Motorola Scholar Awards : 2007-2008

Judges decision on the Motorola Awards

Note: You can view the details of the project in PDF format by clicking on the link on each heading of the project title.

First Prize

PROJECT	:	**SMART EPILEPSY PREDICTION AND LIFE SAVER SYSTEM**
STUDENTS	:	C. S. ANANTHAKRISHNAN
		RAJESH T. REMANAN
COLLEGE	:	GOVERNMENT COLLEGE OF ENGINEERING, CHERTHALA, KERALA

Second Prize

PROJECT	:	**DESIGN OF VIRTUAL INSTRUMENTATION FOR AUTOMATED INSPECTION OF HIDDEN PROBLEMS IN BRIDGES**
STUDENTS	:	A. SOMASUNDARAN
		N. VIGNESH
		S. VENKATESH RAHUL
COLLEGE	:	SRI KRISHNA COLLEGE OF ENGINEERING AND TECHNOLOGY COIMBATORE, TAMIL NADU

Third Prize

PROJECT	:	**WIRELESS SENSOR BASED ONBOARD SAFE RAILWAY SYSTEM**
STUDENTS	:	E. ANAND SOLOMON
		S. JEEVA
		G. SHANKAR
COLLEGE	:	THIAGARAJAR COLLEGE OF ENGINEERING, MADURAI, TAMIL NADU

SMART EPILEPSY PREDICTION AND LIFE SAVER SYSTEM

COLLEGE : GOVERNMENT COLLEGE OF ENGINEERING, CHERTHALA, KERALA
GUIDE : DR. T. K. MANI
STUDENTS : ANANTHAKRISHNAN.C.S
RAJESH T. REMANAN
BRANCH : ELECTRONICS AND COMMUNICATION

1. Introduction

Epilepsy is a very fatal condition which is caused as a result of imbalance in the nervous system. The very common symptoms of epilepsy includes sudden fluctuations in heart beat rate and involuntary muscular movements (seizures). The aura (practical symptom) of epilepsy includes fluctuations in heartbeat, nausea, dizziness etc.

The wireless electronic diagnosing system designed here is exclusively meant for epilepsy patients. The system helps them in accurately predicting the occurrence of seizures. Sudden occurrence of seizures during driving may lead to accidents and its occurrence during sleeping hours can even lead to the patient's death, if no immediate, proper attention is provided by a bystander or a doctor. With the aid of this system, the patient can lead a normal life. Since the occurrence of seizures is unpredictable, it will be a very risky task to leave the patient alone.

The electronic system presented here is a wearable device which predicts the occurrence of epilepsy in a few minutes advance. The device utilizes the signals from human body to detect the occurrence of epilepsy. As soon as the device detects the symptoms, it transmits a coded signal. The signal is decoded by a wireless receiver to produce control signals for switching an alarm device, mobile messaging device and an automatic vehicle control system appropriately. In future,

GPS could be incorporated to trace out the exact location of the patient.

Current technologies for acquiring signals from the patient's body are very much developed. Many sensors are available which can detect the heart beat and muscular movements non-invasively and accurately.

Such non invasive technique for measuring heart beat is pulse oximetry. Using this technique, heart beat can be accurately monitored. Muscular convulsions are collected using micro electromechanical sensors (MEMS) firmly attached to the body. The sensors used are small in size and can be firmly attached to the body. The accelerations resulting from epileptic convulsions are sensed using MEMS accelerometer which is very accurate, precise and small in size.

To provide wireless communication channel low cost network using MiWi protocol is utilized. MiWi is a standard protocol developed by Microchip Inc, USA, based on IEEE 802.15.4.

Heart beats are to be monitored continuously. Any sudden variation in heart beat which is caused by the onset of epileptic seizures is detected and confirmed with the MEMS signal. When the seizure is confirmed, message is transmitted to the surroundings for initiating necessary protective measures for the patient.

The device is designed as a wireless, wearable and personal equipment. The device can sense the aura of pre ictal stage in a few minutes advance and takes the necessary safety measures automatically. Hence a technician's assistance is not required for the patient. Therefore this device will be extremely useful for patients (especially youngsters) who wish to be active in their life. The user gets absolute freedom from wires and can be used when moving.

To practically implement the epilepsy prediction system, the following aspects should be implemented.

1. Sensing biometric signals: Two types of biological signals are required for processing. They are heart beat and muscular convulsions. The heart beat can be measured

using pulse oxy meter and muscular movements can be measured using mems sensor.

2. Processing it and taking decisions: Processing of the signals is done by software programmed into a microcontroller. The software is designed in such a way that it detects the exact symptom of epilepsy.
3. Communication: Communication is set up using a transmitter and receiver module with MiWi protocol
4. Controlling: Automatic vehicle control system, mobile messaging device and an alarm device is integrated to the receiver for protecting the patient.

2. Constraints

1. Smaller size and weight requirement
2. Low power consumption requirement as the device is battery operated.
3. Suitable long life battery
4. Accurate technique or algorithm for foolproof detection of seizure
5. Secure communication between the wearable equipment and the receiving unit
6. Signal processing requirement
7. Cost effectiveness

The application of this system focus on epilepsy patients who wish to move freely without the assistance of others in their life. The system is a wearable device which can detect the aura of seizure in an epilepsy victim very much precisely in time by processing the signals available from the patient's body at the pre ictal state. The system uses a processing device to process the signals from the human body and activates a wireless transmitter which transmits a coded signal. The receiver decodes the signal using another processing unit which results in the production of control signals for activating various safety devices mounted on the vehicle or on the dormitory where the patient commonly resides. For e.g, if the seizure occurs while the victim driving a vehicle or while sleeping the device automatically generates

control signals for the control of vehicle, setting off an alarm circuit and messaging the doctor about the patient's condition via short messaging Service (SMS). The system can be expanded easily in such a way to include Global Positioning System (GPS) for tracing out the exact position of the victim of epilepsy in the future. Thus the device saves the patient from accident or even death and acts as a "LIFE SAVER"

3. Design

The design consists of hardware and software sections. The device hardware mainly consist of three parts namely, (i) Heart beat sensor, (ii) Seizure detector, (iii) Processor and (iv) Wireless transceiver

(i) Heart beat sensor: The heart beat of the patient is to be monitored accurately. For this purpose, a pulse oxy meter is used. Pulse oxy meter measures heart beat by sensing the difference in absorbance of infrared radiation by blood during systolic and diastolic activities of heart. The volume of blood flowing through arteries varies widely during each heart beat. Hence if infrared radiation is incident on it, the absorbance of IR also varies according to the heart beat. These variations are sensed using a photo detector to determine the heart beat.

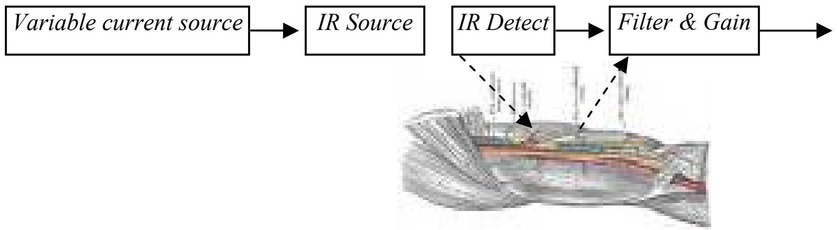

Figure 1: Pulse Oxy meter and its principle of operation

The pulse oxy meter designed here works using reflective principle. The IR source emits IR radiation which is reflected in accordance with the flow of blood. The reflected rays are detected using a photo detector.

