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S2DIA: A Diagnostic System for Diabetes mellitus using SANA platform

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Abstract — **Currently, Diabetes is a very common disease around the world, and with an increase in sedentary lifestyles, obesity and an aging population the number of people with Diabetes worldwide will increase by more than 50%. In this context, the MIT (Massachusetts Institute of Technology) developed the SANA platform, which brings the benefits of information technology to the field of healthcare. It offers healthcare delivery in remote areas, improves patient access to medical specialists for faster, higher quality, and more cost effective diagnosis and intervention. For these reasons, we developed a system for diagnosis of Diabetes using the SANA platform, called S2DIA. It is the first step towards knowing the risks for type 2 Diabetes, and it will be evaluated, especially, in remote/poor areas of Brazil.**

I. Introduction

Diabetes mellitus is a disease that causes a state of high levels of glucose in the blood, leading to several vascular complications. Insulin is a key hormone in the metabolism of glucose. It is responsible for the increase of cell membrane permeability, which in turn allows the cell to receive the glucose and to transform it into energy, which is then used to perform all other cell functions. Diabetes is the loss of the effectiveness of insulin, either by the resistance of its action in the tissues or by lack of this hormone.

Currently, Diabetes is a very common disease around the world. With the increase of sedentary lifestyles, obesity and an aging population, the number of people with Diabetes worldwide will increase by more than 50% by the year 2025, affecting an estimated 380 million people [1]. In Brazil, Diabetes affects about 12% of the population, approximately 22 million people [2]. Furthermore, it is estimated that about 50% of patients do not know that they have Diabetes [4] [5]. Therefore, it is very important to understand the risk factors of this disease.

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In this context, MIT (Massachusetts Institute of Technology) has focused on projects that utilize the benefits of information technology in the healthcare field. For instance, the SANA platform [9] has revolutionized healthcare delivery in remote areas through innovative mobile information services that improve patient access to medical specialists for faster, higher quality, and more cost effective diagnosis and intervention. Thus, healthcare workers can run a procedure and collect patient data using the Sana application, which then uploads the information to OpenMRS for a doctor to review. After reviewing the case, doctors can notify the healthcare worker of the diagnosis by sending the results to the Sana app [9].

Given all these facts, the aim of this work is to develop a system for diagnosis of Diabetes using the SANA platform, called ***S2DIA***. This system is based on several risk factors for type 2 Diabetes, and it makes a pre-analysis of diagnosis in real time, informing the doctor's final diagnosis. Also, it is the first step towards knowing risks for type 2 Diabetes, which is important because every person who knows that they are at risk for type 2 Diabetes is one more person with the power to stop it. Finally, this project will be evaluated, especially, in remote/poor areas of Brazil.

This paper is organized as follows: Section II discusses the symptoms, types and risk factors of Diabetes; Section III addresses MIT's SANA platform; Section IV presents the ***S2DIA*** system; Section V presents an experimental evaluation of the system; finally, in Section VI, the conclusions and remaining challenges are presented.

II. Diabetes Risk Factors

Diabetes is more frequent in the adult population, and it is associated with an increased risk for cardiovascular disease and microvascular complications. The diagnosis of this disease should be performed early and with sensitive and accurate methods, since lifestyle changes and correction of hyperglycemia may delay the incidence of Diabetes and its complications.

The current classification of Diabetes is divided into *Type 1* and *Type 2 Diabetes*. *Type 1 Diabetes* involves the destruction of insulin producing cells in the pancreas. This type of diabetes is rare and happens frequently in young people. In these cases, the lack of insulin production causes an increase of glucose in the blood. *Type 2 Diabetes* is characterized by a disturbance of insulin action and secretion, with a predominance of one or another component [6,8]. *Type 2 Diabetes* is more common than *Type 1*, accounting for approximately 90% of all Diabetes cases and is, consequently, the focus of the study. Table I summarizes the main differences between the two types of Diabetes.

