



Multi-Parametric Health Monitoring System

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Abstract—This article proposes the concept of Disease Detection Algorithm (DDA) for health monitoring. Health is a dynamic process; it is the level of metabolic efficiency of a living organism. The general abnormal condition of a person's body depends on several vital parameters related to health and sometimes results in chronic diseases. These diseases include minimum parameters like heart rate, temperature, blood-pressure, SpO₂, weight etc. To this aim, a system is proposed enabling the monitoring of vital signs and sending data to the physician to monitor patient and have doctor's intervention in critical situations. The disease detection algorithm (DDA) promises to provide higher accuracy of disease detection. Chronic Heart Failure, Hyperthermia, Obesity /Type 2 Diabetes, Type 1 Diabetes, Dysautonomia etc are commonly detected diseases in the proposed algorithm. Wireless Sensor network allows early home interventions thus reducing the number of subsequent hospitalizations system.

Keywords—Wireless Sensor Networks, health at home monitoring, DDA algorithm, vital sign sensors, e-health

I. INTRODUCTION

We all have times of good health, times of sickness, and maybe even times of serious illness. As our lifestyles change, so does our level of health. Deploying new healthcare technologies for proactive health and elder care has become a major priority of this decade, as medical care systems worldwide become strained by the aging populations. Due to increasing occurrence of sudden death events caused by cardiovascular diseases, there is a need to provide a long-time continuous patient monitoring services. Health monitoring may be performed at diverse conditions, within hospital or home, as a medical assistance of a chronic condition, as a part of a diagnostic procedure, or recovery from a minor event. Most often, the disease diagnosed earlier is more likely to be cured or successfully managed. When you treat a disease early, you may be able to prevent or delay problems from the disease. Treating the disease early may also make the disease easier to live with. Diagnostic tests, medical exams, and self-exams, find a disease or other health problem early in its course. Admissions to hospital with chronic diseases have more than doubled in last fifteen years. It is acknowledge that changes in vital signs often advance symptom worsening and medical destabilization. This proposed work provides an overview of a flexible and high configurable platform for multi-parametric health monitoring of vital signs acquisition and processing, integrated with hospital information system. In today's Hi Tech world, wireless communication place the major role in many applications which gives us the idea to use this technology for health monitoring. A Wireless Sensor Network (WSN) is a wireless network consisting of spatially distributed autonomous devices using sensors to monitor physical or environmental conditions.

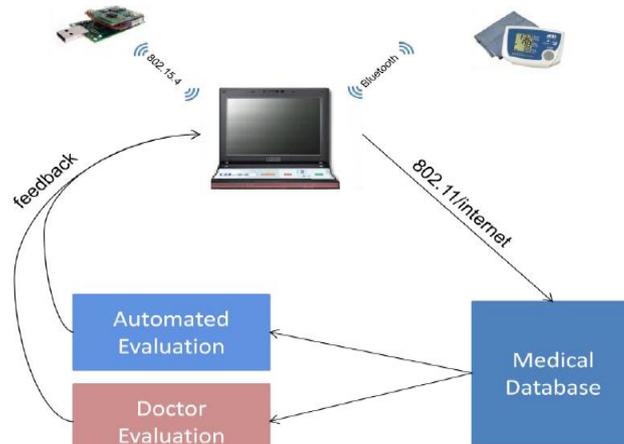


Fig. 1 Health at Home

Wireless monitoring represents a medical practice that involves remote monitoring of patients whose health care provider are not at the same location as the patient. Generally, a patient have a number of monitoring devices at home, and the results of these devices will be transmitted to the central monitoring station.[2] There are other applications too e.g. body position measurement and location of the person, overall monitoring of ill patients in hospitals and at homes. It is very important to explicitly incorporate security and privacy policies to protect the end-to-end communication and

access of sensitive medical information. Wireless Sensor Networks are called to be a key technology to enable continuous and non-invasive monitoring of patients, which is one of the main characteristics of next-generation personal health systems. This system will be able to provide early diagnosis of diseases, improving prevention, as well as personalize quality of care. The device is equipped with sensors that can measure different vital signs, such as electrocardiogram (ECG), blood pressure, respiratory rate, pulse oximetry, body motion, etc. Once these signals are acquired, they can be processed on-board in order to extract information about the daily activities and the health state of the person. In particular, these signals can help to diagnose diseases that are related to alterations of the body metabolism such as obesity, hypertension or diabetes.