A sensor is placed on a thin part of the patient's anatomy, usually a fingertip or earlobe, and light of infrared wavelength is made incident on the body. Changing absorbance of the infrared is measured, allowing determination of the absorbance's due to the pulsing arterial blood alone, excluding venous blood, skin, bone, muscle, fat, and (in most cases) fingernail polish. The circuit of pulse oxy meter consists of a trans-resistance amplifier, voltage follower, difference amplifier, and filter. All these stages are cascaded together to from the complete circuit of pulse oxy meter. The circuit works in 5 V supply. In order to get perfect amplification sans noise, ultra low offset operational amplifier OP07 and FET input operational amplifier LF 356N is selected. A trans resistance amplifier is used in the first stage to convert the photodiode current to voltage. The major design parameter of this sensor is its output voltage and the output frequency. The output frequency is band limited to 15 Hz using filters. Low pass first order butterworth filter is used. Low pass filter is designed at 15 Hz upper cut off frequency with a gain of 1.5. A high pass first order butter worth filter with lower cut off frequency of 0.5 Hz is cascaded with the low pass to remove the dc voltage. An amplifier is set at the output of the meter in order to raise the output signal level to +5V (approx). Amplifier with amplification factor of 50 is designed. Typical output of the sensor is shown on the graph below. Normal heart beat is 72 beats per minute. That is the frequency of the signal is 1.2 H_z for a healthy person. The output amplitude varies from 70mV to 120mV.

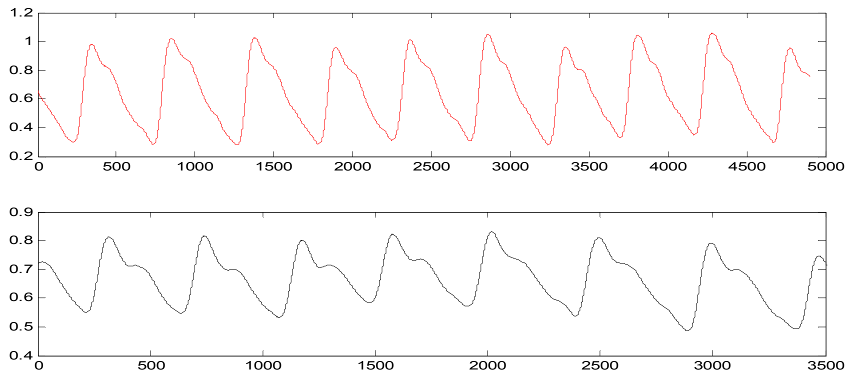

Figure 2. Signal at the output of the pulse oxy meter

(ii) Seizure detector: Seizures are involuntary muscular movements which occur during epilepsy. Muscular movements are sensed using MEMS (micro electro mechanical sensor) accelerometer. A 3D accelerometer is used to sense the muscular movements. The ADXL330 is a low cost, low power, complete 3-axis accelerometer with signal conditioned voltage outputs, which is all on a single monolithic IC. The ADXL330 is a complete acceleration measurement system on a single monolithic IC. The ADXL330 has a measurement range of ±5 *g*. The sensor is a polysilicon surface-micro machined structure built on top of a silicon wafer. Polysilicon springs suspend the structure over the surface of the wafer and provide a resistance against acceleration forces. Deflection of the structure is measured using a differential capacitor that consists of independent fixed plates and plates attached to the moving mass. The fixed plates are driven by 180° out-of-phase square waves. Acceleration deflects the beam and unbalances the differential capacitor, resulting in an output square wave whose amplitude is proportional to acceleration. Phase-sensitive demodulation techniques are then used to rectify the signal and determine the direction of the acceleration.

The demodulator's output is amplified and brought off-chip through a 32 kΩ resistor. The signal bandwidth of the device is set by adding a capacitor. This filtering improves measurement resolution and helps prevent aliasing.

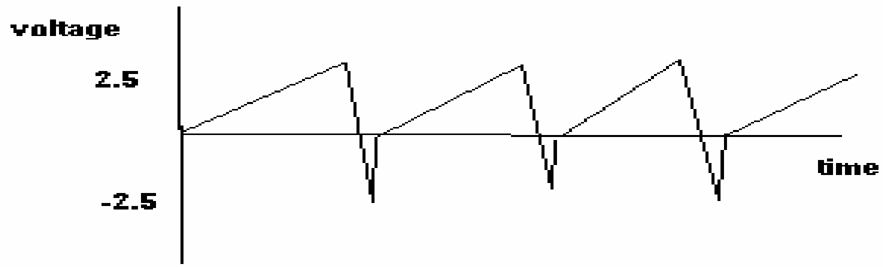

Figure 3. Typical signal output of the MEMS accelerometer

Performance of the project was affected due to the non availability of 3 axis accelerometer. Hence here I have used a single axis accelerometer MMA1260EG from FREESCALE semiconductor for detecting the muscular convulsions. It has a sensitivity of 1.5g. The output is filtered using a n RC low pass filter with values R=1 KΩ ad C=0.10.1µf. The output of the sensor during typical seizure is shown on the graph. The output of MEMS is given to a 10 bit analog to digital converter for digitizing the output.

(iii)Processor: The signals from sensors are processed using PIC18F4620 microcontroller. The microcontroller requires a 10 bit ADC and a comparator circuit for processing the signals from the sensor. PIC 18F 4620 includes built in ADC and comparator. The processor is clocked at 4MHz. The frequency of normal heart beat rate is 1.2 $H_{Z.}$ approximately. Or the time period of the heart beat signal is 0.83 secs. The algorithm detects the sudden decrease in pulse width which is one of the aura of epilepsy. As soon as the variations in the heart beat are detected, the algorithm checks for the typical seizure waveform from the mems sensor. When these two signals coincide, the software takes the decision as an epileptic seizure and generates control signals.

(iv) Wireless transceiver: The device uses MiWi protocol for communication. The MiWi™ Wireless Networking Protocol is a simple protocol designed for low data rate, short distance, and low-cost networks. Fundamentally based on IEEE 802.15.4™ for wireless personal area networks (WPANs), the MiWi protocol provides an easy-to-use alternative for wireless communication. In particular, it targets smaller applications that have relatively small network sizes, with few hops between nodes, using Microchip's MRF24J40 2.4 GHz transceiver for IEEE 802.15.4 compliant networks. The MiWi protocol is based on the MAC and PHY layers of the IEEE 802.15.4 specification, and is tailored for simple network development in the 2.4 GHz band. The protocol provides the features to find form and join a network, as well as discovering nodes on the network and route to them. The card uses PCB trace antenna. The device uses line of sight communication. The range is approx. 200ft.

The wireless transmitter and receiver hardware consist of a motherboard with PIC 18F4620 microcontroller. The motherboard consists of a daughter card with microchip MRF24J40 IEEE 802.15.4 2.4 Ghz transceiver. The board is designed to work at 9V to 3.3 V DC. The MiWi protocol stack can be installed on the board and the required application can be programmed into it. A peer to peer network is formed using the transceivers.

One node is programmed as the network coordinator and the other as an end device. The coordinator is set as the transmitter and the en device as the receiver. The long address is assigned for the network and the short address to the nodes.

The device is designed in such a way that it searches for a network as soon as the module is switched on. The coordinator assigns the address to the end devices and forms the network if one is not detected.

The MRF24J40 is an IEEE 802.15.4-2003 compliant transceiver supporting MiWi™, ZigBee™ and other proprietary protocols. The MRF24J40 integrates wireless RF, PHY layer baseband and MAC layer architectures that can be combined with a simple microprocessor to apply low data rate to a multitude of applications The MRF24J40 device integrates a receiver, transmitter, VCO and PLL into a single integrated circuit. It uses advanced radio architecture to minimize external part count and power consumption. The MRF24J40 MAC/ base band provide hardware architecture for both IEEE 802.15.4 MAC and PHY layers. It mainly consists of TX/RX FIFOs, a CSMA-CA controller, super frame Constructor, receive frame filter, security engine and digital signal processing module. The MRF24J40 is fabricated by advanced 0.18 µm CMOS process and is offered in a 40-pin QFN 6x6 mm2 package.