In general, the majority of diabetic patients does not present symptoms and only become aware of their disease after it is detected during routine blood glucose tests. However, the classic symptoms of Diabetes are: polydipsia (thirst), polyphagia (extreme hunger), and polyuria (excessive urination).

TABLE I. TYPES OF DIABETES [8].

Type 1 Diabetes	Type 2 Diabetes
1. Beta cell destruction, usually leading to a complete deficiency of insulin;	1. Varying degrees of reduction of secretion and insulin resistance;
2. Youth diabetic;	2. Old diabetic;
3. Insulin-dependent;	3. Insulin-eventual;
4. Generally thin.	4. Generally obese.

According to [6,7,8], all people over the age of 45 should be tested for Diabetes every three years. For asymptomatic individuals presenting risk factors for developing Diabetes, these tests should be performed more frequently. Table II presents the main risk factors of Diabetes.

TABLE II. RISK FACTORS OF DIABETES [8].

1. Age above 45 years;
2. Obesity (greater than 120% ideal weight or body mass index 25 kg/m^2);
3. 1st degree family relatives with cases of diabetes;
4. Gestational diabetes or previous macrosomia;
5. Hypertension;
6. HDL cholesterol below 35 mg/dl and/or triglycerides greater than 250mg/dl;
7. Previous alterations of glucose regulation;
8. Individual members of populations at risk (African-Americans, Hispanic-Americans and others).

Therefore, our work is based on these risk factors in order to develop the ***S2DIA*** system within the SANA platform, which will be used to assist in the diagnoses of Diabetes and to monitor patients in areas where medical care is scarce.

III. SANA PLATFORM

The SANA platform was developed by MIT [9], and its main goal is to bring medical care to areas where medical assistance is scarce, mainly providing remote medical diagnosis. The system provides an instant end-to-end infrastructure for media-centric remote decision support by experts. The SANA platform has revolutionized healthcare delivery in remote areas through innovative mobile information services that improve patient access to medical specialists for faster, higher quality, and more cost effective diagnosis and intervention [9]. Then, healthcare workers collect patient data using the Sana application. Next, these will be sent to OpenMRS (*Open Medical Record System*), where one or more doctors will review. Finally, doctors will notify the health worker of the diagnosis by sending results to Sana application. Figure 1, designed by [9], presents the SANA infrastructure. OpenMRS is an application which enables design of a customized medical records system with no programming knowledge (although medical and systems analysis knowledge is required). It is a common framework upon which medical informatics efforts in developing countries can be built. The system is based on a conceptual table structure which is not dependent on the actual types of medical information required to be collected or on particular data collection forms and so can be customized for different uses [14].

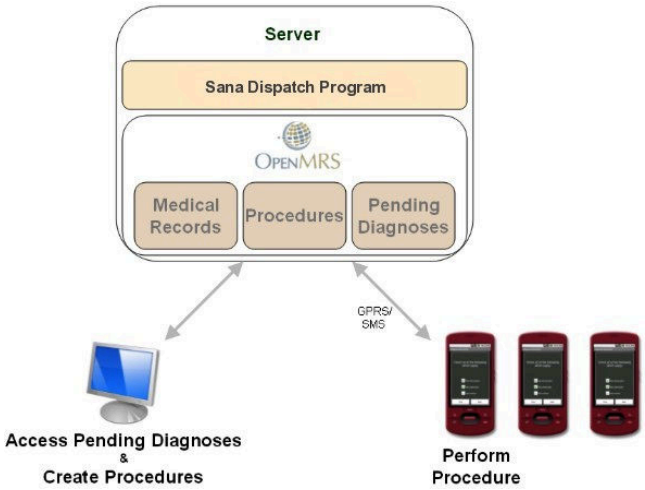

Figure 1. SANA Infrastructure [9].

