
REMOTE MONITORING AND AUTOMATED DIAGNOSIS VIA INTERACTIVE SOFTWARE INTERFACE USING WIRELESS COMMUNICATION NETWORK
"TELEMEDICINE"

BY

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ABSTRACT

Remote monitoring and automated diagnosis via interactive software interface using wireless communication network, tends to come up with ways of diagnosing patient ailment in remote areas which is due to the absence of expert medical personnel in rural areas. The methods involve interconnection of stages as blocks like Collect, transmit, evaluate, modify and intervene process. The process adopt the use of GSM network for Communication. A Pseudo code and Software was developed with the aid of Visual Basic Program to enable login which will reveal captured patient records from a series of developed Software interfaces to provide patient history, Database for onward transmission to the Doctor, the result is viewed via an interface that provided the Doctor's diagnosis and prescription

Keyword: Telemedicine, GSM, Software interface, Patience record

INTRODUCTION

Worldwide, people living in rural and remote areas struggle to access timely, quality specialty medical care. Residents of these areas often have access to substandard specialty healthcare, primarily because specialist physicians are more likely to be located in areas of concentrated population. There is also the challenge of having very few experts especially those managing chronic diseases even in the urban areas. Effective management of diseases especially

chronic diseases can result in improved health outcomes and increased quality of life since more than 80% of primary care visits and two thirds of medical admissions into hospital emergency departments are related to chronic diseases. For example, controlling a parameter such as blood pressure in people with diabetes and hypertension has been shown to reduce mortality and incidence of severe and costly complications such as renal and cardiovascular disease.

(http://www.nehi.net/publications/42/detailed_technology_analysis_home_telehealth>

Health care systems are now changing due to the dynamic nature of technological and scientific medical practices. The health care providers are now swiftly adopting these technologies into their health care procedures. Because of innovations in computing and communication technologies, many elements of medical practice can be accomplished when the patient and health care provider are geographically separated. The separation can be as small as across a town, across a state or even across the world.

Remote patient monitoring is relatively a new area of interest which enables medical professionals to monitor a patient remotely using various technological devices. It is primarily used for monitoring chronic diseases or specific diseases like heart diseases, diabetes mellitus, and hypertension

e.t.c.(<http://www.gsmfavorites.com/document/introduction,2010>)

The transfer of these medical data can be done through a variety of telecommunication technologies including ordinary telephone lines, ISDN, internet, intranets, satellites and mobile phones to mention but a few. This work entails the transfer of medical records taken remotely to a doctor via GSM wireless communication link. Specifically it makes use of the Short Messaging

System (SMS) of the Global System for Mobile communication (GSM). The records are taken by a nurse and stored in the hospital database via a visual basic developed user-interface. Whenever the threshold for certain parameters set by the doctor is exceeded an SMS alert is sent to the doctor indicating an emergency to which the doctor sends back a reply giving directives to the caregiver on procedures to undertake pending his arrival. On the doctor's visit, the history of records taken during his time of absence can be accessed by him for proper diagnosis and prescriptions for the patient which is equally stored in the database. Also if there is a new patient, the record is sent automatically to the doctor.(Burri and Senouf, 2010)

Health Monitoring

The major objective of this work is to make health care services available to isolated communities and remote regions like military bases, ships and the like. It is also aimed at reducing mortality rate especially in developing countries like Nigeria where the needed expertise is limited. The system should be able to significantly reduce the time taken in making health care accessible to them. The burden of inferior healthcare will be taken care of through this system. This system can be extended in its application to areas like fine-tuning the management and allocation of rural health care emergency services by transmitting images