The MRF24J40 consists of four major functional blocks:

1. An SPI interface that serves as a communication channel between the host controller and theMRF24J40.

2. Control registers which are used to control and monitor the MRF24J40.
3. The MAC (Medium Access Control) module that implements IEEE 802.3™ compliant MAC logic.
4. The PHY (Physical Layer) driver that encodes and decodes the analog data. The device also contains other support blocks, such as the on-chip voltage regulator, security module and system control logic.

4. Design of software

The processing unit utilizes the logic implemented in the software for accurate detection of seizures. The software checks the input signal from the pulse oxy meter from the patient's body continuously and measures the pulse width of the signal. This width is converted into heartbeat rate by the software. If there is any abnormalities in heart beat, it can be detected as a change in the pulse width .As soon as the logic detects a change it triggers the vibrator and the system waits for the response. The patient has to press a button on his wearable unit. If the patient is unable to do so due to occurrence of seizure, then response signal from MEMS sensor which senses the muscular convulsions is captured and analyzed. If there are signals of muscular convulsions the software concludes that the patient has seizure and warning message is transmitted using the wireless transmitter. The seizure detection algorithm from the MEMS signals is to check only the sudden abnormality occurring in the human body. This algorithm helps to avoid situations where heart beat rises due to excessive physical work or due to tension etc. The algorithm uses the averaging technique to determine abnormalities accurately.

$P=(P+N)/2$

where p=previous heart beat rate

N=next heart beat rate.

For a person suffering from epilepsy, in the pre ictal stage the heart beat varies abruptly and hence the value of P also changes. This change in the value of P is detected and the

program is made to wait for the signal from the second sensor which senses the muscular convulsions. If muscular convulsions are detected from the second sensor, it triggers the transmitter on which transmits a coded signal which is received by the receiver. The software section contains the following major functional modules:

1. Heart beat rate calculations
2. Seizure detection from MEMS signal
3. Communication control
4. Overall supervision

5. Implementation

The system requires a heart beat sensor, muscular convulsion sensor, a transmitter, receiver, mobile messaging device, alarm device and automatic vehicle control system. All the above said parts are integrated together to a processor to form the device.

The epilepsy prediction system can be practically implemented by incorporating the following components

a) Heart beat sensor: A pulse oxy meter is used as a heart beat sensor.

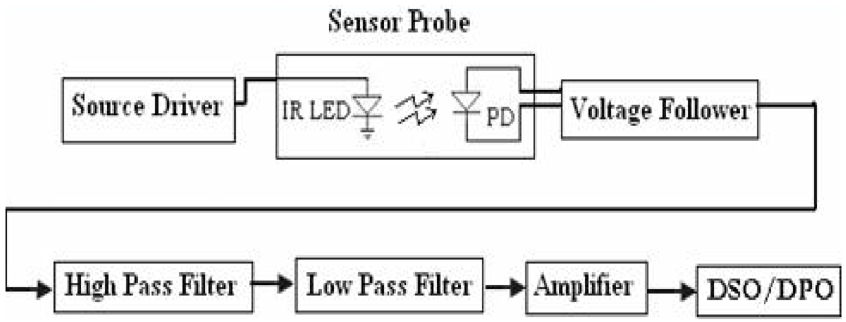

Figure 4: Block schematic of pulse-oxy meter

The implementation of pulse oxy meter is by cascading several stages as shown in the figure 4. A high pass filter is designed with lower cutoff frequency of 15 Hz. .the high pass filter is cascaded with a low pass filter designed to an upper cut off frequency of 0.5 Hz. The amplifier at the final stage raises the voltage from mV level to the required voltage range. An amplification factor of 50 is given to it.

b) Convulsions sensor: An accelerometer is used as a convulsion sensor.

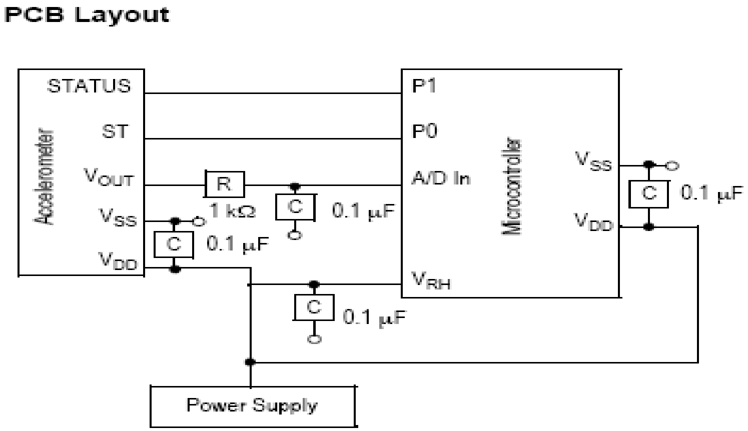

Figure 5: Block diagram of the convulsions sensor

Muscular convulsions are detected using single axis mems IC MMA1260EG. The sensitivity of the sensor is set to 1.55g. The circuit is implemented as shown in the circuit diagram. The output of the sensor is filtered out sing a low pass RC filter externally. The value of R is selected as 1KΩ and C as 0.1µf.

c) Processing unit: The processing unit contains PIC 18F4620 microcontroller which is clocked at 40 MHz.. PIC18F4620 have 64 Kbytes of Flash memory. The microcontroller has inbuilt 10 bit ADC which is used to digitize the output from MEMS module. It also includes a comparator which is used to process the heart beat waveforms from the pulse oxy meter.

The incoming signal is processed using logics implemented in the software which runs the device. The processing unit continuously checks for symptoms in the incoming signal. As

soon as it detects any abnormality, it triggers a warning vibrator and the wireless transmitter.

d) Wireless Transmitter and receiver: Wireless transceiver consist of a board consisting of MRF24J40 IC The transmitter transmits a coded signal which is decoded by a receiver to generate control signals. The control signal activates an alarm device, mobile messaging device and automatic vehicle control system appropriately.

Apart from the above important blocks, a buzzer circuit and a DC to DC convertor blocks are also implemented.

e) Enclosure design

The device is a wearable one (on the wrist). Hence the enclosure is designed suiting to that purpose. The enclosure can be designed in the form of a watch.

