# A Novel Mobile-Cloud based Healthcare Framework for Diabetes

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Abstract: Healthcare is one of the most important sectors in all countries; consuming an average of 9.5% of their domestic product. Among the widely spread endemic diseases, Diabetes is particularly a non-cured one that consumes medical resources, follow-up efforts, regular set of diverse checkups, continual needs for physicians and medical supplies. The current advanced healthcare systems succeeded to be a reservoir of healthcare records focussing on emergency and medical imaging only. At the same time, most of the currently deployed systems cannot provide a daily follow up to patients as well as not being able to help governments to smartly allocate their medical resources. In this paper, we propose a comprehensive framework that incorporates Mobile and Cloud computing with data mining techniques to efficiently provide a real-time smart healthcare framework for Diabetes. Mobile application is emerged as a widely deployed communication tool between the patients and the proposed system hosted on the Cloud. The Cloud is incorporated to accommodate the system due to its known features that makes it possible to acquire continually fresh data from the field. The data is then processed through smart data mining techniques to extract knowledge and draw conclusions for governments. As discussed in the paper, the proposed framework promises a significant enhancement in the resources allocation and utilization, as well as provides a faster emergency response. The proposed architecture has been simulated using Junosphere, a cloud simulator, and it could represent a significant step towards future smart healthcare systems specialized to cover other endemic diseases.

## 1 INTRODUCTION

Countries around the globe spends considerable amount of its resources to provide the best healthcare services to its citizens. Based on 2012 statistics mentioned in (Organization of economics co-operation and development, 2013), developed countries consumed an average of 9.5% of their gross domestic product. For instance, The United States (17.6%), Netherlands (12%), France and Germany (11.6%) were the top four spenders in this sector. One of the most critical diseases that daily consume lot of resources is the Diabetes; as one of the main widespread non-cured diseases. According to the New York Time's magazine, developing countries have a huge percentage of Diabetics that reaches almost 42% of the population. Many of them experience early-stage eye disease, while about 5% are totally blind (Hamdan, 2011). Such high percentages are mainly due to the bad management of the diseases. The only way to avoid impacts of the diabetes is to keep it under regular supervision.

Diabetics suffer from their inability to easily manage their treatments; as it regularly involves taking medications, watching their blood glucose level, keeping their records as well as regularly visiting their physician and performing medical checkups. These boring processes and long queues in medical facilities affect the patients' life-style and by time most of the patients gradually start to neglect their treatments and surround to the implications. Despite the usage of sophisticated healthcare systems in many countries (Löhr, Sadeghi and Winandy, 2010) (Wooten, Klink, Sinek, Bai, & Shar, 2012), this disease is still handled as any disease without efficiently controling this drain of resources. Traditional data collection methods are still used to inspect the diabetes development in the field. Such methods result by their turn in slow feedback cycle and hence obsolete conclusions as well as inefficient action plans. Even, most of the available computer-based solutions can be described as a huge repository of data without real analysis or


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knowledge discovery as it should be.

The need of a smart system that adopts recent IT-technologies with up-to-date communication technologies becomes crucial to cope with this disease and efficiently utilize the available medical resources to provide a better healthcare service to the increasing number of diabetes patients.

In this paper, we propose a comprehensive framework that incorporates Mobile Cloud computing with data mining techniques to efficiently provide a smart healthcare system for diabetes. The smart mobile, as an efficient channel with the patients, is used to vastly acquire patients data at low expenses. The Diabetes mobile application will help patients to fully mange their daily treatment process and will deliver guiding instructions. The Cloud is incorporated to accommodate the system, due to its known features, that makes it possible to acquire real-time diabetes patients' data to be then processed through smart data mining techniques for knowledge discovery. The integrated GPS service available on smart mobiles has been incorporated in the framework to provide patient's spatial location for fast emergency response. As illustrated and discussed through case study, the proposed framework promises a significant enhancement in the health resources allocation and utilization and demonstrates advantages offered to diabetes.

The rest of this paper is organized as follows. Section 2 briefs about Diabetes and its management. Section 3 introduces the background on the mobile-based management systems and current cloud-based healthcare systems. In section 4, we address the proposed framework. In section 5, we illustrate the implementation and simulation of an end-to-end scenario. Finally, the paper is concluded and our future work is reflected in section 6.