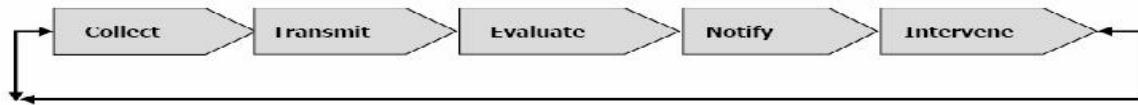


Figure 1: Remote Patient

to key medical centres for long distance evaluation by appropriate medical specialists as patterned in the order shown in figure 1, Finally since the cost of complete remote patient monitoring system which incorporates the sensors used for capturing biometric data is very high, this system goes a long way in making remote monitoring accessible to the common masses who cannot afford the cost of services rendered by those complete systems as they can take their readings manually. (Bisognano M, Boutwell A, 2009)

Principles Applied

The project employs about three major engineering principles in its operations. These principles are:

- (a) Principles of Telemedicine
- (b) Wireless mobile telephone communication principles
- (c) Database Management Principles

Principles of Telemedicine

Telemedicine is a rapidly developing application of clinical medicine where medical information is transferred through interactive audio-visual media for the purpose of consulting, and sometimes remote medical procedures or examinations. Telemedicine may be as simple as two health professionals discussing a case over the telephone, or as complex as using satellite technology and videoconferencing equipment to conduct a real-time

consultation between medical specialists in two different countries. Telemedicine generally refers to the use of communications and information technologies for the delivery of clinical care.

Remote monitoring

Remote monitoring, also known as self-monitoring/testing, enables medical professionals to monitor a patient remotely using various technological devices. This method is primarily used for managing chronic diseases or specific conditions, such as heart disease, diabetes mellitus. Examples of remote monitoring include:

- Home-based nocturnal dialysis
 - Cardiac and multi-parameter monitoring of remote ICUs
- Home tele-health
- Disease management
- **Interactive telemedicine** services provide real-time interactions between patient and provider, to include phone conversations, online communication and home visits. Many activities such as history review, physical examination, psychiatric evaluations and ophthalmology assessments can be conducted comparably to those done in traditional face-to-face visits. In addition, "clinician-interactive" telemedicine services may be less costly than in-person clinical visits.

Benefits and Uses of Telemedicine

Telemedicine is most beneficial for populations living in isolated communities and remote regions and is currently being applied in virtually all medical domains. Specialties that use telemedicine often use a "tele" prefix; for example, telemedicine as applied by radiologists is called Teleradiology. Similarly telemedicine as applied by cardiologists is termed as telecardiology, etc.

Applications

The most commonly used data application on mobile phones is SMS text messaging, with 74% of all mobile phone users as active users (over 2.4 billion out of 3.3 billion total subscribers at the end of 2007) (Coye, DeMello, 2009)

SIM card

In addition to the battery, GSM mobile phones require a small microchip, called a Subscriber Identity Module or SIM Card, to function. Approximately the size of a small postage stamp, the SIM Card is usually placed underneath the battery in the rear of the unit, and (when properly activated) stores the phone's configuration data, and information about the phone itself, such as which calling plan the subscriber is using. When the subscriber removes the SIM Card, it can be re-inserted into another phone that is configured to accept the SIM card and used as normal (<http://userpages.umcb.edu/~khoo/survey2.html>. 2010)

Each SIM Card is activated by use of a unique numerical identifier; once activated, the identifier is locked down and the card is

permanently locked in to the activating network. For this reason, most retailers refuse to accept the return of an activated SIM Card. Those cell phones that do not use a SIM Card have the data programmed in to their memory. This data is accessed by using a special digit sequence to access the "NAM" as in "Name" or number programming menu. From here, one can add information such as a new number for the phone, new Service Provider numbers, new emergency numbers, change their Authentication Key or A-Key code, and update their Preferred Roaming List or PRL. However, to prevent someone from accidentally disabling their phone or removing it from the network, the Service Provider puts a lock on this data called a Master Subsidiary Lock or MSL [23]. The MSL also ensures that the Service Provider gets payment for the phone that was purchased or "leased". (ATIS, 2007)

Data structure

Software interface developed where confined to a Data structures (fields, records, files and objects) optimized to deal with very large amounts of data stored on a permanent data (which implies relatively slow access compared to volatile main memory). (Heinrich, 2010)