The goal is to develop and evaluate algorithm for the automated detection of metabolic disorders, based on a set of vital signs that are monitored using sensor devices. Therefore reliable diagnosis requires state of the art monitoring and communication technologies providing real-time, accurate and continuous body multi-parametric data measurements. The work done in the field of health monitoring systems mainly include sensing devices and sensor signal processing. These are the major fields selected by researchers for remote monitoring of vital signs in chronically diseased patients. Most of the work is carried out in this field, and still large number of experts are working to innovate new ideas in this process. Research on epidemiology of acute heart failure syndromes estimated that hospital admissions are increasing with increase in patients with chronic health problems and it is expected that in 2030 chronic patients will be doubled. Chronic heart failure patients are mostly increasing the hospital admission rate and this has been a large societal and economical issue, accounting for 2% of all hospitalizations [20]. The total healthcare expenditure and hospitalizations represent more than two thirds of such expenditure as the CHF management accounts for 2% of this expenditure. The survey mentions that the health at home monitoring systems may be beneficial. The readmission rates of CHF patients where the current healthcare model is mostly in-hospital based and consists of periodic visits [15]. Previous studies pointed out that in patients with a discharge diagnosis of heart failure, the probability of a readmission in the following 30 days is about 0.25, with the readmission rate that approaches 45% within 6 months. The work is developed within a health at home environment of ambient assisted living program. This paper describes, a health at home monitoring from sensors and data processing perspective, giving a solution to improve the provisioning of healthcare services for CHF patients [17] able to connect in-hospital care of acute phase with out-of-hospital follow-up. With an increase in population, providing basic health care to the people, especially in rural areas is the main objective of health administrators. A remote telemedicine system [2] is the possible way to solve the problem with the support of new advanced technologies. This paper will conclude by discussing future challenges of the domain. In this study, three methods are quantitatively compared using a similar algorithm structure but different transforms are applied to the differentiated ECG. The three transforms used are the Hilbert transformer, the squaring function, and a second discrete derivative stage. The algorithms were compared in terms of the number of false positive and false negative detections produced for records of the MIT/BIH Arrhythmia Database. Different algorithms performed better for diverse ECG characteristics; suggesting that an algorithm can be specified for different recordings, the algorithms can be combined based on each one's characteristics to determine a new more accurate method.

II. PROPOSED METHODOLOGY

The health at home platform connects the patients with the health care providers both at different locations. The system aims at giving highly flexible patient monitoring with vital sign monitoring of the metabolic changes in patients body. The raised alarms of the patients signs or symptoms can be intervened by the health care providers. The feedback acquired from the health care providers costs beneficial and the critical situations are prevented. Fig.1 shows the central gateway called the home gateway which receives the data from sensors and communication takes place point-to-point via zigbee module. In case of alarming situations the patients health care givers or relatives are informed via SMS and all queued data is thus send to the server.

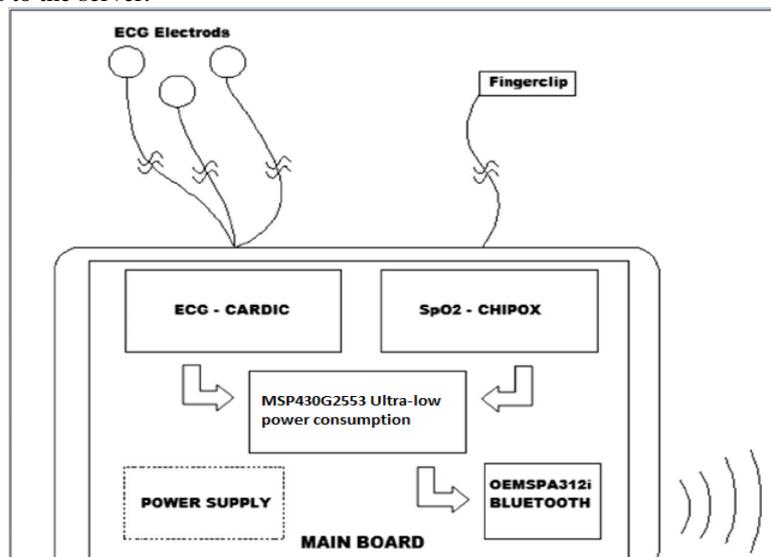


Fig. 2. ECG-SpO2 module

A. Hardware Requirements

The below hardware are intended to use for developing the model.

