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Intelligent Teledermatology System: A Case of Implementing Artificial Intelligence-Based Services in Healthcare Supply Chain

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ABSTRACT

Teledermatology is part of telemedicine which provides remote services of skin disease diagnosis for patients by utilizing information and communication technology. This system has been used for decades and is increasingly used especially during the COVID-19 pandemic. However, none of the existing studies have reported the existence of an integrated web-based and mobile-based teledermatology application that integrates Artificial Intelligence. Hence, in this study, we propose the use of the so-called Intelligent Teledermatology System (ITDS), and how this system can support the healthcare supply chain. The development of ITDS complies with the Case-Based Reasoning approach. This system consists of three main functions: management information system, point of services, and intelligent systems. The ITDS provides complete features so that the supply chain of remote services for skin disease diagnosis can be delivered to patients. Furthermore, this system provides a classification function as part of a decision support

system for dermatologists in making diagnoses. In terms of the supply chain, we have described that the supply chain concept is also applicable to services like teledermatology. Hence, the Intelligent Teledermatology System can be used to support the healthcare supply chain in this case the skin disease diagnosis services.

Keywords: *intelligent teledermatology system, supply chain, supply chain services, teledermatology*

1. INTRODUCTION

Health is one of the most important needs in people's lives. Conventional healthcare services are obtained by the public by visiting service centers such as hospitals or clinics or visiting general practitioners or specialists who open services, as is the case in many countries. However, these services cannot be obtained under some conditions. The first condition is for people living in areas with inadequate transportation facilities to reach health service centers, or transportation facilities are not available when needed. Another condition is where the patient is physically unable to move to the location of the healthcare service because of their physical condition. The next condition is the case where it is not possible for patients and doctors to meet like during the COVID-19 pandemic. For these conditions, Telemedicine is needed. Telemedicine refers to the term providing health services remotely. Because they are separated by distance, health services can only be provided with the support of Information and Communication Technology (ICT) such as telecommunication networks including cellular technology, laptops, mobile phones, and software, namely the applications for communicating using web applications and mobile-based applications. One of the telemedicine services that has been used for decades is teledermatology, a remote service for skin diseases. In conventional services, a dermatologist will visually observe the part of the skin that is experiencing problems using the naked eye or using an aid such as a device called dermoscope to see more detailed images. In teledermatology visual observation with the eye can be replaced by observation using a camera. Meanwhile, for more detailed images, a digital dermoscope can be used.

As mentioned previously, teledermatology has been used for decades, and studies related to teledermatology have also been conducted. Most of the teledermatology studies address the issue of implementing teledermatology in various countries (Almaziad *et al*., 2021; Chow *et al*., 2021; Handa *et al*., 2021). Other studies discuss the implementation of patient and doctor satisfaction levels in providing services, as well as the level of suitability of services compared to conventional services (Eldaly *et al*., 2022; Marchell *et al*., 2017; Santiago & Lu, 2023). During a pandemic, the role of teledermatology is increasingly important and widely used. Many publications report on the use of teledermatology in COVID-19 pandemic periods (Jusuf *et al*., 2023; Kimball & Porter, 2022; Haddad *et al*., 2022).

In terms of the parties involved in teledermatology, at least there are 4 parties involved, patients and general practitioners on the client side, and there are large hospitals or referral hospitals and dermatologists or skin specialists on the provider side. However, it does not rule out the possibility of teledermatology being carried out directly between the patient and the dermatologists (Almaziad *et al*., 2021; Brinker *et al*., 2018; Ibrahim *et al*., 2021; Kling *et al*., 2022).

There are two modes used in teledermatology, the Store and Forward mode (asynchronous mode) and live interactive mode (synchronous mode communicating directly online) using video conference system. The most used service mode is live interactive mode compared to store and forward mode. It can be understood that live interactive is a service that is nearly equal to a face-to-face service, the difference is that the service is done online or virtually. The live interactive usually uses a video conferencing system (Briggs *et al*., 2022; Ibrahim *et al*., 2021; Kling *et al*., 2022; Marchell *et al*., 2017; Naik, 2022) or uses various devices including a camera from a cellphone (Almaziad *et al*., 2021; Brinker *et al*., 2018; Handa *et al*., 2021; Ibrahim *et al*., 2021; Torres *et al*., 2021). Surprisingly the live interactive is performed using social media such as Facebook, and messaging applications such as WhatsApp and WeChat (Mahmoud *et al*., 2022; Naik, 2022). The use of telemedicine portals is also reported such as MyDerm Portal, Mend Family Portal, CareNA, Opdox, eVisit, and Practo (Mahmoud *et al*., 2022).

None of the studies mentioned above have reported the existence of an integrated web-based and mobile-based teledermatology application or software that can be used to support the supply chain for skin disease diagnosis services remotely or teledermatology services. Supply chain of services is meant from the initiation of service needs by patients to the fulfillment of services for patients. Furthermore, these studies have yet to apply artificial intelligence (AI) to assist dermatologists in making diagnoses, including integrating AI into teledermatology applications.

Apart from those related to teledermatology applications, the supply chain in healthcare in mostly related to healthcare products such as drugs, vaccines, and others, and the published articles only discuss about these products (Chakraborty & Gonzalez, 2018; Gao & Wang, 2019; Kritchanchai, 2014; Metge & Islam, 2022; Skowron-Grabowska *et al*., 2022). None of the existing studies was found that propose a supply chain for healthcare services like teledermatology.