Database query language

The work came up with database query language and report writer allows users to interactively interrogate the database, analyse its data and update it according to the users' privileges on data. It also controls the security of the database, this Data security prevents unauthorized

users from viewing or updating the database. Using passwords, users are allowed access to the entire database or subsets of it called *subschemas*. For example, an employee database can contain all the data about an individual employee, but one group of users may be authorized to view only payroll data, while others are allowed access to only work history and medical data.(Alfred ,1904)

If the DBMS provides a way to interactively enter and update the database, as well as interrogate it, this capability allows for managing personal databases. However, it may not leave an audit trail of actions or provide the kinds of controls necessary in a multi-user organization. These controls are only available when a set of application programs are customized for each data entry and updating function.

METHODOLOGY

There are basically four types of system methodology:

1. Prototyping system methodology
2. Expert system methodology
3. SSADM - Structured Systems Analysis and Design Methodology
4. OOADM - Object-Oriented Analysis and Design Methodology

Object-Oriented Analysis and Design approach was used for this work.

System Specification

a) The software subsystem: this deals with the collection of data from patients, the storage of such data, and the retrieval of the data for diagnostic purposes by the doctor and the transfer of needed information to the serial port of the computer system for onward transfer to the doctor in cases of emergency., figure 2 is a Block Diagram Of The Top Down Design of The System

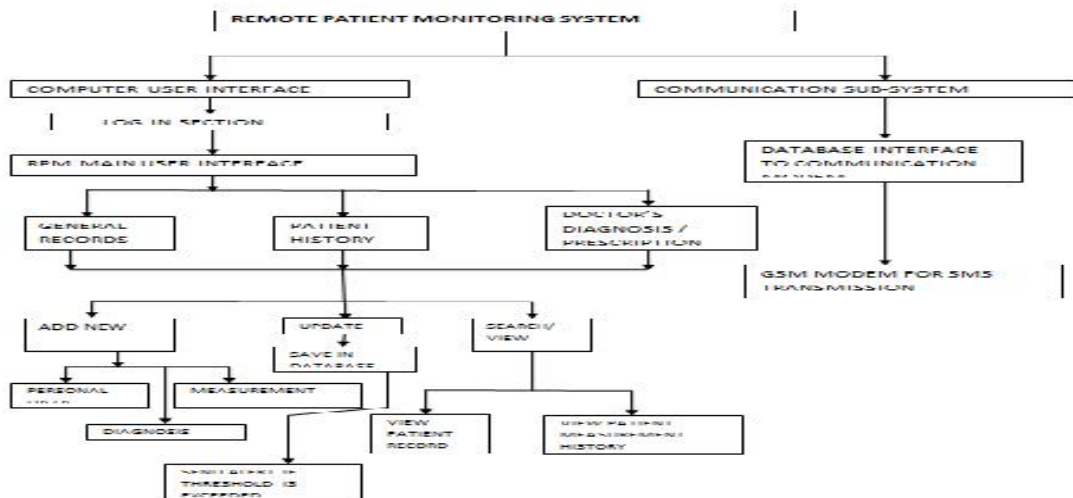


Figure 2: Block Diagram of the Top down Design of the System

b) The Hardware sub-system: this sub-system is concerned with the transfer of information from the database to the doctor in cases of emergency and the transfer of the doctor's response back to the caregiver. It also incorporates the computer system with which the user interacts with the system.

HARDWARE SUB-SYSTEM

The hardware sub-system consists of the computer system with its peripheral devices and a Sagem My X-5 GSM mobile phone with its serial data cable.

- a. The computer system is used for user interactions. It is used for data input, output and storage. The keyboard and mouse serves as the input devices with the input user interface displayed on the monitor. The monitor serves as the output interface. The CPU and its components serve the purpose of processing, control and storage of data using the control program.
- b. The Sagem My X-5 GSM mobile phone with its serial data cable is used for transfer of information needed for diagnosis to the doctor from the database and the transfer of the doctor's response back to the caregiver and database for future reference.

