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A Virtual instrument approach to model Jaw tremor

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ABSTRACT

BACKGROUND: Tremors are the most common movement disorders encountered in clinical practice. The cause of the tremor or heterogeneous. Resting tumor is a classical symptom of Parkinson's Disease (PD). The symptoms related to the motor disorders of PD appear in different forms. Despite its commonness, and the significant reduction in quality of life, pathophysiology of the tremor needs to be understood better. Several models based on rats have been proposed by researchers in the recent past. Further they have used EMG studies for validating rest tremors associated with PD. However, no animal model has yet been generated that exactly recreates all features of any of the known tremor disorders in humans. Modelling of the resting tremor is a challenging task. **OBJECTIVE:** In this context we have proposed a low cost, virtual instrumentation approach, by designing a LabVIEW based measurement system for Jaw tremor modelling. In this system we have developed a model for human jaw tremor system having PD and jaw tremor was induced physically by using a DC motor attached to the lower jaw. The DC motor was controlled from PC interfaced with ARDUINO using Pulse Width Modulation. An Ultrasonic sensor was used to detect any motions in the skull. The generated tremor was measured using a Flex sensor interfaced to PC with ARDUINO. **RESULTS:** The measured tremor was correlated with clinical tremor by obtaining the FFT. The system produced vibrations pertaining to the range of Rest tremor (4 Hz – 6 Hz) prescribed in the Literature. **CONCLUSION:** We found that the proposed system was effective in basic modelling of Jaw tremors. The model will be helpful to understand the pathophysiology of Jaw Tremor and may eventually lead to development of novel treatments for tremors.

INTRODUCTION

PD is a neurological disorder that affect mobility, balance and muscle control. PD is a part of motor system disorders associated with loss of dopamine producing brain cells (Lucas, *et al*., 2016). Dopamine is one of the three major neurotransmitters which help the body to prepare for flight or fright response. PD is found mostly in the age group of 55 – 75 years, but it can also develop in younger adults (Soumya Sharma and Sanjay Pandey, 2016). Early diagnosis of PD is difficult, and moreover it becomes progressive with symptoms become more severe with time. Currently there is less promising cure for PD.

The symptoms related to the motor disorders of PD appear in different forms. Some of them are tremors, bradykinesia, rigidity and instability in posture (Ederson C, *et al*., 2014). Basically tremor is an unintended oscillatory motion, more prominent in the distal rejoins of the body such as arms, legs and jaws. The most common form of tremor closely connected with PD is Resting Tremor. This occurs when the body is at rest and subsides during the onset of motion. PD is the most common cause of rest tremor. (Samà, C., *et al*., 2012) Three different types of tremor syndromes are normally associated with PD.(V. Parra, et,al, 2013, Samà, C., *et al*., 2012) They are tabulated below in Table 1.

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The typical tremor of PD is a 4–6 Hz rest tremor. It is characteristically unilateral at onset and involves the distal upper extremity initially. The classical "pill rolling" tremor consists of movement at the thumb and forefinger. Rest tremor could also be in the form of flexion - extension of the wrist, pronation - supination at the forearm, and abduction - adduction of leg. (Louis ED, *et al.*, 2006, 1H. Takanobu, *et al.*, 2001) Rest tremor in PD not only involves hands but also involves lips, chin, jaw, and legs and rarely the neck, head, or voice (Susan W. Herring, 2007)

Table 1: Types of Tremor

No	Type of Tremor	Frequency range
1	Classical rest tremor or rest plus postural/kinetic tremor of same frequency	4 – 6 Hz
2	Rest plus postural/kinetic tremor of differing frequencies with the latter having a higher frequency	5 – 8 Hz
3	Isolated postural and kinetic tremor	4 – 9 Hz

The biochemical defect behind either resting or postural parkinsonian tremor is unknown. In early studies, mechanical and optic devices were used to record tremor. EMG recordings and accelerometers, assisted by computer analysis, have been utilized to measure the characteristics of rest tremors from hands and limbs. However, most accelerometers record tremor in a single plane. By using computed triaxial accelerometry, the distortion of the normal motion characteristics in patients with PD during voluntary arm abduction–adduction movement was recorded. There was a good correlation between the reduction in the distortion and the clinical improvement in response to medications. However, the quantitative recordings of tremor, although accurate, are time-consuming, costly, and influenced by the emotional state of the patient (T S Miles, 1997). Moreover, it is questionable whether such recordings provide a reliable index of a meaningful therapeutic response. But considering the case of Jaw tremor, owing to its location, suitable sensors are still under research.

