MedPad

Ashutosh Baheti, Sahil Jindal and Dhananjay Dass
Faculty Advisor: Dr. Amit Neogi
The LNM Institute Of Information Technology, Jaipur, India

Abstract- The complexity of today's world and the rising pollution levels has increased the risk of cardiac diseases, high blood glucose rates and mental disturbances. According to WHO 364 million people worldwide are diabetic. An estimated 17.1 million people died from CVDs in 2004, representing 29%of all global deaths. Of these deaths, an estimated 7.2 million were due to coronary heart disease and 5.7 million were due to stroke. A solution needs to be devised where the interface is very handy and user friendly and information can be tackled and dealt with many format like SD-MMC Card, Mobile phones. In case of emergency the GSM connected with Gadget should directly make a call to Emergency number with IVRS activated .This info of patients can be further used by family doctors on their cell phones who can suggest some measures and panacea for the such diseases which causes panic in everyone's mind.

1. Introduction

Today the world demands people to be working round the clock, ignoring their health. This has led to rise in deaths due to cardio vascular diseases. In 1990, there were an estimated 1.17 million deaths from coronary heart diseases in India and this number is expected to almost double to 2.03 million by 2010[1]. In India alone an estimated 19.3 million people had diabetes in 1995, and this is expected to almost triple to 57.2 million in 2025[2]. Hypertension is even more prevalent, and was affecting an estimated 118 million inhabitants in India in 2000; this number is expected to double to 214 million in 2025[3]. Epilepsy is a chronic neurological disorder that affects people of all ages. Around 50 million people worldwide have epilepsy. Based on the total projected population in India in the year 2001, the estimated number of people with epilepsy would be 5.5 million. The number of new cases of epilepsy each year would be close to half a million [4]. We want to design a reliable and a portable device for data acquisition and analysis of Electrocardiogram (ECG), Electroencephalogram (EEG), Blood Glucose and Blood Pressure. This device would also have a location allocation using GPS which can be forwarded to a Mobile along with a handful information of blood pressure level. Real time ECG, EEG data can be sent to a PC wirelessly using GSM. Proper signal acquisition is carried out using filters for noise suppression and amplifiers to enlarge the signal amplitude as much as possible, while keeping it within the input voltage range of the analogue-digital converter(ADC). The task of ADC is then to digitize the analogue voltage with a resolution high enough to represent the original signal. In other words, the quantization is the process of mapping a continuous range of values by a finite set of integer values. These values can then be collected by a microcontroller (MCU) which maintains the connection with the wireless transmitter. It is always dependent on the application, what we consider to be high enough voltage resolution. In EEG and EEG measurement the biggest challenge is the elimination of the body's DC offset and the 50Hz hum, which the human body –as an antenna- collects. An instrumentation amplifier is a type of differential amplifier, and as such it is perfect fit for this application. Its differential inputs with very high common mode rejection ratio- eliminate much of the DC offset and the interference picked up from the AC mains. Often the preferred implementation of signal amplification consists of two stages. The first differential amplifier gets rid of a substantial part of the noise while amplifying the signal. It is then further filtered before it is fed into second amplifier, which augments its amplitude close to the input range boundaries of the ADC. When it comes to measurement, instrumentation amplifiers are often used thanks to their great accuracy and stability of the circuit, both short- and long-term. These features make them desirable in our monitoring device. Once the signal is filtered and amplified, we are intent on recording with maximum accuracy on a battery powered device. In order to achieve that, we have to choose an A/D converter offering high resolution along with reasonable conversion time. Using GSM data from the ADC can be wirelessly transmitted onto a PC through a microcontroller. This data can be manipulated using Matlab.