6. Photographs

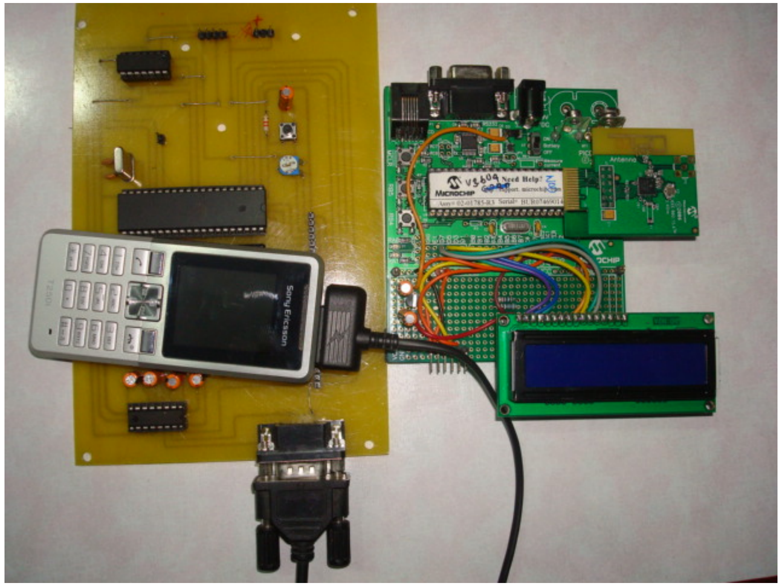

Figure 6: Epilepsy sensor, transmitter and receiver

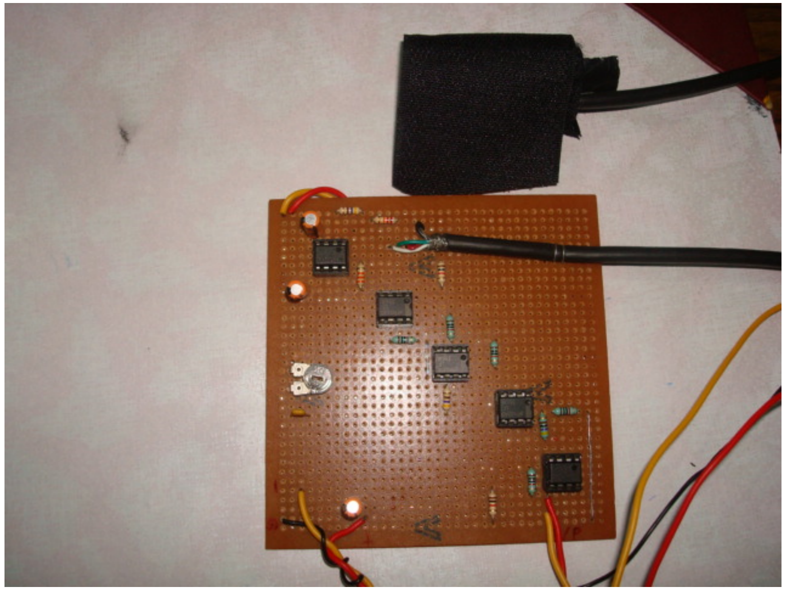

Figure 7 : Pulse oxymeter

7. Software tools used:

1. MPLAB Integrated development Environment
2. Microchip C18 compiler
3. Keil Integrated development environment

8. Testing

(i) Testing of Pulse oxy meter: The pulse oxy meter was tested by wounding the probe of the device on the index finger of a person and the output were viewed on a DSO. The output is shown in the graph given below. The pulse oxy meter successfully detected the heart beat waveform from the patient's index finger. The out put frequency was 1.2 H_z . And the voltage level was in the range of 100 to 120 mV.

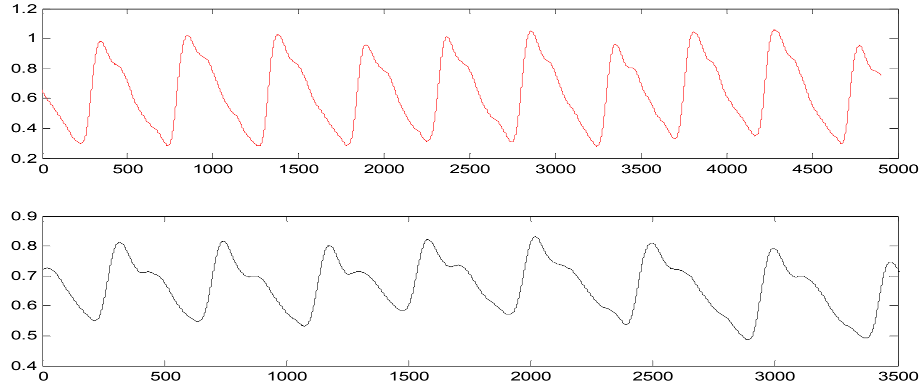

Figure 8: Output graphical wave form from pulse oxy meter

(ii) Testing of MEMS sensor:

The MEMS sensor is connected to the body of the patient using straps. Typical epileptic seizure waveform is shown in the figure below. The sensor output is expected to be of the shape as shown below. This stage is not yet fully tested and testing is under way.

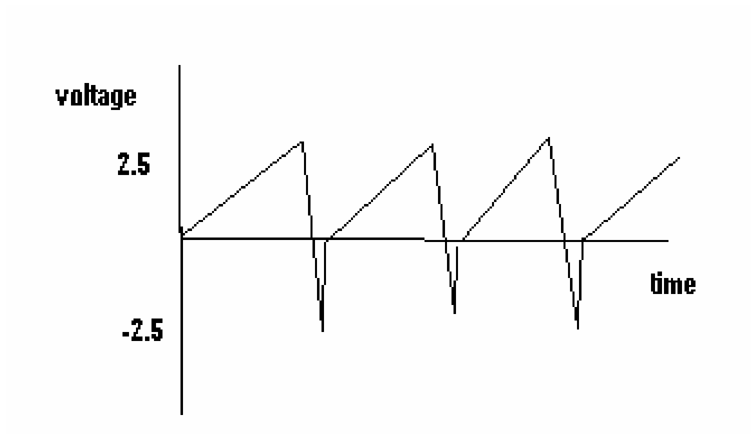

Figure 9: Typical signal from the MEMS sensor during seizure

(iii)Testing of software: The inputs from the sensors were provided to the PIC controller in which the software was programmed. Wave forms describing different conditions of the patient were given as input and tested successfully.

(iv)Testing of communication module The transceiver is directly connected to the microcontroller in which the software was programmed. As soon as the software detected the epileptic symptom, the transmitter was triggered. Using Zena network analyzer, the network was detected at a frequency of 2.4G Hz. A peer to peer single node network was formed which transmitted the message to the receiver node. The system designed here processes the heart beat continuously and abnormalities are detected accurately. The device transmits the signal only when seizures of epilepsy are detected. The performance of the device is not restricted by movement of the patient. By using this device the patient can move freely without worries

9. Problems encountered

We have encountered many problems as noted below:

1. Non availability of 3 axis accelerometer: We could not procure the 3 axis accelerometer and hence testing is only performed with a single axis accelerometer. However, the system gives better results only if a 3 axis accelerometer is used in for detecting muscle contractions.
2. Noise and temperature effect on the sensor outputs: Major problems were encountered due to noise picked up by the sensors. Use of shielded cable and grounding solved the problems to a satisfactory level. Heating effect of active components like op amps also created problems like drifting and thermal noise. This was solved by operating the op amps at a lower voltage.
3. Problem with suitable wearable enclosure: A suitable wearable enclosure is not designed. Compact PCB must be designed to fit all the components inside a wearable enclosure.

10. Cost of building

Major cost of the project is mainly due to the purchase of development boards and the PCB fabrication which are as shown below:

Cost of PCB fabrication	-	Rs 1750
Cost of discrete components	-	Rs 452
Cost of transmitter/receiver module and processing circuit:	-	Rs 9982

The total cost is around 12500 Rs only.

However it is estimated that the production component cost of the project will be around 5000 Rs only.

11. Advantages and benefits

The benefit of the project is that a lightweight, rugged, low-cost, wearable (on the wrist) device is developed which helps a victim of epilepsy to do all sorts of activities like others do.

- The device will be extremely cost effective since it uses simple sensors and technology for the detection.
- The sensors are small in size and can be firmly attached to the body
- Batteries can last long as the device consumes only little energy
- The device doesn’t restrict the movement of the patient.
- The system is easily expandable paving the way to incorporate much more sophisticated devices like ECG detector in the future
- Standalone application

12. Improvements

The system is easily expandable to incorporate GPS system and to capture and transmit various patient parameters like ECG , body temperature etc.

13. Conclusion

A light weight, rugged, cost-effective wearable device is developed which helps millions of victims of epilepsy around the globe. With the device in possession an epilepsy victim can move around freely like normal people sans worries.