SOFTWARE SUB-SYSTEM

Software sub system comprises of seven modules: the Log-in module, the Remote Patient Monitoring System User Interfacel, the General Patient Record module, the Patient History module, the Doctor's

Prescription/Diagnosis module, the system database and the SMS communication module.(Bose ,1927), The pseudo code in section 4.0 was used in developing the software sub-system.

PSEUDOCODE FOR THE SYSTEM SOFTWARE

```

Begin
If Login = Ok Then
Display RPM user interface
Select Case selected page
Case General Patient Record
If Add New then
Clear all boxes
Else if save then
Load data to database
Send new patient alert to doctor
Else if view data by code Then
Display data for selected code
Else if exit then
Go back to RPM user Interface
Else NOP
Case Patient History
If Add New then
Clear all boxes
Else if save then
Load data to database
Send SMS if limit is exceeded
Else if view data by code Then
Display data for selected code
Else if view full history then
Display all the records take for
the patient
Else if exit then
Go back to RPM user Interface
Case Doctor's Prescription/ Diagnosis
    
```

```

    If Add New then
        Clear all boxes
        Else if save then
            Load data to database
        Else if view data by code Then
            Display data for selected code
        Else if exit then
            Go back to RPM user Interface
        End If
    Else
        Display incorrect password.
    End if
END
    
```

The login interface consists of a rectangular frame. At the top left, it says "Log In:". Below this are two input fields: "User Name" and "Password". At the bottom left is an "Ok" button, and at the bottom right is a "Cancel" button.

Figure 3: Login Interface design

The main menu of the Remote Patient Monitoring System is displayed in a rectangular frame. On the left side, there is a box containing the options: "Add New", "Update", "View", and "Exit". On the right side, there is a box containing "Contents" and "About Us". The title "Remote Patient Monitoring System" is at the top left, and "Help" is at the top right.

Figure 4 Remote Patient Monitoring System first user

The "GENERAL PATIENT'S RECORD" interface is a form with multiple input fields. The fields are arranged in two columns. The left column includes: Patient Name, Patient Address, Patient Code, Age, Date of Admission, Time of Admission, Height, Blood Group, Temperature, and Blood Pressure. The right column includes: Sex, Tribe, Weight, Genotype, Pulse Rate, and Plasma Glucose. At the bottom right, there are buttons for "Add New", "Save", and "Next". At the bottom left, there are buttons for "View", "EXIT", "Previous", "Last", and "First".

Figure 5: General Patient's Record Interface Design

Database Specifications

Database design is the process of developing database structures from user requirements for data. It starts with requirement analysis, which identifies user needs for data. It then proceeds by translating these user

requirements into first a conceptual then a physical database design. The meaning and usage of each data elements were recorded and any inconsistencies were resolved with the users. Sample user views formed from the data obtained are shown in figures 4 and 6.

Figure 6: Interface for Patient History

Table 1: Doctor’s Prescription Table

FIELD NAME	FIELD TYPE	FIELD SIZE
Patient Code	Number	3
Patient Name	Text	50
Doctor’s Name	Text	50
Diagnosis	Memo	
Prescription	Memo	

Table 2: General Patient Record Table

FIELD NAME	FIELD TYPE	FIELD SIZE	KEY
Patient Name	Text	50	
Patient Address	Text	100	
Patient Code	Integer	3	Primary key
Tribe	Text	50	
Occupation	Text	50	
Age	Date/Time	10	
Sex	Text	6	
Height	Single	5	
Weight	Single	6	
Date of Admission	Date/Time	10	
Time of Admission	Date/ Time	8	
Blood Group	Text	2	
Genotype	Text	2	
Temperature	Single	5	
Pulse Rate	Integer	3	
Blood Pressure	Text	7	
Plasma Glucose level	single	4	

Figure 3 is an administrator login to enable access while the interface in figure 7 takes patient record. a history of various patient can be kept with interface in figure 9.