# 2 DIABETES MANAGEMENT

In this section, we present a brief about the Diabetes and the disease management.

Diabetes is considered as one of the main non-cured diseases, once infected it remains forever. Diabetes occurs because the body can't use glucose properly, either owing to a lack of the hormone insulin or the insulin available is not effective. This decease has three major types; type I, type II and Gestational diabetes. Having diabetes increases the risk of other health problems, but there are lots of things to do to minimize them; such as maintaining a healthy lifestyle, attending regular check-ups and monitoring glucose levels (BBC - Health: Diabetes, 2013). According to the charity Diabetes UK, more than two million people in UK have the condition and up to 750,000 more are believed to have it without realizing (Hamdan, 2011).

In fact, diabetes is a condition that needs to be managed daily. Diabetes management can refer to dealing with short term events; such as high and low blood glucose to control it over the long term by getting to grips with understanding the condition. Keeping an eye on the blood glucose levels is the key to everyday management of type I and II; as it helps to plan eating, schedule exercise and take medication (Diabetes matters, 2013). Management of diabetes involves more than keeping blood glucose levels under control. It also encompasses keeping blood pressure and cholesterol levels under control, maintaining weight and dealing with the emotional impact of the condition. Diabetes is far from an easy condition to keep under control to the extent that there are a number of different educational courses designed to help people cope with the daily challenges (Diabetes.co.uk, 2013).

# 3 BACKGROUND

In this section, we present the diabetes mobile-based management systems available and the currently implemented cloud-based e-health systems.

## 3.1 Diabetes Mobile-based Management Systems

With the wide use of mobile phones and applications development in different mobile operating systems, different applications have been developed in this field. Known ones are Glucose Buddy, BGluMon, WaveSense and Vree.

Glucose Buddy is a mobile application in Apple Store; featuring log for blood glucose, medication, food and exercise log. Prints out reports are generated in the form of grid table, without analysis (glucose buddy, 2011).

BGluMon (Blood Glucose Monitor), found in Apple Store, is used to watch the patient's blood glucose level on daily basis. It includes the functions of recording and exporting data. Graphs are generated in an advanced way that cannot be useful for novice users (bglumon, 2012).

WaveSense developers had a new idea for measuring blood glucose level; by an invented meter that can be connected to iPhone or any other Apple device and can measure blood glucose level through strips specialized for this meter. After measuring the

blood glucose level, data is saved into WaveSense application automatically (IBG Star, 2012). But this meter and its strips are available only in certain countries; which limit the use of this application.

Vree, also developed for Apple iOS, is specialized for type II diabetes. This application has multiple functions; such as glucose, medication and nutrition tracking; focusing only on type II that none of its functions and calculations can be used for other types of diabetes (Vree, 2012).

On the other hand, the only application in the Android Market is used to get patients information, manage diabetes by tracking food, medication, weight and level of glucose in the blood. By tracking these values, the application can display a summary of the patient's progress and hence archive it (On Track, 2012). Yet, it is limited in other functionalities such as connectivity.

### 3.2 Healthcare Cloud-based Systems

As for e-health systems currently implemented, examples include @HealthCloud, Health Cloud eXchange (HCX), Emergency Medical System (EMS), and HealthATM kiosks.

@HealthCloud is a mobile healthcare information management system that is based on cloud computing and Android OS. It enables healthcare data storage, update and retrieval using Amazon Simple Storage Service (S3). It includes a PHR application that acquires and displays patient records stored in the cloud and a medical imaging module to display medical images on the device. It also supports native multi-touch technology which allows better manipulation of medical images (Doukas, Pliakas and Maglogiannis, 2010).

HCX is a distributed web interactive system that provides a private cloud-based data sharing service allowing dynamic discovery of various health records and related healthcare services. HCX allows sharing health records between different EHR systems and. automatically adapts to changes in the cloud (Mohammed and Fiaidhi, 2010).

EMS is an emergency medical system that accesses PHRs of patients and helps provide timely care. It mainly consists of PHRs platform, EMS application and a Portal to access the former. EMS uses a private cloud to store data; in particular PHR data. It helps facilitate a timely access of relevant information by authorized people in case of emergencies (Koufi, Malamateniou and Vassilacopoulos, 2010).