Acknowledgements

The team is grateful to express their sincere gratitude to honorable principal Prof. Dr. T. K. Mani who has extended unlimited moral support and due encouragement throughout this attempt. The material support extended by Prof. Jayasree, research scholar, International school of photonics, CUSAT and Mr. Niras, Engineer, Kochi refineries Limited, by supplying the relevant electronic circuitry and technical advice where beyond words. The medico-technical support given by Dr. Jayakumar of Caritas hospital, Kottayam and Dr. Gigi Kuruttukulam of Lakeshore hospital, Kochi were beyond compare.

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DESIGN OF VIRTUAL INSTRUMENTATION FOR AUTOMATED INSPECTION OF HIDDEN PROBLEMS IN BRIDGES

COLLEGE : SRI KRISHNA COLLEGE OF ENGINEERING AND TECHNOLOGY, COIMBATORE, TAMIL NADU
GUIDE : PROF. P. GANESHKUMAR
STUDENTS : A.SOMASUNDARAN
S.VENKATESH RAHUL
N.VIGNESH
BRANCH : ELECTRONICS AND COMMUNICATION

1. Introduction

The concept of nondestructive testing (NDT) is to obtain material properties of in place specimens without the destruction of the specimen nor the structure from which it is taken. However, one problem that has been prevalent within the concrete industry for years is that the true properties of an in-place specimen have never been tested without leaving a certain degree of damage on the structure.

Virtually all concrete structures exposed to nature experience deterioration over time. Inspection personnel have difficulty determining the quality of *in-situ* concrete that has experienced decay without direct material sampling. The disadvantage to material sampling is that an inspector must remove a portion of the structure, usually by means of coring, and make repairs to the sample area. Removing cores from a concrete structure is an intrusive process that can weaken the structure and usually leads to long-term durability concerns. Hence the thermography method can be applied.

Thermography is the determination of surface temperatures of objects and bodies with the help of infrared photography. A special-purpose camera captures what the human eye cannot see. The camera consists of an infrared permeable lens, a transmission line and a sensitive detector. The detector converts radiation into electric signals. After processing they are transformed into pixels so that the thermogram appears on the screen. Infrared thermography can be performed on most buildings with the following concerns: insulation, a leakage, moisture, electrical, heating and cooling problems. Moreover, there are other similar applications such as construction defects, to qualify or quantify if there are materials added as specified, and so on. All these applications can be carried out relatively easily without performing destructive testing.

The theory of infrared thermography is based on three well-known radiation

- The law about the relation between emission and absorption found by Kirchoff.
- Planck’s law of radiation
- Stefan–Boltzmann law.

Kirchoff ’s law means that a body that absorbs much also emits much. When a “grey” body stands opposite a “black” body, absorption and emission are equal in the thermal balance. Thermography is based on the emission of objects. Therefore it uses the emission coefficient as the ratio of emissivity *E* of a real body to the emissivity s *E* of the black body under the same temperature.

$$\varepsilon = E/E_s \text{ (equation 1)}$$

Table 1: Emission coefficients of construction materials

Material	**ε**
Concrete	0.94
Sand	0.93
Brick	0.93–0.94
Limestone	0.96
Render/plaster	0.90–0.96

Glass	0.93–0.96
Wood	0.96
Roofing felt	0.93
Gypsum	0.90
Paint	0.90–0.95
Clay	0.95
Brick earth	0.93

The main application of infrared thermography in the civil sector lies in construction thermography. Fortunately, most materials used in the building industry have emission coefficients between 0.90 and 0.96 (Table 1). Therefore good assessment of thermal properties of a building can be made with only one exposure with the same. Post-processing of the thermo grams for zinc or copper clad components can then still be done with the computer. A basic condition for using thermography on buildings is a difference of 20 K between the inside and the outside temperatures. In the literature 10 K are sometimes considered enough. It means that examinations of buildings are reasonable only during the winter when the surrounding temperature lies around the zero point. Inside exposures are of greater significance because atmospheric conditions such as wind, rain, snow or sun as well as conditions of the building itself like ventilated facades have an effect on the results of the exposure. While heat bridges can be seen from outside, there are cold bridges observable inside. Cold areas clearly stand out on walls, loft conversions, corners on the floor or window frames. But heated floors and heaters on walls can also be made visible. The position and length can be exactly determined. Furthermore, it is possible to find leaking or plugged heating systems, badly done insulation or hidden timbered framework, which has been plastered over. Pictures taken with thermographic cameras are admitted in court because they provide unambiguous proof of botched construction works. Construction frames benefit from them as well since they can photograph critical areas in order to design targeted constructional measures before reconstructing old buildings.

The specifications of the IR camera used in the project are given below.

Specifications

1. Environmental specification

Operating temperature	
Range	-15°C to +50°C
Storage temperature	
Range	-40°C to +70°C
2. Imaging Performance	
Field of view	25° x 25°
Minimum focus distance	0.3 m
Focus	Manual
Detector type	Focal Plane Array(FPA),uncooled
microbolometer	120 x120 pixels
Spectral range	7.5 to 13 μm
3. Image storage	
Type	Built-in FLASH memory (50 images)
File formats	Standard JPEG
4. Measurement	
Temperature range	-10°C to +350°C
Thermal sensitivity	< 0.2°C at 25°C
Measurement mode	Fixed spot in the middle of the image
Menu controls	Palettes (color or black and white), auto-adjust (automatic/manual)
Set-up controls	Date/time, language, power down, display intensity Measurement corrections
Emissivity	variable from 0.1 to 1.0
Display	3.5" color LCD, 16K Colors
5. Battery system	
Type	Li-Ion, rechargeable, field replaceable
Operating time	7 hours continuous Operation. Display shows battery status
Charging system	In camera, AC adapter
AC operation	AC adapter 90-260 V AC, 50/60 Hz

2. Methodology

IR Camera captures the thermograph image of the area under test. Infrared (IR) is widely used for nondestructive testing. This offers noncontact, wide area detection of subsurface defects, and can be used as an alternative or complement to conventional inspection technologies. Also it has very fast inspection rate.

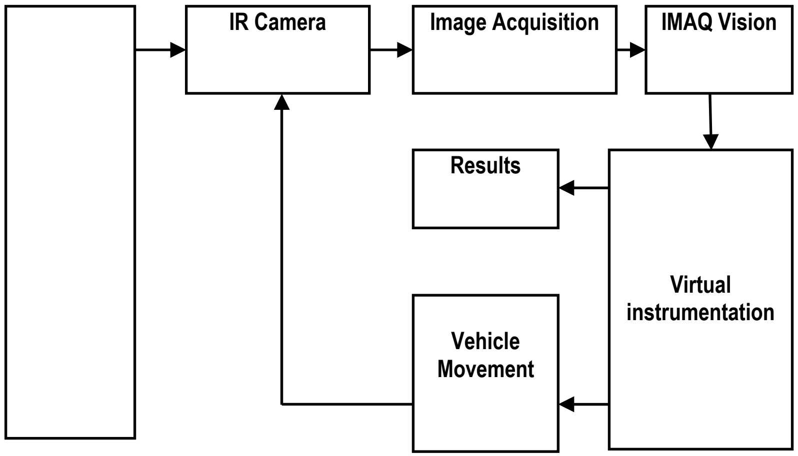

Figure1. Block Diagram

The acquired image is then processed using IMAQ Vision Builder software. First the luminance plane from the image is extracted. Then two processes namely Pattern matching and Gray scale tracking is done as required. Initially pattern matching is done in order to find the superficial and internal cracks. Here many ROI of different types of cracks are collected and saved in database. Then this ROI is matched with acquired image, by which can locate the defects with the help of parameters such as center(X, Y), corners of the bounding box and it's score.