1) MSP430G2553

The MSP430G2x53 series is ultra-low-power mixed signal microcontroller with built-in 16-bit timers, up to 24 I/O capacitive-touch enabled pins, a versatile analog comparator, and built-in communication capability using the universal serial communication interface. In addition the MSP430G2x53 family members have a 10-bit analog-to-digital (A/D) converter. Typical applications include low-cost sensor systems that capture analog signals, convert them to digital values, and then process the data for display or for transmission to a host system.

2) Sensing Requirements

TABLE I SENSING REQUIREMENTS

Parameters	Sampling	Basic version	Advance version
3lead ECG	500S/s/lead(12bit/s)	Yes	Yes
SpO2	3S/s(10bit/s)	Yes	Yes
Weight	1S(32 bit float)	Yes	Yes
Blood pressure	1S/type(32bit int)	Yes	Yes
Acceleration	3axes x 1S/s/axis(8bit/sec)	.....	Yes

Other sensing elements are temperature sensor, heart-beat pulse sensor, galvanic skin response (GSR) sensor. The temperature sensor is based on reliable temperature sensor chip DS18B20 with cable length of 1 meters. This is a sealed (waterproof) and pre-wired digital temperature probe, based on DS18B20 sensor. It lets you precisely measure temperatures in wet environments with a simple 1-Wire interface. While the sensor is good up to 125°C the cable is jacketed in PVC so we suggest keeping it under 100°C. The heart-beat pulse sensor consists of a super bright red LED and light detector. The LED needs to be super bright as the maximum light must pass spread in finger and detected by detector. Now, when the heart pumps a pulse of blood through the blood vessels, the finger becomes slightly more opaque and so less light reached the detector. With each heart pulse the detector signal varies. This variation is converted to electrical pulse. This signal is amplified through an amplifier which outputs analog voltage between 0 to +5V logic level signal. GSR device measures the electrical conductance between 2 points, and is essentially a type of ohmmeter. GSR is a change in the heat and electricity passed through the skin by nerves and sweat. Its maximum sampling rate is 100 S/s and resolution 10ns.

3) Zigbee module

The 802.15.4 XBee modules provide two friendly modes of communication – a simple serial method of transmit/receive or a framed mode providing advanced features. XBees are ready to use out of the package, or they can be configured through the X-CTU utility or from your microcontroller. These modules can communicate point to point, from one point to a PC, or in a mesh network. The PCB antenna version provides a lower profile footprint for applications with limited space while the wire antenna version allows for more flexibility in adjusting for optimal range at the same output power. Only series 1 modules can work with series 1 type modules you cannot mix up series 1 and series 2 modules to setup communication.

B. Software Requirements

Energia for the MSP430 Micro Controller created by Texas Instruments is a program that allows to enter the code from an external file in order to compile it or verify it. The program can automatically verify the code and import different libraries in the current data file. Embedded C programming uses most of the syntax and semantics of standard C, and it is an efficient programming language as it supports access to input-output and provides ease of management of large embedded projects. The signal processing chain is implemented in C language leveraging different libraries to support other communication modules.

C. Sensor Interface Block Diagram

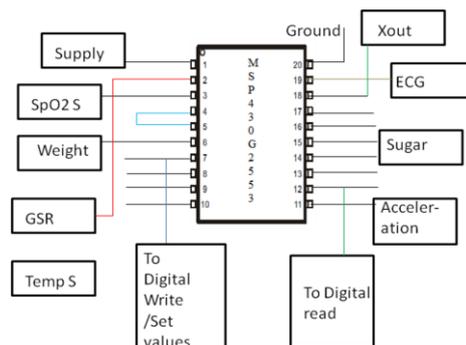


Fig. 3 Sensor interface block diagram

The sensors are connected to the MSP430 microcontroller according to the pin configuration of the ultra-low power controller. Fig.3 shows the block diagram of the interfacing of sensor elements to the microcontroller. The microcontroller has an inbuilt ADC converter which makes computation easy and less complicated. Most sensors give digital output whereas some give analog output. Pattern of the output generation of each sensor differ individually.