Hence, in this study, we propose the use of Intelligent Teledermatology System (ITDS) to support the supply chain for teledermatology. We also describe the design and implementation of the Intelligent Teledermatology System (ITDS) and describe the implementation of artificial intelligence in ITDS as a feature to support dermatologists in making decisions or as a decision support system. We also propose the application concept of the supply chain to services like teledermatology.

The contributions of this article are:

a. We propose the use Intelligent Teledermatology System (ITDS), an integrated web-based and mobile-based teledermatology application or software that can be used to support the supply chain for skin disease diagnosis services remotely or teledermatology services.
b. We integrate the artificial intelligence methods into the Intelligent Teledermatology System to support dermatologists in making a diagnosis.
c. We propose the concept of a supply chain for skin disease diagnosis services remotely or

teledermatology services, not for a product as has been known so far.

The remainder of this article is organized as follows. Section 2 describes teledermatology, and its related issues such as mode of services, advantages, and security issues. Section 3 discusses how the supply chain can also be applicable to deal with services instead of products, in this case, the skin disease diagnosis that is delivered remotely in teledermatology. Then, Section 4 describes the proposed Intelligent Teledermatology System (ITDS) in terms of its design and implementation of the design. At the end of this article, we put the analysis in Section 5 and Conclusion in Section 6.

2. TELEDERMATOLOGY

As explained in the previous section, teledermatology is part of telemedicine which provides remote skin disease services by utilizing information and communication technology as well as advances in computers and informatics.

2.1 History of Teledermatology

Comprehensive review of Teledermatology can be found in the article written by Coates *et al*., (2015). According to them, teledermatology was actively carried out by the United States Ministry of Defense in the early 1990s. Then, the first scientific article reporting the use of teledermatology was published in 1995. Since then, publications related to teledermatology have increased significantly. Teledermatology has great potential to revolutionize dermatology service delivery by providing equitable services to remote areas and enabling general practitioners to refer the diagnoses of patients to dermatologists in the referral or larger hospitals remotely (Tensen *et al*., 2016).

2.2 Mode of services

Teledermatology can currently be developed by utilizing video conferencing equipment and other information communication technology (ICT) equipment using two modes namely. the store and forward mode and live interactive mode (Brinker *et al*., 2018; Mahmood *et al*., 2021; Ruggiero *et al*., 2022).

In the Store and Forward mode, data in the form of photos or skin images or microscopic images of the patient's skin taken at the clinic or primary care or clinics receiving the services is stored beforehand to be sent to the service provider side in this case a large hospital. Then at a certain time, a dermatologist at the referral hospital will carry out a diagnosis of the data received. The results will be sent back to the primary care or clinics. Meanwhile, in the live interactive mode, the patient in the primary care or clinics and the dermatologist at the referral hospital interact directly. Dermatologists carry out consultations using video conferencing devices, observe certain parts of the skin and take photos or ordinary images or microscopic images using a microscope.

2.3 Advantages and Disadvantages of Teledermatology

Teledermatology can overcome the problem of the spread of dermatologists who are currently concentrated in big cities. Teledermatology expand the range of skin disease services to areas covered by telecommunications networks, decreasing the travel costs while reducing the risk of patients in transit. Furthermore, teledermatology can reduce the digital divide where all people without exception will be able to enjoy this service (Santiago & Lu, 2023b).

Although it has several advantages, teledermatology has some disadvantages (Almaziad *et al*., 2021). There is a lack of personal contact in teledermatology. There is also a possible misunderstanding in the interpretation of the transmitted data. The important issue is the security of the data which is sometimes not considered in creating such a web-based application. Furthermore, not all skin conditions can be diagnosed remotely using teledermatology, especially skin cancer.

2.4 Patient Data Security

In the digital world, the issue of security and data security is very important. Just like applications running on the web or on other mobile devices, teledermatology services need to implement data security mechanisms. In America, teledermatology services can use the standards issued by the Centers for Medicare & Medicaid Services (CMS) namely, the HIPAA standard of the Health Insurance Portability and Accountability Act. (Yeboah *et al*., 2021)

3. SUPLY CHAIN OF HEALTHCARE SERVICES IN TELEDERMATOLOGY

So far, discussion of supply chains has been related to products, including supply chains in the health sector (Chakraborty & Gonzalez, 2018; Kritchanchai, 2014). This is quite reasonable because the knowledge comes from the industry that produces the product. However, as technology develops, customers need not only products but also services, including healthcare services. This section aims to explain that the supply chain concept can also be applied to healthcare services, in this case remote skin disease diagnosis services or teledermatology. Throughout this article, we use the term product supply chain to refer to the supply chain related to product, and the term service supply chain or teledermatology supply chain refer to the supply chain related to teledermatology.

The concept of the supply chain that is applied to teledermatology can be seen in **Figure 1**, where teledermatology services are services that will be received by customers, in this case, patients or the public. There are various kinds of these services, and as explained in the next section. To be able to sell these services, various resources are needed, including media for communication such as telecommunications networks, for example, cellular communications (4G and 5G), devices for communication such as computers, laptops, or cell phones, and applications or software based on Web, mobile, and Clouds. These resources are identical to the raw material in the product supply chain. By software engineering process, these resources are manufactured to obtain the applications

software in the form of web-based applications and mobile-based applications. This is identical to the manufacturing process of a product in product supply chain. The next stage is the process of applying teledermatology services to customers or patients. This application process involves the role of the patient, general practitioner, and primary care or clinic on the client side who receive the services and the dermatologist and hospital on the provider side who provide the service. As shown in **Figure 1**, the demand for the services initiated by patients should be fulfilled by the dermatologist, their schedule, and the services provided by the hospital. The combination of them is the same with inventory in product supply chain. The chain of processes shown in **Figure 1** is executed repeatedly to fulfill services requested by patients. The flow of services provided to patients can only be implemented with the software or teledermatology applications. The telecommunications networks and telecommunications equipment including computers or laptops, and these resources are the same as the logistic system in product supply chain.