System Database

The Database Specifications are intended to support program coding and database generation by the development group. The database for this project was designed using Microsoft Access 2003 database management system. The database of the Remote Patient Monitoring System has the following table structures shown in tables 3 and 4

SYSTEM IMPLEMENTATION

1 INPUT/OUTPUT SPECIFICATIONS

This section display design screens of input data and screens of sample reports which are the

ultimate expectations from the software as shown in figures 7 to 13. This section describes implementation requirements of the software, hardware operating systems and memory requirements for installation of the software, and detailed implementation arrangements.

SOFTWARE REQUIREMENTS

The following operating system can run Visual Basic 6.0

Windows 98 or NT, Windows 2000 Service Pack 4, Windows XP Service Pack 2, Windows Server 2003 Service Pack 1, Windows Vista ,or windows 7

5.2 IMPLEMENTATION ARRANGEMENT

In order to achieve the Remote Patient Monitoring System, the page layout design was implemented using Visual Basic 6.1. The figures 7 and 8 which shows the implementation of some pages.

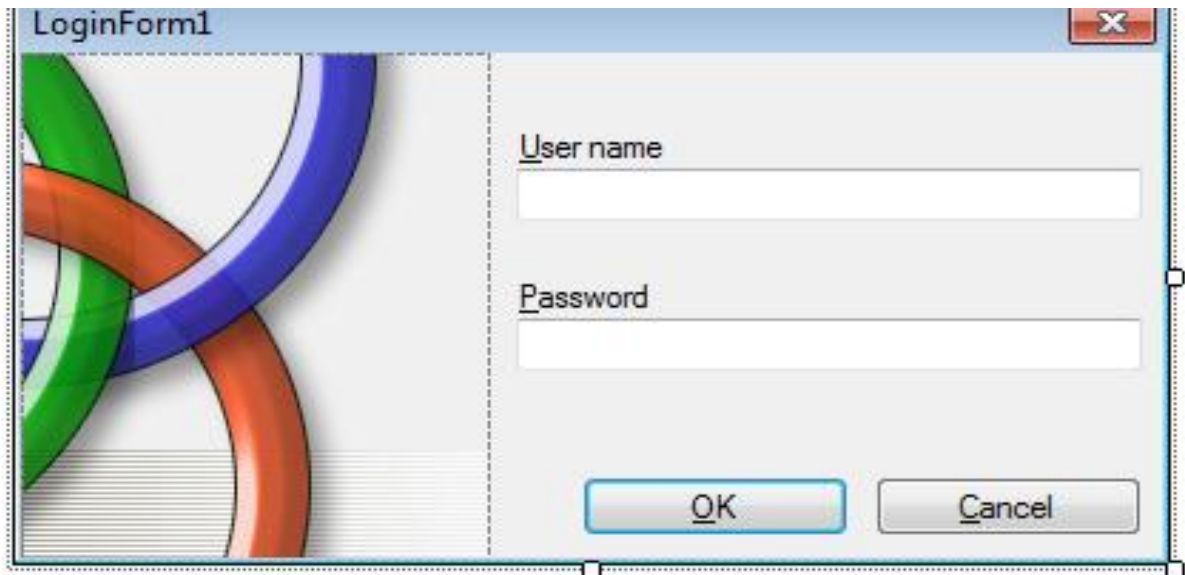


