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Research Article

Automated Detection And Improvement Of Dysgraphia: Analyzing Handwriting Pressure With Sensor-Based Technique

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ARTICLE INFO	ABSTRACT

Dysgraphia is a learning disability that affects fine motor skills and can cause a hindrance in the academic growth of students if not treated and detected early. This work focuses on a novel Arduinobased approach to get pressure values using Force Sensitive Resistors (FSRs) written on a piece of paper placed on the board. The collected pressure values are analyzed on 68 people with dysgraphia to run a feedback loop using visual and audio signals making a reinforcement learning system such that if the pressure value is above the proposed threshold then the pressure applied and the writing angle needs to be changed. The threshold value is calculated after an extensive survey of students with dysgraphia by collecting their pressure values, analyzing them, and consulting an educational psychologist. This feedback loop helps to diagnose dysgraphia by providing quantifiable data and real-time feedback on improvement which can be viewed on a laptop or a phone. This approach offers a way to address problems with fine motor skills and improve academic performance. This method can help educational psychologists provide a tool to students for their improvement.

Keywords: Dysgraphia · Fine Motor Skills · Learning Disabilities · Healthcare · Handwriting · Screening Tool.

1 Introduction

Learning disabilities are defined as the difficulties in acquisition of knowledge, skills or both in learning, and include dyslexia, learning disorder number one. Common examples of these disabilities are the neurodevelopmental kind that affects an individual's education and daily life undertakings. There are many types of learning disabilities and one such category includes specific learning disabilities and these learning disabilities focus on having a problem with one or more of the basic psychological processes that are used to acquire, understand, and use spoken or written language [1]. Dyslexia is one of the specific learning disabilities or SLDs, the primary symptoms of which involve pure reading difficulties as well as other language information processing skills. Dyslexia can be explained as a learning disability that has an impact on children and adults. As per current statistics, dyslexia is not a rare disorder, it has also been noted by some researchers that dyslexia is a learning disability that may be hereditary and one of the most widespread. As per [2] 1 out of 10 people in the world have dyslexia which accounts for 780 million people in the world. Currently, there is no cure for Dyslexia as of now but through early intervention and diagnosis, the skills could be improved. The first step in curing dyslexia is acknowledging the problem and knowledge about the condition is extremely crucial to overcome this. This is achieved through the elicitation of slow reading and text-to-speech format of learning with different kinds of exercises as suggested by the educational psychologist. Dysgraphia, another type of SLD affects the writing skills of individuals where they face difficulties in articulating their thoughts leading to spelling mistakes and writing difficulties. It is related to Fine Motor Skills, spatial perception and working memory [3]. Dysgraphia is not a form of autism but it is common in kids with autism spectrum disorder (ASD) where it extends from 5% to 10% in the world. Formalized handwriting assessments and Beery Developmental Test of Visuomotor Integration (VMI) [4]. are the tests for checking whether a person has dysgraphia. Fine

Motor Skills have a direct link to handwriting assessments and dysgraphia. These are motor skills that specify the ability to control the small muscles in the hands and fingers when writing, drawing, or picking objects such as pencils. These fine motor skills are associated with gross motor skills, making it easier for the human bodies to make large movements. These skills are related to SLDs as they influence direct movements and their assessment is essential for detecting SLDs. These assessments include humans looking at the text and analyzing it accordingly. There is no firm metric for assessing these skills which could make it partial. The proposed study immensely focuses on fine motor skills, engaging a pressure threshold technique for evaluation. This work consists of a pressure-sensitive writing board connected to an Arduino that gives out visual (the light) and sound (the beep) alerts when the writing pressure is beyond a set limit. Since it makes the individual lower his or her writing angle and also relieves pressure, it can also be considered an element of a reinforcement learning system. The process of calculation of the threshold involved detailed analysis of writing techniques of children with dysgraphia and consultation with a psychiatrist who mainly deals with this condition of children.