In Gray scale tracking the structural defects such as blisters, air ducts, chloride corrosion, and fake material can be found out on basis of its threshold values. The manual threshold operation allows us to indicate the defects in the extracted image. Also it can display the histogram of a portion of image by drawing an ROI around the defective region. Then particle analysis can be done to these selected ROI. This analysis gives all the parameters of the defect such as pixel, area, width, diagonal, shape etc. These values can be saved in spreadsheet for further analysis. The Lab View Block for the IMAQ script is created to make the results useful for automating the fault identification.

The automation process is done with the help VI Environment. Here the results obtained from Image processing like area and defect size in pixel are converted into real world measures like defect length in mm, and the location of defect in x, y co-ordinates are converted into distance from starting point of the bridge. The indication of defects is done with the change in movement vehicle which carries the IR camera. The first pause for few seconds in the vehicle indicates the start of the defect and the next pause for same delay indicates the end of the defect. These delays are produced by control pulses whose period is same as that of delay. The speed of the vehicle is also made to be different while it tracing the defective surface when compared to the normal surface. This is achieved by varying the number of cycles.

The hard ware unit consists of a vehicle having totally stepper motors. All the four stepper motors work in a synchronous a manner during the forward and backward motion. But during the right turn the stepper motors at the right side alone rotates and the remaining two stops until it turns about 180 degrees and vise versa. The remaining movements of the vehicle for indicating the location of the faults are as described above.

3. Results and discussion

As mentioned above the objectives are to over come the draw backs of the traditional methods such as Visual inspection and Hammer sounding, for which using two methods called pattern matching and grayscale tracking.

a. Pattern Matching

Pattern matching involves comparing the predefined patterns (cracks) with the acquired image, which gives the results (details about the defects) such as number of defects closely related to the predefined pattern, and their degree of closeness (score), center (X,Y co-ordinates), and corners of the bounding rectangle.

The score is the integer assigned to the match that present in our acquired image.

Score -1000 shows perfect match

Score – 0 shows no match

Following are the image and predefined pattern (crack) taken for pattern matching.

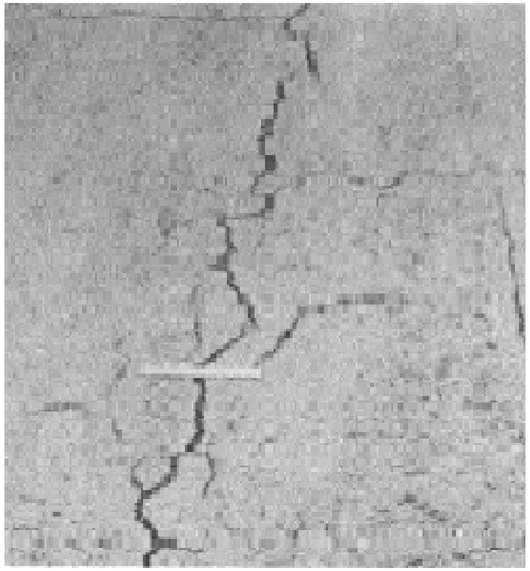

Figure 2. Acquired IR Image

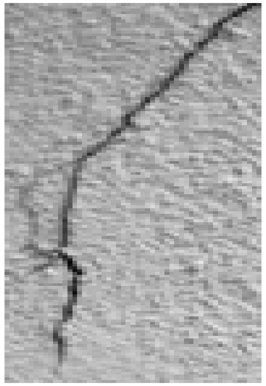

Figure 3. Predefined Pattern

The resulting image in pattern matching is given bellow. The details about the defects (Numerical data) obtain in pattern matching are as follows

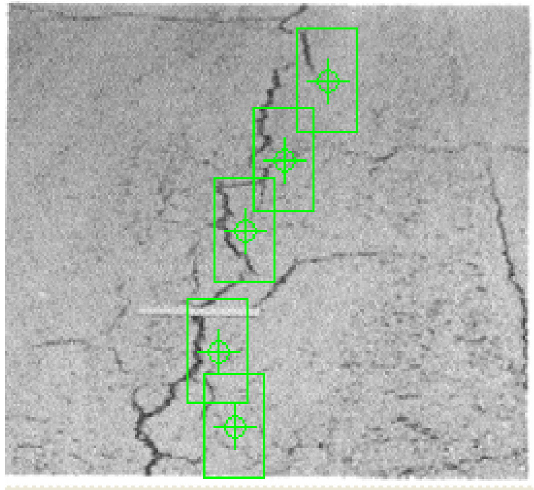

Figure 4. Matched Defects

Results ...	1	2	3	4	5
Center X	107.000	90.000	141.000	159.000	98.000
Center Y	111.000	130.000	140.000	231.000	214.000
Score	1000	667	608	562	553
Angle	0.000	0.000	0.000	0.000	0.000

Figure 5. Pattern Matching Results

b. Gray Scale Tracking

Gray scale tracking is purely based on the temperature profile of the construction materials used. It is used to locate structural defects such as blisters, air ducts, chloride corrosion, and fake material resides inside the bridge on basis of its threshold values. Before getting into Gray Scale Tracking it should have a detailed study about the materials used. And should know the temperature profile of each and every objects used in our case. The color extracted IR image results in black and white (single color or grayscale) image. Hence, the gray value corresponds to the object of particular temperature. Thus the materials having particular temperature profile can be easily tracked using this gray scale tracking.

Infrared image taken for the processing The resulting image during the gray scale tracking is of gray scale tracking is as follows.

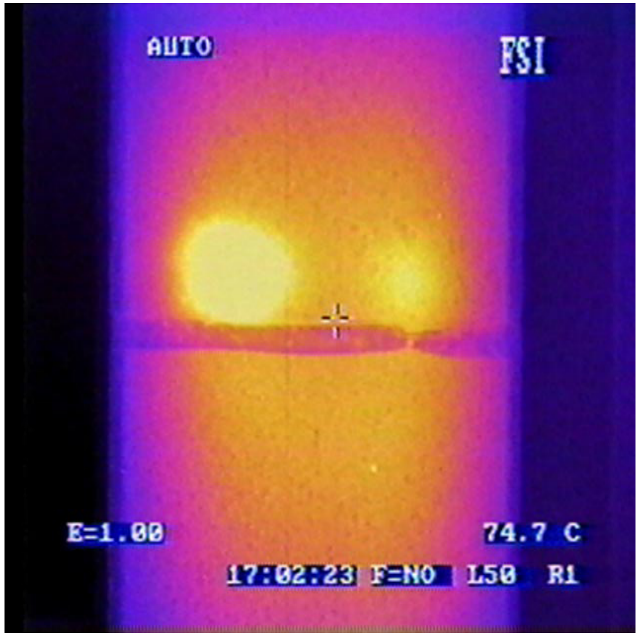

Figure 6. Acquired IR Image

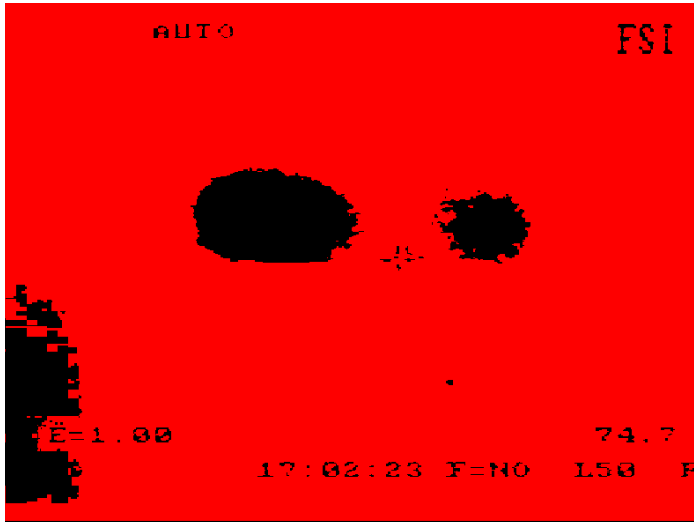

Figure 7. Gray scale tracking – Image Result

Locating the defects I gray scale tracking involves particle analysis. It gives the details about the faults such as pixel, area, width, diagonal, shape etc.