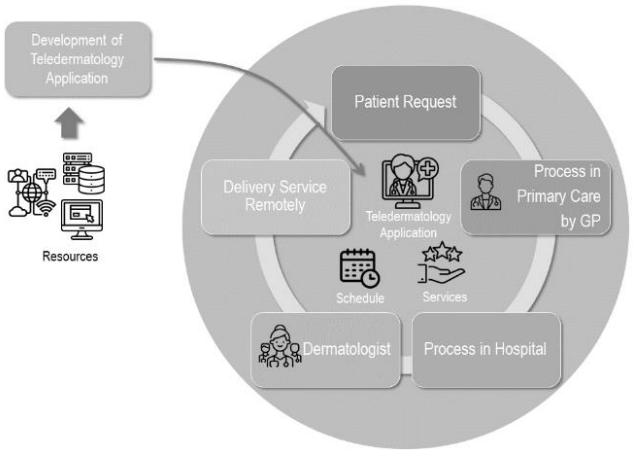

Figure 1 Supply Chain of Skin Disease Diagnosis Done Remotely in Teledermatology

3.1 Five Components in Supply Chain of Healthcare Services

In the supply chain, there are five main components usually dealt with. The five components are: planning, sources, inventory, production, and information. In the case of teledermatology, the five components of supply chain are also applicable. The Planning component in teledermatology systems is the process that starts when the client opens the application. In other words, the planning component is how the client's request will be handled until the client gets and achieves the desired goal. Then, in the case of the service supply chain, the patient requests services from a teledermatology application. The Sourcing component is an effort of an entity in the supply chain to meet the needs of resources that will later be used for operational needs. In teledermatology supply chain, sourcing can be in the form of efforts such as selecting and selecting primary care or clinics that will later become partners. The Inventory component is referred to resources that will later be processed into output for the customer. In teledermatology supply chain, the inventory component is the same as the tuple or a set of the elements of dermatologists who provide the services, their available schedule, and the services provided by the referral hospital. The Productions component in the industry includes efforts to fulfil orders from customers. In teledermatology, the Production component is the running cycle of the processes in the chain shown in **Figure 1** to fulfill the request of services from the patient. The Information component in teledermatology supply chain can be divided into two kinds of information, internal information, and external information. External information is general information that is shared among supply chain entities, such as information on the number of patients, dermatologists' schedule information, and client demand information in the application. Meanwhile, internal information is information from teledermatology application developers themselves. This information is more confidential and is rarely shared with supply chain stakeholders.

3.2 Flows in Supply Chain of Healthcare Services

Supply chain management that manages the flow of teledermatology is also applicable such as product flow, information flow, and financial flow (Motiwalla & Thompson, 2012). The product in teledermatology is skin disease diagnosis services. Hence, the product flow is the flow of these services to the patients. The product flow of teledermatology can be classified into the downstream flow category. This means that the services flow from the point of origin in this case the dermatologists to the point of consumption in this case the patients, namely, diagnoses results, prescriptions, and counseling services. The information flow in a supply chain is a flow that works in two directions so that it is mutually beneficial for all stakeholders. In the supply chain of an internet-based and data-based industry such as teledermatology, the dissemination of information greatly benefits. All entities in the supply chain can quickly act and react based on the information obtained. For example, a referral hospital can provide historical data on the number of patients with severe skin diseases, and the number of dermatologists available to provide teledermatology services. Then, the primary care or the clinic as the client can manage their resources and promote them to the public. On the other hand, the primary care or clinic can also provide the information about infrastructure they have to run teledermatology services. The successful flow of information in a supply chain will certainly be successful if all parties agree to share certain information. Therefore, a bond of trust is needed between stakeholders. The financial flow of a supply chain consists of the downstream flow and the upstream flow. The downstream financial flow in teledermatology deals with the cost in the development period and in the operational period. In the development period, the downstream flow includes costs for developing teledermatology software or applications, training, investment costs for teledermatology equipment, and storing data and applications in the cloud. During the operational period, the downstream flow includes costs for equipment rental, costs for the technical team and managerial team of teledermatology, costs for clinics, and costs for hospitals. Meanwhile, the upstream flow in the form of revenue in the teledermatology system comes from patients who use teledermatology services.

3.3 Skin Disease Diagnosis Services in Teledermatology

There are many types of skin diseases that are served by dermatologists. In general, skin diseases can be classified into five types namely, pediatrics, cosmetics, tumors, allergy and immunology, type I and type II infections. For teledermatology services, almost all skin diseases can be served except for types of diseases that require offline procedures such as taking a biopsy. Most of the skin diseases are already reported in the literature (Naik, 2022), or specific to the most common in-person consensus diagnoses (Marchell *et al*., 2016). Some researchers also concentrate on certain types of skin diseases such as acne (Jusuf *et al*., 2023), and erythema (Trevisan *et al*., 2022).