HealthATM kiosks are developed for patients to manage their own personal health data, integrating services from Google's cloud environment. It provides timely access to relevant health data to patients and strengthens patients' communication with their care providers (Botts, Thoms, Noamani and Horan, 2010). Although, it is also a cost effective solution of personal healthcare management; as they makes use of cloud computing architectures, the systems currently cannot be directly handed over to patients; for constant training, outreach and education are must.

### 3.3 Discussion

The currently available mobile-based management systems are limited for personal use only with scattered capabilities that are not all gathered in one application. In general, they are designed to help a single patient to manage his own diabetic case without any interaction with their physicians.

On the other hand, the cloud-based medical systems are designed to maximize the benefits of treatment and emergency intervention enhancement, while others to save and share healthcare records especially big sized data like medical images. Some of them leverage the benefit of combining the mobile and Cloud. However, this benefit has not been yet interactively addressed through an integrated framework that provides a practical solution for a real medical problem as we do in this paper.

## 4 PROPOSED FRAMEWORK

In this section, we present a comprehensive framework that incorporates Mobile Computing and Cloud computing with data mining techniques to efficiently provide a smart healthcare system for fully supporting Diabetes.

With the fast and widely available smart phones, the mobile application is meant to be a fast and portable efficient connection method between the system and the citizens. Through such communication channel, data can be vastly and vigorously acquired from the field at low expenses and in a parallel manner along the country saving valuable time and resources. Guiding instructions are also delivered to the citizens anywhere and anytime through the same channel. In addition, diabetes medical sensors are integrated with the mobile to help the patient in his daily life.

The Cloud, on the other hand, is incorporated to accommodate the system due to its broadly 24/7 availability, scalability, and huge storage capabilities

that makes it possible to support huge number of concurrent users access on the run. This feature by its turn makes it possible to acquire continually fresh updated medical record and feedbacks from citizens.

The acquired data will be then processed through data mining techniques and knowledge discovery algorithms to smartly benefit from such huge pool of fresh data. Important and useful relation between data can be efficiently deduced; specifically the spatial distribution of the data sources (known by the smart mobiles GPS) will bring a long list of advantages and edge of knowledge in this field. Reports will be generated regarding Diabetes with updated patients' spatial distribution; which allows to efficiently reallocating medical resources. Most importantly, spontaneous response in emergency case can be delivered to citizens; through medical sensing and GPS signal sent to emergency units.

The proposed framework is an efficient solution to the above mentioned problems. Having mobile computing as an interface with citizens permits an interactive communication with them; storing their personal health records updated. The proposed framework promises a significant enhancement in the health resources allocation and utilization problem, as well as healthcare service provision.

This section is organized as follows. Sub-section 3.1 lists the intended beneficiaries and contributors. Sub-section 3.2 illustrates the architecture and sub-section 3.3 details the modules of the framework.

## 4.1 Beneficiaries

The beneficiaries and contributors in the proposed framework are intended to be:

- *Diabetic Patients (or rather the citizens enrolled in the governmental medical insurance):* Patients store their own health-related data through the mobile application; the Personal Health Record (PHR). Patient can enter all info related to his disease management; such as daily blood glucose level, regular check-ups.
- *Medical care institutions:* Medical care institutions maintain and manage PHRs entered by patients; updating them with medical information to be stored as Electronic Health Records (EHR) in the cloud and shared with professionals specialized in Diabetes. Diabetes professionals can import data in EHRs; such as x-ray photos or laboratory tests.
- *Emergency units:* Emergency units receives location signal from the citizen mobile GPS, in case of emergency. Emergency units can then handle the case giving spontaneous response.
- *Governments:* Analyzing data with high refresh rates gathered from the country population, generated reports about diabetes distribution help in efficient resources reallocation.
- *NGOs:* Acquiring any kind of reports, it could be generated out of the large and well-analyzed data collected. This can help such organizations to effectively direct their resources for better serving the community.

## 4.2 Architecture

The proposed framework is based on Mobile Cloud Computing. The framework architecture is illustrated in Figure 1.

Cloud Computing has made a revolution on the computing world by the non-traditional mechanisms in computing. Governments, getting use of the widely know advantages of cloud infrastructure; can efficiently provide their healthcare services at lower cost computing infrastructures.

On the other side, smart phones and tablets are considered as the representative for the various mobile devices as they have been connected to the Internet with the rapidly growing of wireless network technology. Ubiquity and mobility are two major features in the next generation network which provides a range of personalized network services.