2 Literature Review

The paper by Margaret J. Snowling et al. [5] discusses the definition and understanding of dyslexia, a particular learning disability marked by difficulties with reading and spelling. It also talks about other Development Language Disorders(DLD) which often happen with dyslexia and have various educational implications involving dyslexia. The paper delves into the idea that to improve outcomes for those affected by dyslexia, there needs to be a deeper comprehension of the multifaceted nature of the condition, acknowledging its dimensional aspects and the significance of treating co-occurring disorders. This paper was used as an inspiration to advance into other forms of Development Language Disorders which led the research to dysgraphia.

The paper by Jayakanth Kunhoth et al. [6] explores the application of machine learning algorithms to diagnose dysgraphia in children. This study focuses on capturing handwriting data both "On-Surface," using a pen directly on a tablet, and "In-Air," where the pen is moved away from the tablet. By extracting and analyzing features from these two distinct modes of data capture, the researchers trained various machine learning models to classify whether an individual exhibits signs of dysgraphia which was shown by V.W. Berninger in the paper [7]. A key contribution of the paper is its method for reducing the number of features required for training, achieving significant accuracy with fewer features compared to previous approaches. It has findings from the paper by C.T. Fuentes [9] which explains the handwriting impairments in children. This reduction in feature set helps streamline the model training process and enhances the efficiency of the diagnostic system. Additionally, the paper provides a thorough analysis of handwriting features, distinguishing between normal and abnormal writing patterns. These insights underscore the importance of analyzing how handwriting evolves over time and how it is physically executed, offering valuable implications for improving diagnostic tools and interventions for dysgraphia.

The paper by Zvoncakova et al. [8] discusses the problems related to writing skills and their association with Developmental Dysgraphia (DD). The work focuses on creating an assessment for deficiencies related to handwriting from an educational and psychological perspective. It has findings from the paper by P. Johnston, & D. Scanlon, [10] which explains the handwriting impairments in children. It is a novel quantitative technique for evaluating handwriting proficiency. To capture children's handwriting and graphomotor skills, they use Wacom Intuos Pro L digitizing tablets and Wacom Ink Pen special ink pens. This method is not accessible to all students as the availability of tablets and special inks are not clear. Simple graphomotor elements and complex figures relating to DD symptoms and cognitive abilities (memory and visuospatial skills) are included in the assessment templates.

3 Proposed Methodology

This section describes the architecture of the approach and the methods used for its implementation. The proposed system employs a multi-staged approach to get the values of pressure from the text written by the user, ultimately aiming to identify potential cases of Dysgraphia and improve their fine motor skills in a feedback loop for their academic growth.