4. A CASE OF IMPLEMENTING SUPPLY CHAIN OF AI-BASED HEALTHCARE SERVICES USING INTELLIGENT TELEDERMATOLOGY SYSTEM (ITDS)

This section describes the development of the proposed Intelligent Teledermatology System (ITDS) in terms of the design and the implementation of the design. Some parts of the description mention the involved parties, such as primary care or clinic, general practitioner, referral hospital, and dermatologist. The aim is to describe the potential application of ITDS by these parties. We do not explain the results of the ITDS application.

The development of the Intelligent Teledermatology System uses a Case-Based Reasoning (CBR) approach, an approach that mimics human behavior in solving such cases. **Figure 2** illustrates the CBR approach that consists of 4-step processes: Retrieve, Reuse, Revise, and Retain. We add the role of the Deep Learning (DL) method in Artificial Intelligence (AI) in this approach. The Retrieve step aims to find similar cases, the Reuse step is to adapt and use similar cases to resolve a new problem, the Revise step is to adjust the new solution, and the Retain step is to store the resulting experience. Based on the CBR approach, the proposed Intelligent Teledermatology System can be described as follows. In the Retrieve step, the skin disease image as a new case from the patient is classified using the trained Deep Learning (DL) model to get the best match criteria for a certain disease. Therefore, this result of the DL model can be used to solve the new case after it is approved by the dermatologist. Then, the Reuse step is performed. If the DL model gives incorrect results, the dermatologist can correct the results resulting in a corrected disease label on the skin disease image, and the DL model is then retrained by ITDS, which enters the Revise step in CBR. The retrained DL model is then stored in ITDS to represent the Retain step in CBR.

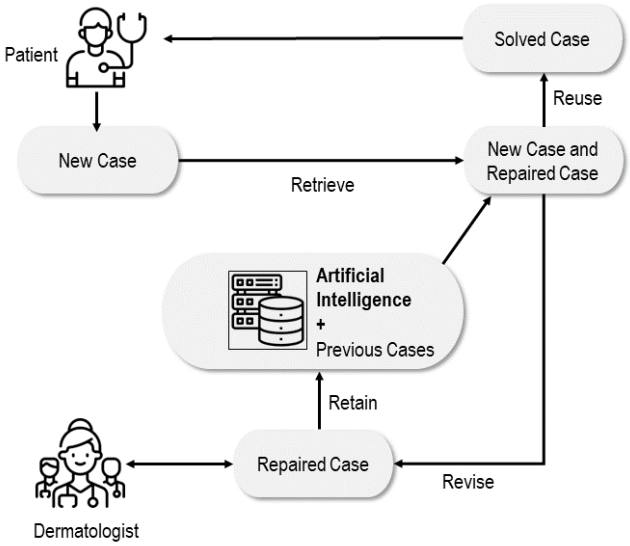

Figure 2 Case-Based Reasoning in Intelligent Teledermatology System

4.1 Design of the Intelligent Teledermatology System

The Intelligent Teledermatology System provides the supply chain of healthcare services for patients with skin disease. The parties that can be served by ITDS are shown in **Figure 3**.

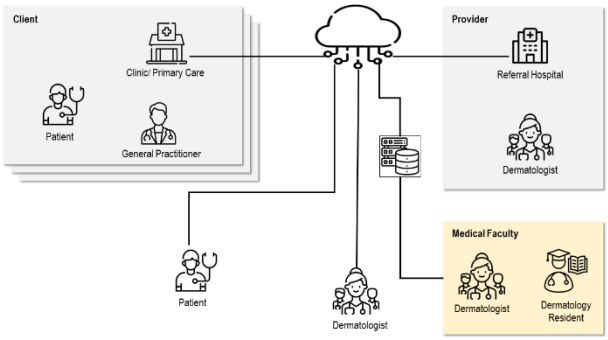

Figure 3 The Business Context of Intelligent Teledermatology System in delivering services

The Intelligent Teledermatology System is an integrated system consisting of three main functions: Management Information System, Point of Services, and Intelligent System.

Management Information System

This group of functions focuses on managing various types of data and information that include the functions for managing following data such as patient data (manage and track patient data, including demographic information, medical history, and other health records), patient visit data (date and time of visit, purpose of visit, and results of visit), referral data (primary care or clinics, and hospitals, patient disease reports, previous medical actions, and results of referrals from the hospital), diagnostic data (results of a diagnosis of a patient), treatment data (type of treatment, date of treatment, and results of treatment), product data (product descriptions, prices, and stock), and appointment data

(appointment date and time, appointment purpose, and other relevant records).

This group of functions also manages financial reports (all financial transactions that occur during medical treatment), and manages notifications (upcoming appointments, tasks to be completed, and diagnosis results).

Point of Services

This group of functions focuses on sales and payment transactions, and consists of teledermatology order service (allows patients to add products to a virtual shopping cart and then proceed to the checkout process when they are ready to make a payment), invoice (generates an invoice for each sales transaction, including details such as items purchased, quantity, price, and total cost), and payment gateway (allows users to make payments via various methods such as e-wallets and virtual account bank transfers).

Intelligent Systems

This group of functions focuses on using advanced technologies and algorithms to implement the Case-Based Reasoning approach and to increase the efficiency and effectiveness of systems. This group consists of functions for skin disease classification using the Deep Learning model. This feature uses a deep learning model to classify various types of skin diseases. This model is trained using large amounts of skin image data, enabling it to identify the patterns and distinctive features of various skin diseases. This group is also used for dataset management and re-train the deep learning models. This feature manages the datasets used to train and test deep learning models. This feature also allows users to add new data to the dataset, allowing the model to continuously learn and adapt to new patterns and trends.