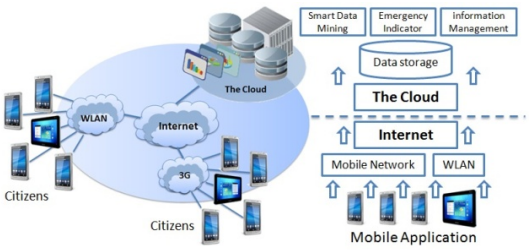


Figure 1: Framework architecture.

## 4.3 Modules

The framework is composed of two modules sets; one on the mobile side for citizens' functionalities and the other on the cloud side for governments and healthcare sector functionalities. Interaction of different modules is depicted in Figure 2.

The description of modules is as follows:

- *Mobile Application:* is the citizen's interface for PHR data. The application is deeply analyzed to include the major diseases with their types, different degrees of severity and medications. It is meant to be the data input channel of citizens. Such mobile application is an effective companion for the patient; providing updated

guiding about his health case. In case of emergency, a signal is sent to the emergency units, allocating his position by GPS, for his life saving. Medical sensors for glucose level are integrated with the smart phone.

- *Privacy Control module:* Health information requires extra protection; as its disclosure can have serious repercussions in the content owner's private and professional life. Husky eHealth 2.0 (Levy, Sargent and Bai, 2011) is a prototype of healthcare social network system with a trust-aware tag-based privacy control scheme is embedded in the framework for privacy control. The scheme protects private information from unauthorized access using both tagging and trust ratings information.
- *Cloud Data Repository:* a repository of data stored on the cloud representing a real updated PHR for diabetics to be used for effective data mining analysis.
- *EHRs module:* a system of EHRs updated by medical and health professionals and will be used for effective data mining analysis.
- *Medical Image Archives Management:* Server-side part of the service realizes medical image archives management, pre-processing and rendering of these images in the cloud. Main functions of client-side are interaction with the end-user and visualization of rendered information (Vazhenin, 2012).
- *Emergency Case Indicator:* Emergency units receives location signal from the citizen mobile GPS, in case of emergency. Emergency units can then handle the case; giving spontaneous response.
- *Data mining Module:* Health records and feedbacks from citizens are processed through smart data mining techniques and knowledge discovery algorithms. Generated reports about

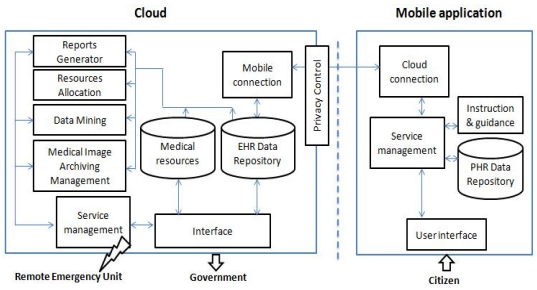


Figure 2: Framework modules.

diabetes distribution are the input in resources management and reallocation. Another set of reports help NGOs to effectively direct their resources for better serving the communities.

- *Medical Resources allocation module:* Resources are easily reallocated based on the reports for better service provision and cost cutting.

# 5 IMPLEMENATATION

To illustrate the benefit of the proposed framework, an end-to-end scenario is discussed passing through the entire components of the proposed framework. First, we show how data is acquired from the patients through the developed mobile application and then stored on the Cloud. Second, we describe the knowledge and conclusions that we can extract from the acquired data through the data mining techniques adopted on the Cloud. This scenario has been simulated using Junosphere, a cloud simulator. This simulation will clearly demonstrate the benefits provided by the proposed framework to both diabetic patient and government decision makers. Results are then demonstrated and the applicability of the framework in different countries is discussed.

## 5.1 Mobile-based Application for Diabetes Management

The mobile-based application (Salama and Shawish, 2013) was developed to provide a comprehensive set of functionalities that help the diabetic to easily and smartly supervise his disease on daily basis. These functionalities cover a careful follow-up of the patient's glucose level, nutrition, and medications. It also keeps him always connected with his physician, up-to-date with new diabetes treatments, in addition to many other services that make the patient able to fully manage his diabetes.

Using this application, the patient can add his log; including result of daily glucose level, medications information, and display all the past results. The results are analyzed and shown as visualized graphs. The application also embeds an updated guide for the patient, to plan healthy eating, and schedule exercises, gathering all new information about the disease from different specialized portals. Figure 3 is a sample of a patient log using the developed mobile application.

