

Towards a GSM Enabled Remote Monitoring Medical System

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Abstract—Telemedicine is becoming an important part of the modern healthcare system with the increasing interest in expanding access to quality healthcare in remote or rural areas. We present an innovative telecare system with GSM functionality, detailing its architecture as well as design processes and procedures that were undertaken during the development. Design science research (DSR) was used in the design and development of the system. Different system blocks were designed separately and then integrated as a functional unit system. The system was compared against the calibrated medical instruments for verification. The results showed that the system performed as anticipated against the calibrated medical equipment.

Keywords— *GSM, telemedicine, Heartrate,*

I. INTRODUCTION

Healthcare systems across the globe are adopting the usage of telemedicine for diagnostic and treatment purposes [1][2]. Telemedicine is the application of information and communication technologies (ICTs) in the delivery of healthcare in areas that do not have the necessary expertise to handle certain procedures or medical advice [3]. Also, it may involve the transmission of necessary health care information from the medical specialist in one geographical area to a patient in another geographical area [8]. Traditionally, the term telemedicine often encompasses a broader definition of remote healthcare that does not always involve clinical services. Of late, however, it has included a growing number of ICT applications such as the usage of web or non-web enabled systems and other forms of ICTs [2] [4].

Essentially, developed countries were at the forefront of implementing telemedicine but the trend is changing with developing countries, still in their embryonic stages of telemedicine, taking a keen interest in expanding the quality of health care access to rural areas [4] [6]. There are various reasons as to why telemedicine is used in developing countries. These include but are not limited to, lack of medical resources, distance and lack of expertise. It is seen as ways and means of providing medical expertise in areas where geographical barriers make conventional consultation impossible. It generally allows specialist-have-nots hospitals and clinics that are situated in rural areas to provide good quality health care to patients through the use of ICTs [4][3]. Also, the use of telemedicine, in some countries where it is implemented, has

reduced some costs that were associated with healthcare provision [5] [6].

Several studies, of course in different countries, have been conducted on the usage of telemedicine in medical diagnostics [4][5][8]. In South Africa (SA) telemedicine has been intensified on different medical fronts and has been seen as the most promising way of reaching the medical- have-nots. Within SA telemedicine, if harnessed properly, will have noticeable benefits for the country, where resources (both human and infrastructural) are hard-pressed [4]. Although one can list a lot of benefits, there are some potential obstacles to wide-spread implementation of telemedicine. These obstacles are characterized by various circumstances, particularly the obvious inadequate funding, insufficient social infrastructure and defective policy and institutional framework.

The main aim of this paper is to design a wireless system that can measure and show the patient vital signs on the display screen, identify and report when out of range measurement/readings are detected and send this data to the doctor's cell phone using GSM technology. The paper is arranged as follows: section II provides the Theoretical framework of this study, Section III presents the methodology used in this study, section IV presents the system testing and evaluation, section V presents the results and we conclude in section VI.

II. THEORETICAL FRAMEWORK

In essence, telemedicine is not a separate specialty, but an enhancement to existing services [3-5]. Fragments of theories and academic literature have demonstrated successful development and use of telemedicine services such as in consultations, diagnoses and treatment [2] [4] [5]. In recent times, development of telemedicine technology has continued to evolve. Extant literature has shown a lot of success in the development of telemedicine technology [8][9][10]. For example, Pottayya, Lapayre and Garcia [8] proposed a novel platform for telemedicine called VAGABOND (Video Adaptation framework, crossing security GAteways, Based ON transcoDing) which works on TCP (Transmission Control Protocol). VAGABOND is composed of Adaptation Proxies (APs), which have been designed to take into consideration user preferences, device heterogeneities, and network dynamic bandwidth variations. Others such as Goel et al. [9] designed and developed a novel modular telemedicine platform,

Intelehealth, which would enable health systems to connect, remotely, doctors with patients in rural clinics using a customizable Android-based platform and a cloud-based electronic health record system at the backend (OpenMRS). Others such as in [7] designed a web-based hospital-wide mobile medical monitoring system is described. Telemetry devices are attached to patients to acquire, store and process continuous data about their state of health which medical staff may examine and make comparisons with historical data. In [10] an advanced telemedicine system that supports mobile patients in their daily life and provides real-time access and remote control in critical situations is designed. The combination of different communication types is introduced in this system to meet all requirements. As part of the telemedical system, a Tele-Service-Center with an automated data analysis is integrated into the infrastructure to support the treatment of the patients. We must state at this moment that apart from the above examples there are several other examples of telemedicine. The reader is referred to other literature such as in [1] and [2].