Characterization of the jaw tremor is possible if it can be modelled and tested. To enable this, we have proposed a basic mechanical jaw tremor model using Human skull with jaw driven by a motor which vibrates at the predetermined rate. The vibrations of the jaw are record by using an Arduino based system and interfaced to a LabVIEW measurement system. This type of system provides a way for modelling the behavior of jaw tremor and classification of tremor.

2. Design of Jaw Tremor Model:

In Parkinson's disease (PD) and related parkinsonian disorders, a variety of animal models exists, each of which makes a unique contribution to our understanding of the human condition. These models have been derived in a variety of species (i.e., pig, nonhuman primate, rodent, and cat) using multiple techniques, including pharmacological manipulation, administration of neurotoxicants, genetic models, and surgical lesioning (Rajesh Pahwa, 2007). Although these models were not identical to the human condition with respect to behavioural characteristics, brain anatomy, or disease progression, they have provided significant advancements in understanding of the underlying mechanisms and treatment of movement disorders, such as PD. There is no "best model" available for PD. Investigators needs to select the most appropriate model for their specific research question under investigation (Rajesh Pahwa, 2007).

We have proposed a simple jaw tremor human model by using a human skull. The jaw movement would be one of the most complicated movement involving human joints owing to the anatomy of the masticatory system (T M Van Eijden, 1997).

The Human masticatory system is comprised of the maxilla and the mandible. They are pivoted via both side Temporomandibular joint at each condoyle in the mandible (T M Van Eijden, 1997). The mandible is actuated to carry out movement by masticatory muscles with respect to the maxilla which composes the whole skull with other bones (S. Patel, *et al.*, 2009). Teeth are available on both sides of the jaw to function cutting and grinding of food. (Fig 1)

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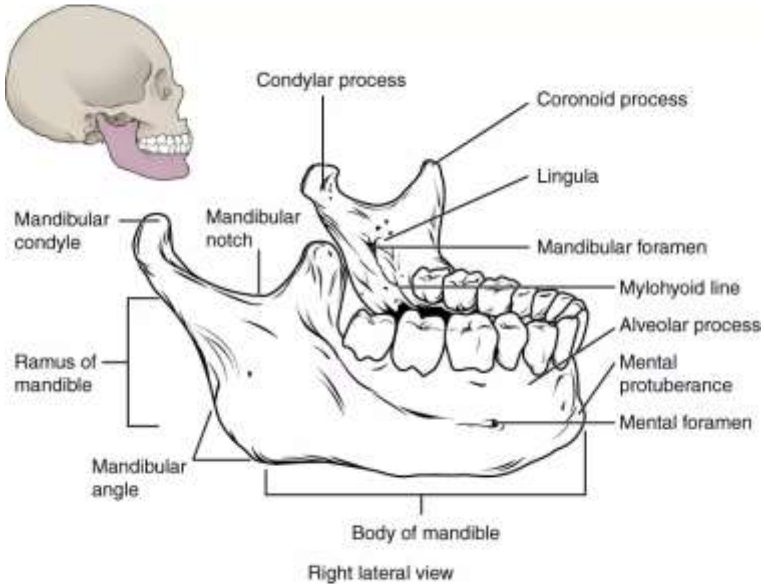

Fig. 1: Anatomy of Human jaw

We have used a DC motor to produce the Jaw tremor. The Real Human skull was obtained from a Hospital. The mandible joint was removed manually and connected to the skull by means of small elastic wires to hold in position and allow opening and closing of Jaw. To produce the required tremor, a DC motor with speed control using OPAMP was employed initially. Later accurate Speed control was achieved by interfacing the DC motors with PC using LabVIEW. Initially before the motor was attached to the skull, speed control was tested. (Fig 2)

The speed control of a DC motor was controlled using LabVIEW. DC motor was interfaced with computer using Arduino. The method of controlling the speed of the DC motor was done by employing pulse width modulation (PWM). PWM signal was generated as a digital signal, using counters. The duty cycle variations of the signal results in change in speed of the motor. Opto-coupler was used to measure the speed of motor with the help of disc connected on motor shaft. Opto-coupler generates an output in form of pulses. Number of pulses were counted and converted to Revolutions per minute RPM with help of Arduino Uno. The speed was sent to PC with LabVIEW software using USB. Block Diagram from LabVIEW is shown in Fig 3. Measured speed was compared with set point to calculate error. This error forms the input to a PI controller which delivers the control signal output as Pulse width modulated signals. These signals were used to control DC motor speed.