III. DISEASE DETECTION ALGORITHM

The proposed algorithm is the part of the added contribution for the project. The concept of the algorithm depends on the step by step procedure of the calculation and detection of the parametric value and accordingly detects the disease. The Disease Detection Algorithm (DDA) starts at an initial state and initial input, the instructions describe a computation that, when executed, proceeds through a finite number of well-defined successive states, eventually producing "output" and terminating at a final ending state. A link for the parameters and the diseases is created by co-relating these parameters which can give 80-90 percent accuracy. The parametric alteration in human body can also be send to the hospital-care givers for more detailed analysis, and critical monitoring of patient from home-gateway can be made possible. The parametric values include temperature, blood pressure, pulse oximetry, weight, ECG, sugar level, acceleration, sweating, spasm. The parameters co related and early stages of diseases like Chronic Heart Failure, Dysautonomia, Arthritis, Obesity/Type 2 Diabetes, Hyper Activity Disorder, Type-1 Diabetes.

The normal, abnormal, subnormal and critical values for each parameter are studied and these values are compared by the monitored parametric values. For each parameter the normal, abnormal, subnormal and critical values for human body are mentioned below.

A. Parameter Set Values

The temperature parameter is normal when the temperature sensor measures value 98.6 Degree F (37 Degree Celsius) and the abnormal condition measures greater than 100 Degree F (37.8 Degree Celsius), below 96 Degree F (35.6 Degree Celsius) is the subnormal condition and all of this is overlaid by the critical case in which a the body temperature of human body is extremely more than normal value i.e. it is greater than 106 Degree F (41.7 Degree Celsius). This may lead to major diseases caused due to rise in temperature. The pulse oximetry is the oxygen level in human body which should range between 95% to 100 % in a normal being but if it is below 95% it leads to abnormal conditions. Most critical case is below 90% of SpO2 measure for human. Other parametric values and variety of conditions are mentioned below:

1) Blood Pressure

Blood pressure is measured as systolic and diastolic. The normal blood pressure in human beings is 120/80mmHg (mili-meter mercury).

TABLE III BLOOD PRESSURE SET VALUES

Conditions	Systolic (upper)	Diastolic (lower)
Normal	120 mmHg +/- 10	80 mmHg +/- 10
Pre-hypertension (subnormal)	120 to 139 mmHg	80 to 90 mmHg
High Blood Pressure (Stage-I) Hypertension (Abnormal)	140 to 159 mmHg	90 to 99 mmHg
High Blood Pressure (Stage-II) Hypertension (Abnormal)	160 or Higher	100 or Higher
Critical (Hypertensive)	Higher than 180	Higher than 110

2) Glucose level

TABLE IIIii GLUCOSE SET VALUES

Conditions (Target levels)	Before meals	2hrs After meals
Non-Diabetic	4.0 to 5.9 mmol/L	Under 7.8 mmol/L
Type-2 Diabetic	4 to 7 mmol/L	Under 8.5 mmol/L
Type-1 Diabetic	4 to 7 mmol/L	Under 9 mmol/L

3) QRS duration

TABLE IVV QRS SET VALUES

Conditions	Duration in Seconds
Lower	0.01 – 0.03 s
Normal	0.04 – 0.12 s
Higher	0.121 – 0.35 s

The above mentioned values are biologically verified and mentioned after the detail study of each parameter in accordance with the guidance by a doctor. The system works on the health at home monitoring. The home gateway helps at connecting the patient's vital parametric data with hospital care givers. Patients signs symptoms, and raised alarms can be received by healthcare providers and accordingly doctors intervention can be made. The disease detection system will help the patient monitor the disease and the metabolic changes in patients body can be detected along with the disease name. Although this may perplex the output depending on per-patient body behaviour and may require the doctor to interrupt for pre-disease detection analysis. For this purpose the proposed home gateway will play a major role in collecting data and sending it to the hospital caregivers.