III. DESIGN PROCEDURES

A. Methodology

The method of research that was used in this study was a quantitative study called design science research (DSR). Fig.1 shows the summary of the design procedures followed in this study. In essence, DSR focuses on the development and performance of artifacts with the explicit intention of improving their functional performance. The study involved the design of a system with wireless GSM functionality. Both simulation and system testing were carried out.

B. Design requirements

The two core components in this system were the microcontroller and the GSM module. The microcontroller was for processing data and which was sent through the GSM terminal to the doctor's cell phone. The heart-rate sensing was achieved by shining an infrared light on the tip of finger which was reflected on to a photodiode. The photodiode sent the rate change through the amplifier to the microcontroller for reading. The body temperature sensor used was the DS18B20 digital thermometer, which is waterproof and more flexible to allow for easy measurement.

C. Circuit design

The full diagram of the circuit used is as shown in Fig. 2. The power supply was built on a breadboard for testing and evaluation. The output voltage supply was 5.044V from the LM7805 regulator. Table 1 shows the system technical specifications. Fig.2a shows a SIM900A mini GSM module board that was interfaced with the microcontroller (see Fig.2b). After powering-up, the network LED was designed to blink for approximately one second, then the ring LED would turn off after four consecutive network LED blinks. After that the GSM module would establish a connection to the network system module.

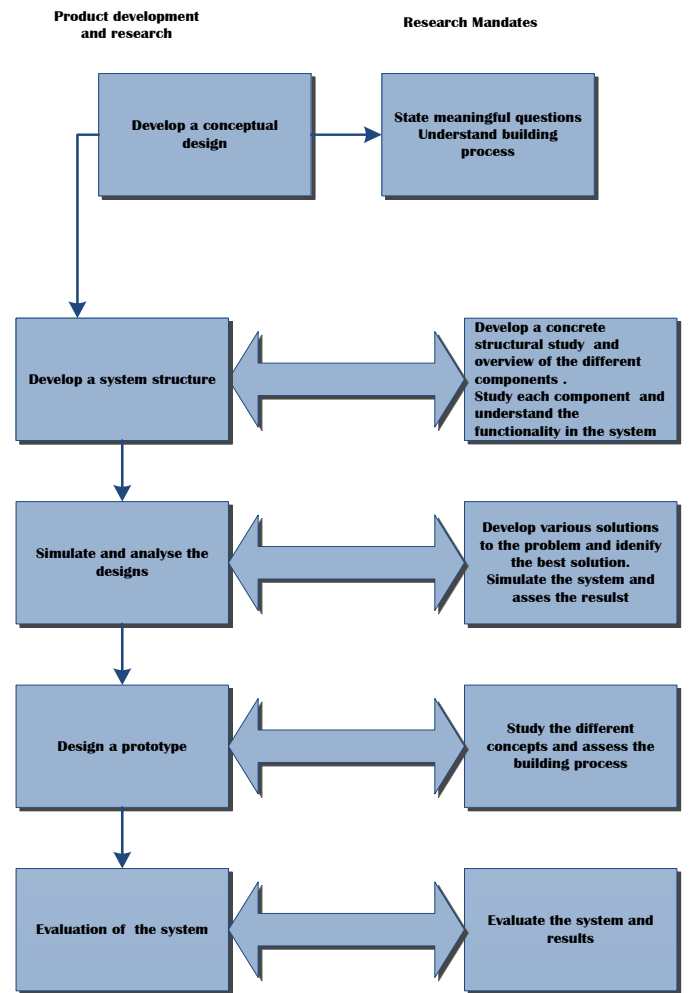


Fig. 1: Summary of research design followed in this study.