Figure 7: Log in Interface Implementation

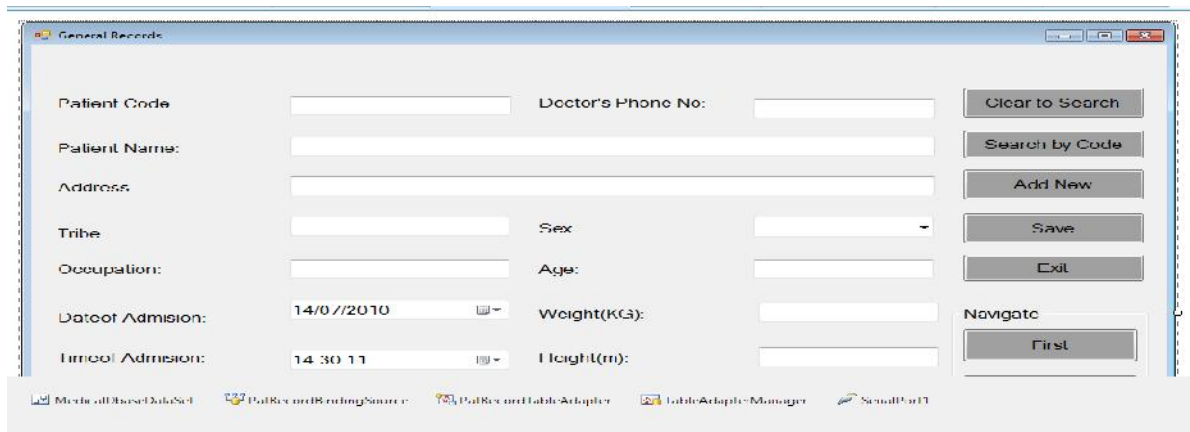


Figure 8: General Patient Record Interface Implementation

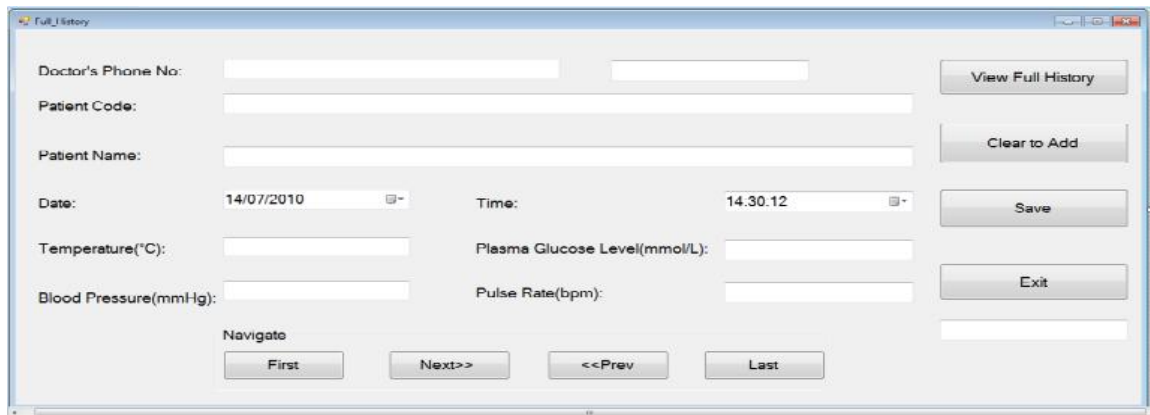


Figure 9: Patient History Interface Implementation Figure 10 Database Implementation

The database was implemented using access 2003 Edition. The figure 11, 12 and 13 below shows the design and implementation of the database tables.

Doctor's Prescription

Patient Code:

Patient Name:

Doctor Name:

Date: Time:

Diagnosis:

Prescription:

Search by Code

Clear to Search

Add New

Save

First

Next

Prev

Figure 10: Database Implementation

Microsoft Access

PatientsUpdate	Patient Name	Address	Phone	Occupation	Sex	Age	Date of Birth	Time of Birth	Weight	Height	Specialty
1	Emmanuel Okoh	Nwaku	1430	Business	Male	31	09/12/2010	10:00:00	75	5-6 AA	
2	Ikenna Okoh	Abaka	1430	C/S	Female	25	18/09/2010	10:00:00	60	5-4 AA	
(New)						0			0		

Figure 11: Patient Update Table Implementation (Design)

Microsoft Access

PatientHistory	ID	PatientCode	PatientName	Date	Time	Temperature	BloodPressure	Prescription	Date/View/Field
1	1	Emmanuel Okoh		09/12/2010	10:00:00	21	120/80	5-4	60
2	2	Amaka		05/12/2010	10:30:00	21	113/77	30	40
(New)						0		0	0