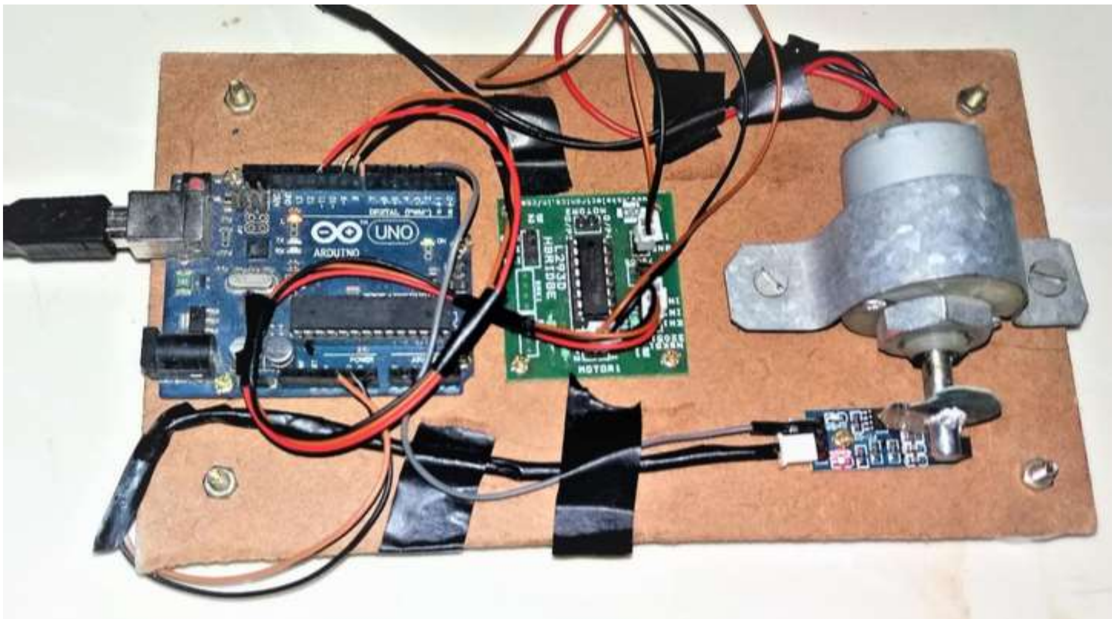

Fig. 2: Speed Control Initial Testing Setup

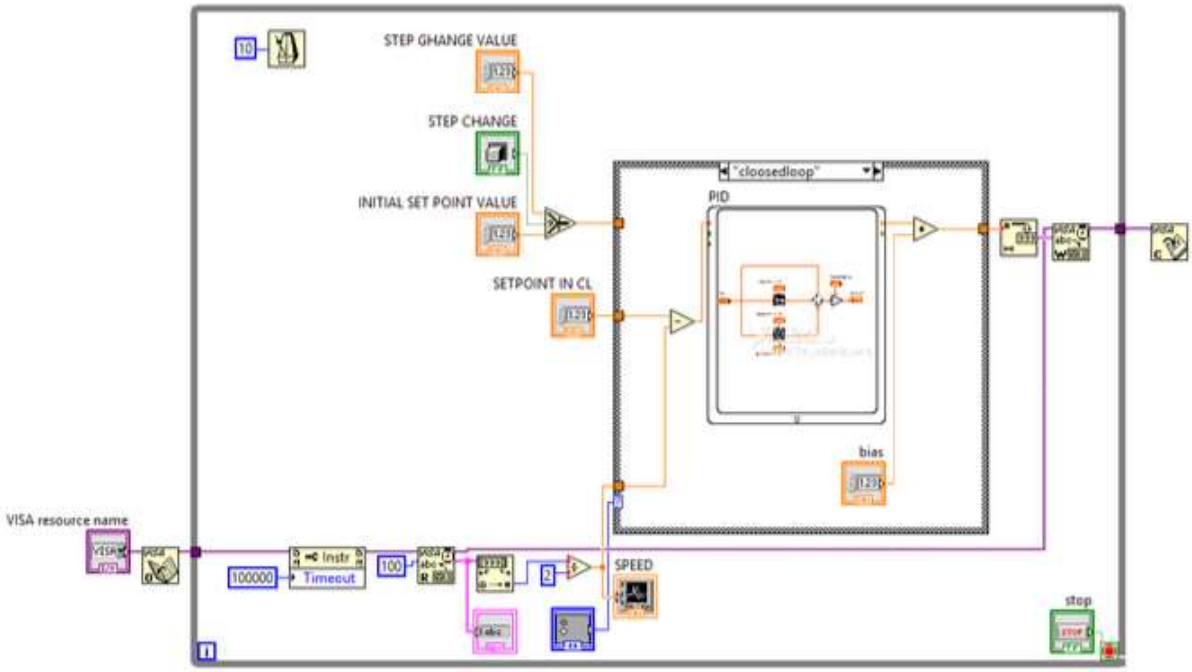

Fig. 3: Speed control of DC Motor in LabVIEW

Further an Ultrasound sensor was placed inside the skull region. HCSR04 was used for this purpose. The output of the HCSR06 (Giuliana Grimaldi and Mario Manto, 2010) acts like a switch. Motion will be detected by the sensor and it switches OFF the DC motor. Thereby the tremor induced by our system will characterise a Rest tremor better. Since a Rest tremor subsides on the detection of motion.

3. Design of Jaw Tremor Detection system:

3.1 Flex Sensor:

We have used a Flex Sensor for sensing the tremor. The sensor consists of resistive carbon element on a thin film substrate. When the substrate is bent, the sensor produces a resistance output correlated to the bend radius, the smaller the radius, the higher the resistance value. The diagram of Flex sensor is shown in Fig 4.

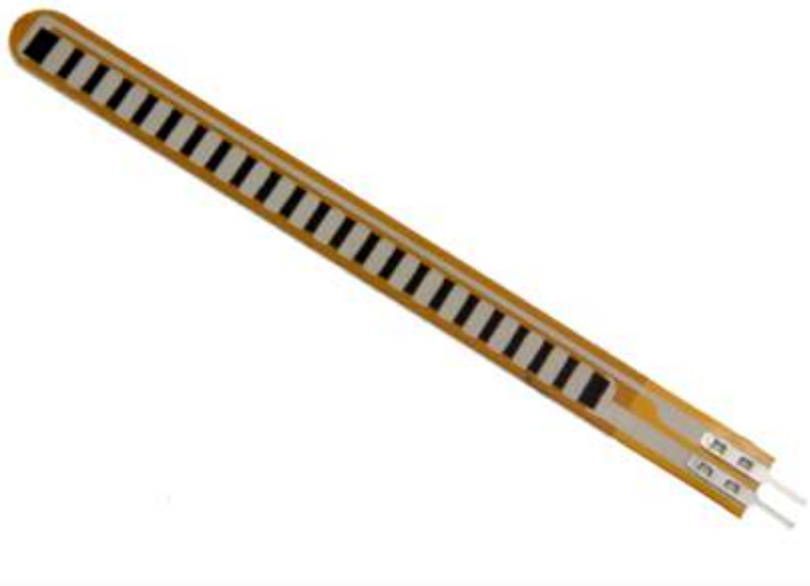

Fig. 4: Flex Sensor

We have attached the Flex sensor between the upper and lower jaw. Thus when the movement of the jaw is enabled, the flex sensor contracts and expands, thereby changing its resistance. (Fig 5)

Fig. 5: Flex Sensor attached to the Mandible

The output of Flex sensor is interfaced to the PC serial port using ARDUINO. The overall system is given in the Fig 6.

