

Mobile Virtual Assistant for Continuous Ambulatory Peritoneal Dialysis Complication Detection

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ABSTRACT

Peritoneal dialysis (PD) is an alternative treatment of home-based dialysis for Acute Kidney Injury (AKI). A patient who undergoes PD requires self-management skills to deliver and manage dialysis at home effectively. The effluent dialysate of PD patients can be an indicator for early diagnosis complications in Peritoneal dialysis. Under normal circumstances, the appearance of effluent dialysate is transparent to yellowish clear. Changes in turbidity level or color of effluent dialysate indicate an extra or intraperitoneal abnormality. This study aims to develop an image processing model to detect and classify effluent dialysate of PD patients for early warning of complications. The model was built into the mobile application system. The dataset was obtained from patients, and secondary data were used. Image augmentation is used to enhance the quantity of data by nine times. The data set were divided for train and validation within the 8:2 ratio. The result shows that our system has a high accuracy of 94.7% and minimal loss.

Keywords: SahabatCAPD, Image Processing, Mobile Virtual Assistant, Telehealth, Self-Monitoring

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1. INTRODUCTION

Peritoneal dialysis (PD) is an alternative treatment of home-based dialysis for Acute Kidney Injury (AKI). There are two types of PD: Continuous ambulatory peritoneal dialysis (CAPD) and Automated Peritoneal Dialysis (APD); both allow patients or caregivers to deliver the dialysis themselves at home by training beforehand. The advantage of patients using this treatment is the increased flexibility and the ability to continue engaging in their everyday activities, including working and socializing [1]. Despite the advantage, barriers to the uptake of Peritoneal Dialysis may include the variety of self-management skills patients or their caregivers are required to have to deliver and manage dialysis at home effectively. The failure of the patient's self-management can result in the possibility of hospitalization and an increased rate of infection [2].

Besides of that, monitoring in PD patient have been challenging occurred globally [3]. Based on a study by in 2016 [4], Many patients had difficulty identifying the symptoms of PD complications and misleading it as a gastrointestinal problem even though they had trained to report immediately if any problem occurred. The traditional approach to overcoming these barriers is to make frequent phone calls or home visits and use paper-based logbooks to record PD treatment undertaken at home. However, the log of these parameters can only be reviewed during scheduled in-person visit or complication has forced the patient to seek care. The major drawback of this asynchronous care review and delivery model is that

it could take a long time until the patient sees their healthcare professionals. Therefore, they cannot take early anticipatory corrective actions to reduce the odds of future complications [5].

Effluent dialysate of PD can be used as a diagnostic tool. In a normal circumstance, the Effluent dialysate of PD patients is transparent or yellowish clear. The change in its appearance can be indicative of intra- or extraperitoneal abnormality [6]. Image processing can offer a solution by detecting and classifying the changes in the appearance of effluent dialysate. The Convolutional Neural Network (CNN) architecture can be used as data-driven deep learning for recognizing complex pattern tasks in analysis and classification. Within layers of processing, models can learn given datasets [7]. For convenient operation, the detection system is built into a mobile application. This study aims to develop an image processing model to detect and classify effluent dialysate of PD patients for early warning of complications.

2. METHOD

A. Obtaining the Data Set and Labeling

Table 1. Effluent Dialysate Classification



The main objective of this paper is to identify and classify the appearance of effluent dialysate bags in PD patients using machine learning techniques. The drawback is that a dataset is not yet gathered to train the system; it also needs to be correctly labeled. The datasets obtained around 104 were gathered from PD patients to capture everyday PD effluent dialysate and secondary data. Then images are classified into two categories normal and abnormal (Table 1). All the primary data from PD patients are labeled normal, and the abnormal labels were gathered from secondary data. A negative class is added to enhance the accuracy of detecting effluent bags. The datasets were then divided into train and validation data within ratio 8:2. Pre-processing using image augmentation is used to enhance the quantity of the dataset by nine times.