The mobile-based Diabetes management application requires logging of the following data (Salama and Shawish, 2013):

- Patient basic info; name, date of birth, gender, smoking status, other medical records, other genetic records, place of residence
- Daily records of blood glucose figures, insulin

dosages, records of medications.
- Food and exercises logs
- BMI (Body Mass Index), BMR (Basal Metabolic Rate), and Calories Burned Calculator
- Records of health downs
- Current location, through GPS

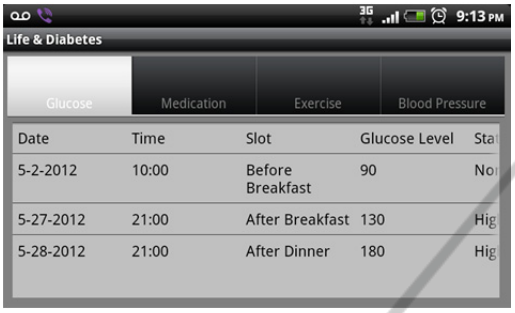


Figure 3: Interface of Patient log.

Having the data items logged on regular basis in an easy manner, the patient will be able to perform his medical follow-up correctly and his medical history will also be kept. On the other hand, such data will be securely saved on the Cloud side to be further processed through knowledge extraction techniques; as clarified in the below section.

## 5.2 Cloud Simulation

The cloud architecture has been simulated using Junosphere, a cloud simulator (Junosphere, 2013); leveraging the features of building complete topologies, connecting physical devices and passing real traffic to the simulation. A topology is built using two VMs, two VJX routers with 16 ports (vjx0 and vjx1) that are connected to each other through port em1 and a Centos (Linux) server. The two VMs are acting for generating bulk data entry for simulation purpose and the Centos server is acting as

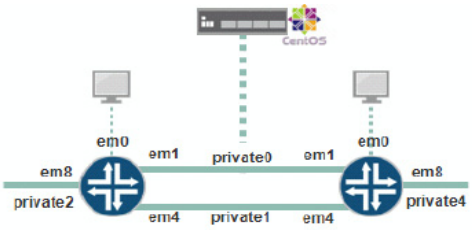


Figure 4: Cloud simulation.

data repository and reports generator. Mobile devices are also connected to the built topology by Junosphere connector. Figure 4 is a screen shot of the simulated topology.

## 5.3 Results

Data with high refresh rate, gathered through the mobile application from the citizens, are processed through knowledge extraction techniques. The below information can be straight forward deduced:
- Spatial distribution of the patients, medication needs, and the disease severity.
- Daily follow-up of the patients' status.

While the following knowledge can be easily concluded:
- Real needs, usage and excess of medical resources.
- Efficiency of the healthcare centers locations.
- Coverage of the needed physicians
- Efficiency of medical campaigns in rural areas
- Real needs of diabetes medications and their availability
- Factors causing diabetes and high records based on location

Taking the diabetes in UK as an example, the distribution of the diseases in UK is shown in Figure 5 (Diabetes amputation rates show huge regional variation , 2012), while the distribution of people with diabetes who received all basic care processes recommended in the Department of Health's standards of care is illustrated in Figure 6 (QiC Quality in Care, 2012). In fact, the National Audit Office (NAO) report published in 2012 stated that only half of the 2.34m people diagnosed with diabetes received the nine annual basic care processes. Meanwhile, both maps show how much efforts and resources should be redirected to other regions where diabetes is present with high percentages, instead of being wasted in unneeded areas. Having accurate information from diabetics and actual spatial distributions would help overcoming resources allocation problems.

The extracted information will help the decision makers and researchers in the following:
- Efficient distribution of medical resources, based on real needs
- Smart planning for building healthcare units
- Planning for healthcare and medical mobile campaigns, based on new disease spread
- Efficient planning for medications industry, based on real demand with no excess in production
- Smart prediction of similar future patterns for diabetes
- Directing NGOs to put their efforts in the right places, where the disease needs real effort
- Putting research efforts in the right track; in terms of factors causing the diseases and effective treatment

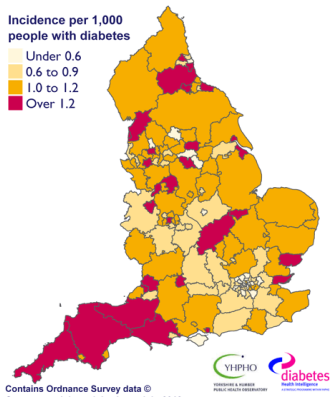


Figure 5: Diabetes Distribution UK.

