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Development of Retina Healthcare Service System Using Smart Phone

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Abstract

In this paper, we have developed a Retina Healthcare Service System through which the patient himself/herself can manage his/her retina health. In the case of conventional portable ophthalmic cameras, patients cannot check their eye health on their own because most of them are used by doctor in environments where ophthalmography cannot be performed properly. This system consists of web, app and camera modules, and when a patient mounts a camera module for fundus photography on his / her smart phone and then photographs his / her fundus through the app, the image is transmitted to a server, and the transmitted image reads the fundus the patient's fundus image status in the fundus image reading model learned using deep learning. When the doctor expresses his/her opinions about the patient's eye condition based on the reading result and the fundus photograph, the patient can check through the app and judge whether to receive ophthalmologic treatment.

Keywords: *Diabetic Retinopathy, Deep Learning, Healthcare, Fundus Camera*

1. INTRODUCTION

The social aging of countries called advanced countries is emerging around the world, which is recognized as a serious problem that leads to high urbanization and an increase in chronic diseases. In Korea, the elderly population growth rate was the highest among the OECD countries for the past 40 years. By 2050, about 40% of the total population will become the elderly, resulting in high prevalence rate, and increase in medical expenditure due to a rapid increase in the number of patients with social chronic diseases caused by aging.

Among rapidly increasing chronic disease patients, especially eye disease is even more serious. In Korea, according to the 2015 Ophthalmic Survey Report of the Health Insurance Review & Assessment Service, glaucoma patients, one of the three major ophthalmic diseases, have increased by more than 46% over the past five years, from 520,000 in 2011 to 760,000 in 2015 and patients with macular degeneration have also increased by 48% over 5 years, from 85,000 in 2011 to 126,000 in 2015 and patients with diabetic retinopathy have also increased by about 36.8%, from approximately 240,000 in 2010 to approximately 328,000 in 2015, showing an especially high increase trend.[1]

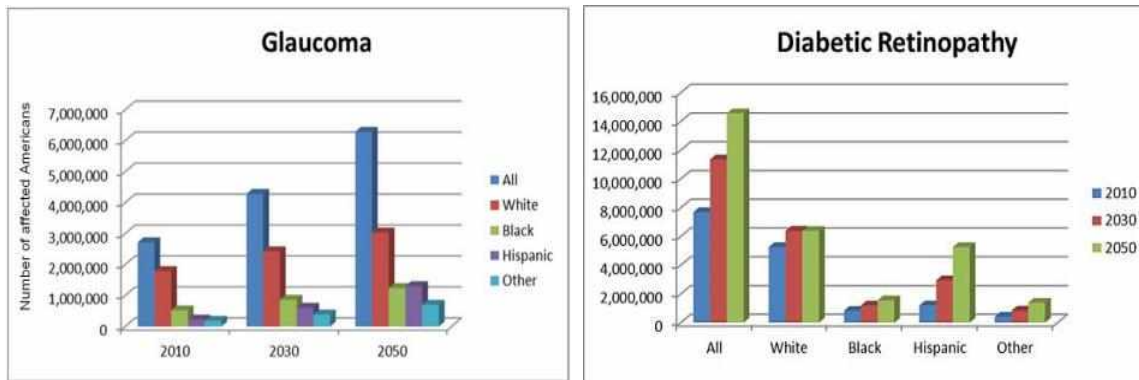


Figure 1. Increase Trends of Glaucoma and Diabetic Retinopathy by 2050

In addition, the prevalence rate of eye disease is also high in the world, Figure 1 of the 2010 Eye Disease Survey Report of the National Institutes of Health shows that patients with severe glaucoma are estimated to be over six million people in 2050 and those with severe diabetic retinopathy are expected to be more than 14 million, showing a gradual increase of the major 3 major eye diseases by 2050. The report released by the Alliance for Aging Research, (AAR), the US non-profit organization, more than 126 million people around the world are affected by diabetic retinopathy and patients with macular degeneration are approaching approximately 2 million, and approximately 191 million people will be affected by diabetic retinopathy by 2030, of whom approximately 90 million are directly threatened to their vision. In 2050, about 3.8 million people will suffer from macular degeneration, and patients whose eyesight is threatened will be 14.6 million people, showing high growth rate.