TABLE I. TECHNICAL SPECIFICATIONS

Item	Specification		
	Supply Voltage	Current	Working Temperature
DS18B20 (Thermometer)	3-5Volts	5uA (DQ pin)	-55 to 125 degrees
Microcontroller	4-5.5Volts	15mA	-20 to 100 degrees
Mcp602	2.7-6Volts	325uA	-40-120 degrees
GSM module	4.5-5.5Volts	1.5-2A	-10 to 55 degrees
LCD	5Volts	2.5mA	Up to 50 degrees

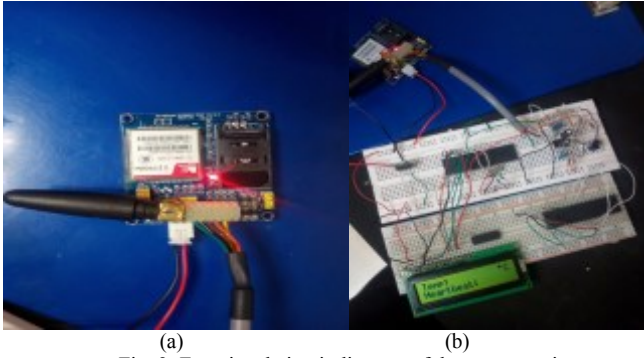


Fig. 2: Functional circuit diagram of the system unit.

IV. SYSTEM TESTING AND EVALUATION

A. System testing procedures

Comparative testing procedures were carried out in order to verify the system functionality. The first test that was done was to compare the simulated GSM transmission with the prototype transmission system. The time taken for simulation transmission and the system prototype transmission were compared. Also, temperature and heart rate measurements were compared and validated (see Fig.3 and Fig. 4). The tests were conducted against calibrated instruments capable of producing desired set points or pre-set conditions as per international medical standards. The temperature measurements from the DS18B20 sensor, which were displayed on the mobile phone platform, were compared to the controlled temperature measurements inside the C2000 incubator from Drager Medical. A number of tests were done in order to compare if the readings on mobile phone were in line with the C2000 incubator temperature readings.



Fig. 3: Comparative analysis of the system with C2000 incubator measurements.

For heart rate measurements, the SPO2 heart rate measurement system from Fluke Biomedical was used. In order to take the heart rate, a finger was placed on top of the photodiode LED. The measurements that were performed are

called reflective measurement because the photodiode receives the reflected light from the skin (some being absorbed by the red blood cells). The measurements that were taken from the SPO2 heart rate measuring equipment were compared to the ones that were transmitted by the system through the GSM technology onto the doctor's mobile phone.



Fig. 4: Heart-rate measurements

V. EVALUATION AND DISCUSSION OF RESULTS

The results presented in this section are those obtained during the testing procedures as described in the methodology. Tests include the temperature, heart-rate measurements and validation of such on mobile cell phone. Also, the simulated transmission results and the GSM transmission system results are presented here. Fig. 5 shows the results of the two parameters i.e. temperature and heart rate displayed on the mobile cellular phone.

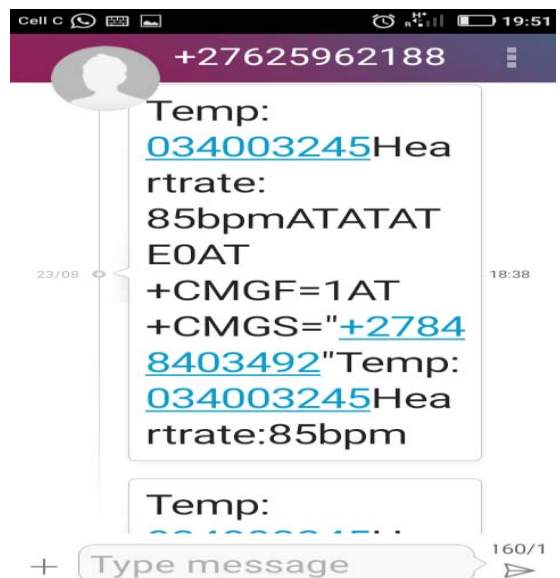


Fig. 5: Mobile phone measurement from the two machines

Comparatively, Fig. 6 shows the results of the measured temperature inside the incubator and the ones displayed on the

mobile phone. The results clearly show that there is very little difference in the measured and those displayed on the mobile phone of the doctor. This is a clear indication that the prototype is capable of displaying the same results as those displayed by the incubator. The results showed that the temperature inside the incubator corresponded to the measured value, although there was some 0.3-0.7 degrees discrepancy between the two results. This was within the acceptable range as per manufacturer's standards.

