

# Cloud Computing Application Model for Online Recommendation through Fuzzy Logic System

## Modelo de Utilización de la Computación en la Nube para Realizar Recomendaciones a través del Sistema de Lógica Difusa Online

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### Abstract

Cloud computing can offer us different distance services over the internet. We propose an online application model for using health care systems that works by using cloud computing. It can provide a higher quality of services remotely and along with that, it decreases the cost of chronic patients. This model is composed of two sub-model, each of which uses a different service. One of these is software as a service (SaaS), which is user related, and the other one is Platform as a service (PaaS), that is engineer related. Doctors classify the chronic diseases into different stages according to their symptoms. As the clinical data has a non-numeric value, we use the fuzzy logic system in the PaaS model to design this online application model. Based on this classification, patients can receive the proper recommendation through smart devices (SaaS model).

**Keywords:** Cloud computing, Medical attention system, heart failure, fuzzy logic system

### Resumen

La computación en nube nos puede ofrecer diferentes servicios a distancia a través de Internet. El sistema sanitario puede beneficiarse del uso de cloud computing para proporcionar un servicio de atención al paciente crónico de mayor calidad incorporando servicios que se pueden realizar de forma remota, esto ayudaría a tener un sistema de atención personalizado y al mismo tiempo más sostenible. Este modelo está compuesto por dos sub-modelo que cada uno usa un

servicio cloud diferente, se utiliza el software como un servicio (SaaS) para la atención al usuario y la plataforma como servicio (PaaS) para el desarrollo de servicios. Las enfermedades crónicas se pueden clasificar en diferentes etapas según sus síntomas. Como los datos clínicos tienen un valor no numérico, se propone la utilización de un sistema de lógica difusa en el modelo PaaS para dar soporte al diseño. Basado en esta clasificación, los pacientes pueden recibir la recomendación adecuada a través de dispositivos inteligentes (utilizando SaaS).

**Palabras claves:** Computación en la nube, sistema de atención médica, insuficiencia cardíaca, sistema de lógica difusa.

### 1 Introduction

Demographic results show that both developed and developing countries are having to deal with an ageing population and as we expect with advancing age, chronic conditions will be more obvious, so it will detract from the quality of care. In general, the healthcare system tries to reduce costs and make better use of resources in minimum time while talking about improving healthcare system efficiency.

Improving quality is related to patient satisfaction, so it's necessary to reduce wait times and annoying delays for patients. Chronic patients often need to access healthcare systems and many of them need to be readmitted even though they are not in an emergency or dangerous situation. Likewise, many chronic diseases are preventable or predictable. Many chronic conditions are relevant to lifestyle choices that are within our control. Reducing unnecessary attendance of chronic patients to the health care system and controlling their visiting time could be an important solution to improving healthcare system efficiency.

Using technology and smart devices to monitor and control chronic patients remotely can be a great help to reduce the burden of visitors and enable us to manipulate discipline in the healthcare system [1],[2].

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So we will gain better patient management and consequently better quality of services. Thus, offering an e-healthcare system can reduce complications due to chronic conditions with efficient follow-up, and provide online environmental monitoring of patients.

To have secure, accessible, flexible and economical services, we use cloud computing to design the proposed model. The model enables transmission of a patient's health status, vital signs and risk factor data remotely from the respective healthcare setting. So the patient is going to be monitored remotely and the systems will be updated by receiving the patient's data. Healthcare staff can access the patient's data when they need to improve information, knowledge and this leads to a better quality of care [3] [4].

Heart Failure is one leading causes of death among the chronic diseases. The prevalence of heart failure depends on the definition applied, but it is approximately 1 to 2 % of the adult population in developed countries, rising to  $\leq 10\%$  among people over 70 years of age. Significant heart failure signs and symptoms can be measured simply by the patient remotely and be sent to clinical severe [5]. This two reasons, make heart failure a priority over other diseases for working on. Usually, clinical data is many-valued data and it is not in the precise value of zero or one, in other words this data is close to human language. That is why we use the fuzzy logic system to design our proposed model. This research is carried out with the collaboration of healthcare staff at the Emergency Department of Hospital Universitari Parc Tauli (one of the biggest hospitals in Catalonia, Spain ) which provides care service to a catchment area of about 500,000 people, receiving over 160,000 patients annually in its ED[6]. We have designed a model to consider how a heart failure patient can be monitored online through a cloud, and how a change in clinical parameters can modify the stage of health plus the quality of the healthcare system, Then we are going simulate this model to evaluate and organize diverse visions and aspects of the structural model. So simulation provides us with this possibility to qualify the proposed model more safely [7].