As mentioned above, the number of patients with eye diseases due to aging and chronic diseases is rapidly increasing, but medical welfare costs, medical expenses, and medical manpower cannot increase rapidly in real life, so efforts to supplement technically insufficient parts are constantly being made under the leadership of developed countries. In 2010, the United States announced policy on health-care and predicted that the economy scale associated with health-care would close to \$ 2.8 trillion equivalent to 17% of the entire economy, which is interpreted in the same sense as the development of Health-care 3.0 in Korea, meaning that the global treatment mechanism is changing to preventive medicine, diagnosis for the purpose of prevention that can more effectively solve patient suffering, social health deterioration, high medical expenditures and increase of national medical welfare, which are the disadvantages of medical practices for medical treatment.

Therefore, recognizing that eye diseases, which are caused by aging and chronic diseases as described above, are becoming global health threats beyond the national level, this study presents a Retina Healthcare Service that allows the patient to manage his / her own eye health in a way that can solve it more effectively.

The Retina Healthcare Service System is a system that allows patients to manage their own eye health in which when a patient himself/herself takes a picture of his or her fundus with an app, a doctor writes his / her opinion on the fundus photo on the web to help the patient to determine whether he /she should have eye treatment. In the case of diabetic retinopathy among eye diseases, the possible fundus photographs are categorized and displayed in the system, enabling the doctor to look at them more carefully. Unlike previous studies that detected changes in the fundus where characteristic changes in diabetes occur through image processing, we use Google's Inception-v3 deep learning model to detect diabetic retinopathy with higher accuracy [2- 10].

2. RETINA HEALTHCARE SERVICE SYSTEM

In this paper, we developed a total Retina Healthcare Service System that allows the patient to manage his/her own eye health, which consists of APP, WEB, and camera module as shown in Figure 2 After mounting the camera module on his/her smartphone, the patient takes his or her fundus pictures through the Retina Healthcare Service APP and uploads it to the server. And then, the patient's eye health condition is judged on the server through deep running. On the WEB, the doctor sends feedback about the patient's eye health

condition based on the fundus photograph of the patient and the deep learning result.

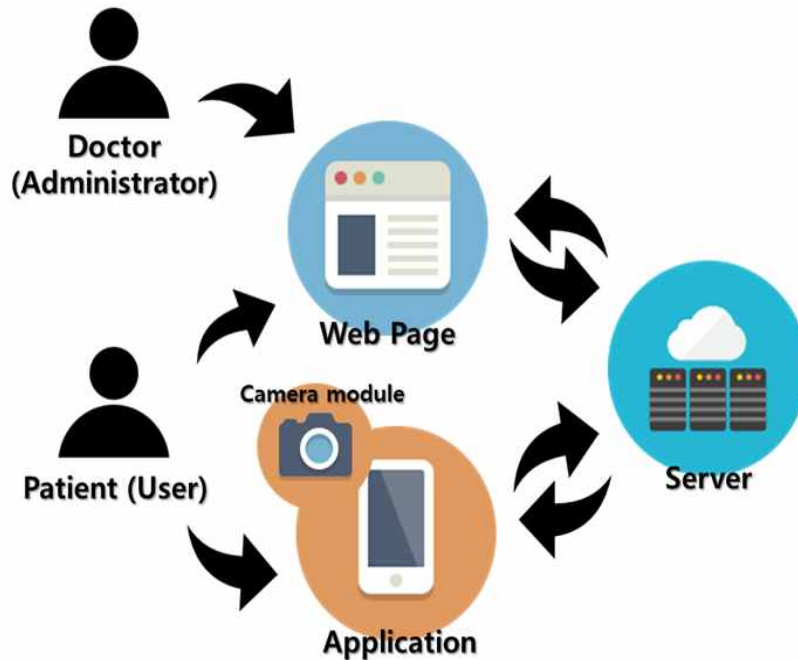


Figure 2. System Configuration Diagram

2.1 Development of Fundus Camera Module

We developed a smartphone fundus camera module for taking a fundus photograph of a patient. To create a module, drawings are drawn with SolidWorks, and camera module prototype is developed using a 3D printer. 3D printer is considered to be the most suitable for producing hardware used in small products at school level. The costs of materials (PLA, ABS) consumed in production are low, and the production process of heating, milling, and lathe is complicated when made of acrylic and plastic in terms of small size products. Also, since it is a small product, using 3D Printer can dramatically shorten production timer.

To take a picture of the fundus, the light must be able to enter the pupil to shoot the inside. Therefore, in order to take a fundus photograph, a pupil scattering agent is used to force the pupil to spread. In this project, a module is made so that shooting can be made in a dark environment in order to shoot without using a pupil scattering agent which cannot be easily obtained by ordinary people. It is possible to enlarge the pupil by darkening it, however the picture is blurred because the camera cannot focus. Therefore, using the IR LED lighting shown in Figure 3 allows the camera to focus with the IR LED before shooting, and shooting is made by lighting embedded in the smartphone.