2. Electroencephalogram (EEG)

2.1 Theory and Concepts

EEG can be roughly defined as the mean electrical activity of the brain in different sites of the head. More specifically, it is the sum of the extracellular current flows of a large group of neurons. EEG recordings are achieved by placing electrodes of high conductivity in different locations of the head. Measure of the electric potential can be recorded between pairs of active electrodes (bipolar recordings) or with respect to a supposed passive electrode called reference (monopolar recordings). These measurements are mainly performed on the surface of the head (scalp EEG). EEG is sensitive to continuum of states ranging from stress state, alertness to resting state hypnosis and sleep. Normal scalp EEG recording are usually taken with the subject relaxed in three modalities with eyes closed, eyes open and under hyperventilation, photo stimulation etc. Brain oscillations are divided in frequency bands that have been related to different brain states, functions or pathologies[5]. Alpha rhythms have a frequency range of 7.5-12.5 Hz. They appear spontaneously in normal adults during wakefulness, under relaxed state and mental inactivity conditions. Beta rhythms have a frequency range of 12.5-30 Hz. They are best defined in central and frontal locations, they have less amplitude than alpha waves and they are enhanced upon expectancy states or tension. Theta waves have a frequency range of 3.5-7.5 Hz and are enhanced during sleep. In wake adult theta activity is considered abnormal and it is related with different brain disorders. Delta rhythm varies between 0.5-3.5 Hz and is a characteristic of deep sleep stages.

2.2 System and Specifications

The EEG signals obtained are very low voltage signals and the signals also picks up noises so a pre-amplifier of high CMRR is used to amplify the signal. Further filters and non-inverting amplifiers are used to obtain the required signal. A block of the system is shown below.

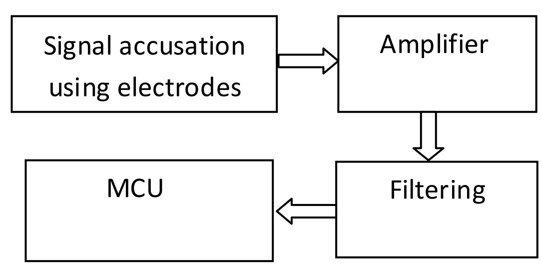


Fig 2.1 Block diagram of EEG system

2.2.1 Signal Accusation Using Electrodes

EEG signal are most prominent at P8 and P7 positions when measurements are made using a reference electrode [6]. So these positions were used in recording. Dry scalp reduces the conductivity of electrodes. In order to improve the conductivity electrode gel was used.

2.2.2 Amplifier

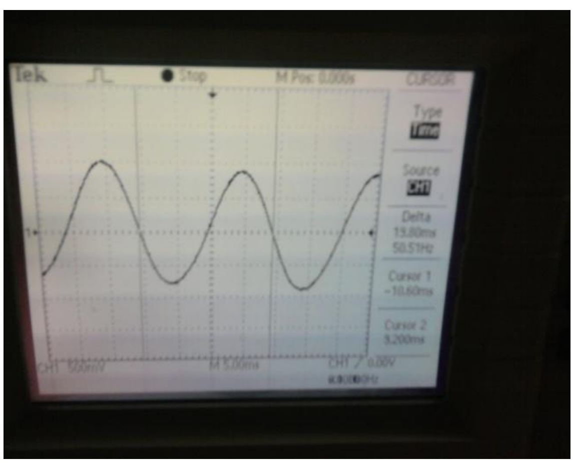
The signals acquired are of the range of a few mV. In order to process the signals they need to be amplified. First order amplification is done using high quality instrumentation amplifiers. We used AD620 for first stage amplification. A total gain of 500 was taken from the system.

2.2.3 Filtering

The signal observed after amplification has various noise components. In order to filter out the EEG signal a Butterworth high pass filter of cutoff frequency 0.16 Hz followed by low pass filter of cutoff frequency 48 Hz is used. The filtered signal is then digitized and sent to microcontroller for further processing.

2.3 Results

The following waveform was detected after filtering out the EEG signal. The signals were observed by subjecting the body to rest.