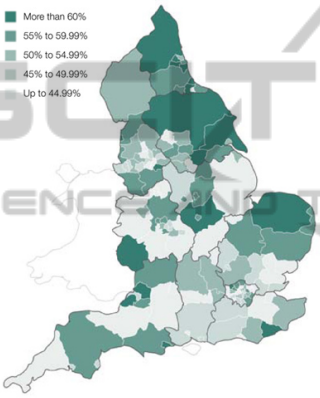


Figure 6: Diabetics who received all basic care processes.

Governments with current strong healthcare systems are meant to enhance their services by effectively reallocating resources. The literacy rate, people awareness, financial conditions, healthcare investments, population covered under healthcare insurance policies are much better in these countries. Meanwhile, this framework represents a cost cutting in the health sector by implementing efficient resources allocation and lowering the IT infrastructure cost. With the advances in their health sector, better service could be provided; by implementing enhanced secured EHRs and emergency indicator.

On the other side, healthcare scenario in developing countries doesn't report a good status. A large percentage of people are residing in rural areas. The population density is high near big cities. Rural areas, low density population areas or hilly areas have shortage of medical facilities with the existence of primary care centers only, where people rush to the urban areas for expert medical advice or in case of emergency. The literacy rate in the developing countries is very low and the illiteracy rate is very high in the rural areas. Those people aren't much aware of their healthcare needs; they do not follow the regular checkups and emergent. Hence, being connected with those people through mobile application will make their life easier; while the government will be updated of approach the doctor in case the situation become their medical condition and could easily allocate more resources in case of needs.

## 5.4 Expected Benefits

The proposed framework presents mutual benefits for both diabetics and governments. The mobile application helps the citizens on personal basis managing their disease case and on-going life easily. Storing the patient records regularly helps the physician in correctly prescribing the case. Since the physician can update the record with more detailed medical information, the complete medical history for the patient is, then, stored and kept. The cloud storage allows easier retrieval from any spot of the healthcare system along the country.

From governments' perspective, the use of cloud is a cutting cost in the IT infrastructures for e-health services. In addition, the extracted knowledge from the acquired up-to-date data promises a significant enhancement in the healthcare related decision making process. Adding the emergency case indicator connected to GPS satellites helps in providing better service and life saving.

## 5.5 Comparative Evaluation

Comparing the proposed framework with the current mobile ad cloud-based solutions, we can easily notice that the proposed one enable the data saved by the diabetes patient to be share with his physician opening the chance for more interaction especially in critical cases. This is in addition to the combined set of functionalities that are scattered among a group of separate applications. The proposed framework also enabled the anonymously collected medical data to be further analysed on the Cloud, opening a perfect chance for knowledge discovery based on a high rate of fresh data and hence smarter decision making.

On the other hand, the available mobile-based solutions are limited to personal use only without any external interaction, while Cloud-based solutions focus on saving healthcare records especially big sized data like medical images from hospitals and medical centres without a true effort the extract knowledge out of this data.

# 6 CONCLUSIONS AND FUTURE WORK

The proposed framework smartly combined the broadly available technologies; smart phones and Cloud computing; in addition to intelligent data mining techniques to efficiently provide a smart healthcare framework for Diabetes.

With the fast and wide availability of smart phones, the mobile application represent a low cost, fast, and vigorously tool that help the government to acquire knowledge from the citizens in a parallel manner, while saving valuable time and resources. It has also been recognized as a fast communication channel to deliver guiding instructions and spontaneously manage emergencies.

With broad availability, scalability, and huge storage capabilities, the Cloud, on the other hand, showed a perfect ability to accommodate the healthcare system holding tones data of millions of concurrent users. The data mining techniques and knowledge discovery algorithms have smartly benefit from the huge amount of fresh data. Important and useful relations between data have been deducted allowing an efficient utilization and reallocation of medical resources, in addition to predict disease patterns and hence efficiently cope with them.

Our future work focuses on the development of interactive mobile applications covering more endemic diseases with the appropriate connection with the cloud-bases healthcare system.

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