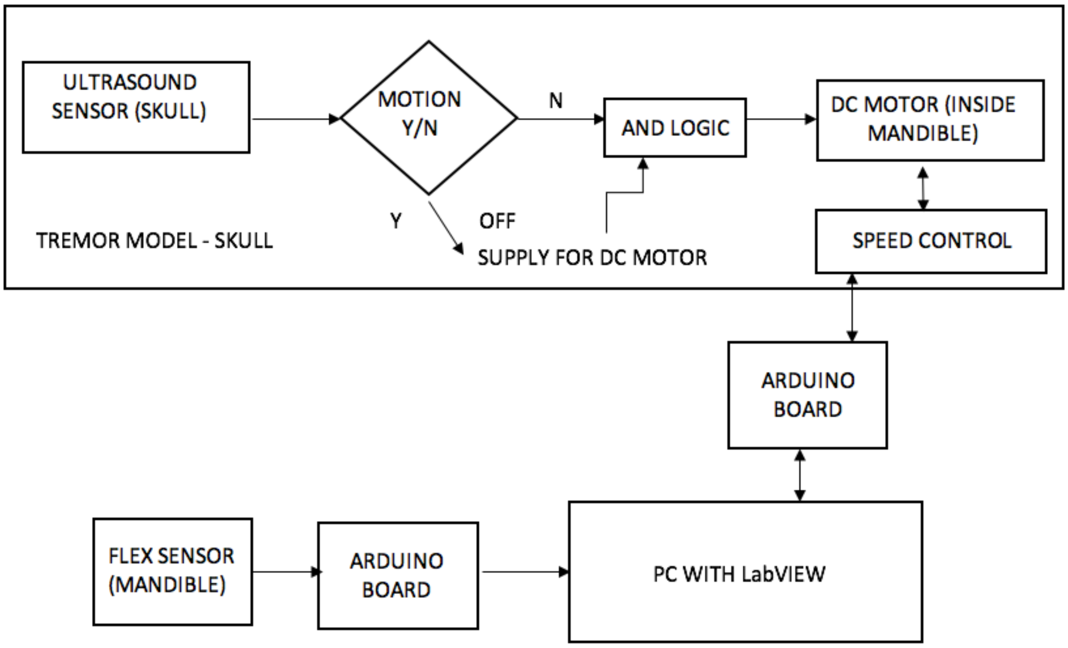

Fig. 6: Block Diagram of Jaw Tremor model with Detection System

3.2 Interfacing with ARDUINO:

The output of Flex sensor was connected to a voltage divider. Hence jaw motion induced resistance change, translates the resistance change as voltage change. The output of voltage divider circuit is fed to the ARDUINO. Since the supply to the voltage divider was 5V, the resistance change (10K to 35K) in Flex sensor yielded an output in the range of 0 to 5V. The circuit diagram of Voltage divider circuit was shown in Fig 7.

Arduino Uno is a microcontroller board based on the ATmega328P. It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz quartz crystal, a USB connection, a power jack, an ICSP header and a reset button. The output of ARDUINO will be a serial data attached to the PC via a USB cable.

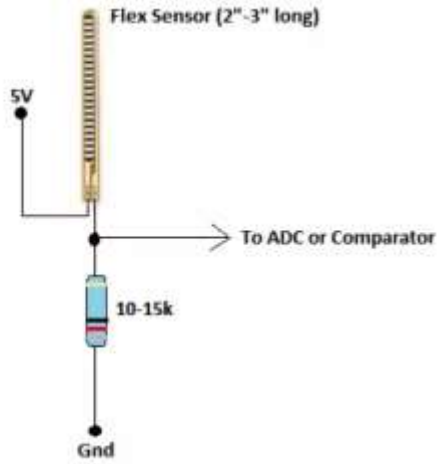

Fig. 7: Voltage Divider Circuit

3.3 Design of Virtual Instrument using LabVIEW:

In LabVIEW the virtual instrument was created using VISA function. The VISA Open, VISA Read and VISA Close functions were used from the Instrument Control Toolbox. Initially when the USB interface was provided the data was visualized using Measurement and Automation explorer. Later inside the VI the sampling time was chosen to be 600 ms. The data was saved in an excel file. The Signal processing subVI was used to calculate the frequency of the Tremor by counting the number of zero crossings. The overall setup with PC is shown in Fig 8.