B. Concept and Architect

The model was designed based on Convolutional Neural Network (CNN). The CNN has the ability to extract features in detail within minimal data input and time processing. Due to limited datasets obtained and the variety of smartphone image quality used. The method used is transfer learning using pre-trained model MobileNetV2 with batch size 16 and learning rate 0.0001. Model is optimized using Adam Optimizer and applying the loss binary cross-entropy function. Figure 1 shows the architect of the image processing model for the classification of PD patients' effluent dialysate. Then the model is integrated into the application system using Firebase Machine Learning. This model was used to detect the appearance of effluent dialysate every when patients finished the dialysis treatment.

The model was evaluated in mobile application android based. The application will be processing the image data of effluent dialysate captured when the patient finished treatment and inputting the additional data into the logbook feature of the application. The detection result will be shown within a millisecond after the image is captured.

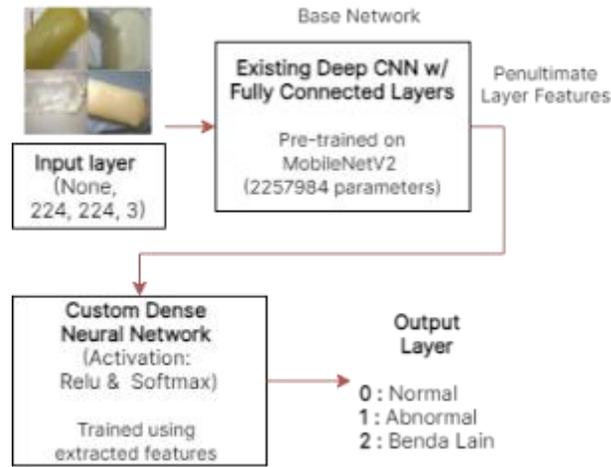


Figure 1. Architect of the Image Processing Model

C. System Development

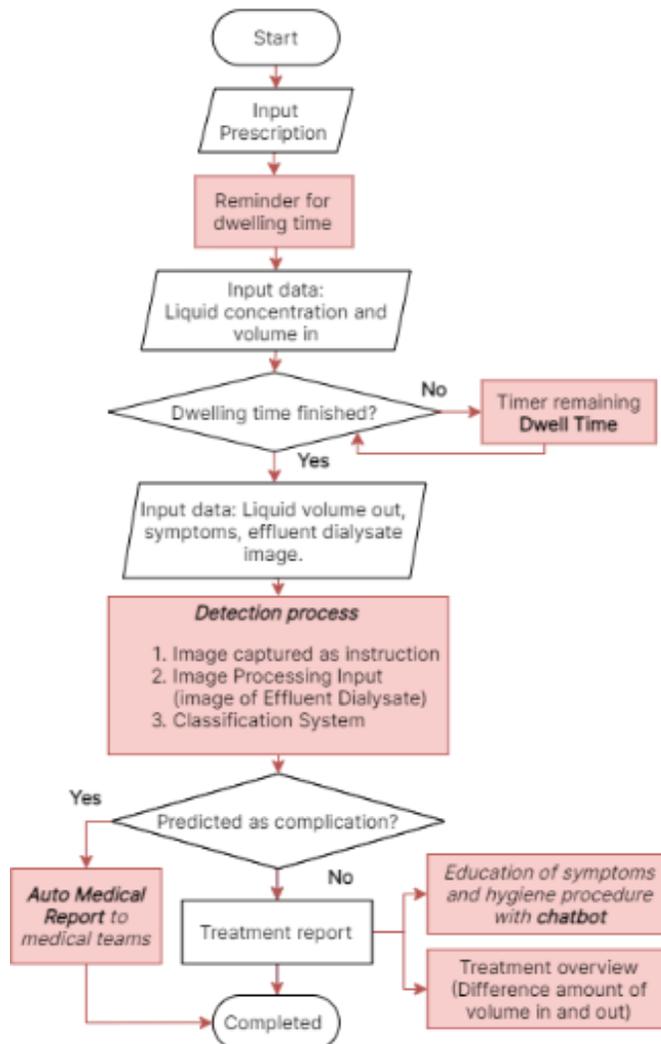


Figure 2. Application Workflow

The first step of system development is by designing the UI and UX of the application. It was then transformed into android with Integrated Development Environment Android Studio. Besides image processing for detection, Logbook was developed to provide essential input data for clinicians to anticipate future complications. All the data inputted were processed with machine learning as an automatic classification to predict each treatment. Then it is stored in the database logbook in the application Firebase Cloud Firestore that certified ISO 27001 and SOC 1, SOC 2, SOC 3 [8]. This method was chosen to secure the data and ease follow-up data to clinicians accessed through the web for monitoring.

