

Development of Vibration Based Optical Fiber Sensor for Tremor Measurement

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Abstract

Parkinson's disease is a neurological disorder characterized by involuntary tremors affecting various parts of the body. The condition can result from dysfunction in specific regions of the brain, as well as factors such as incorrect medication, drug use, and alcohol consumption. Existing diagnostic tools for Parkinson's-related tremor analysis often have high costs, bulky designs, and limited comfort, which can restrict natural hand movement and reduce user compliance. This project proposes a compact, low-cost tremor measurement system using a fiber optic sensor to detect tremors in the hand or finger, particularly in individuals with Parkinson's disease. The thin and flexible nature of fiber optics allows for accurate tremor measurement while enabling a wider range of natural hand movements. An MPU6050 accelerometer is also integrated to provide comparative motion data. Arduino Uno is used for data acquisition, while MATLAB is employed for real-time signal processing, frequency analysis, and visualization. Preliminary results are expected to show that the system can accurately measure tremor amplitude and frequency within the range typically observed in resting Parkinson's patients which is 4–6 Hz. Comparative analysis between the fiber optic and accelerometer measurements will validate the reliability and accuracy of the proposed method. The outcome of this project is a portable diagnostic tool suitable for early detection, ongoing monitoring, and quantitative assessment of Parkinson's disease in both clinical and home-based settings.

1. Introduction

Tremor syndrome is a neurological condition characterized by sudden movements or vibration in certain part of the body. It is also known as Parkinson's disease. Tremor is the most commonly observed movement disorder in adults [1]. There are two main types of tremors, which are resting and action tremors. Resting tremors usually occur when the body is at rest position, such as while sitting or standing still. Action tremors occur during movement or while perform certain activities [2]. Resting tremors in Parkinson's disease typically affect the upper limbs, such as the fingers or hands, and can significantly impair daily activities [1][5].

Accurate measurement of tremors is essential for clinical diagnosis, monitoring disease progression, and evaluating treatment effectiveness [5][6]. Conventional measurement methods often rely on accelerometers or gyroscopes, which have been widely applied in previous studies [5][8]. However, many of these devices are bulky or rigid, restricting natural finger movement, causing discomfort, and potentially altering the measurement

results. In sensitive and small measurement areas such as the fingers, the size and weight of the sensor can interfere with natural motion, reducing accuracy [8].

In this project, development of fiber optic sensor is to measure tremors on certain finger position. As we know optical fiber can be classified into two which are extrinsic and intrinsic. Extrinsic detect change in the outside fiber while intrinsic see thing happen inside the fiber [3]. Their flexibility and minimal intrusion make them particularly suitable for applications where preserving natural movement is crucial, such as tremor measurement in Parkinson's patients. While optical fiber technology has been applied successfully for vibration detection [3][4], its potential for fine finger tremor measurement in direct comparison with conventional accelerometers remains underexplored.

Through this study, an optical fiber sensor will be developed because the larger sensor use may interfere with a patient natural finger movement. To validate its performance, measurements from the optical fiber sensor will be compared with data from an MPU6050 accelerometer. The finding of this project maybe could be led to the development of more effective and cost-efficient measurement technology in the medical field, At the same time, it could aid in providing tools for medical professionals and researchers to monitor neurological conditions [1][5][10].

2. Methodology

The methodology of this system involves the integration of various electronic components and software to ensure proper operation. The overall process and the function of each part are illustrated in Figure 1 and Figure 2. These diagrams represent the operational flow of the tremor measurement system, which uses both a fiber optic sensor and an accelerometer.

Fig. 1 shows the block diagram of the systems completely. In the glove section of the system, the main sensing components are the light source, fiber optic cable, photodiode, and accelerometer. A 5 V red laser diode is used as the light source, transmitting light through the fiber optic cable to a mini solar cell that acts as the photodiode receiver. Both the fiber optic sensor and the accelerometer are mounted on the finger section of the glove to capture vibrations accurately. The fiber optic sensor detects variations in light transmission caused by finger movement, while the accelerometer measures the corresponding physical motion.