B. Parameter and related diseases

The figure given below shows the correlation of the diseases and the parameters in common.

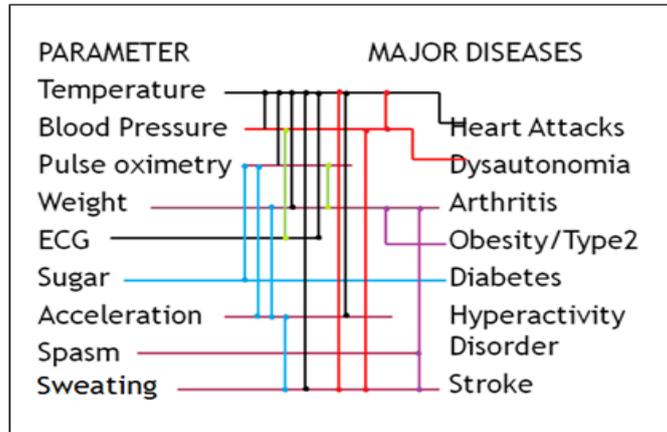


Fig. 2 Parameters and related diseases

The correlation between the parameters and the diseases helps the system to detect the disease at the early stage as the set values are the symptoms of the abnormal conditions of the disease. The patient monitoring with this algorithm makes it easy to detect the disease for human beings and if alarming condition occurs the disease can be intervened by the doctors and special treatments for the particular can be provided by hospital caregivers.

TABLE V DISEASE DECLARATION CHART

Diseases Parameters	Hyper- thermia	Dysauto- nomia	Obesity/ Type2 Diabetes	Type1 Diabetes	CHF/ Heart Attacks	Arthritis
Tempera- ture	>107 deg F	>=105deg F	.....	.....	.....	<96.5 to 99 deg F
Blood pressure	140/90mmHg	<110/70 mmHG	>=150/100 mmHg	>=140/90 mmHg	>=161/94 mmHg	.....
Spo2	<90%	=90 to 94%	<85 to 90%	<95%	<80 to 90%	<65 to 79%
Weight	>= 30BMI	.....	>=30 BMI	>=25 to 29.9BMI	<=30BMI	>25 to 27.9 BMI
ECG	>0.04 to 0.121 s	o.o1 to o.o3 s	.....	QRS Duration 0.121 to 0.35 s	.....	.....
Sugar	.....	.....	BM-4 to 7 AM-<8.5	BM4to7AM<9 mmol/L	< 7.8 mmol/L	.....
Accele- ration	0-12 Hz >0.2 6.6 g	.....	.....	.....	0-12 Hz <0.5 to 9 g	.....
Spasm	.....	.....	.....	.....	.....	330 mmHg PES
Sweating	pH <4.0	pH <6.5	>5.0	>7.0	>7.0pH	.....

The parameters and diseases in the above Table IV represent the declaration of the disease as these values are found to be the critical values in the patients. The disease like hyperthermia, dysautonomia, obesity, chronic heart failure, arthritis depends on the metabolic changes in the parameters like temperature, blood pressure, SpO2, weight, ECG, sugar, acceleration, spasm, sweating. All these parameters directly or indirectly affect other parameter and thus the disease detection can be possible through this type of algorithm. DDA is therefore useful in the health care monitoring systems as the algorithm provides an approximate value of the conditions of human metabolic change. The research is based on the own contribution of the project and the proposed algorithm promises to acquire higher accuracy in terms of its results, verified by a medical professional. Whereas, the results may vary person to person on the basis of its in-body response or behavioural pattern of an individual.

IV. CONCLUSIONS

The existing clinical enterprise practice is consistent with the proposed system. It incorporates the capability to scale the overall patient monitoring management process. The Sensitive information is protected with end-to-end communication explicitly. DDA helps with the detection of disease at early stages with the normal, abnormal, and critical levels of patient's dynamic metabolic conditions.

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