The following is the tabulation that gives the location of the defect in the given surface as well as subsurface. This table contains the parameters of the defects such as,

1. No. of pixels it occupies
2. Area (in pixels)
3. Center of mass X
4. Center of mass Y
5. Width
6. Height
7. Longest segment length
8. Perimeter
9. Diagonal Unit etc.,

Object #	Pixels	Area (unit)	Number of	Holes area	Total area	Image area	Ratio Area	Ratio Area
1	5.04E+05	5.04E+05	104	25334	5.29E+05	5.94E+05	84.92	95.21
2	5	5	0	0	5	5.94E+05	0	100
3	4	4	0	0	4	5.94E+05	0	100
4	16	16	0	0	16	5.94E+05	0	100
5	2	2	0	0	2	5.94E+05	0	100
6	3	3	0	0	3	5.94E+05	0	100
7	5	5	0	0	5	5.94E+05	0	100
8	9	9	0	0	9	5.94E+05	0	100
9	1	1	0	0	1	5.94E+05	0	100
10	1	1	0	0	1	5.94E+05	0	100
11	3	3	0	0	3	5.94E+05	0	100
12	18	18	0	0	18	5.94E+05	0	100
13	34	34	0	0	34	5.94E+05	0.01	100
14	105	105	0	0	105	5.94E+05	0.02	100
15	27	27	0	0	27	5.94E+05	0	100
16	239	239	0	0	239	5.94E+05	0.04	100
17	10	10	0	0	10	5.94E+05	0	100
18	8	8	0	0	8	5.94E+05	0	100
19	16	16	0	0	16	5.94E+05	0	100
20	1	1	0	0	1	5.94E+05	0	100
21	248	248	0	0	248	5.94E+05	0.04	100
22	5	5	0	0	5	5.94E+05	0	100
23	30	30	0	0	30	5.94E+05	0.01	100
24	40	40	0	0	40	5.94E+05	0.01	100
25	248	248	0	0	248	5.94E+05	0.04	100
26	24	24	0	0	24	5.94E+05	0	100

Figure 7. Gray scale tracking – Pixel Results

4. Conclusion

Infrared thermography provides an invaluable service to forensic engineering and constructional defect investigations in that it allows the engineers a non-destructive method to substantiate their visual findings to find what is happening behind or inside the bridges. Flaw detection and evaluation of blisters by means of infrared thermography is possible. The advantages of infrared thermography over the destructive testing techniques are that sizeable sections, such as blisters, can be scanned fast and efficiently, without the need to be destroyed during testing. This results in major savings in factors such as time, people, work and machinery

It has implemented a fully automated system, which ensures accuracy to find the faults in the bridge surfaces. By implementing this project in the construction areas, fault identification can be done in an efficient manner. It is clear that IR thermography can provide the maintenance engineers with both the qualitative and quantitative information relating to the structural defect.

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WIRELESS SENSOR BASED ONBOARD SAFE RAILWAY SYSTEM

COLLEGE : THIAGARAJAR COLLEGE OF ENGINEERING, MADURAI, TAMIL NADU
GUIDE : MR. K. HARIHARAN
STUDENTS : G. SHANKAR
S. JEEVA
E. ANAND SOLOMON
BRANCH : ELECTRICAL AND COMMUNICATION

1. Introduction

The Railways is the chief mode of transport for the people across various strata in the society. In such a situation there is a need for ultimate security to be implemented across the railway network. Conventional Railway networks lack the necessary infrastructure to respond swiftly to the emergencies such as fire accidents.

An Automatic wireless sensor based on board railway safety system is a project that involves implanting sensor nodes at specific points in the carriage. These sensor nodes are used for collecting data such as room temperature, concentration of smoke in air, intra and inter bogie temperatures automatically. These collected data are processed to monitor room temperature and bogie temperature.

2. Problem Definition

- The coach should be monitored continuously and the collected data are to be processed for issuing a fire alert.
- The inter-bogie and intra-bogie temperatures has to be measured and processed for on board wheel safety system.

- Automation of the bogie temperature measurement and monitoring thereby eliminating the need for manual monitoring as in conventional system.
- Since the bogie temperature is transferred wirelessly between the nodes, a network that has a high reliability is required..
- A mechanism has to be devised to periodically transfer all the data from the Centralized Data base in the train to the Data base off board.

A Panoramic view of the Problems Tackled by the System

The fire alarm although available in the conventional system they are prone to false triggering and they panic the passengers in other carriages by means of alarm. These problems have been over come in this system by using two sensors smoke and temperature, only when both are triggered the fire alert message is passed on to the base node in the engine. Based on the fire alert message appropriate actions are taken rather than agonizing the passengers.

The alignment of wheel along the tracks is based on the intra and inter bogie temperature. Hence as these bogie temperatures are of paramount importance they are measured by the Railway officials at every station manually. To measure the temperature of the respective bogies the Railway employees have to walk a long distance covering the entire distance of train. The Indian Railways too spend a huge amount of money for such a manual monitoring. These manual monitoring is tedious, prone to human errors and not precise. Thus this System helps to overcome this problem by measuring the bogie temperatures periodically and transmitting it to the off board database via the base node.

3. Design

Design of Sensor Node

The sensor node consists of fire sensor and bogie temperature monitoring sensor.

Design of Temperature Sensor

LM 35 has been chosen as the temperature sensor as it has the following properties. The LM35 does not require any external calibration or trimming to provide typical accuracies of ±1/4°C at room temperature and ±3/4°C over a full −55 to +150°C temperature range. It is also of low cost and it can be glued to any surface.

Design of Smoke Sensor

Smoke sensor should be a logical type i.e. this system uses a sensor which will detect the presence/absence of smoke. It should also be cheap and of low cost, that made us to develop our own indigenous smoke sensor. The smoke sensor is based on the principle of photo detection with IR transmitter and receiver on either side.

Design of Transceiver node

Design Parameters

This system uses CC2500 as transceiver. The features and interfaces are discussed below, the CC 2500 is a Small size (QLP 4x4 mm package, 20pins) in a True single chip operating frequency range: *2400-2483.5 MHz.* The transceiver has a high sensitivity and it operates at a data rate up to 500 Kbps.

Design of Networking Protocol

The networking protocol that are available in literature were not suited for our application, hence we have designed our own indigenous transport protocol.

Protocol Description

The description of the various mechanisms involved in the protocol designed for the system has been described briefly in the following topics.

Initial START UP Mechanism

Initially when the carriages are connected to the engine and the power is switched on the START UP_PACKET is transmitted to make the nodes aware of the address of the nodes on either sides and the address of the source. This start up mechanism is absolutely essential as the coach alignment changes from time to time could change even before the train reaches the destination.

Consider a train with three carriages for analysis, the steps involved in start up mechanism is as follows:

Step 1: Start signal is initiated by engine by sending the STARTUP_PACKET.

Step 2: The acknowledgement signal is sent to the Engine by the nearby node. Then the Engine module goes to meditation state that it does not respond to wakeup signal by the nearby nodes and acknowledgment signal until the ID_COMPLETE packet is received.

Step 3: The STARTUP_PACKET is again transmitted by the first node to the next node. This is again acknowledged with acknowledgement signal. The first node then goes into idle state i.e. does not respond to the wakeup signal and acknowledgment signal until the ID_COMPLETE packet is received. This process is again repeated by the second node and it goes on.

Step 4: The process is continued until the packet reaches the Engine. After each node has received the ID_COMPLETE packet, it starts processing the sensors and sense for the abnormality.