Role of Users

Other than the functions for the operation of ITDS, the access of ITDS is also managed using the following role of users. The ITDS system has five distinct main roles, each with its own responsibilities and functions within the system. The first role is the Super Admin role that has full control over the ITDS system). They are responsible for managing the overall running of the system and making important arrangements such as setting up payment gateways. The Super Admin role can also manage joined health facility data and system user data. In other words, the Super Admin role ensures that the system is functioning properly, and all users can access and use the system effectively. The Patient role allows patients to enter the system and perform various activities such as making appointments, ordering products, viewing their medical records, and viewing promotions on available treatments at health facilities. Thus, the Patient role allows individuals to access and manage their own health information. The Clinic Admin role is to allow the administration officer to manage various types of data in the system, including patient data, visit data, treatment data, and product data. They are also responsible for confirming appointments and product orders. Thus, the Clinic Admin role ensures that the daily operations at the clinic run smoothly and efficiently. The Clinic Doctor admin role allows the general practitioner or medical staff to make a diagnosis or refer the patient to a specialist in the hospital if necessary. They play an important role in the patient care process, ensuring that patients receive appropriate care based on their health conditions. The Hospital Admin role has the same function as the Clinic Admin role, but they operate at the hospital level. They also have the additional responsibility of managing referrals, both onsite referrals and online referrals. This ensures that patients requiring further treatment or specialist care can be referred to the right facility or doctor. The Hospital Doctors role allows a dermatologist to make the final diagnosis of a patient in the hospital or a diagnosis based on referral data from the clinic. They ensure that patients receive an accurate diagnosis and appropriate treatment, whether in the hospital or as part of the referral process.

Overall, each role within the ITDS system plays an important part in ensuring that the system functions properly and patients receive the service they need. With clear and well-defined rules, the system can operate efficiently and effectively.

4.2 Implementation

The implementation of the ITDS system on the web platform and Android application is designed to meet the specific needs of clinics and hospitals. The system is divided into two service categories: core services and support services. Within the core service, there are two main use cases: local visits and referrals. Because this study is related to teledermatology, we only describe the referral process for certain diseases. The activity diagram for the process to refer the patient from the clinic or primary care unit to the referral hospital is shown in **Figure 4**.