The Arduino Uno serves as the microcontroller for data acquisition, collecting signals from both the fiber optic sensor and the accelerometer. The acquired data is then transmitted to a computer for analysis. In the analysis stage, MATLAB is used to process and visualize the data in both the time domain and the frequency domain. The optical fiber measurement is based on changes in the reflected light pattern received by the mini solar cell, while the accelerometer provides motion readings for comparison and validation.

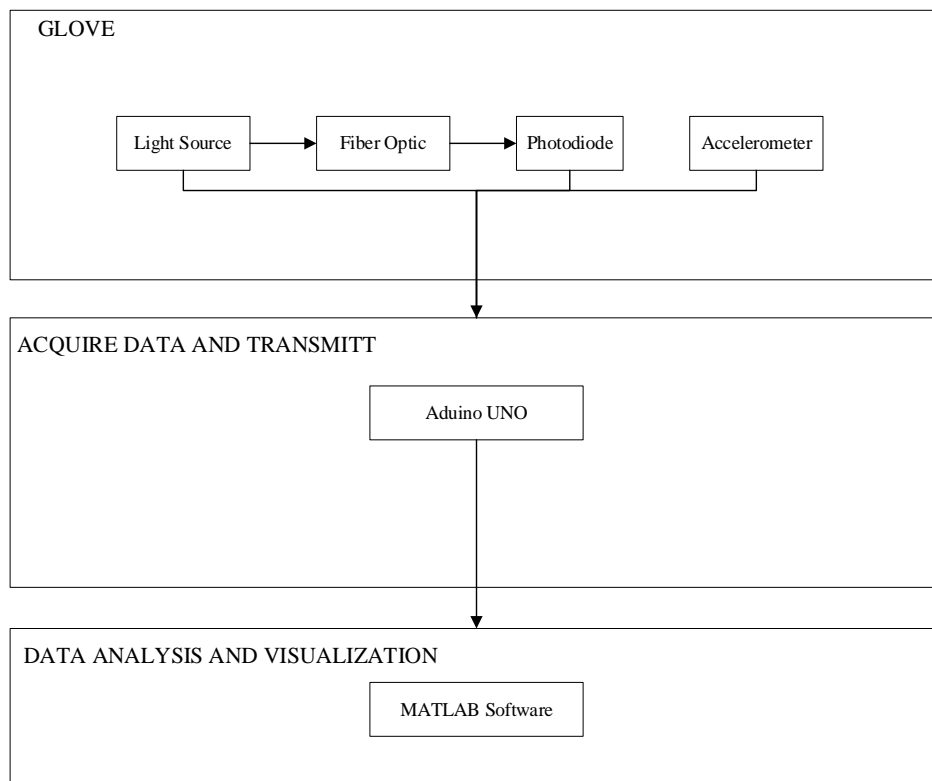


Fig. 1 Block Diagram of Development of Vibration Optical Fiber Sensor for Tremor Measurement

Fig. 2 presents the flowchart illustrating the complete process of the tremor measurement system, which utilizes both a fiber optic sensor and an accelerometer. The process begins with the user placing their hand into the glove, where both sensors are securely attached. Once in position, the sensors detect any movement or vibration from the finger. Tremor measurement starts when the photodiode detects reflected light from the optical fiber and the accelerometer records finger motion. The collected data is then sent to the Arduino Uno, which processes the signals before transmitting them to MATLAB. In MATLAB, the data is displayed and analyzed in both the time and the frequency domain