D. Evaluation

The model was evaluated based on technical, technology, and medical term. The accuracy of the model solution to detect and classify the effluent dialysate was assessed and compared based on the ISPD guidelines for Peritoneal Dialysis [9]. The usability testing for application is based on ISO 9241 standard to evaluate specific users' effectiveness, efficacy, and satisfaction [10]. The third is the System Usability Scale (SUS) for quick measurement of the application's usability [11].

3. RESULT AND DISCUSSION

A. Accuracy Model Prediction

The TensorFlow library assessed the image processing accuracy of the solution given to detect and classify the effluent dialysate. The result shows that the model system has a high accuracy of 94.7% and minimal loss. In Figure 3, the model was built in batch 16 parameter and learning rate 0.0001.

The visualization of the confusion matrices using the scikit-learns confusion_matrix function is shown in Figure 3. The results of this evaluation show that the class predictions perform well in the image processing model of this application that has been trained using pre-trained MobileNetV2. The model correctly classifies normal as normal, abnormal as abnormal, and other objects as other objects. There is one fairly minimal prediction error i.e., one abnormal class sample is detected as abnormal. Therefore, this detection error will be minimized by the input of other factors that indicate complications, such as the difference in the volume of incoming and outgoing effluent dialysate fluid and the presence or absence of complaints.

The prediction was confirmed with a laboratory test of effluent dialysate based on ISPD guidelines. The effluent dialysate is categorized as abnormal when the leucocyte number was higher than 1000 cells per μL or PNM > 50% [9]. All the confirmation tests between system prediction and laboratory analysis results were shown 100% correct as shown in Table 2.

Table 2. Accuracy of system prediction and laboratory analysis

Image of effluent dialystae	Classification	
	Laboratory assessment	System Prediction
	Abnormal (WBC 7860 PNM 92%)	Abnormal Output Normal Abno... 99% Benda Lain
	Abnormal (WBC 820 PNM 92%)	Abnormal Output Normal Abno... 99% Benda Lain

	Normal (28 PNM 10%) [12]	<p>Normal</p> <p>Output</p> <p>Normal  91%</p> <p>Abno... </p> <p>Benda Lain </p>
	Abnormal (WBC 961 PNM 85%) [12]	<p>Abnormal</p> <p>Output</p> <p>Normal </p> <p>Abno...  97%</p> <p>Benda Lain </p>

B. Usability Testing

The usability testing for application is based on ISO 9241 standard to evaluate specific users' effectiveness, efficacy, and satisfaction. Five PD patients tested the system prototype as volunteers. Each tester has a different background, with an age range of 28-45 years old. The main task was eight based on the system flow for data input, detection, and prevention of PD patients' complications.

Table 3. Usability Testing Result

Task	F1	F2	F3	F4	F5
	55 years old	41 years old	28 years old	45 years old	27 years old
Registration					
Input prescription					
Data Input Logbook					
Detection of effluent dialysate					
Reminder					
Editing Logbook					
Chatbot					
Medical Record					
Note	Success			Need assistance	

The results of processing the test data in Table 3 show the quantitative value of the completion rate—user success in carrying out the specified task of 92.5%. In addition, a qualitative conclusion was obtained from this usability testing that differences in age and habits affect fluency. The application flow is following clinical procedures and CAPD replacement habits and the importance of onboard information.

In order to optimize the evaluation of application usability, testing is continued when the application is published in the Google Play Store public test using the System Usability Scale (SUS) method. SUS was developed in 1986 [11] and proved valid and reliable as a usability test tool. The test was carried out on five people in the previous test by providing the application downloaded on the user's smartphone. During seven days of testing with the SahabatCAPD application that has been connected to Firebase, the usage statistics during the testing process are shown in Figure 4.