2.2 EEG signal observed using small time scale

3. Electrocardiogram (ECG)

3.1 Theory and Concepts

An ECG is a measurement of electrical activity of the heart muscle as obtained from the surface of the skin. ECG is the electric manifestation of the contractile activity of the heart's myocardium. The P, QRS and T waves characterizes the ECG signal. Any disturbance in the regular rhythmic activity of heart is known as arrhythmia. Most of the ECG machines use a 12-lead system[7], whereas in this project a 3-lead system is used. If the heart's electrical activity is viewed as a simple dipole, these three leads record the projection of this dipole onto the sides of the 'Einthoven Triangle', i.e. the equilateral triangle formed by the vectors of the limb leads. The electric signals of the heart obtained from the patient's body are of very low strength and are mixed with noise. The instrumentation amplifiers and non-inverting amplifiers further used provide a gain of about 200. Three different type of noises are present in the signal the dc electrode offset potential, 50 Hz AC induced interference and the muscular noise picked up by the electrodes.

3.2 System and Specification

The electric signals of heart obtained from the patient's body are of very low strength, low frequency and mixed with noise. The instrumentation amplifier amplifies the low strength signals and filter eliminates the noise. Using notch filter eliminates the 50 Hz supply noise picked up by body. Block diagram of the system is shown below.

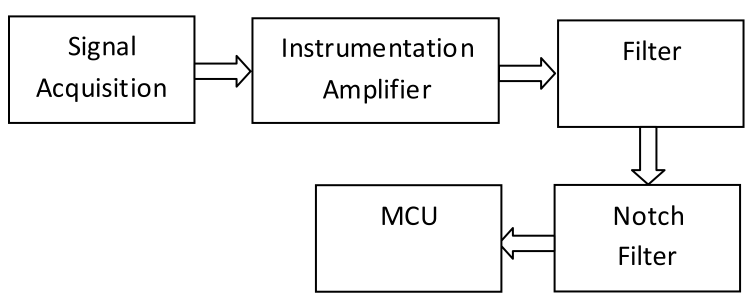


Fig 3.1 Block diagram of ECG system

3.2.1 Signal Acquisition

In practice three bipolar leads and nine unipolar leads are used but in our case we use three unipolar lead to form the Einthoven Triangle. Pasting electrodes are used one is placed on Right arm another on Left arm and one on Left leg.

3.2.2 Instrumentation Amplifier

AD620 instrumentation amplifier has been used. This is intended for low level signal amplification where low noise, low thermal and time drifts, high input impedance and accurate close loop gain are required. Besides, high CMRR and high slew rate are desirable for superior performance. As ECG signal is of very low amplitude instrumentation amplifier is used to amplify it at an initial level so that it is not loaded.

3.2.3 Filter

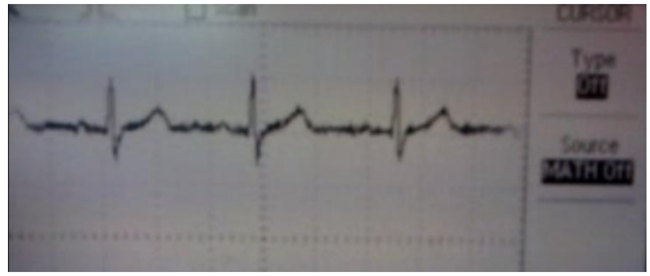
A Butterworth Band Pass filter of range 0.1-150 Hz[8] was used to filter out the signal. Filtering eliminates out the noises present in the signal only noise left is a 50Hz AC hum.

3.2.4 Notch Filter

In order to reduce 50Hz power line frequency hum notch filter is very essential. It should be highly precise at 50Hz. After this the signal is digitalized and sent to the processing unit.