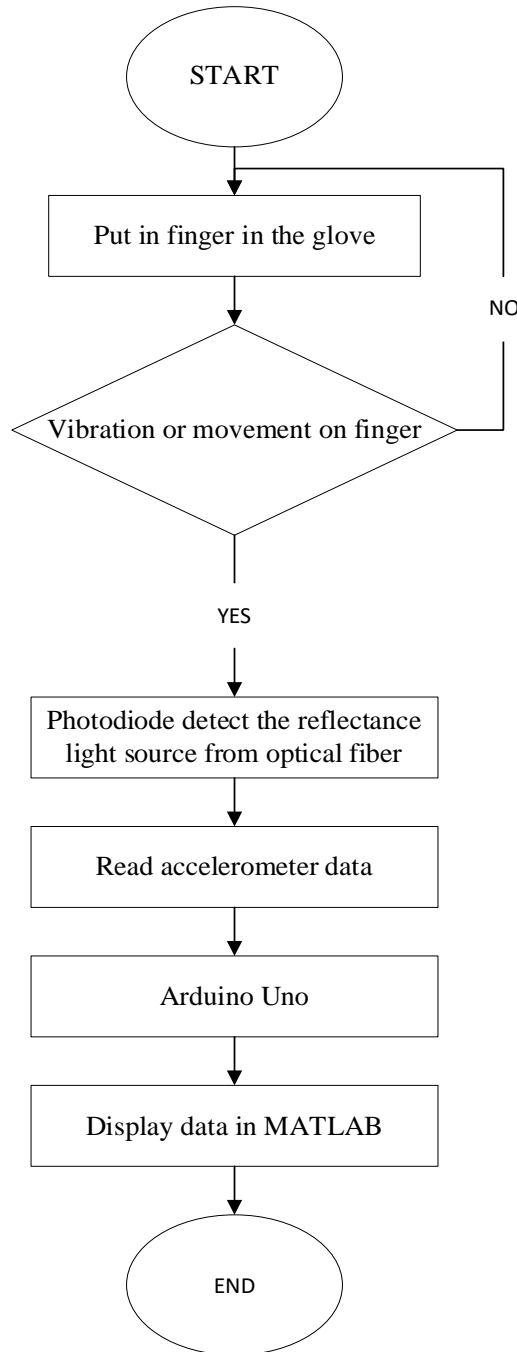


Fig. 2 Flowchart Development of Vibration Optical Fiber for Tremor

3. Result and Discussion

The system was developed to measure the vibration for tremor detection. The measurement for the tremor consists into placement of optical fiber which is at the top and side of the finger with the accelerometer MPU6050. The different placement of the optical fiber is intended to evaluate sensitivity at each position and determine which location provides the most accurate readings. Both sensors are used to compare the measurement reading between optical fiber and MPU6050. Data from both sensors are analyzed in the time domain to observe tremor

amplitude over time, and in the frequency domain to identify dominant tremor frequencies. The tremor measurement can analyze through the pattern of the graph from the movement of the finger.

3.1 Comparison Data Analysis between Optical Fiber and Accelerometer at the Top Position

In this section, both the optical fiber sensors and the MPU6050 accelerometer were positioned at the top side of the glove. The finger was moved repeatedly between 15° and 35° with the condition of hand in rest position shown in Fig. 3, to match the defined trigger range. During the movement, the optical fiber sensor's voltage output measured via a mini solar cell and the MPU6050 accelerometer's readings primarily along the Y and Z axes were simultaneously recorded.



Fig. 3 Hand position to take reading optical fibre at top placement

The results from figures 4 and 5 present the sensor output in time domain and frequency domain. The finger movement remained within the 15° to 35° range, repeated continuously to obtain 20Hz frequency sample. The result indicates that both sensors demonstrated a noticeable increase in signal activity within the 15° to 35° range, confirming it as the effective tremor trigger zone. The optical fibre sensor showed a consistent voltage spike corresponding to time, suggesting good sensitivity to angular displacement. The MPU6050 exhibited sharp changes in acceleration values within the same angle range, though with higher sensitivity to minor vibration artifacts. In the frequency domain, both sensors showed dominant peaks around 4Hz to 6Hz, verifying the simulated tremor frequency.