This paper is organized as follows: the second section is about the steps in the design of the E-health model, in section 3 we give an overview about the E-health model through a cloud, in section 4 we talk about the fuzzy logic process, section 5 will deal with conclusions and in section 6, we talk about competing for interest and at the end of the paper there are the acknowledgment.

## 2 The steps in the design of the E-health model

Digitizing healthcare information and communication provides stronger access to various healthcare services for patients and it speeds up service delivery and information exchanges. As we see it, e-health is a solution

to improve healthcare system efficiency. So we need to implement an e-health system. In order to achieve a successful implementation, first, we need to design a model and increase the theoretical approach. This provides a better explanation and understanding of the strengths and weaknesses of the system. This model is designed based on the data in the real system. Data helps to analyze the problem of the current system, but in order to see how and why this suggested model succeeds or fails, we use simulation before implementation. This is because, firstly, simulation gives us this chance to consider a different scenario with real or virtual data. Secondly, we can have a deep look at a different aspect of the designed model, thirdly, it can minimize our spending in time and finally, it is affordable and easy to use. The next step is analyzing the result that is gained by simulation. This result can help to evaluate the proposed model and predict the best model for implementation. All these steps are shown in Figure 1. In this study, our E-health model is composed of two sub-models, one of which is the patient model that determines the level of danger of the patient and the other is the online recommendation model that sends some recommendations to a patient based on their level of danger.

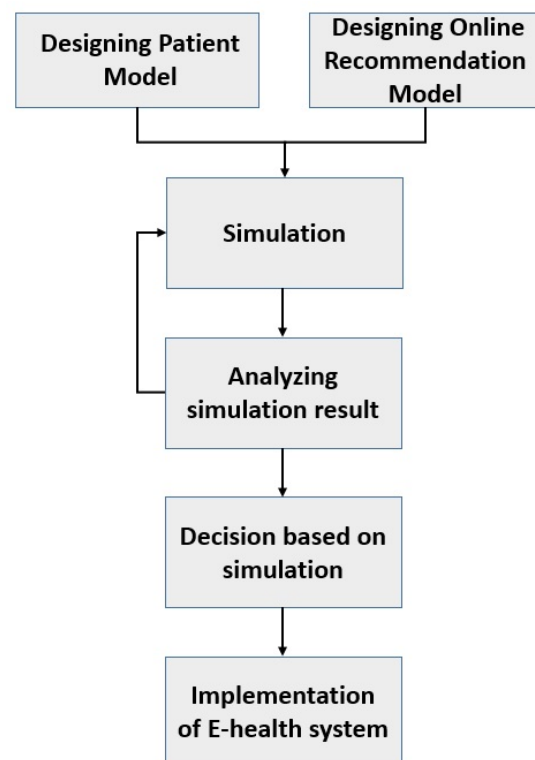


Figure 1: Steps design of E-health system

### 3 The components of the e-health model through cloud

In the online monitoring system, the amount of vital and clinical data is huge and it is expanding so fast. Furthermore, it needs to be available 24/7. Space storage or devices that can save all this data or provide the services can be costly or slow. All these matters lead us to bring up the issue of cloud computing. One characteristic of cloud computing is a pay-per-use basis or using a subscription fee [8], the latter of which has the potential to be extended based on the demand and consumption. Cloud can provide us with a wide range of medical data, applications and services anytime, anywhere. Cloud computing provides a strong infrastructure and offers distance services for a healthcare system over the Internet. Figure 2 shows the general idea of the suggested cloud computing model, which is composed of two service models as follows [9].

- **Software as a Service (SaaS):** This service is used as a Web interface that is designed as follows :  
Inputs: patient monitoring, historical data of the patient  
Process: prediction of patient evolution  
Outputs: NYHA Classification (figure 4), recommendations to the patient and to the healthcare staff
- **Platform as a Service (PaaS):** This is a development of the simulator that is achieved by a collaboration doctors and engineers

The healthcare staff and the patient can connect to cloud over the internet and use the proposed application. The patient can send clinical data and receive recommendations or an appointment, concurrently healthcare staff can store and access a patient's data. All of this intercommunication happens in SaaS. PaaS determines how this intercommunication happens.