Figure 3. IR LED Lighting

Figure 4 shows the camera module output and Figure 5 shows the assembly of the two modules. IR LED lighting can be turned on / off with the white button.



Figure 4. Before Assembling The Camera Module



Figure 5. After Assembling The Camera Module

2.2 Development of Retina Healthcare Service APP

The user (patient) uses the app on the smart phone(Device), and it is composed as shown in Figure 6 Only users registered through member registration can login and use it. For taking pictures, the basically embedded in the smartphone should be used. The fundus photos can be checked in the app and the smartphone's own photo library.

The Retina Healthcare Service app is primarily used by the user (patient) and is available for login and membership. The user photographs his/her fundus and transmits it to the mobile phone and server to store it. The administrator (doctor) can check the stored pictures to leave comments on the eye health status, and the user can check the comments in the app.

Membership is only available to general patients, and the administrator registers the members directly in the DB for medical licence verification and doctor verification. Through the DB linked to the web, the doctor checks the patient's highly risky retinal outcome read through the deep learning and informs the patient of the risk.

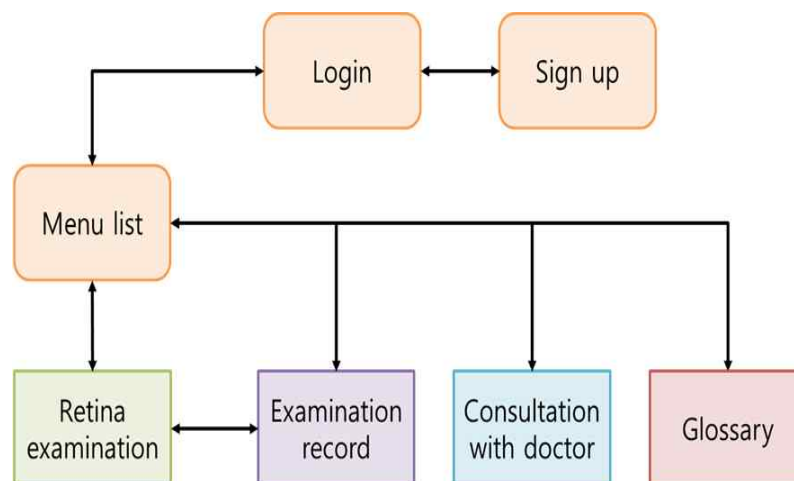


Figure 6. App Configuration Diagram

Each page composing the App is basically composed of Design Layout (xml) and Function Activity (java), and additional functions required are modularized into Java class. The functions include Request for interworking with DB and a model object for temporarily storing data received from the DB.

When performing the fundus examination using app, the user selects the right eye and the left eye, and selects whether to take a picture with the camera or video. In order to take a picture with the camera, the user is authorized to access the camera inside the Android, and if the version of Android is above marshmallow, the user should set it up separately here because he/she is not authorized to access when installing. When performing the fundus photographing, the user stores the taken pictures in the smart phone and uploads it to the server according to his/her selection. Since the internal storage access right is required to store the data in the smartphone, the user also receives the internal storage right when receiving the camera right earlier.

Right eye shooting and left eye shooting are performed according to Right_UploadActivity.java and Left_Upload-Activity.java, respectively. The image is saved once in the internal storage /Picutres/FundusImage/_(Right or Left)_Fundus.Jpeg. This image file is a temporary file that is stored in internal storage and on the server when the image is resized and rotated.



Figure 7. Main Screen



Figure 8. Fundus Examination Screen



Figure 9. Fundus Photographing

The patient can check the fundus image taken by him/her through the examination record menu on the main screen. To check the fundus image at a glance, the user adjusts the size of the fundus image and outputs it to the list. Since the images shown in the list are created and saved in advance, the operation time is reduced compared to resizing the original image. If one fundus image is selected from the fundus list, ImageClicLitener.java is called to go to the doctor comment screen. The user can see the original image of the image, and the doctor and patient can write and check the comment on the image. The operation on the screen can be performed through DetailActivity.java and ImageAdapter.java, CommentListAdapter.java. The doctor or patient comment connects to the server through CommentListAdapter.java, loads the data recorded in the DB, and uses the object of Comment.java to use it inside the actual App.