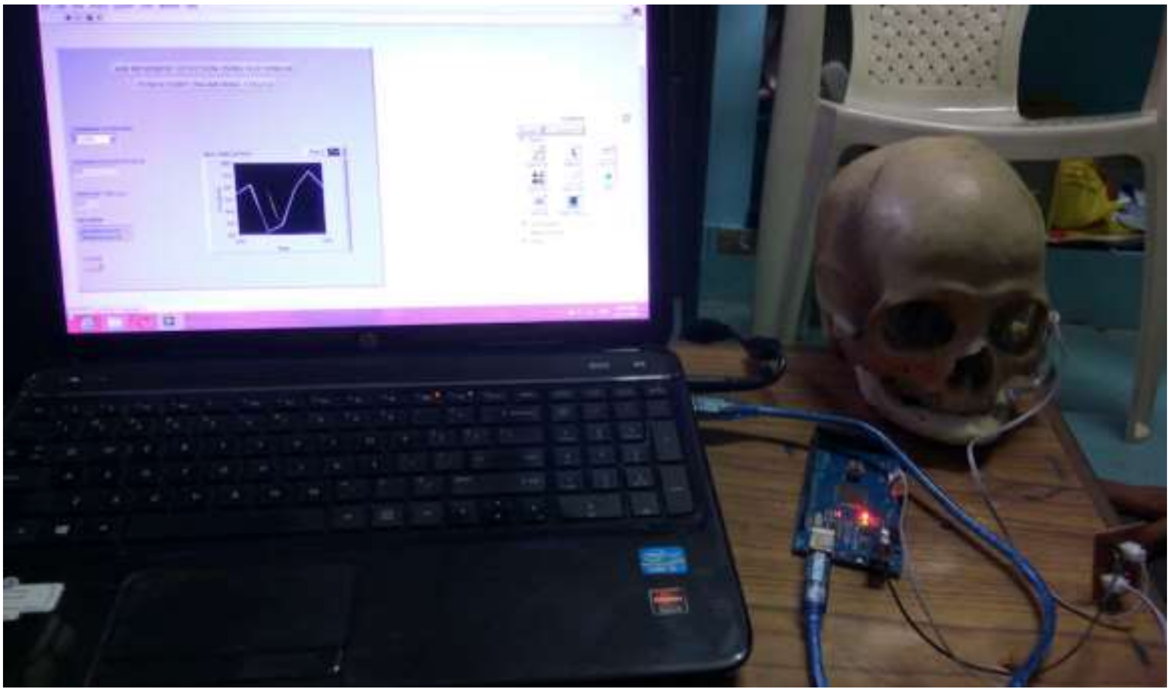

Fig. 8: Jaw Tremor Detection system using LabVIEW

4. Validation:

The signal recorded was transformed into frequency domain using FFT. The FFT was used to obtain the frequency content of the signal. The FFT spectrum of jaw tremor signal is shown in Fig 8. The results were compared with the clinical Rest Tremor Frequency. 50 Trial data were recorded and the mean was 5.653 Hz. Also the FFT spectrum revealed a peak around 0.2 Hz.

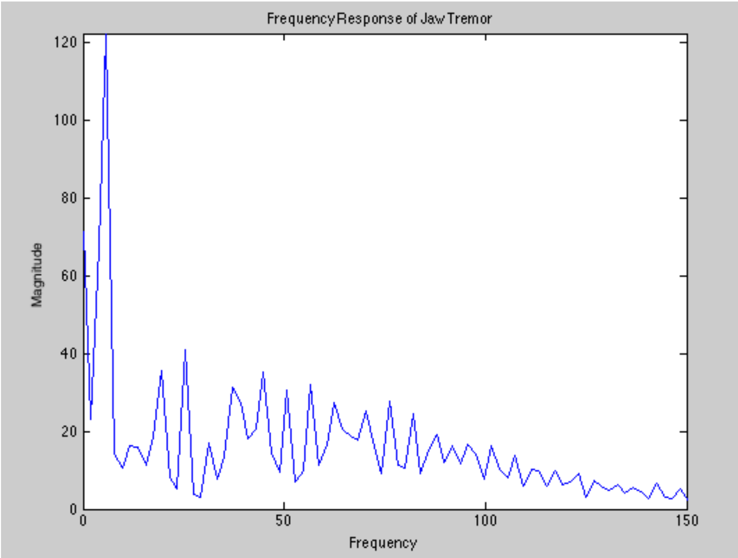

Fig. 8: FFT of Jaw Tremor

To ensure the correctness of the recorded signal, measured tremor frequency was compared with the work of Ederson Cichaczewski, *et al*., 2014. They have investigated the Electrophysiological characteristics of tremor in Parkinson's disease. As per their report, Patients with PD presented tremors with average frequency of 5.29±1.18 Hz at rest. Comparison of Rest tremor with Literature was shown in Fig 9.