#### 3.1 Software as a Service (SaaS):

SaaS provides Cloud-based software solutions (e.g. clinical systems) where consumers such as healthcare providers receive access to the software capabilities of the cloud. This layer is user-related, meaning it is accessible to users. In this model, the users are health care staff and patients. E-health care systems focus on clinical parameters related in order to provide services to treat the chronic patients remotely. Chronic patients require follow-up to improve their adherence to treatment (compliance with the recommended preventive measures), and to evaluate changes in their pathology. The data is gained through monitoring or by being entered by the patient or healthcare staff and can be used for part of the treatment and sometimes for evaluating a diagnosis of the patient's condition [10],[4]. As we can see in Figure 3, in the SaaS model of the e-healthcare system after the patient has succeed in

connecting to the system over the internet, their data is considered and the problem is analyzed. If a patient is in a dangerous situation, an urgent appointment is made for them. Otherwise according to the patient's condition and available data. If it is possible, the system makes a recommendation for the patient, if not, the patient should connect to an online doctor or an expert who can provide them with personalized assistance. This model helps patients avoid an urgent situation [11][12] [13].

#### 3.2 Platform as a Service (PaaS):

In PaaS layer, the customer has possible control over the design, building, testing, updating and development of the online healthcare applications. So this service is used and seen by engineers. As Figure 3 shows, the chronic patient needs to receive a recommendation. The model for sending the recommendation is designed in PaaS model by use of a fuzzy logic system.

##### 3.2.1 Fuzzy logic system and heart failure classification

Usually, in the domain of a healthcare system, the clinical data value is uncertain, dynamic, sophisticated and expressed in natural language. So there is no precise or direct translation from human language to computer language. That is why we use the fuzzy logic system to deal with the uncertainty in our clinical data set value for designing our online application in PaaS model.

As we mentioned before, we start our study from heart failure disease.

Doctors usually classify patient's heart failure according to the severity of their symptoms into four classes. It places patients in one of four categories based on how much they are limited by physical activity. This classification is shown in Figure 4. Figure 5 shows the progression of a heart failure patient in the simulation graph. Any changes in the signs and symptoms can have an effect on the heart failure categories and change it from one class to another. In the progression of acute heart failure in Figure 6, A shows a good recovery after the first acute episode followed by a stable period. B shows that the first episode is not survived. C shows poor recovery followed by deterioration. D shows ongoing deterioration with intermittent acute episodes and an unpredictable death point. The significant heart failure signs and symptoms can be measured by the patient remotely and be sent to the clinical care department. These include:

edema, obesity, heart rate, heartbeat, blood pressure, saturation of oxygen and body temperature.

The clinical signs, demography, patient history, etc can determine the class of patient's disease and based on this class, the patient can receive the suitable recommendation and treatment.