IV. *S2DIA* SYSTEM

S2DIA was developed to give pre-diagnosis of type 2 Diabetes and, also, to inform the doctor's final diagnosis. It can be used mostly in remote/poor areas where medical assistance is scarce because the packetization, a synchronization model, and multi-modal data transport allow any system implemented into Sana to operate even in poor cellular coverage areas. While the system is mobile-centric, it is designed to provide alternatives such as Wi-Fi and tethered uploads for bandwidth-constrained situations [9].

Based on the SANA system and Diabetes risk factors presented in Table II, the acquisition of data in ***S2DIA*** was developed and shown in Figure 2. The ***S2DIA*** analyzes the patient's features as well as their previous and current health conditions. It also allows the user to attach a picture of the patient's entire body, which is then sent remotely to a doctor for analysis. In order to respond to the first question shown in Figure 2, it is necessary that the patient have an account on the SANA Server platform or the patient can be registered at the moment of execution of the ***S2DIA***. Also, with the use of other software, it is possible to register the patient's fingerprints.

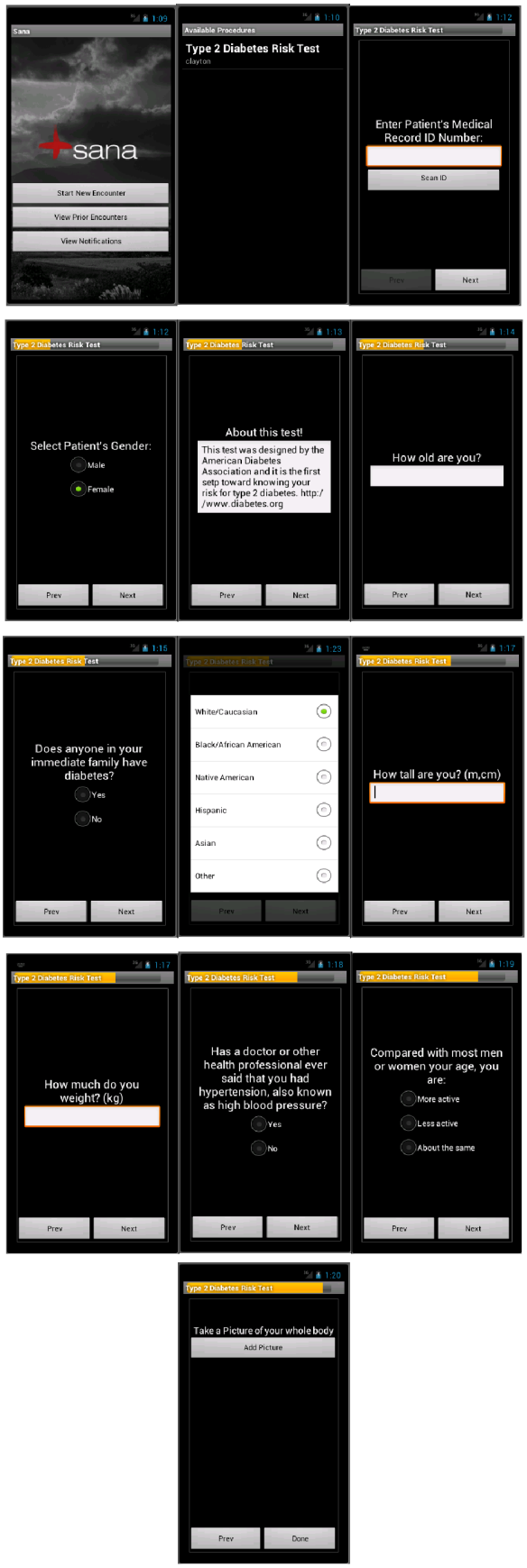

Figure 2. SANA screens from the ***S2DIA*** System.

V. Experimental Evaluation

We obtain some results from data acquired by ***S2DIA*** (Figure 2). All information was stored in OpenMRS database, approximately 100 records of patient, in which are related to *Type 2 Diabetes* risk factors (Table II). To inspect the behavior of our approach, all records were checked by medical specialist, after we were realized statistical analysis.