3.3 Results

The P, QRS and T waveform was observed using the procedure described above. While making the observations the body was subjected to rest and three leads were used one on the left hand one on the right hand and one on left leg



3.2 ECG Wave

4. Blood Pressure

Blood pressure is the force exerted by blood inside the blood vessel or a cardiac cavity. Blood pressure comes from the heart activity as a pump and its measurement is important to the monitoring of the cardiovascular system[9]. For each heartbeat, blood pressure measurement varies between systolic and diastolic pressure. Oscillatory technique was used for blood pressure measurement. In this method, the arterial flow is blocked by inflating the pneumatic system (cuff) above the systolic pressure level. The oscillometric technique operates on the principle that as the occluding cuff deflates from a level above the systolic pressure, the artery walls begin to vibrate or oscillate as the blood flows turbulently through the partially occluded artery and these vibrations will be sensed by the transducer system that monitors cuff pressure. As the pressure in the cuff decreases, the oscillation increases to maximum amplitude and then decreases until the cuff is fully deflates and blood flow returns to normal. When the oscillation crosses the cuff pressure, the systolic pressure is identified. As the pressure in the system continues to decrease slowly, up to the point it is under the cuff pressure, the diastolic pressure can be measured [10].

4.2 System and Specification

During a measurement cycle, the microcontroller activates the inflation and deflation of the pneumatic system. The cuff pressure is detected by a piezoelectric transducer and converted into an electric signal proportional to the pressure. The signal observed is of few mV. So it is further amplified and processed. A block diagram is shown below

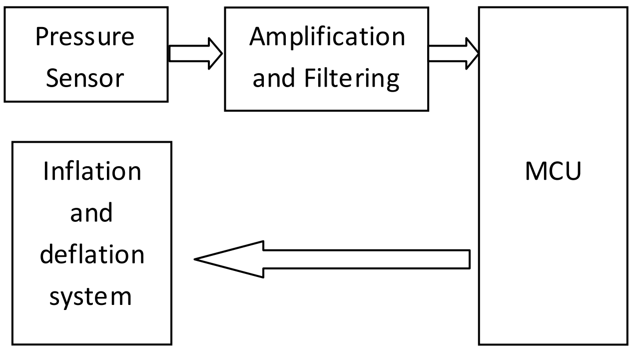


Fig 4.1 Block diagram of Blood Pressure system.

4.2.1 Pressure Sensor

To measure the arterial pressure a pressure transducer MPX2050 was used. This sensor has a linear output proportional to the applied pressure. The sensor output has two signals, the pressure signal and the signal that contains the oscillation information.

4.2.2 Amplification and Filtering

The pressure signal is pre amplified using a instrumentation amplifier AD620. Signal is further filtered using a Butterworth Band Pass filter of cutoff frequency 6.63-19.9Hz. The oscillatory component is filtered using Butterworth Band Pass filter of range 0.48-4.8 Hz and then amplified. These two frequencies were chosen to guarantee that oscillation signal does not have distortion or can be lost [11].

4.2.3 Inflation and Deflation System

The inflation and deflation system is formed by a pneumatic pump and an electro valve. The pneumatic pump inflates the system, while the electro valve drains the system.

4.3 Results

The following curves were observed

4.2 Blood Pressure Signals

5. Blood Glucose

5.1 Theory and Concepts

Diabetes is a disease where the body does not properly use or produce insulin. The major problem with diabetes is that the underlying causes of it are currently unknown. At this time, there is no cure for diabetes so life-long treatment is the only alternative. These treatments can consist of blood glucose monitoring combined with insulin injections, keeping to a strict diet to control sugar intake, and exercise. The method for measuring the glucose concentration in a whole blood sample will be of the amperometric type.

