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Non-Invasive Measurement of Stress Levels in Knee Implants

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Abstract

The main objective of this project is to help the knee patients by developing a hardware including multiple sensors to monitor the pressure/stress which is applied to the implant. The sensing elements which are hermetically sealed on kneecaps are used to track the flexibility, direction, and temperature. These sensors will monitor the knee values and send to the patient/care taker using GSM and enables the buzzer to indicate the patient with a warning sign. These buzzer and GSM will be enabled whenever the sensor output exceeds the specific levels suggested by the doctor. The LCD is controlled by the controller to display the values of the sensors which are mounted on the implantation. This message and warning sign will help the patient to understand the problem levels so that the patient will reduce the stress on the knee. This equipment will helps to improve/treat the knee implant patients by monitoring continuously.

1. INTRODUCTION

Recent days the people are facing this knee problemsa lot due to the lack of Bone Mineral Density. This knee is one of the important and complex structure in the human body cause a human can not even stand properly without this knee joint. In day to day life we are applying a lot of pressure on the knee joints while walking, playing, jumping, etc., causes high pressure on the knee which may leads for knee replacement also known as Total knee arthroplasty(TKA), is a medical procedure to replace the weight-bearing part of the knee joint to relieve pain and disability. The Total Knee Arthroplasty is beneficial and proven that it is successful. It is most commonly used treatment for osteo arthritis these days. This surgery is bit complex contains extensive pre-operative planning, specialized implants and tools, prolonged duration. It takes longer time to perform than the normal knee replacement. Enev this treatment is difficult when the patient is very old. It includes following stages:

- **Pre-surgery:** It includes X-rays, laboratory tests, BMD tests, knee aspiration and in some cases we need magnetic resonance imaging (MRI) also.
- **Surgery:** The implant is removed and replaced with bone grafts iron screws used to fill larger areas of bone loss Finally, specialized revision knee implants will be inserted.
- **Post-operative care:** After the surgery, the patient should take care and continue the treatment like therapy and medications.

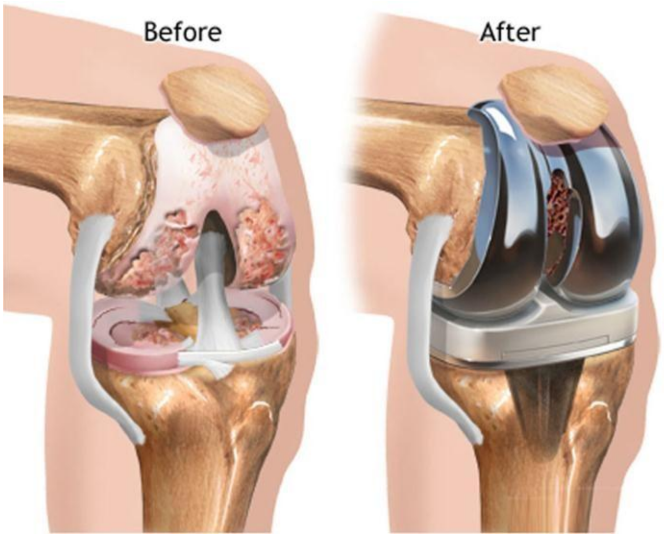

Fig.1: Knee Replacement

This Knee replacement is not completely successful in single shot sometimes it needs multiple surgeries based on the requirement. The patients have to understand the failure cases also in this treatment. There are five primary reasons why a knee implant fails:

- **Wear and loosening:** Friction caused by joint surfaces rubbing against each other wears away the surface of the implant causing bone loss and loosening of the implants.
- **Infection:** Like a normal surgery we need to take care about it or else there is a possibility for Infection
- **Fracture:** Fractures may occur around the knee while implantation that disrupt its stability and requires revision surgery.
- **Instability:** It may become senseless sometimes due to the soft flush around the implanted material.
- **Stiffness:** Loss of range in motion which causes pain and a functional deficit.