We will have a huge amount of data on the health

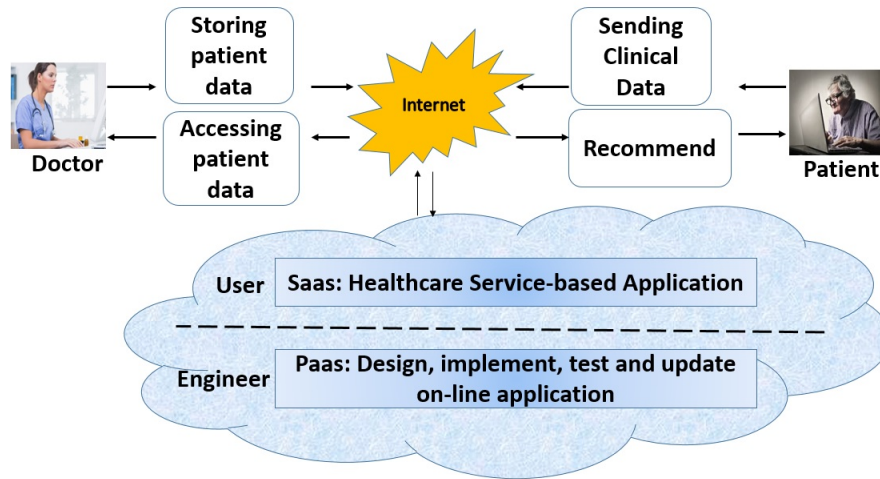


Figure 2: E-health online Algorithm

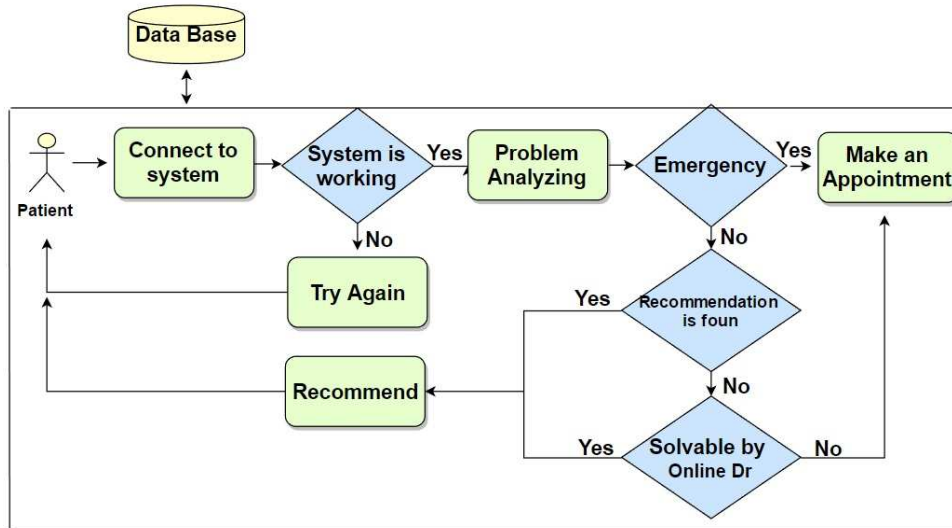


Figure 3: Finding recommendation model

variables that should be formulated to produce the output. [14]. The fuzzy logic system is an approach for computing based on a non-numeric value form of data.

#### 4 Fuzzy logic process

Each fuzzy system design includes the determination of input variables, output variables and fuzzy inference, which is a primary application of fuzzy logic. In the proposed model, input variables are heart failure sign variables and output variables are classes of heart failure. Figure 7 shows inputs, outputs and the model for heart failure classification by use of a fuzzy logic system.

##### 4.1 Input/output variables

Clinical variables are our inputs and class of heart failure is output. Membership function for input and

output is defined from crisp set to present the degree of truth. We get clinical variables as input for classifying heart failure disease into different stages. By using these inputs and their range, we can design membership functions of input variables. With Formula 1,2 and3 for each language expression, we can obtain its membership as follows. Figure 8 shows the membership function chart the variable. The output is the class of chronic disease. These outputs also have to be defined with Formula 1, so we consider a different output variable which is divided into the fuzzy set (State1, State2, State3, and State4).

$$\mu_{\text{Low}}(x) = \begin{cases} 1 & x < a \\ \frac{b-x}{b-a} & a \leq x < b \end{cases} \quad (1)$$

$$\mu_{\text{Normal}}(x) = \begin{cases} \frac{x-a}{b-a} & a \leq x < b \\ 1 & b \leq x \leq c \\ \frac{d-x}{d-c} & c \leq x < d \end{cases} \quad (2)$$





NYHA Class	Level of Clinical Impairment
I 	No limitation of physical activity. Ordinary physical activity does not cause undue breathlessness, fatigue, or palpitations.
II 	Slight limitation of physical activity. Comfortable at rest, but ordinary physical activity results in undue breathlessness, fatigue, or palpitations.
III 	Marked limitation of physical activity. Comfortable at rest, but less than ordinary physical activity results in undue breathlessness, fatigue, or palpitations.
IV 	Unable to carry on any physical activity without discomfort. Symptoms at rest can be present. If any physical activity is undertaken, discomfort is increased.

Figure 4: New York Heart Association (NYHA) Functional Classification of Breathlessness, used in patients with heart failure, grading I-IV.