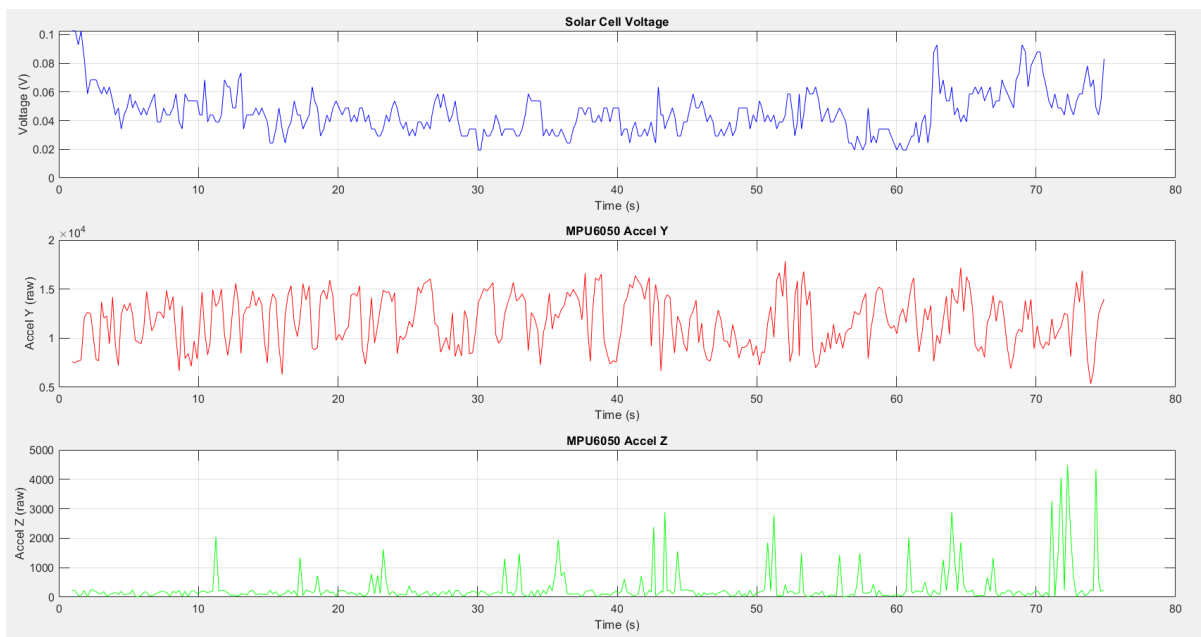


Fig. 4 Measurement in Time Domain

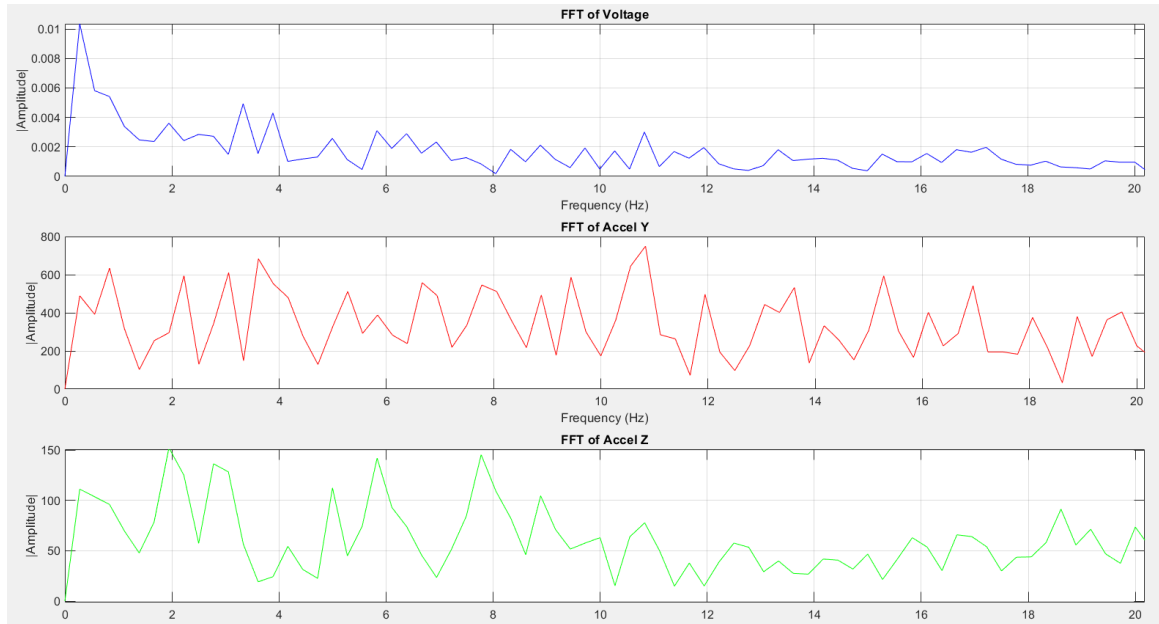


Fig. 5 Measurement in Frequency Domain

3.2 Comparison Data Analysis between Optical Fiber and Accelerometer at the Side Position

This section discusses the comparative analysis between the optical fiber sensor and the MPU6050 accelerometer. In this configuration, the optical fiber sensor was positioned on the right side of the finger, while the MPU6050 accelerometer remained on the top of finger as shown in Fig. 6. Similar to the previous configuration, the movement of finger is a repetitive motion between 15° and 35° to emulate tremor conditions.



Fig. 6 Hand position to take reading optical fibre at side placement

At the right position, the optical fibre sensor exhibited slight reduced sensitivity compared to the top position. As shown in Fig. 7, the recorded voltage values displayed lower spike amplitude than the optical fibre at the top position. This suggests that the fibre orientation relative to the laser path and finger movement affected the light transmission and overall sensitivity. However, the sensor still showed distinguishable voltage peaks aligned with finger vibration and movement. The MPU6050, when positioned at the top, continued to show strong acceleration

changes during the motion range. In the frequency domain from figure 8 shows the tremor detection peak began at approximately 5 Hz.