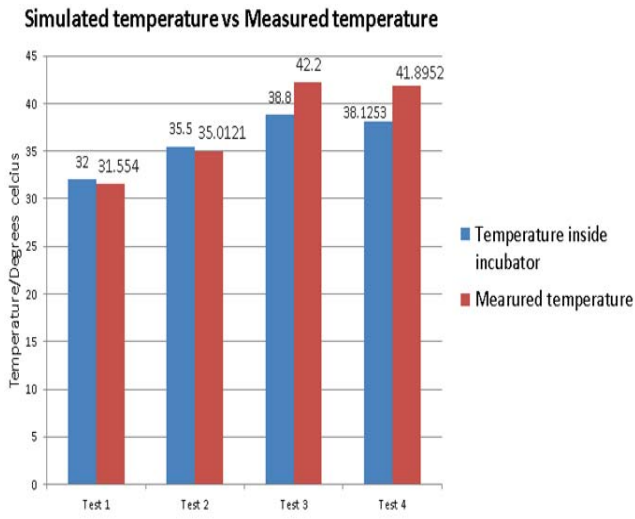


Fig 6: Temperature results

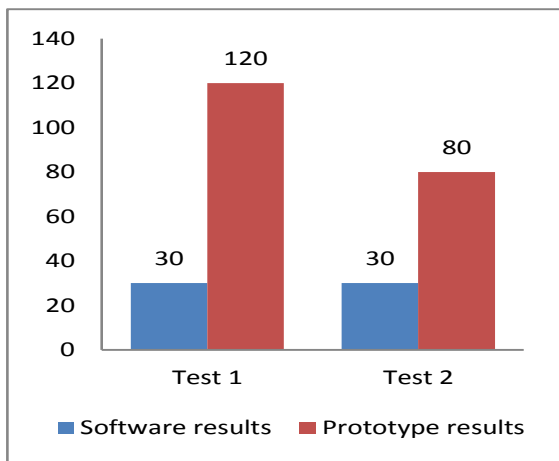


Fig. 7: GSM transmission results

Fig. 7 shows the difference between the simulated transmission and that sent by the system GSM module. The difference can be attributed to the transmission path of the prototype. Transmission path characteristics such as multipath fading and attenuation can have significant impact on the time taken for the signal to reach the doctor's phone.

Fig. 8 represents heart rate values taken from the simulator against those displayed on the mobile phone. It was observed that there was a minimal difference between measurements from the machine and those observed on the mobile phone.

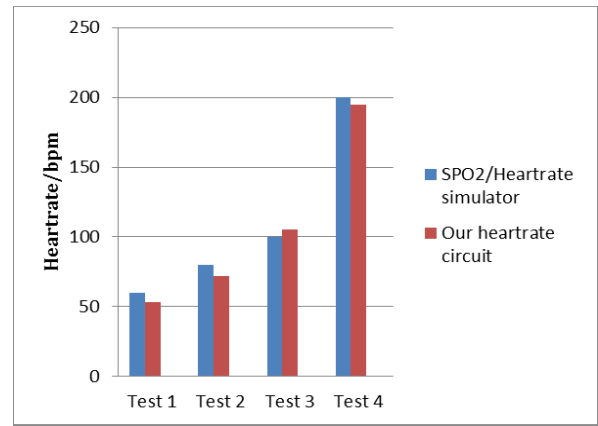


Fig. 8: Heart-rate measurement test

VI. CONCLUSION

In this study, we developed a GSM-enabled telemedicine equipment. The heart rate and temperature measured from the medical equipment were in line with those observed on the mobile phone. The system could further be improved by incorporating other technologies such as WhatsApp, Facebook to make it more interactive.

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