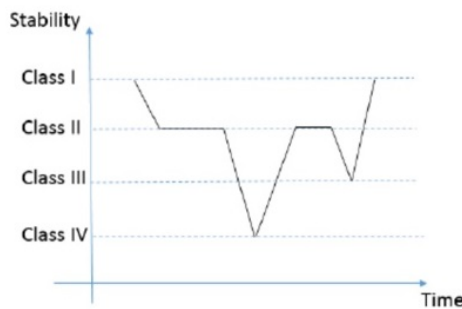


Figure 5: Heart failure classification

$$\mu_{\text{High}}(x) = \begin{cases} \frac{x-c}{d-c} & c \leq x < d \\ 1 & x \geq d \end{cases} \quad (3)$$

## 4.2 Fuzzy Rules Base

After defining the membership function, we have to design the rule-base composed of expert IF-THEN rules[15]. Some parts of these rules are shown in Figure 9. These rules are driven by a different combination of clinical variables[16]. For example:

Rule 1: IF EDEMA =Yes and Obesity= Yes and Heart Rate = High and Blood Pressure = High and Saturation of Oxygen =High and Temperature = High and Previous class = Class 4 THEN the State of Patient = Class 4.

## 4.3 Defuzzification

This step is the process that maps a fuzzy set to a crisp set. The proposed model can use the inference system whose output membership function is a fuzzy

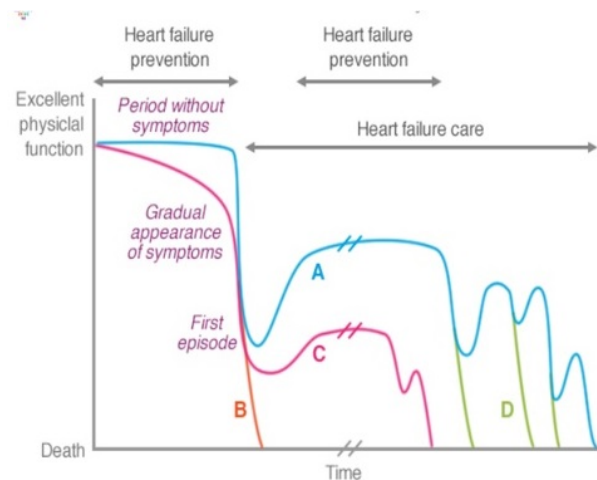


Figure 6: Heart failure classification

set. There are some different methods for the defuzzification whose center of gravity is most prevalent in defuzzification technique. This crisp set is an integer number. Formula 4 shows the method's center of gravity[16],[17] as follows:

$$D^* = \frac{\int D \cdot \mu_M(D) dD}{\int \mu_M(D) dD} \quad (4)$$

## 5 System implementation

### 5.1 The steps in the design of the e-health system

Figure 10 expresses the steps in the design of the e-health model. The first step is to design the patient model. In these steps, based on clinical value and patient history, the patient's level of danger is determined and then, in the next step, the future situation of the patient is predicted. Finally, the recommendation is sent to the patient and the health care system is alerted.