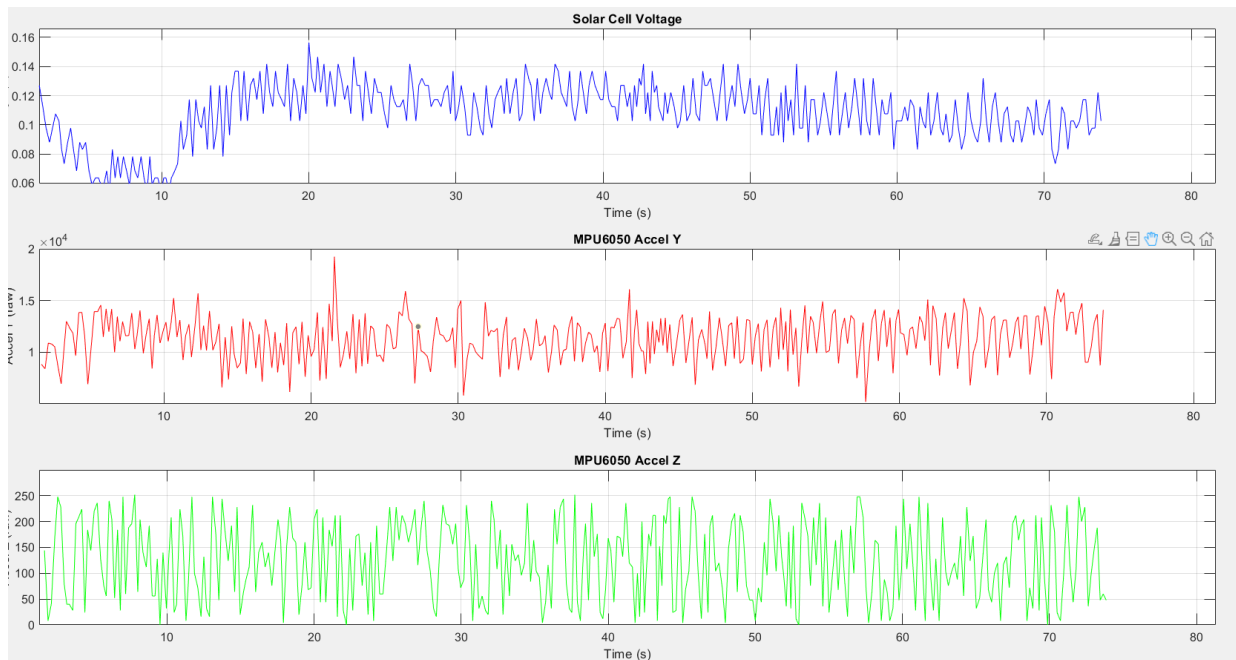


Fig. 7 Measurement in Time Domain

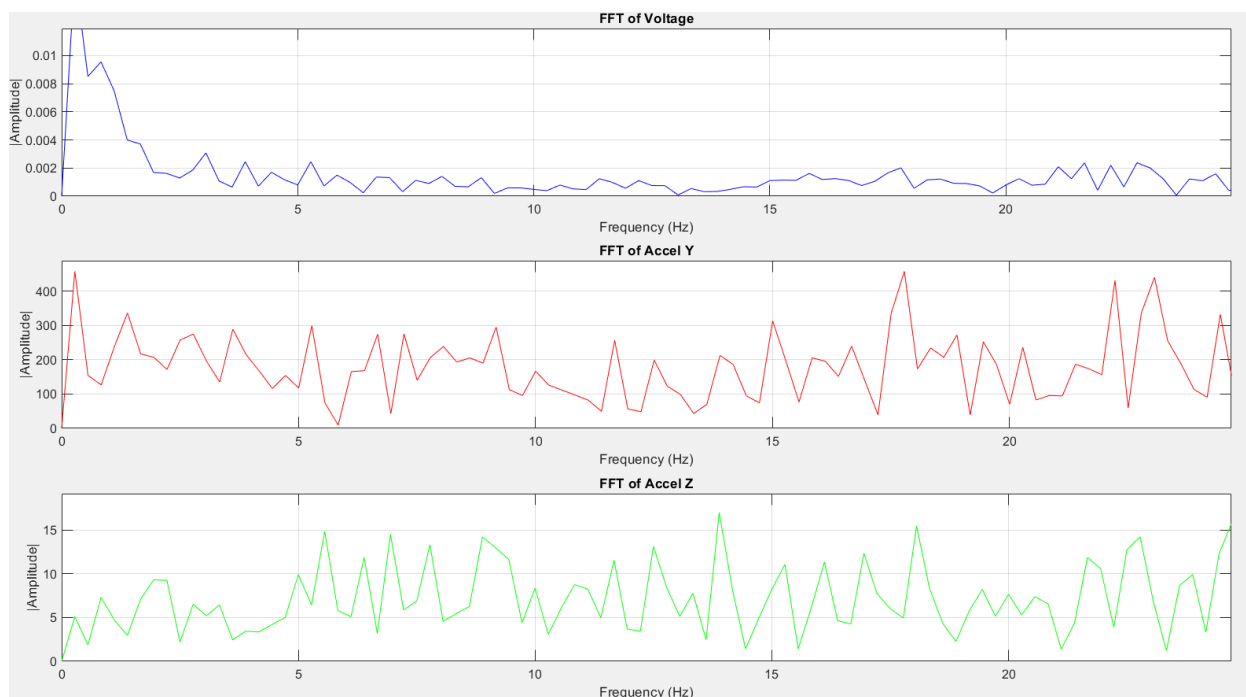


Fig. 8 Measurement in Frequency Domain

At the right position, the MPU6050 continued to produce higher-resolution vibration readings, while the optical fibre sensor's signal was more dependent on the precise alignment with the laser. Nevertheless, both sensors continued to exhibit frequency peaks close to 4 Hz, confirming the system's effectiveness in detecting simulated tremors.

In conclusion, the top-side placement provided more stable and stronger voltage readings for the optical fibre sensor, whereas the right-side placement showed greater variation, indicating that the fibre performance is highly sensitive to physical orientation. On the other hand, the MPU6050 remained robust in both configurations, although affected by axis orientation.

