food logging and dietary recommendations

through AI modules which minimizes the need for a physical dietitian for instant dietary recommendations. Besides, additional information is collected such as the dietary analysis method and guideline to follow while developing the diet recommendation AI module.Since the MobileNetV2 model has a faster inference time while running on mobile devices which is the targeted device of the proposed system while having only a slight disadvantage in terms of its accuracy, it will be the chosen model to be used for further development of the classification model.

4. CONCLUSIONS

Although the popularity of technological solution for dietary management is still relatively low in local market, the preliminary research of the proposed system yielded a result which suggested that the existence of such a system could be beneficial for local T2DM patients as people are confident that artificial intelligence technologies could play a part in aiding the dietary management process. Therefore, the author will continuesthe development of the proposed system and also conduct another research which will involve more T2DM patients to better obtain opinions from them as to assess the appropriateness of the proposed system.

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