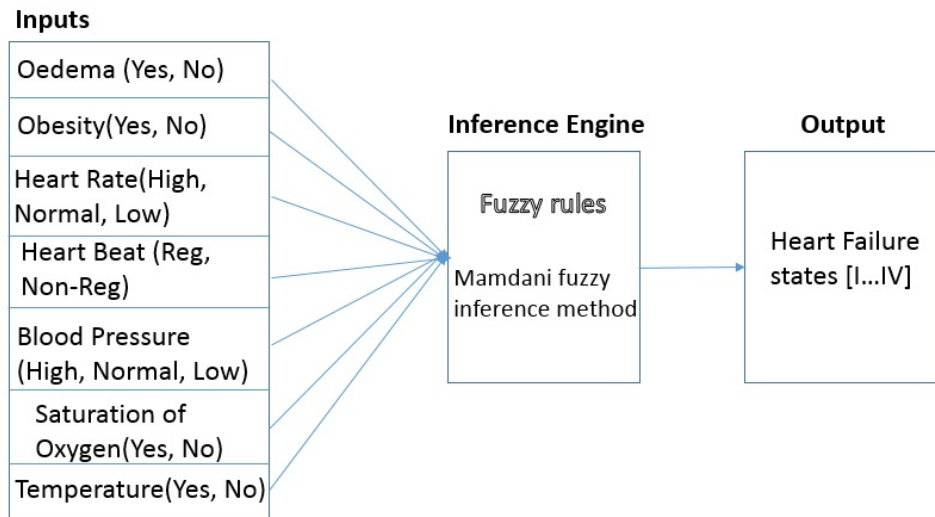


Figure 7: heart failure classification based on clinical variables

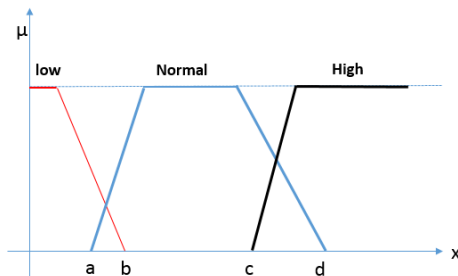


Figure 8: Membership graphic

## 5.2 Integrated e-health cloud model

As we can see in Figure 11, the clinical data of the patient is measured by the patient remotely and sent to the system by using a cloud service (SaaS) over the internet. This data is sent through a SaaS layer to a Paas layer by use of smart devices. The Paas layer applies a fuzzy logic system and this data is used as an input for the fuzzy logic system. The output of the fuzzy logic system shows in which class a patient is placed and according to the class, a suitable recommendation is sent to the patient or the patient is connected to an online doctor. The doctor or healthcare staff are able to access this data and give treatment advice and update the patient's last situation.

## 6 Conclusions

Cloud computing can utilize the healthcare system by providing online monitoring services, application and keeping the data in storage. This data is proposed for analyzing by using fuzzy logic, classifying the patient. Based on this classification, the recommendations is

sent to the patients and alerts are created to the healthcare system. It provides a better quality of service for the health care system and a better quality of life for the patient. It is helpful for the healthcare system management to have the possibility of predicting the critical time and situation of the hospital by using simulation. This proposed model has the possibility of being extended to each type of chronic disease and also being extended to more health variables as well as living and medical conditions. The designed model can be redesigned as long as the analysis of simulation outcome shows that the result is precise and rational enough for the real world.

## Competing interests

The authors have declared that no competing interests exist.

## Acknowledgment

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Rule No	OEDEMA	Obesity	Heart Rate	Heart Beat	Blood Pressure	Saturation of Oxygen	Temperature
Rule1	Yes	Yes	High	Reg	High	High	High
...							
Rule38	Yes	Yes	Normal	Non-Reg	High	High	High
...							
Rule289	No	No	Low	Non-Reg	Low	Normal	Normal

Figure 9: Expressing the IF-THEN rules

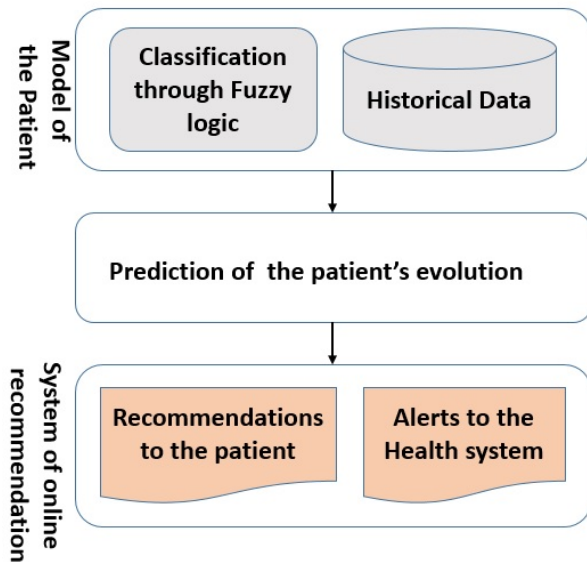


Figure 10: The steps in the design of the E-health model

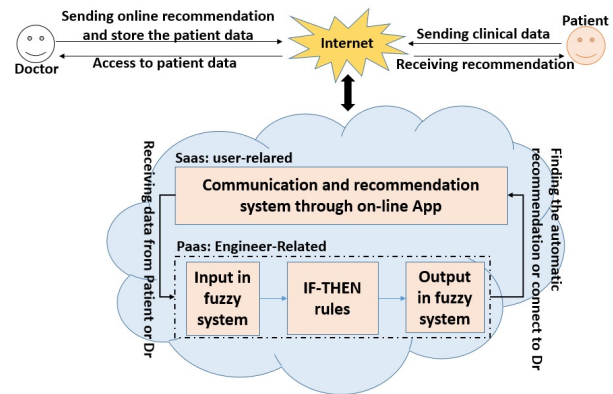


Figure 11: Integrated E-health model using cloud

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