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A statistical report is included in the below diagram regarding knee problems.

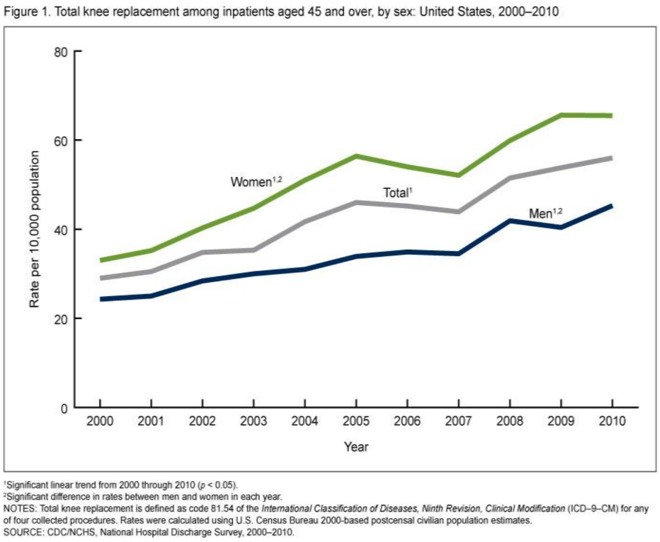

Fig.2: Report regarding knee problems

EXISTING SOLUTION

It is difficult to check the internal problems of the knee after implantation so there are few traditional methods to maintain the knee implant like timely check-ups and invasive chips but the present Existing solutions are invasive and very time consuming or may lead to infections if we neglect.

PROPOSED SYSTEM

Our proposed system is a cost-effective and non-invasive method to detect the stress levels at knee implant. By using the flex sensor, pressure sensor, andtemperature sensor we can monitor the knee implant continuously which are included in this current proposed solution(kneewear).

In our proposed system Flex sensor, Pressure sensor &Temperature sensors will be connected in the knee wear to measure the data at knee implant and send the output in analog format. These sensors will monitor and detect the problems like overpressure, high Temperature and over bending of the knee plant and the data will be sent to the Microcontroller Arduino. Here the Arduino can receive the analog data from the sensors and convert the data into digital as Arduino is built up with internal ADC. The data will be compared with the programmed values. if the sensor values are more than the specified values that means the pressure/temp/force is high at the knee implant then the controller immediately indicates the patient with a warning buzzer and enables the LCD to display the problem level so that the patient will get to know what is happening at the knee implant. Simultaneously the microcontroller will initiates the GSM module to send the sensor data and problem levels to the concerned people like doctor nearest caretaker.

In this GSM module will be controlled using the AT Commands which are already programmed in Arduino. This Communication will be initiated first then the required data can be transferred as per the problem level.

This entire equipment is powered with power supply board as we need to provide different voltages for different modules we need to provide the different supply voltages. Power supply unit/board will help us to power up the entire unit with different voltages. In this equipment, we have to take care of powering up the modules cause these modules may get damaged with the higher voltages.

- With our proposed system we can improve the success rate of knee implant treatment/surgery.
- We can avoid the timely check-ups
- We can monitor the Knee implant continuously

The block diagram for the proposed system is given below

BLOCK DIAGRAM :

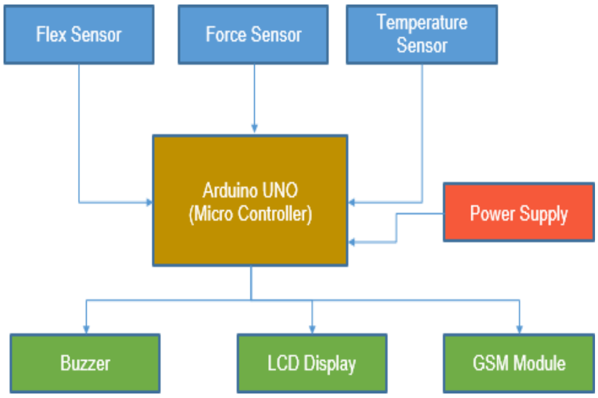

Fig. 3: Block diagram of proposed system

ARDUINO UNO:

The Arduino Uno is a development board based on the ATmega328 microcontroller having 14 Digital I/O pins(can generate 6 PWM output) and 6 Analog input pins and it works with 16 MHz crystal Oscillator. This board will work with 5v supply which we can provide with adopter/Battery. Arduino Uno is very flexible to program as it has its own IDE called Arduino IDE. As we know that Arduino is a family having different types of development boards with different microcontrollers, we need to select the board and write the code accordingly. Arduino IDE is an open source so that we can download it from the internet. Arduino microcontroller and IDE are shown below.

Arduino Uno is an Open source Microcontroller comes with preprogrammed with a bootloader that allows uploading new code to it without the use of an external hardware programmer. Generally,It communicates using the original STK500 protocol. Rather than requiring a physical press of the reset button before an upload, the Arduino/Genuino Uno board is designed in a way that allows it to be reset by software running on a connected computer. One of the hardware flow control lines (DTR) of the ATmega8U2/16U2 is connected to the reset line of the ATmega328 via a 100 nanofarad capacitor. With the help of this line, we can restart the development board through software.

Fig. 4: Arduino uno

Fig. 5: Rduino software

Arduino comes with built-in LED and physical Restart button to restart the microcontroller flexibly. Arduino will behaving a COM port so that we can connect it directly with the computer to download/flash the code.

GSM

GSM stands for Global System for Mobile Communications, is a standard developed by the European Telecommunications Standards Institute (ETSI)GSM was invented to describe the protocols for second-generation digital cellular networks used by mobile phones and today it is the default global standard for mobile communications. A GSM module or a GPRS module is a chip circuit which is used to establish communication between a mobile device or a computing machine and a GSM or GPRS system. The modem (modulator-demodulator) is a critical part here.

The GSM module needs AT commands, for communicating with processor or controller, through serial communication, Controller/processor send these commands to the gsm module then module sends back a result after it receives the command. These AT commands are almost common for all GSM modules and few will be varied. Before starting the communication with the GSM module suggested restarting the module.

AT commands:

AT commands are commands which are used to control the modems where AT stands for Attention.

Types of AT Command:

There are 4 basic types of commonly used AT commands:

1. AT: Used to check the interaction between the computer and the module. This command is usually replied with an OK if the port and the module can connect correctly.
2. +CMGF: Used to setup the SMS mode. By adding 1 or 0 with the command text or PDU mode can be selected.

   SYNTAX: AT+CMGF=<mode>
3. +CMGS: Used to send SMS to any phone number

   SYNTAX: AT+CMGS= serial number of the message to be sent.
4. +CMGW: Used to store a message in the SIM. After the execution of the command, the '>' sign appears in the next line where the message can be entered.