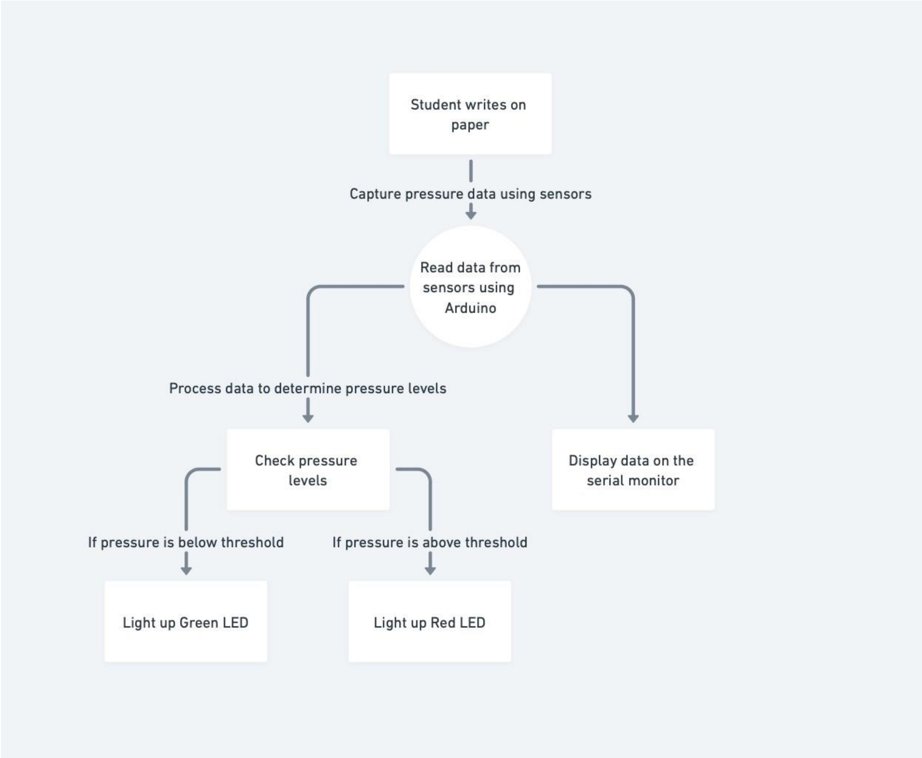

Fig.1: Pressure Sensing System

The proposed methodology is described in *Fig.1* with the workflow of the project. The major task is to keep track of the pressure applied while writing by a student and observing it through sensors attached to an Arduino board. The approach for determining pressure was inspired by M. W. Lovett, in [11] who did extensive research on reading disabilities and writing skills. The preferred amount of pressure applied is displayed through an indicator for real-time confirmation of the optimal pressure exertion. In the proposed methodology, a student writes on a piece of paper kept on the board with the pressure sensing setup which captures pressure data using resistors. This work takes into consideration the pressure applied by the palm of the hands and the angle at which the piece of paper has been kept. It further reads the data using Arduino and uses this data to determine the pressure levels to further check if the value is above or below the threshold. The pressure values captured while writing on the board are saved for further analysis. The light turns green if the pressure applied is below the threshold and turns red if it is above the threshold. It creates a feedback-based reinforcement system where a user gets to know about their mistakes and iterate them, again and again, to get their writing skills in order and effectively improve their academics and fine motor skills.

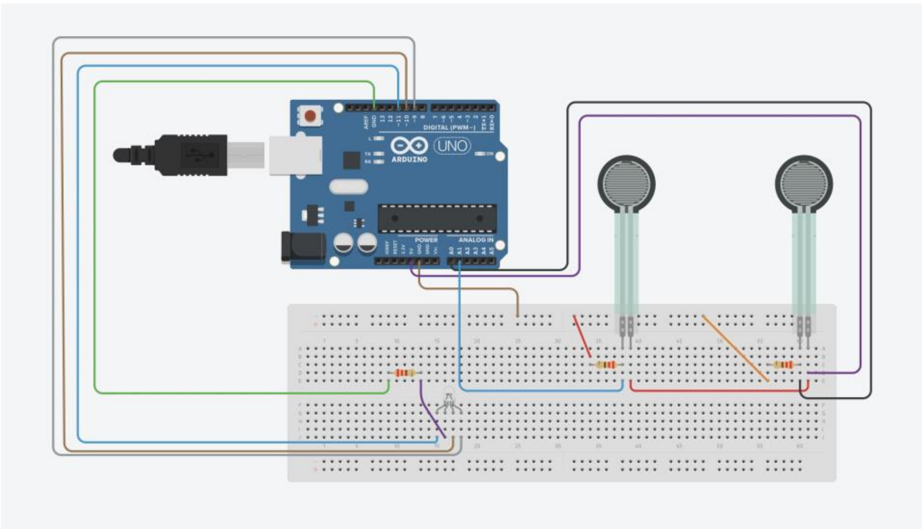

Fig.2: Circuit Diagram Architecture

The circuit setup shown in the *Fig.2* includes an Arduino Uno connected to two force-sensitive resistors (FSRs) on a breadboard. These FSRs are used to detect pressure levels when force is applied to their surfaces. Each FSR is part of a voltage divider circuit, with one terminal connected to an analog input pin on the Arduino and the other terminal connected to the ground through a resistor. The Arduino reads the analog signals from the FSRs, which vary based on the applied force, allowing it to process the pressure levels. Based on the pressure readings, the Arduino can provide feedback by controlling outputs such as LEDs and buzzers. It creates a feedback-based reinforcement system where a user gets to know about their mistakes and iterate them again and again to get their writing skills in order. This setup is ideal for this work requiring sensitive pressure detection, for teaching handwriting techniques or for therapeutic applications for conditions like dysgraphia.