Figure 12: Patient History Database Implementation

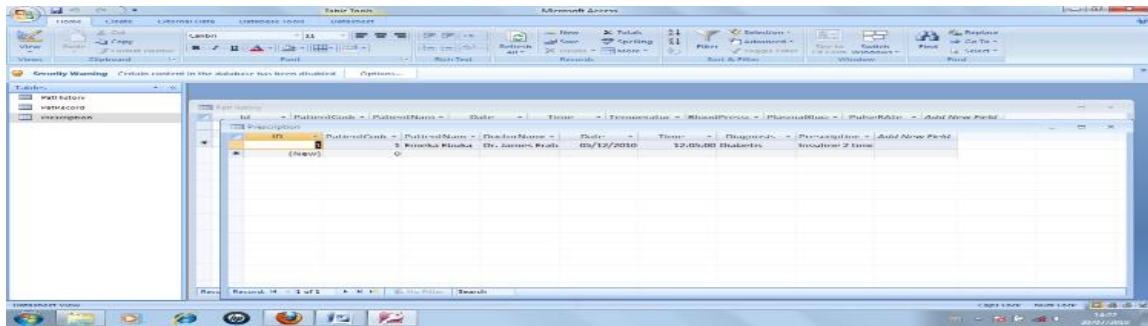


Figure 13: Doctor's Diagnosis/ Prescription

SYSTEM TESTING

Software Sub-System Testing

The software subsystem testing is divided into four modules:

The Log In module, Remote Patient Monitoring System menu module, General Patient Record module, Patient History module and Doctor's Prescription module

1. The Log In module was first developed and tested to ensure that only authorised users have access to the system. This tested ok
2. Remote Patient Monitoring System menu module was also developed and tested to ensure that the link to each data access is displaying the appropriate access addressed.
- 2 General Patient Record module was also tested to ensure that the patients' records taken are stored in the database and the

record of any patient whose code is searched is displayed. It was also tested to ensure that an SMS alert is sent automatically to the doctor whenever a new patient's data is saved in the database.

Patient History module was also tested to ensure that the records of the different parameters being measured at different time intervals are stored in the database and displayed in tabular form for the doctor when required. . It was also tested to ensure that an SMS alert is sent automatically to the doctor whenever a patient's parameter exceeds the upper and lower thresholds set for it.

Doctor's Prescription module was the final module tested. This was done to ensure that diagnosis and prescriptions made by the doctor at his visit is stored and can be accessed by the caregiver when needed when needed. The System testing is tabulated as shown in table 3.

PERFORMANCE EVALUATION

The traditional method of monitoring patients cannot be compared with this system which is automated, saves time and the limited resources available. Currently, several different types of integrated RPM (Remote Patient Monitoring) devices exist. These devices act as an aggregator of information from multiple peripheral devices (e.g., blood pressure cuff, scale, glucose monitor, pulse oximeter, prothrombin time/international normalized ratio (PT/INR) meter, thermometer, electrocardiogram ECG, peak flow meter, stethoscope, and pedometer) that transmit or plug directly into integrated technologies. Many integrated devices are activated daily by the patient or caregiver. They ask patients to answer a series of questions, collect and report peripheral device data, provide educational information, and even support audio or visual contact with clinicians for real-time intervention or assistance. Some instruments can also self-activate and alert patients and caregivers that a test or medication must be taken. Data are subsequently transferred to health care professionals, where they are triaged through patient-specific algorithms to categorize risk and alert appropriate caregivers and clinicians when answers and/or data exceed predetermined values. Many of these tools store previous test results through a specific device program or a web-

based program. RPM devices also provide patient education via reading or hearing health tips. Devices can be a conduit of communication between patients and healthcare Professionals through audio and/or visual settings allowing for real-time intervention, coaching, and patient education. Patients have highly varied needs for remote patient monitoring technologies. Some patients want a simple,