Fire Alert Mechanism in the Protocol

When the sensors detect a fire alert, the fire alert is sent with the help of a URGENT_PACKET. This packet has the highest priority over other packets. When this packet is transmitted all other nodes suspends its functions and just transmits the URGENT_PACKET.

Thus the important ideas of the novel transport protocol have been brought about.

4. Implementation:

Fire Sensor

The fire sensor consist of a smoke and a temperature sensor, when there is a large temperature variation in a compartment(> 3 degree C –after testing) and when the smoke amount triggers the smoke sensor the fire alert is passed on to the base node.

Temperature & Smoke Sensor

In this system, we are using LM35 as temperature sensor. Temperature difference is used to issue a fire alert. . It uses the principle of photoelectric detection. The prototype model has been developed and it is tested. It consists of a IR transmitter and a IR receiver.

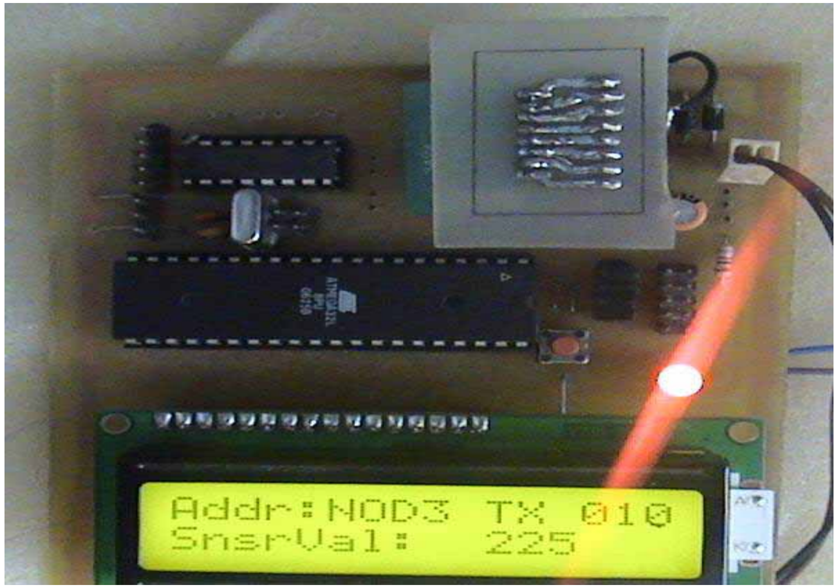

Figure 1: Prototype model of temperature Sensor

The placement of the temperature and smoke sensor was decided after extensive testing the position of placing smoke sensor is shown below.

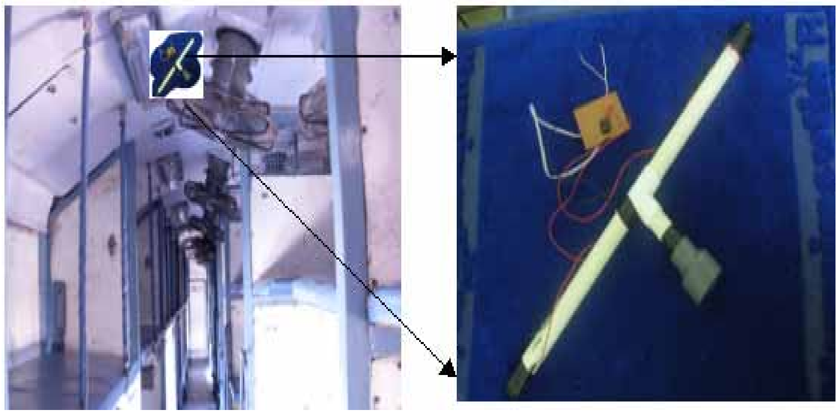

Figure 2: Placing of smoke sensor in a carriage

Implementation of Bogie Temperature Monitoring

To monitor the bogie temperatures continuously the temperature sensor is placed in the axle and the placing of the temperature sensor for bogie was decided after consultation with railway authorities and extensive testing.

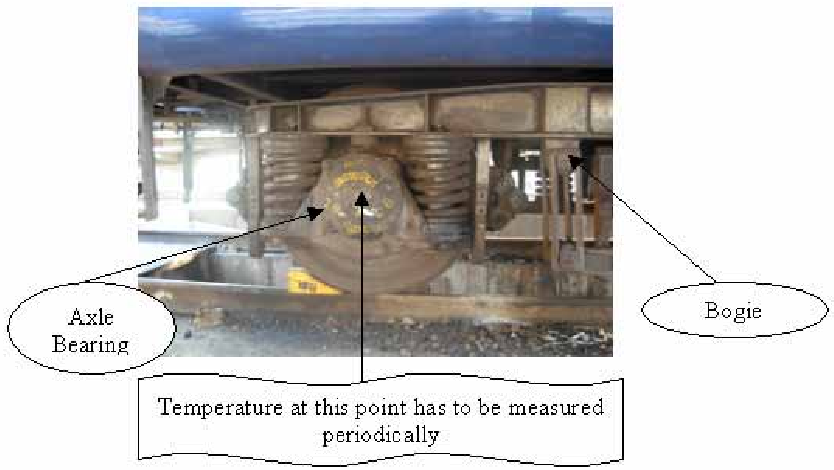

Figure 3: Bogie Temperature monitoring

6. Software tools used:

- ADS (HP –Advanced Design System) for designing the antenna.
- AVR Studio – for programming the micro controller.
- RF Studio and packet sniffer for analyzing the data sent in network.

7. Testing

The system was tested for range in an open environment, and then it was tested in a real time environment in a Stationary Train carriage.

Range Testing

The range of the system was tested using the experimental set as shown below.

The transmitter is kept stationary, and the distance of the receiver is continuously varied. The RSSI value is calculated for each of the distance and it has been tabulated in the table.

Sl. no	Distance(feet)	RSSI(dBm)
1	0	-5
2	100	-95
3	125	-96
4	150	-96
5	175	-95
6	200	-95
7	210	-96

Table : Distance Vs RSSI

Testing in Real Time Environment:

The testing of the sensor nodes was done in a real time environment in the actual train carriage 2nd class AC chair car in the Madurai – Nizamuddin Sampark kranti express after prior permission from the Southern Railway authorities.

Test 2

Aim: To find the variation of temperature at the various points in the compartment.

Experiment: The receiver was placed in the slab near the seats, while the transmitter was placed at various points in the carriage and temperature at the various places were calculated.

Figure 4: Receiver setup in real time environment

Observation:

Sl.no	Position of Tx	Temp(degree C)
1	Below lower seats	35.1
2	Middle berth(R)	35.2
3	Middle berth(L)	35.4
4	Upper Berth(L)	35.3
5	Upper Berth(R)	35.2
6	Side upper	34.9
7	Side lower	35

Table 2: *Position of Tx Vs Temperature*

The above testing was done at mid afternoon 2 pm.
Range = (highest value)-(lowest value)
= 35.4 – 34.9 = 0.5 (degree)C

8. Result:

The temperature variation within a single compartment was less than 0.5°C. The threshold of variation of the temperature can be up to 10°C for dynamic conditions.

9. Problems Encountered

- Range of transceiver
- Placement of nodes
- Variation of Channel model as train moves.

10. Advantages

- Holistic automation of wheel monitoring
- Quick emergency response
- Ruggedness and flexibility

11. Improvements

- This setup can be extended to any sort of working environment for automatic safety system.
- This system can be deployed to analyze the channel variation over time and environment in moving condition.

12. Conclusion

The System has been designed and implemented after optimizing it on a number of factors. The System helps in efficient data transfer with the help of the indigenously developed Networking protocol and physical layer systems. The placing of nodes in the appropriate places is also done after extensive testing. The Complete automation of bogie temperature monitoring, and quick fire alert are the high light of the System.

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