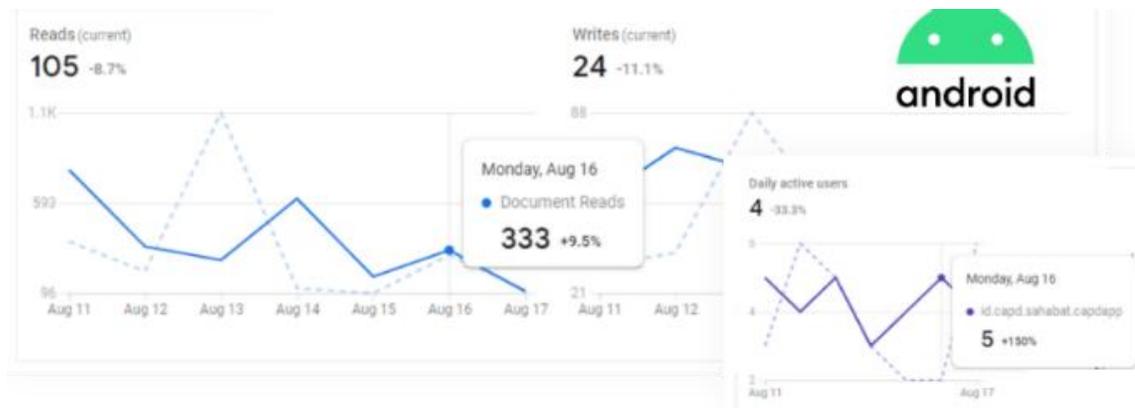


Figure 4. SahabatCAPD Users Statistics in a Week

After using the application for seven days, users are given scaled questions according to usability test standards. SUS testing is carried out as an advanced form of usability testing when the application has been created and before it is launched on the Google Play Store. SUS is a questionnaire that can measure system usability according to the user's subjective point of view. The SUS instrument is a questionnaire consisting of 10 questions items. The testing scale starts from 1 (*strongly disagree*) to 5 (*strongly agree*) as shown in Table 4.

Table 4. Result of SUS (System Usability Scale)

User	Questions										ΣOdd Point	ΣEven Point
	1	2	3	4	5	6	7	8	9	10		
F1 (55 years old, using CAPD since 2020)	2	1	5	1	1	1	5	1	5	1	18	5
F2 (41 years old, using CAPD since 2016)	5	2	5	4	5	2	5	2	5	4	25	14
F3 (28 years old, using CAPD since 2017)	4	4	5	1	4	2	4	2	5	1	22	10
Total Average											21.67	9.67
X = Σ odd – 5 = 21.67 – 5 = 16.67	Y = 25 – Σ even = 25 – 9.67 = 15.33		SUS Score = (X + Y) x 2.5 = (16.67 + 15.33) x 2.5 = 80									

Based on Matrix Standard SUS Evaluation, the SahabatCAPD application gets a score of 80.0, including the Excellent, Acceptable, and Promoter categories. Based on the overall tests, the SahabatCAPD application has met the three test criteria, both in terms of usability testing, solution suitability accuracy testing, and System Usability Scale testing. Those criteria show that the SahabatCAPD Application can perform functionally and assist medical personnel as a CAPD patient monitoring system.

4. CONCLUSION

SahabatCAPD is a machine learning-based CAPD mobile virtual assistant application system with a chatbot, logbook, and reminder features as an early prevention effort for the risk of PD complications. The CAPD virtual assistant system has been tested as a preventive and early educative tool for complications in PD patients with an accuracy of 94.7% and the final score of SUS testing reaching 80.0 (Excellent, Acceptable, and Promoter) in user experience. In terms of data validation, the SahabatCAPD application has also been tested based on ISPD Guideline for Peritoneal Dialysis standards with the appropriate match of results. SahabatCAPD application has copyright, commercial, and development potential. The implementation of SahabatCAPD, which uses virtual digital, enables the distribution of optimal and independent PD therapy health services by patients, especially in remote areas. It is hoped that this application will be used as an early detection tool of complications and help lower the mortality rate of PD patients

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