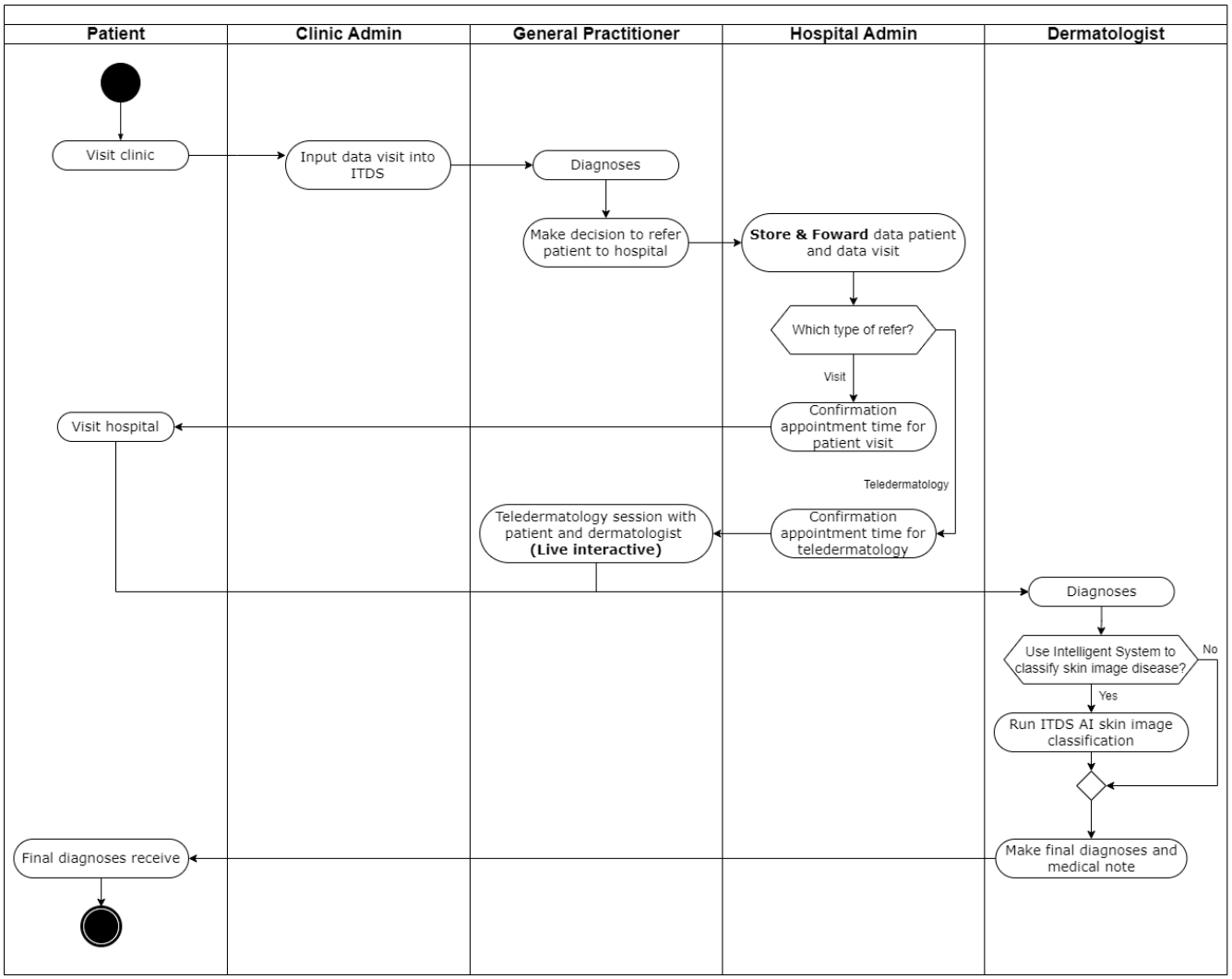

Figure 4 The Activity Diagram to show the Business Process of the Intelligent Teledermatology Syste

The flow of processes is as follow. Patients who have skin problems visit primary care or clinic. Patient data is entered by the administration officer and examined by the general practitioner (GP) who may choose to refer the patient to the referral hospital. There are two types of referrals, namely, visiting referrals and teledermatology referrals. The type of referral is chosen based on the recommendation of the general practitioner and the need of the patient. In visit referral, the patient must come to the referral hospital. In teledermatology referrals, the patient and the clinic submit a request to perform teledermatology with a specialist at the referral hospital in the asynchronous or store and forward mode, or in the synchronous or live interactive mode. In both modes, patient data and medical records will be sent to the referral hospital and the notifications will appear so that the hospital administration officer knows if there is new referral data. For the live interactive teledermatology, the appointments will be arranged by the administration officer of ITDS in the referral hospital. For both type of teledermatology services, the dermatologist at the referral hospital will provide a final diagnosis and notes regarding examinations from the referral process that has taken place. Before giving a final diagnosis, the doctor can also see the predicted results of the patient's skin image classification. The results of the diagnosis will be sent to the clinic or patient and a notification will appear.

4.2.1 Store and Forward Teledermatology

In the Store and Forward teledermatology, referral patient data from the clinic will appear on the dashboard that is seen by the dermatologist. Dermatologists will examine patient data one by one and make a diagnosis. They can choose to use the automatic skin image classification features of the ITDS for assistance. The dermatologist can add the resume of the diagnosis and finalize the diagnosis. Finally, the diagnosed patient data will be sent back to the clinic or primary care.

4.2.2 Live Interactive Teledermatology

In the live interactive mode, the administrator of the ITDS in the hospital schedules the teledermatology session, confirming the appointment time with the patient and the general practitioner. The live interactive teledermatology session will involve the general practitioner, the patient, and the dermatologist. During this session, the dermatologist can remotely assess the patient's condition, ask questions, and provide medical advice. This live interaction allows for real-time communication and immediate feedback, which can be crucial for diagnosing and treating skin conditions effectively. After the teledermatology session, the hospital doctor makes the final diagnosis. They can choose to use the automatic skin image classification feature of the ITDS for

assistance. The dermatologist can add the resume of the diagnosis and finalize the diagnosis of the live interactive teledermatology. Finally, the diagnosed patient data will be sent back to the clinic or primary care.

4.2.3 Intelligent Systems for Intelligent Teledermatology System

Skin disease classification feature can support dermatologists in making diagnoses. This feature uses the Deep Learning model. Before their operation, this model is trained using large amounts of skin image data. During the operation, this feature will produce the 3 closest skin diseases based on the closeness score of the classification results that in turn will be displayed to the dermatologists. The flow of the classification procedure is shown in **Algorithm 1** which consists of several modules or procedures. As shown in **Algorithm 1**, when a dermatologist push the classification button, the system will first call the Procedure loadModel() to load the deep learning model, then continue to call the Procedure classify() to perform the intelligent classification process. The returning results are 3 diseases represented by the index. Hence, to get the name of the disease the Procedure getClass() is called, followed by calling the Procedure displayClass() to display the name of the 3 skin diseases.

Algorithm 1 The Activity Diagram to show the Business Process of the Intelligent Teledermatology System

```
Define MODEL_PATH, model
Call loadModel()
Call classify ()
Call getClass ()
Call displayClass ()
Procedure loadModel()
  Begin
    Load model from MODEL_PATH
    If error in loading model, print error
  End
Define server to serve images from "/images" directory
Procedure classify (Request, Response)
  Begin
    Try
      Fetch image from request
      Preprocess image to match model requirements
      Predict class of image using model
      Extract top 3 classes with highest prediction scores
      Send top 3 classes as response
      Catch any error
      Send error message as response
    End Try
  End
Procedure getClass(Index)
  Begin
    Load classes
    Return class at given Index
  End
Procedure displayClass(class Index)
  Begin
    Load class Index
    Return disease class name
  End
```

4.2.4 Security Implementation in Intelligent Teledermatology System

The Intelligent Teledermatology System (ITDS) incorporates a range of security features designed to protect the integrity and confidentiality of user data and ensure secure transactions. Firstly, the system uses JSON Web Token (JWT) for authentication and authorization, ensuring that only authorized users can access the system and perform specific actions based on their roles. This is further bolstered using Google Recaptcha v3, which helps prevent brute force attacks on public forms by distinguishing between human and automated access. To protect against cross-site request forgery (CSRF), the system employs CSRF tokens in forms, ensuring that requests are only accepted from legitimate sources. Similarly, the system uses Ajax to verify that requests are indeed from Ajax, adding another layer of security. For user verification, the system uses OTP (One-Time Password) verification, providing an extra layer of security by requiring users to verify their identity using a unique password sent to them.