The ability to augment patient self-management tools and skills is critical to the value of integrated RPM devices. Table 4 is a comparison of some of the available RPM systems with this system. By way of evaluation this project work performs considerably well compared to some of the other software. It is more user friendly than most of them as can be seen in table 4 as the user with average education especially those in our remote villages can make use of it without much difficulty. It is also more cost effective than most of the available systems which are mostly imported from the developed world and includes wireless measuring and sensing devices that are very expensive. Inexpensive, portable technology while others may require an expensive, integrated, home-based technology. There is a wide spectrum of technologies in between, from simple to complex that meet the needs of nearly all patient segments in the most appropriate way.

Table 3: System TestingTable 4Performance Evaluation

USER INTERFACE	EXPECTED RESULT	ACTUAL RESULT
General Patient Record	It should be able to store, upload and alert the doctor by sending the message “New Patient Received” via SMS whenever a new input containing Patient’s basic records is made.	An SMS alert was received by a GSM handset with the content “New Patient Received” when a new patient data was added to the database
Patient History	It should be able to store and upload patient measurements taken at intervals of four hours and alert the doctor by sending the message “New Patient Received” via SMS whenever any of the parameters being measured and recorded exceeds the threshold set by the doctor for the patient. E.g for a particular diabetic patient, the doctor set a plasma glucose level range of 3.3-5.5mmol/L, it should also be able to display the patient history in tabular form for any particular patient	An SMS alert was received by a GSM handset with the content “Emergency Patient Emeka, Ebuka with code 1 has a low plasma glucose level of 2.7mmol/L” when a plasma glucose level of 2.7mmol/L was recorded for the patient Emeka Ebuka
Doctor’s Diagnosis	It should be able to store and display doctor’s diagnosis and prescription	Tested ok

Table 4: Performance Evaluation

FEATURES/ PRODUCT	Remote Patient Monitoring system by Nkoli Anyafulu	Biotronik Home Monitoring	Medtronic Carelink	Boston Scientific Latitude	St. Jude Merlin.net
Wireless communication with implanted device	No implanted device. Thus acceptable to most patients	Radiofrequency	Radiofrequency	Radiofrequency	Radiofrequency
Data Transmission	GSM network	GSM network	Analog Phone line	Analog Phone line	Analog Phone line
Transmitter	Mobile	Mobile	Stationary	Stationary	Stationary
Frequency of Transmission	Once there is an emergency or new patient is admitted. Can also transmit on schedules	Daily FU; Alert events	Scheduled FU; Alert events	Scheduled FU; Alert events	Scheduled FU; Alert events
Physician notification	SMS, thus it can work where there is no internet access	SMS, e-mail, fax.	SMS, e-mail	Fax, phone	Fax, e-mail, SMS
Special Features	Alerts once there is an emergency, just requires only a GSM network availability, it is cheap as the user can continue using available measuring and sensing devices. It is flexible and no risk of effects of implantable devices	Alerts fully configurable online	Optional lung fluid status alert. Configurable red and yellow alerts	HER data export ability. Optional wireless weigh scales and blood pressure cuffs	Alerts fully configurable online. Possibility of sending automated phone calls to patients

CONCLUSION

Remote Patient Monitoring System has been tested and found to achieve the following:

This system has the ability of manually capturing vital health data like heart rate, blood pressure, temperature, and plasma glucose level of a patient which is stored in the hospital database and can be transmitted to a doctor when a set threshold is exceeded for better management of diseases. The software includes a medical data manager (MDM) that automatically checks patient's new data against patient's record and doctor's set thresholds. It was able to automatically send alert to the doctor when there was a disturbing change in the patient's vital signs, for example high blood pressure for a hypertensive patient. This ensures rapid response by a doctor or medic to any problem that arises.

This system is a big relief to those in the remote regions where experts are not located as they can still access the expertise of those experts especially in a nation like Nigeria where there are few experts especially those managing chronic diseases like diabetes, hypertension etc. This will help in reducing mortality rate.

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