5.2 System and Specification

The first step to measure glucose in the blood is to convert the glucose concentration into a voltage or current signal, this is possible with special sensor strips for amperometry. The sensor uses a platinum and silver electrode to form part of an electric circuit where hydrogen peroxide is electrolyzed. The hydrogen peroxide is produced as a result of the oxidation of glucose on a glucose oxide membrane. The current flowing through the circuit provides a measurement of the concentration of hydrogen peroxide, giving the glucose concentration. The sensor used as a blood glucose meter is based on a glucose oxide electrode. The glucose oxides are immobilized in a platinized activated carbon electrode. The enzyme electrode is used for amperometry determination by using an electrochemical detection of enzymically produced hydrogen peroxide. The sensor is composed of various electrodes: a glucose oxide membrane layer, a polyurethane film that is permeable by the glucose, oxygen, and hydrogen peroxide. Amperometry measures electric current between a pair of electrodes that are driving the electrolysis reaction. Oxygen diffuses through the membrane and a voltage is applied to the Pt electrode reducing O2 to H2. These reactive electrodes are amperometric type sensors that use a three electrode design. This approach is useful when using amperometric sensors due to the reliability of measuring voltage and current in the same chemical reaction. Three electrode models use a working electrode (WE), reference electrode (RE), and a counter electrode (CE). After this current is produced, it must be changed to voltage for processing by the microcontroller (MCU). This action is performed by the transimpedance amplifier. Finally, the MCU detects and processes this signal with the ADC module. For example, here is a practical way to explain amperometry. A voltage is applied in the WE and RE electrodes with a range of -200 milivots to 8 volts. This is used to define the voltage at which the sensor is able to perform at the maximum current. This value is around 4 volts with a current of 18 microamperes After selecting the 4 volts as an operating value, we obtain a stabilization time between 2 and 4 seconds. This means a reliable measurement can be obtained in this time since the maximum current is reached.

5.3 Results

The waveforms observed were

6. GPS and World Wide Web

6.1 GPS System

Known as the Global Positioning System (abbreviated as GPS) is a radio based navigation system formed worldwide, consisting of an array of 24 satellites that broad cast radio signals to GPS receivers [12]. One could consider GPS receivers are basically radio receivers with serial communication interfaces as their output transducers, where the information could be sent to other independent devices with higher levels of computational power and larger storage capabilities than a GPS receiver could have, such as a computer. **A** GPS receiver refers to the GPS satellites to calculate its own location in a very accurate manner. The basic operation of a GPS system actually is measuring distances on altitudes close to the surface of earth, by means of referring to the time it takes for radio signals to travel between the receiver and the satellite. Thi**s** method enables the calculation of the objects latitude, longitude, altitude, and three dimensional speed vectors. **As** a conclusion, one could consider GPS technology as uniquely addressing each square meter on our planet. GPS system was used to locate the position of the patient so that in case of emergency a message containing the location of patient can be sent using a GSM module.

6.2 World Wide Web

MedPad could be broadly divided into three parts: Sensor frontend, MCU mediator and the data delivery end. While the function of sensor frontend is to transmit the raw information (EEG, ECG, Blood Glucose) to MCU (Atmel or Arduino in our case), the function of MCU is to store the received data in a digital form inside an onboard SD-MMC card. The data for a particular month is stored in the corresponding Log Files. For ex: Suppose it's the July of 2005 and MCU takes the data from sensor every 15 minutes. After passing it through an ADC, digital data is stored in the file named 7-2005 along with the timestamp and geographic coordinates taken from GPS. The format of the file is CSV(comma separated varibales).

D2005-07-17,U1121558400000,T23:23:00,N18,M24,S31,L70.02464,13.03648,6;

D2005-07-19,U1121731200000,T06:35:00,N19,M69,S31,L95.06794,22.08465,21;

The above format is of the following manner:
D<Date>,U<UnixTime>,T<UTCtime>,N<SerialID>,M<Sensor1reading>,S<Sesnor2reading>,L<coordinates>

Data delivery end is an equally important part of the entire project. It functions in the following manner:

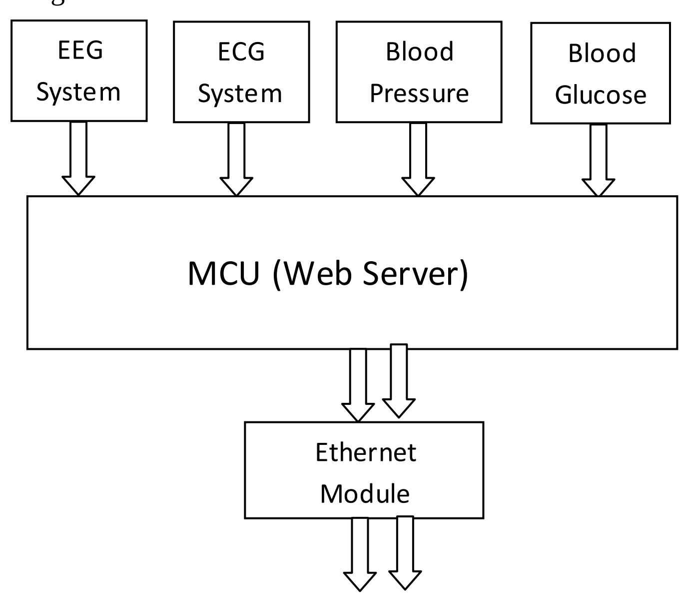
- A web server is implemented on the MCU which transmits the information to the client, who wants to seek the data of patient.
- The web connectivity to the MCU is provided by fixing an Ethernet Shield (Arduino in our case) over it and in turn connecting the shield to either Wi-Fi or RJ-45 cable.
- Ethernet shield[4] allows us to provide a static IP address to the module or to configure a DHCP server and then request an IP address.
- Now, let's take a scenario in which a client preferably doctor needs to check the EEG, ECG and other body parameters of the patient whose MCU is configured with an IP address 192.168.177. The mode to retrieve the desired information is to send an URL request to the patients MCU.

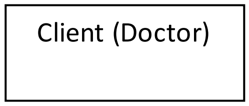
192.168.1.177/rest/services/<startingdate>*<ending date>

- Upon receiving the request of above kind, web server implemented on the MCU responds with the patients data it recorded from the <starting date> to the <ending date>. The format of the date is <mm-dd>.
- The response to the client is not the raw data stored in the log file [1], but the data is embedded into a KML file and then sent to the client. KML file is a support file designed to show geographic and other features on earth browsers like Google Earth. Snapshot of the response [2] and the way it is displayed by Google Earth [3] is shown below.

7. MedPad as a System

The data from EEG, ECG, Blood Pressure, Blood glucose systems were digitalised using a 16 bit A/D converter and then sent to a microcontroller unit using At-mega 128 microcontroller. The processed data was sent to server using GSM. The location of the patient was also sent using a GPS module. The block diagram is shown below.





7.1 Block diagram showing MedPad as a System

8. Conclusion

Using a microcontroller a reliable, cheap and efficient health monitoring system can be designed. The operating cost of the system is also low. This system can be easily operated and can be used to maintain a database of the patient. We can make a more portable device if we use wireless sensors.

9. References

1. Ghaffar A, Reddy KS, Singhi M. Burden of non-communicable diseases in South Asia. *BMJ 2*004; *328:*807-10.

2. King H, Aubert RE, Herman WH. Global burden of diabetes, 1995-2025: prevalence, numerical estimates, and projections. *Diabetes Care* 1998; *21* : 1414-31.

3. Kearney PM, Whelton M, Reynolds K, Muntner P, Whelton PK, He J. Global burden of hypertension: analysisof worldwide data. *Lancet* 2005; *365* : 217-23.

4. Sridharan R, Murthy BN. Prevalence and Pattern of Epilepsy in India. *Epilepsia 1999; 40(5);631-636.*

5. Niedermeyer E. The normal EEG of the waking adult. In: E. Niedermeyer and F.H. Lopes da Silva (eds). Electroencephalography: Basic Principles, Clinical Applications and Related Fields. Baltimore: Williams and Wilkins 3rd ed., 1993a, pp: 131-152.

6. Glimore RL(1994): J Clin. Neurophysiol RL Glimore(ed.); American Electroencephlographic Society guidelines in electroencephlography, evoked potential. And polysomnography, J. Clin. Neuophysiol. 11: (1, January) 147 pp.

7. Menown IB, Mackenzie G, Adgey AA, Optimizing the initial 12-lead electrocardiographic diagnosis of acute myocardial infarction, *Eur Heart J* 21(4):275–283,2000.

8. Cutmore TR, James DA, Identifying and reducing noise in psychophysiological recordings, *Int J Psychophysiol* **32**(2):129–150, 1999.