4. Conclusion

In conclusion, this final year project has successfully developed and evaluated a vibration-based optical fibre sensor system for tremor measurement, offering a low-cost and effective alternative to conventional methods. Through calibration testing using a servo motor and comparative analysis with the MPU6050 sensor, the study identified the angular range of 15° to 35° as the most responsive region for detecting tremor-like movements. The system demonstrated clear signal outputs from both the MPU6050 and the optical fiber sensor, confirming its ability to capture relevant vibration patterns. Actual hand testing further validated the sensor's performance, with optimal placement of the optical fiber at the top of the finger yielding the most consistent and sensitive light interruption patterns. Despite certain limitations in the servo motor's ability to simulate high-frequency tremors, the results affirm the system's potential when properly calibrated and positioned. Moving forward, the implementation of a more advanced motor, integration of artificial intelligence for tremor classification, optimized sensor placement within a wearable design, and real-time wireless communication can significantly enhance the system's functionality, accuracy, and user-friendliness. This project lays a strong foundation for future research and development toward a smart, portable, and adaptable tremor monitoring device that could benefit both clinical diagnostics and biomedical engineering applications.

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Conflict of Interest

The authors declare that there is no conflict of interest regarding the publication of the paper.

Author Contribution

*The authors confirm contribution to the paper as follows: **study conception, design, data analysis and manuscript preparation:** Nurul Amirul Anuar; Wan Suhaimizan Wan Zaki. All authors reviewed the results and approved the final version of the manuscript.*

References

- [1] A. Lenka and J. Jankovic, "Tremor syndromes: An updated review," *Frontiers in Neurology*, vol. 12, Jul. 2021, doi: 10.3389/fneur.2021.684835.
- [2] D. R. Williams and D. Sirisena, "My hands shake: Classification and treatment of tremor," *Australian Family Physician*, vol. 38, no. 9, pp. 678–681, Sep. 2009.
- [3] Y. R. García, J. M. Corres, and J. Goicoechea, "Vibration detection using optical fiber sensors," *Journal of Sensors*, vol. 2010, pp. 1–12, Jan. 2010, doi: 10.1155/2010/936487.
- [4] M. Elsherif et al., "Optical fiber sensors: Working principle, applications, and limitations," *Advanced Photonics Research*, vol. 3, no. 11, Jul. 2022, doi: 10.1002/adpr.202100371.
- [5] S. H. Ali, A. Akhtar, M. A. Khan, and M. Bilal, "Detection of Parkinson's tremor in real time using accelerometers," in *Proc. 2021 IEEE 7th Int. Conf. Smart Instrumentation, Measurement and Applications (ICSIMA)*, Bandung, Indonesia, 2021, pp. 5–9, doi: 10.1109/ICSIMA50015.2021.9526327.
- [6] A. Al-Kazwini, A. Halilah, A. Hendi, I. Al-Saeed, A. Al-Azamat, and W. Al Zyoud, "Frequency detection of hand tremors using customized accelerometer," in *Proc. 2021 IEEE National Biomedical Engineering Conf. (NBEC)*, Kuala Lumpur, Malaysia, 2021, pp. 112–116, doi: 10.1109/NBEC53282.2021.9618761.
- [7] A. S. Reddy, S. Khan, P. Ravali, and K. V. Prasad, "Smart glove for tremor detection," in *Advances in Engineering Research*, 2023, pp. 119–125, doi: 10.2991/978-94-6463-252-1_14.
- [8] E. M. Rini and E. S. Haq, "Detection hand tremor through each finger movement based on Arduino for Parkinson's patients," in *Proc. 2021 Int. Conf. Computer Science, Information Technology, and Electrical Engineering (ICOMITEE)*, Banyuwangi, Indonesia, 2021, pp. 225–230, doi:10.1109/ICOMITEE53461.2021.9650157.
- [9] M. Yousef, M. Hafizh, S. Sassi, and G. Adeli, "Development of a wearable wireless sensing device for characterization of hand tremors through vibration frequency analysis," *J. Vibration Eng. Technol.*, vol. 11, no. 7, pp. 3109–3120, Oct. 2022, doi: 10.1007/s42417-022-00734-2.
- [10] M. Manimaraboopathi, Y. Niranjana, N. Prakash, and D. S. Gayathri, "Measurement and analysis of hand tremor using IoT," *Int. J. Recent Technol. Eng. (IJRTE)*, vol. 7, no. 6S3, pp. 157–161, Apr. 2019.