In terms of financial transactions, the ITDS uses encrypted keys for the Payment Gateway, ensuring that financial data remains secure during transactions. The system also verifies callbacks from the Payment Gateway, adding an additional layer of security to financial transactions.

4.2.5 User Interface of Intelligent Teledermatology System

The implementation of Intelligent Teledermatology System (ITDS) on the web platform and Android application allows for increased efficiency and effectiveness in patient management and referral processes. With the integration between Management Information Systems, Point of Services, and Intelligent Systems, ITDS can provide better services to patients and facilitate better collaboration between clinics and hospitals.

Figure 5 and **Figure 6** respectively show examples of the user interface of the web-based application of ITDS and the mobile application of ITDS. Both figures contain the results of the classification of skin diseases using Deep Learning methods and display the diseases that have the closest predictive value to the classification results. The name of the three skin diseases are displayed below the text "Hasil Smart Detection"

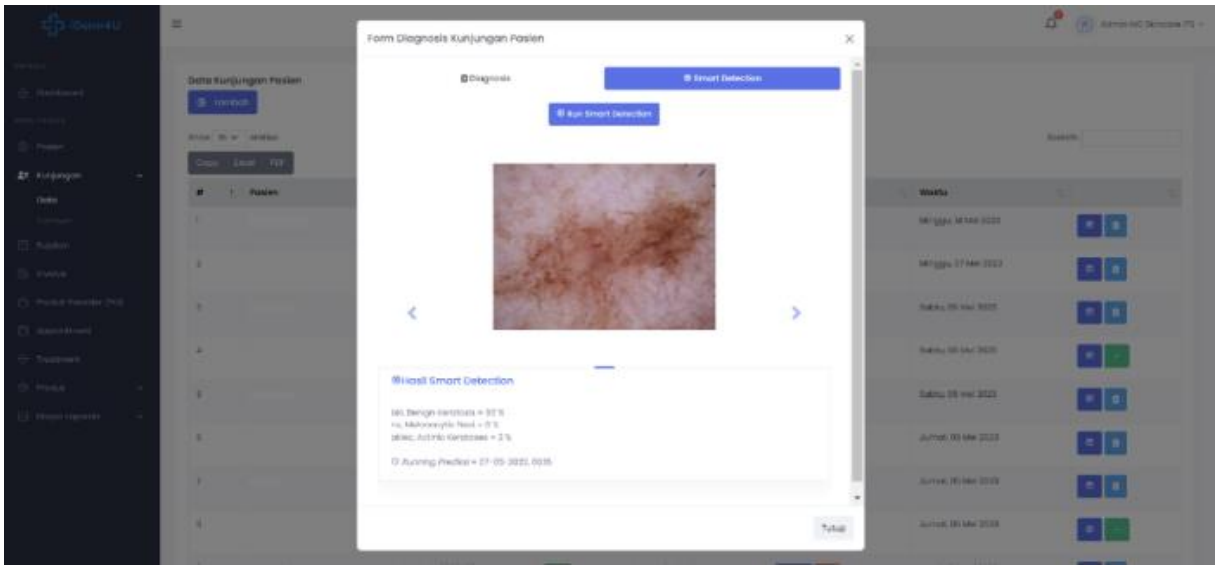

Figure 5 The Results of the Implementation of the Skin Image Classification Model on the Web-based Application (Healthcare Provider Side)

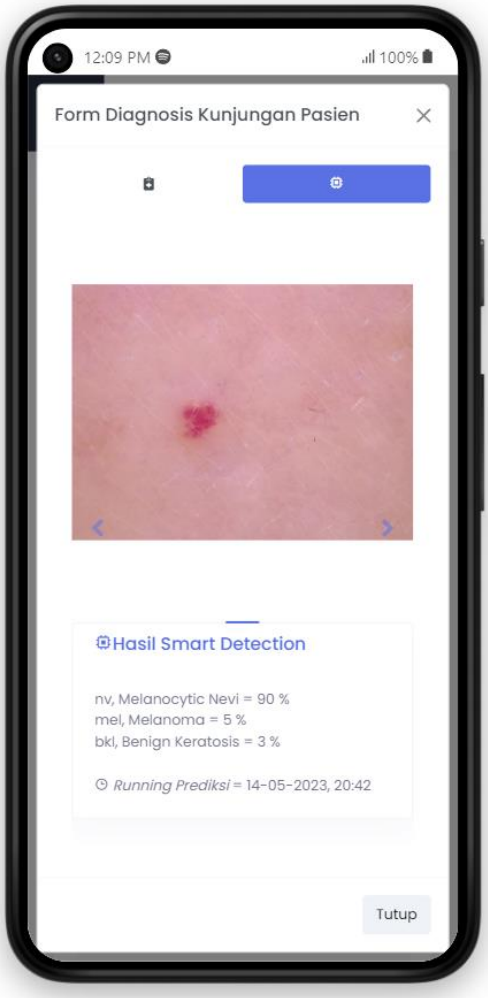

Figure 6 The Results of the Implementation of the Skin Image Classification Model on the Mobile-based Application (Healthcare Client Side)

5. ANALYSIS

In the context of the healthcare supply chain, Intelligent Teledermatology System (ITDS) systems plays an important role in managing and optimizing the flow of information, products, and services from healthcare providers to patients. The MIS function enables the management of patient data, visit data, referral data, treatment data, product data, appointment data, promotional data, financial reports, notifications, and dashboards. This facilitates the efficient and effective flow of information within the supply chain, ensuring that all parties involved have access to the information they need to perform their tasks.