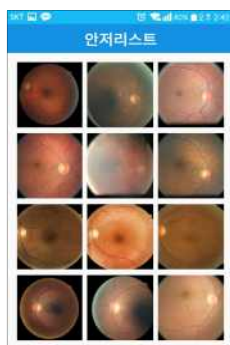


Figure 10. Funds List Taken



Figure 11. Image Selection and Comments (Doctor's Opinion)

2.3 Development of Retina Healthcare Service WEB

The user (patient) or manager (doctor) uses the web, and the expert checks the fundus image of the user assigned to him / her and writes a comment on the image. Comments are written mainly about the health condition that appears in the image.

The user checks the image taken by the App and refers to expert comments about the image to judge whether or not to receive the medical care. It is also designed to communicate with other users.

Membership is only available to general patients, and the administrator registers the members directly in the DB for medical licence verification and doctor verification.

Through the DB linked to the web, the doctor checks the patient's highly risky retinal outcome read through the AI algorithm and informs the patient of the risk.

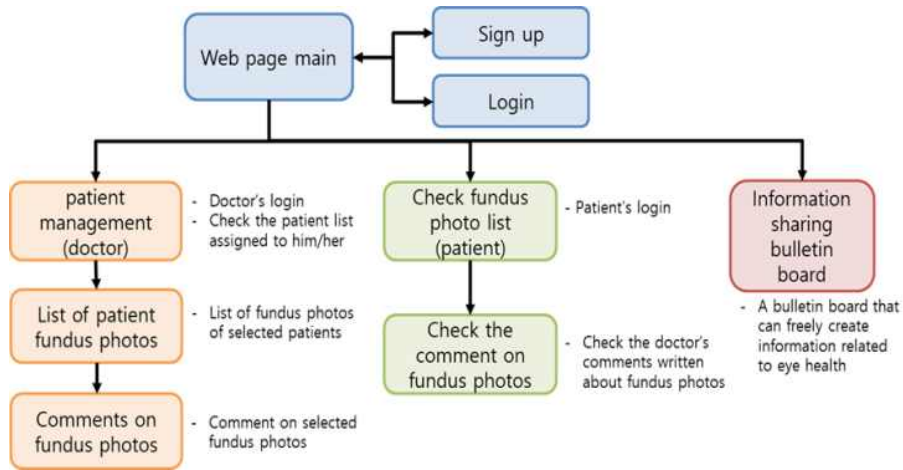


Figure 12. Web Configuration Diagram

Each Web page in the Web project consists of Mapper, Service, VO, Dao, and Controller. The Mapper writes the query statement to be sent directly to the DB, and VO declares an object of the table structure connected in the Mapper. Service creates objects by inputting DB data to VO object through Mapper. Dao is designed to use the VO object in the controller, and the controller has the function of the actual web page.

The main screen and login screen in Figure 13 and Figure 14 below are implemented through HomeController, LoginInterceptor, UserVO, and usermapper. At login, LoginInterceptor checks the user through user mapper and UserVO and confirms membership registration. UserController is a part created in the app for DB interlock in which Response to request from app is implemented. Controller RequestMapping is '/user/*', and ResponseBody RequestMapping is a response to a request sent from the DB when sending to or requesting data from the DB in connection with login or membership in the app such as login.do, android_join.do, join_check.do, and loginPost.do.

Membership or patient management is also done in UserController, and membership is newly added to DB by using query like web after receiving request from app. When logging in, the doctor brings a list of patients assigned to him/her and checks the patient management.

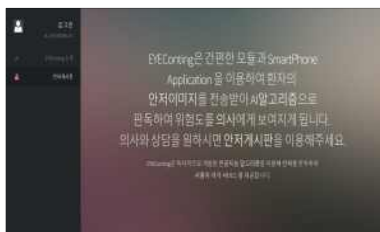


Figure 13. Main Screen



Figure 14. Login Screen

The member fundus list is a list of fundus images that the member has taken so far. When an image is taken from the app, it will be sent to the server and stored in the folder of the patient's ID. It is implemented in UploadController and deals with image objects with UploadDao, UploadVO, UploadService, and uploadmapper.

There is '/upload/upload.do' as Request Mapping for receiving images taken from Android. When a file is sent to the request, the file name is set based on the current date and time, and the file size is changed to 640x360 and saved. Whether the save was successful or not is sent to the app.