9. Carvalho L. C. "Instrumentação Médico - Hospitalar". Manole. Barueri, São Paulo. 2008

10 Boylested L. R., Nashelsky L. "Dispositivos Eletrônicos e Teoria de Circuitos". Prentice Hall. Rio de Janeiro. 1998.

11 Boylested L. R., Nashelsky L. "Dispositivos Eletrônicos e Teoria de Circuitos". Prentice Hall. Rio de Janeiro. 1998

12. Kaplan, E. *D.*, Feb, 1996, *"Underslunding GPS: Principles and Appliculions".* Artech House

```
▼<Placemark>
  ▼<TimeStamp>
     <when>2005-06-05T13:23:00z</when>
   </TimeStamp>
   <name>4.) 2005-06-05</name>
  ▼<ExtendedData>
    ▼<Data name="Serial ID">
       <value>4</value>
     </Data>
    ▼<Data name="Date">
       <value>2005-06-05</value>
     </Data>
    ▼<Data name="Time">
       <value>13:23:00 UTC</value>
     </Data>
    ▼<Data name="Temperature(celsius)">
       <value>16</value>
     </Data>
    ▼<Data name="Glucose(mg/L)">
       <value>31</value>
     </Data>
   </ExtendedData>
  ▼<Point>
     <coordinates>68.37468,22.78923,32<
   </Point>
 </Placemark>
▼<Placemark>
```

Figure 1 Snapshot of the KML response to the client

Figure 2 Arduino Ethernet Shield which provides the web connection to patient's MCU

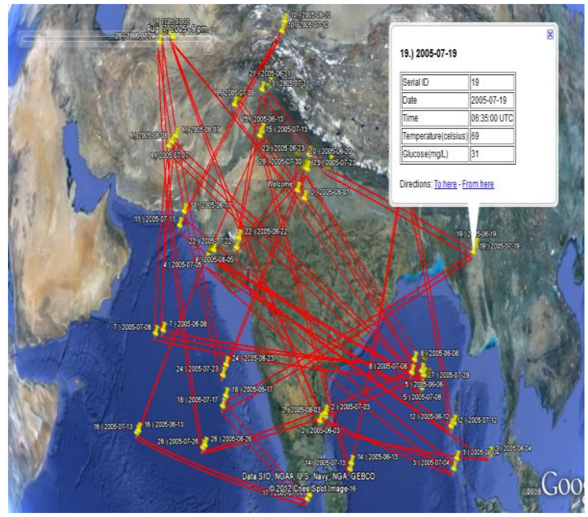


Figure 3: The snapshot of the KML response as displayed by Google earth. The red line shoes the path of MCU and the yellow buttons show the places where readings have been taken. On clicking the button, one can see the patient's body information at that instance as displayed in the white dialog box. Note: This is not the actual data but a mock up data added to test the data delivery part.

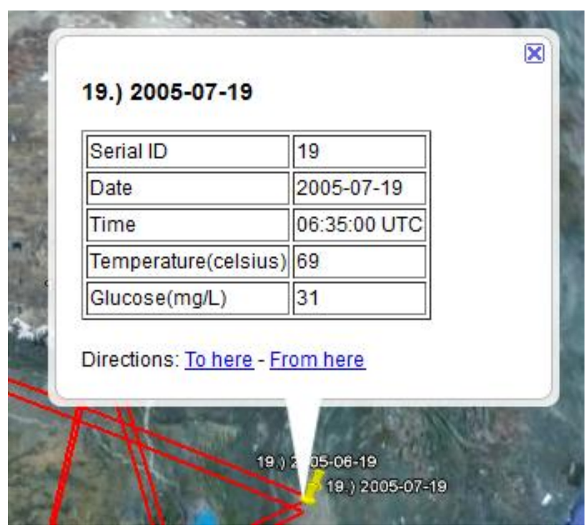


Figure 4: Dialog box showing patients information as displayed by Google earth on clicking the yellow placemark button.