Then, relying on our sample data, Figure 3 shows the graph of *degree of risk for Type 2 Diabetes (percentage)* by *gender*, in which approximately 70% of men are more probable to have *Type 2 Diabetes* than women. Another important analyze, excluding diabetic patient, Figure 4 shows the graph of *degree of risk for Type 2 Diabetes (percentage)* by *age*, where the patients (*independent of gender*) with until 38 years old present stable risk of obtaining the disease, whilst the patients above that age the risk increase linearly.

However, it is important to emphasize that our sample data is small and therefore the statistical analysis may not be representative when compared to a larger and complex medical datasets. Nevertheless, many interesting data may be obtained from real data, especially, in poor areas of Brazil, where ***S2DIA*** will be evaluated later.

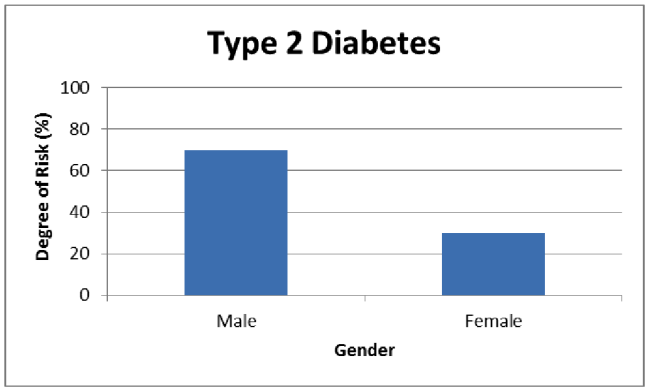

Figure 3. Degree of Risk for Type 2 Diabetes vs. Gender.

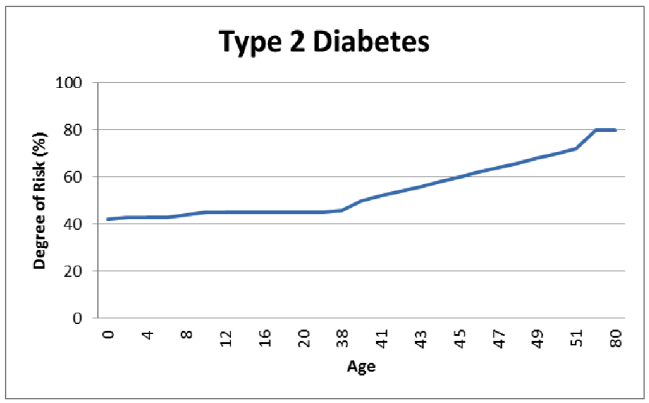

Figure 4. Degree of Risk for Type 2 Diabetes vs. Age.

VI. Conclusions and Remaining Challenges

In this paper we presented ***S2DIA***, a system for pre diagnostics of Diabetes using the SANA platform. It is based on several risk factors for *Type 2 Diabetes*, and it makes a

pre-analysis of these factors in real time, informing the doctor's final diagnosis. Also, it is one of the first steps towards knowing the risk factors for *Type 2 Diabetes*. As described above, it can be applied mostly in remote/poor areas because the packetization, a synchronization model, and multi-modal data transport allow any system implemented into SANA to operate even in poor cellular coverage areas.

During the development of this work, several aspects were identified that need to be further developed, such as: (i) extension of the SANA platform to allow the use of a glucose meter with USB communication; (ii) implementation of an intelligent system in the SANA platform to perform pre-diagnosis of patients with Diabetes and to help the doctor with his/her final diagnosis. In [11] an intelligent system for diabetes diagnostics was proposed, but it does not work with the technology of SANA. Finally, (iii) testing and validation of ***S2DIA*** system in remote and poor areas of Brazil where healthcare is scarce. Furthermore, the data obtained will be important for monitoring of individuals (group) that have high risk of Diabetes.

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