If one fundus image is selected from the member fundus list, it goes to fundus examination and comment screen. Request Mapping is '/coment/*', and a comment on the current image stored in the DB is uploaded. The object for the Comment is stored in ComentVO, and the function for the object is implemented in ComentDao for use in ComentController. The image name is received as a parameter in UploadDao for handling image objects and the Comment registered in the image is returned in the form of List.

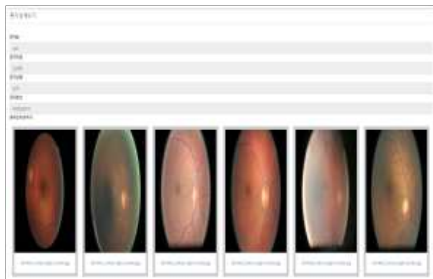


Figure 15. List of Member Fundus photos

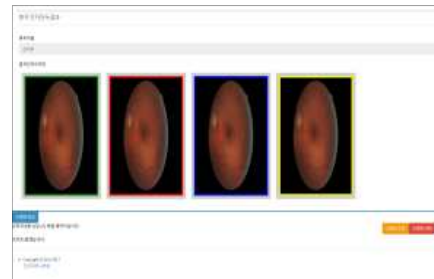


Figure 16. Fundus Examination and Comments

2.4 Retinopathy Readout Algorithm

In the early stage of this study, the retinopathy readout algorithm through deep learning was directly implemented. However, it takes a lot of time to learn once due to the performance of the currently prepared equipment, and this project should be done continuously, making it difficult to carry out the project. Therefore, this study primarily used the Inception-v3 learning model distributed by Google to perform learning, obtain a learning model, and apply it to the project.

The deep learning algorithm was used by retraining Google's Inception v3. For the data set used in the learning, we use kaggle's data set of Diabetic Retinopathy Detection Competition. There are a total of 35,124 images in the left eye and right eye, 9,314 images of diabetic retinopathy, and 25,810 images of normal fundus images. 90% of them are used for learning and 10% for random images.

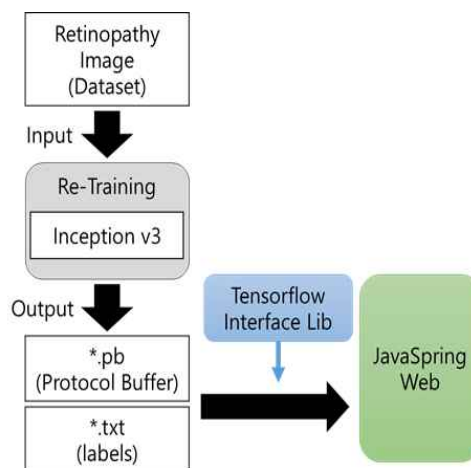


Figure 17. Configuration of learning System application system

Once the learning is completed with Inception v3, the Tensorflow library can be used to obtain the pb(protocol buffer) file, which is the learned model file and the text file in which the label is saved. When an Android app is implemented, using these two files and the Tensorflow Interface library and using a model already learned even in the app enable deep learning.

In order to check the learned results, the models learned with Inception v3 were loaded from the jupyter notebook into the model file (*.pb) and the label file (*.txt) and the results shown in Table 1 and Table 2 were obtained through the test image.

Based on the currently learned contents, the diabetic score was higher in diabetic images, showing a big difference between Diabetic score and Normal score (more than 0.2) and the normal or Diabetic score was high in normal images, showing a small difference (less than 0.2). Based on this, it is possible to classify and read diabetic and normal. In the Table 1. below, the actual normal images are judged to be Diabetic but they are judged to be normal because the score difference is less than 0.2.

Table 1. Results of learning model test (Excluding images)

Image Labeling	Normal Score	Diabetic Score
Normal	0.43134	0.56866
Normal	0.49760	0.50240
Normal	0.43209	0.56791
Normal	0.53262	0.46738
Diabetic	0.05979	0.94021
Diabetic	0.25149	0.74851
Diabetic	0.19511	0.80489
Diabetic	0.17156	0.82844

3. Result

In this paper, a Retina healthcare service system has been implemented in which patients can manage their own eye health on their own. The system consists of an app, a web and an angler camera module, where a patient can take a picture of the angler through the massage camera module and the app, and the results can be checked and diagnosed by a doctor via the web.

As shown in Figure 18 below, the main process of the Retina Healthcare Service System proceeds with module preparation, fundus photography in the app and saving photographed fundus pictures in the server, writing a doctor's opinion about a photo taken on a web page and patient's checking the doctor's opinion on the app.