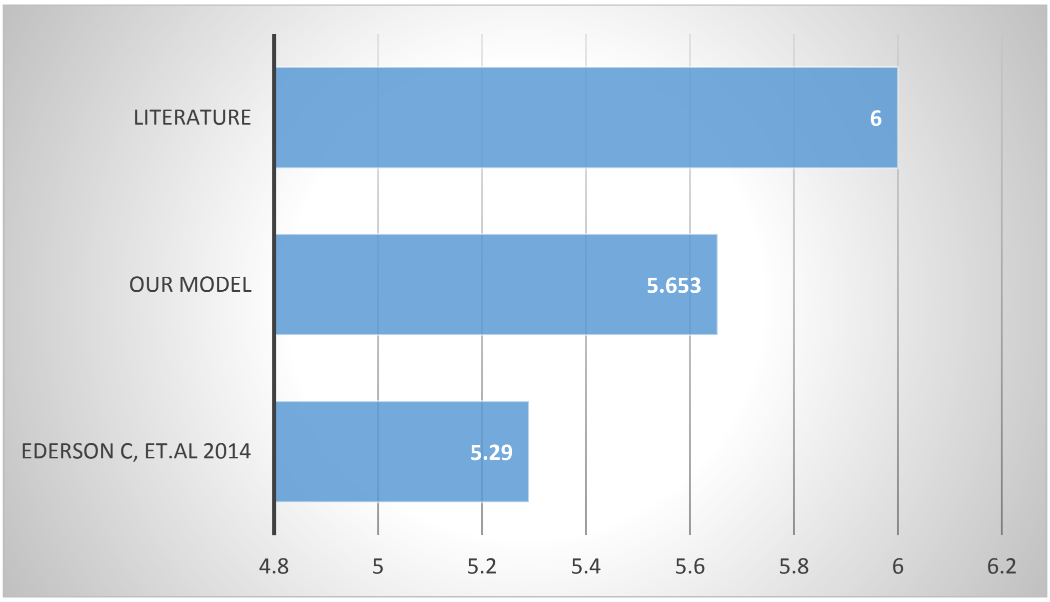

Fig. 9: Comparison of Rest Tremor Frequency

Conclusion:

An attempt was made to model the basic jaw tremor. We have developed a human model for human jaw tremor system having PD. A DC motor was fixed to the mandible and jaw tremor was induced physically. DC motor was controlled by using PC interfaced with ARDUINO by enabling serial communication using USB. We have employed PWM technique to control the DC motor. We found that our speed control was able to track the frequency changes better, which was mainly due to the PI controller employed in the control loop. Vibration corresponding to the range 4 – 6 Hz was generated using our proposed speed control methodology. We have also developed LabVIEW front panel to enable automatic control of DC motor with a simple Graphical User interface (GUI). Also an ultrasonic sensor senses any motion of the skull and switches OFF the motor.

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The tremor signal was detected using a Flex sensor. The output of Flex sensor provides a Resistance change in output which was translated into a voltage change by employing a voltage divider. The output of the voltage divider was interfaced with a LabVIEW measurement system using ARDUINO. The signal was recorded suing the LabVIEW measurement system. 50 recording were obtained and the average was 5.653 Hz. This data was correlated with statistics reported by Ederson C *et al*, 2014 and the Basic Frequency range of rest tremor prescribed in Literature (Rajesh Pahwa, 2007). We found that the frequency spectrum was correlating well with the range of Rest Tremor.

To summarize, the key points of our designed system are

- Our system was able to generate Rest tremor around 5.635 Hz. Later this can be used to differentiate tremor due to sources other than PD.
- Jaw tremor was precisely controlled with a special arrangement using PWM to control the vibrating frequency of Jaw motion.
- An Ultrasonic Sensor has been employed to detect any motion which characterizes the rest tremor better.
- We have employed ARDUINO, an open source platform for the entire system design
- The system has a GUI, easy to operate by the Clinician
- The Tremor was measured and interfaced with PC, and presented with a GUI. Such a system can later be used to measure Tremor from real patients.

The model will be helpful to understand the pathophysiology of Jaw Tremor and may eventually lead to development of novel treatments for tremors. This will be useful in studying about the tremors and their significance in PD by employing a biofeedback treatment. Such a system can be extended to include more jaw motions and handle different types of tremor.

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