   SYNTAX: AT+CMGW=" Phone number"> Message to be stored Ctrl+z

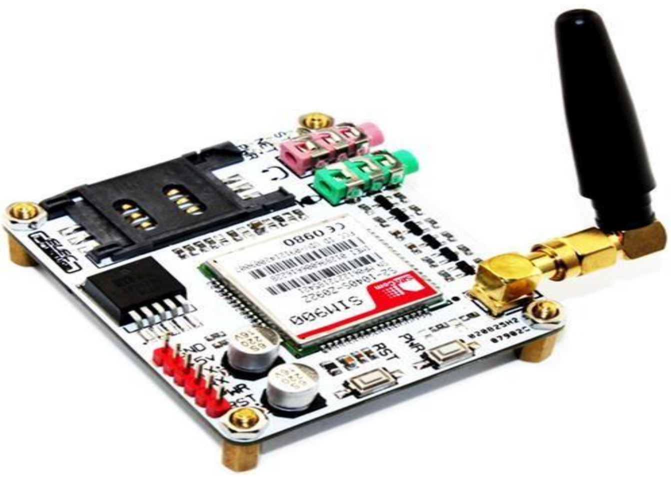

Fig. 6: GSM Module

FLEX SENSOR

The flex sensor is a thin strip, around 4.5inches in length that is used to monitor the patient joint angle. When the sensor is attached on the knee and bent; the flex sensor will give the output voltage which will describe the patient's knee angle of rotation. One side of the sensor is printed with a polymer ink that has conductive particles embedded in it. When the sensor is straight, the particles give the ink a resistance of about 30k Ohms. When the sensor is bent away from the ink, the conductive particles move further apart, increasing this resistance (to about 50k-70K Ohms when the sensor is bent to 90°, as in the diagram below).

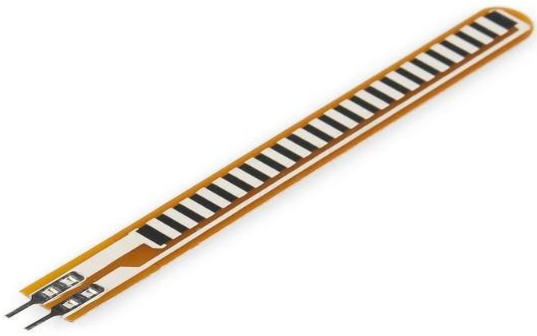

Fig.7: Flex sensor

TEMPERATURE SENSOR

The temperature sensor is used to measure the temperature called as LM35. Here we are using this sensor to measure the temperature at the knee implant. It does not require any external calibration or trimming to provide typical accuracies of ±¼°C at room temperature and ±¾°C over a full −55°C to 150°C temperature range.

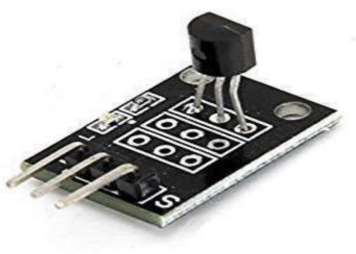

Fig. 8: Temperature sensor

FORCE SENSOR

One of the most affected components of the artificial kneeimplant is the ultra-high-molecular-weightpolyethylene (UHMWPE) insert, due to its geometry and the high forces acting upon it. Therefore, monitoring the strain, associated with knee imbalance and forces acting upon the prosthesis, can give continuous feedback on the status of the artificial knee implant. Strain gauge sensor is used for the monitoring of loads acting upon an artificial in knee implants.

Fig. 9: Force sensor

EXPERIMENTAL RESULTS

The outputs verified from the experimental setup are noted down and presented below

Weight laid (in kg)	Force Sensor Output (ADC Units)
0	0
2	32
5	60
7	85

Angle bent (approximately)	Flex Sensor Output (ADC Units)
0	180
15	311
30	425
45	612
60	746
75	865
90	1029

General output of temperature sensor is 32 at room temperature& varies accordingly if the temperature increases.

Fig. 10: Messages showing the patient's condition.

In our proposed system we are using Flex sensor, Temperature sensor & Pressure sensor to measure the knee angle,temperature& pressure accordingly. Whenever the sensor detects something abnormally, it will calculate and compare with the max levels described in the program. If the sensor value exceeds the max level the GSM will send the information alert to the concerned caretaker and physician as discussed in earlier sections.

CONCLUSION

In major cases, the knee implantation is failing because of lack of care after knee implantation. Here we can overcome this failure with our proposed system which helps to monitor the patient's implant continuously with multiple sensors like Flexibility, Temperature & Pressure sensors. In our proposed hardware, we are using GSM modules for long distance communication so that we can send the alert notifications to the concerned caretaker and physician for instant help/treatment. With this equipment, we can reduce the problems of knee implantation.

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