Point of Services function has the function to manage sales and payment transactions, including features such as Product Orders, Invoices, and Payment Gateways. It facilitates the flow of products and services in the supply chain, ensuring that products and services reach patients in the most efficient and effective way.

However, what really sets an ITDS system apart is its Intelligent Systems function. This feature uses AI technology to increase system efficiency and effectiveness. For example, the skin disease classification feature uses a Deep Learning model to classify various types of skin diseases. This not only speeds up the diagnostic process but also increases the accuracy and consistency of the diagnosis. Additionally, the dataset management and re-train model Deep Learning features allow the system to continuously learn and adapt to new patterns and trends, ensuring that the system remains relevant and effective over time.

In doing so, the ITDS system demonstrates how AI can be used to improve the efficiency and effectiveness of the healthcare supply chain. By integrating AI into the system, services using ITDS can achieve a good level of efficiency and effectiveness. This shows the potential of AI to change the way the healthcare supply chain is managed and optimized.

5.1 Impact on Diagnoses as Decision Support System

The role of technology in medicine is very important, including for diagnosis. The Intelligence Teledermatology System (ITDS) which is equipped with a classification module will display the skin disease images to several closest disease classes based on the percentage of accuracy, then doctors can determine the disease based on their expertise.

Thus, ITDS can be used as a tool for a Decision Support System.

The system can also learn on the fly from the results of a diagnosis made by a doctor. The level of proximity to the disease is displayed sequentially from the highest level. If the doctor does not choose the disease in the first order as the result of the diagnosis, then the model for classification needs to be retrained to produce a more accurate classification model. In this way the doctor remains authorized to make a diagnosis, and the ITDS provides a mechanism for a Decision Support System with a classification model that is always being improved.

5.2 Impact of ITDS on Dermatology Education

The automatic classification of the Intelligence Teledermatology System (ITDS) can be used in medical education in the department of dermatology. The photos stored and processed by ITDS can be used in studying skin diseases. As shown in **Figure 3**, ITDS is designed to be used by dermatologists and dermatological residents with certain access rights. ITDS allows residents to view pictures of skin diseases and study the results of diagnoses made by dermatologists. The positions of a dermatologist and a dermatologist resident can be in different locations, for example, a resident is placed in a remote area of a primary health care center while a dermatologist is in a referral hospital or a larger hospital. In this way, ITDS helps to broaden the reach of skin disease education. In addition to education between dermatologists and dermatological residents, with certain access rights, it is also possible for dermatologists to share knowledge in making a diagnosis.

5.3 Impact on the Supply Chain of Healthcare Services

If in the economy a consumer needs a product, then in the healthcare sector, patients, or the public need health services. Fulfillment of health services to the public meets the principles of the supply chain. The Intelligent Teledermatology System (ITDS) provides a series of features that facilitate the implementation of a comprehensive supply chain in fulfilling skin disease services. The chain of processes is executed repeatedly to fulfil services requested by patients. ITDS also provides additional features that doctors can use in making a diagnosis and learning.

With the use of ITDS or teledermatology in general, it will expand the reach of the supply chain to patients in all areas that were previously difficult to reach. The service flow logistics system is made possible by the existence of telecommunication and internet infrastructure as roads, while the modules provided by ITDS can be used as a means of transportation. With the use of ITDS or teledermatology in general, it will expand the reach of the supply chain to patients in all areas that were previously difficult to reach by means of transportation if the patient area is within the area covered by the telecommunication system. The service flow logistics system is made possible by the existence of telecommunication and internet infrastructure as roads, while the modules provided by ITDS can be used as a means of transportation. Furthermore, the inventory of this system is a tuple of the following three components, namely, available dermatologists, schedules of the available dermatologist, and services provided.

6. CONCLUSION

We have presented the design and development of a so-called Intelligent Teledermatology System (ITDS). ITDS development complies with the Case-Based Reasoning approach which consists of 4 steps: Retrieve, Reuse, Revise, and Retain. This system provides groups of features, namely, management information system, point of services, and intelligent systems. ITDS provides the teledermatology service in two modes: store and forward mode and live interactive mode. The proposed Intelligent Teledermatology System provides complete features including features for security so that skin disease diagnosis services can be delivered to patients who initiate the need for services. This system provides a classification function, and the results of classification can be used as part of a decision support system for dermatologists in making diagnoses. ITDS allows for the study of skin diseases for dermatology students and residents.

We have described that the supply chain concept is also applicable to healthcare services such as teledermatology. As in the product supply chain, we have explained that the teledermatology supply chain also has five main components, namely, planning, sources, inventory, production, and information. Meanwhile, in terms of supply chain management, the teledermatology supply chain also has three main flows, namely, product flow, information flow, and financial flow.

By looking at the features available in Intelligent Teledermatology Services and how these features can maintain the concepts in the supply chain management can be applied to teledermatology services, Intelligent Teledermatology System can be used to support the supply chain for healthcare services, in this case, remote services for skin disease diagnosis.

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