Figure 18. Main function processes

3.1 Module Preparation - Patient

Mount the camera module on the smartphone (Android) as shown in Fig. 32 and Fig. 33 to take fundus pictures. The camera module is divided into a main part and a lens part, and the lens part has a switch for turning on / off the pre-lighting for shooting.



Figure 19. Mounting The Camera Module(1)



Figure 20. Mounting The Camera Module(2)

3.2 Fundus Photographing - Patient

After executing the app on the smartphone equipped with the camera module, the patient should log in with his / her own ID or log in after signing up as a new member. When selecting the fundus examination on the menu screen, the patient should select either the right eye or the left eye to be photographed. Then he/she should select camera (photo) or video shooting and press the fundus photographing button.



Figure 21. App Login Screen



Figure 22. App Menu Screen



Figure 23. App Fundus Examination Screen

When the fundus photographing is started in the app, the user executes the camera app inside the smartphone, and performs the photographing after closely putting the lens portion of the camera module on the eyeball. After shooting, the picture is saved inside Android and uploaded to the server via the save button.



Figure 24. Fundus Photographing

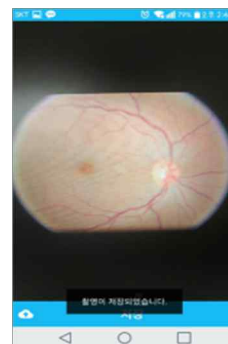


Figure 25. Saving the shot Picture

3.3 Making Comments about Fundus Pictures - Doctor

On the web page, the doctor logs in and checks the list of photos taken by his/ her patient in the patient management. If selecting one of the pictures from the list of pictures, the doctor should predict the lesion through the deep learning and write his/her opinion (comment) on the fundus picture.



Figure 26. Web page – Patient management Menu on the main screen

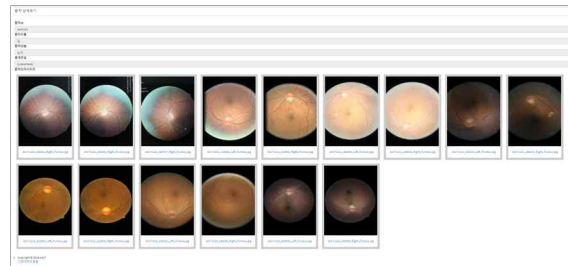


Figure 27. List of fundus images taken By the patient

The lesion is predicted through the deep learning and when it is determined as normal, it is displayed in green on the image frame. When it is judged abnormal, it is displayed in red on the image frame. Then, the comment writing button is pressed to write a doctor’s opinion (comment) on the reading result and the picture.



Figure 28. Fundus Image determined as Normal and writing A doctor's opinion (Comment)



Figure 29. Fundus Image determined as Abnormal and writing A doctor's opinion (Comment)

3.4 Check a Doctor’s Opinion (Comment) - Patient

On the main screen, the user can check the list of fundus pictures taken so far through the examination records, and go to the doctor’s comment screen. The user can check or create a doctor’s comment on the fundus picture on the screen.

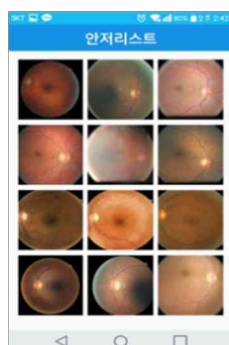


Figure 30. App Examination Record screen

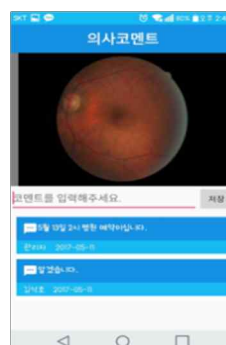


Figure 31. App Doctor's Comment screen

4. CONCLUSION

In this paper, we developed the Retina Healthcare Service System using smart phone. The patient takes a picture of his/ her fundus through a camera module mounted on his/her smartphone and then sends it to the server, and predicts the progress of his / her lesion with the model learned through the deep learning on the web. Based on these prediction results and photographed photos, the doctor writes his/her opinions about the fundus state of the patient, and the patient checks this to judge whether he/ she should receive medical care.

This is a system for managing the patient's own eye health rather than a medical purpose, and it was developed with the purpose of helping the patient to judge whether or not the eye health is abnormal and to receive medical care.

Currently, only diabetic retinopathy can be classified through deep learning, but future studies plan to add classifiable eye diseases, improve fundus camera module, and use it in various types of smart phones.

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