3.1Material Used

The materials used for creating the project were as follows: The Arduino Board is the central Processing Unit of the system. An open-source electronics board that has been created as a microcontroller working to bring electronics within reach. It has digital and analog input/output pins that allow it to use different types of sensor and actuator components. Pressure Sensors are used to convert the physical force applied by the student into electrical signals for further analysis. Capacitive touch sensors were used in this project as they can record pressure values ranging from light to heavy. Light Emitting Diodes(LED) emits light when these electrical signals are passed through them. A breadboard is used to set the LED lights and pressure sensors using wires. These devices are connected to the monitor to get an analysis of the pressure values generated.
The major steps used in designing the system were to get in-depth knowledge of the IOT products used and to create a pressure-sensing device concerned with the angle of the user. Through experimental research on various students with dysgraphia and ADHD, it was discovered that the angle at with they hold the paper makes a lot of difference in the pressure applied thereby affecting their writing skills.

4 Experimental Results

This section describes the experimental results of the proposed methodology to evaluate the effectiveness of the pressure-sensitive feedback system for students with dysgraphia. As mentioned earlier in the circuit setup the actual working prototype shown in the *Fig.2* analysis is done to find out about the threshold to classify students into 2 groups for further improvement of their fine-motor skills. 68 test subjects were evaluated in the working prototype of the methodology shown in *Fig.7* and various analysis methods were accommodated for calculating the threshold value.

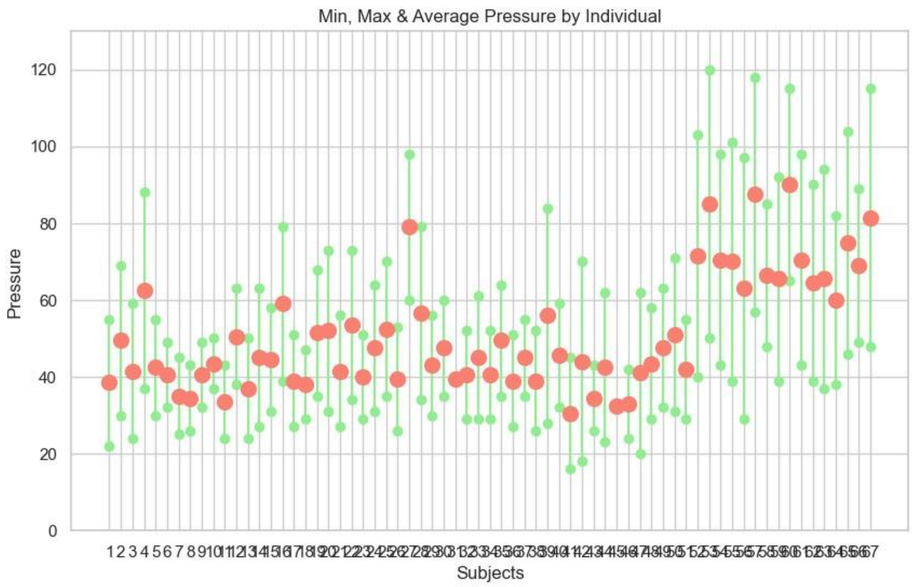

Fig.3: Pressure Values

The graph in *Fig.3* provides a comprehensive analysis of pressure readings collected from 68 test subjects, highlighting the minimum, maximum, and average pressure readings for each individual. The average readings are depicted in orange, offering a clear visual representation of the central tendency in pressure application among the subjects. This data includes students diagnosed with dysgraphia, a learning disorder that affects writing abilities. These individuals often exert more pressure when writing due to difficulties in fine motor control and spatial planning, which is reflected in the higher average pressure readings compared to their peers without dysgraphia. The plot shows distinct variations in pressure ranges across individuals, with some subjects exhibiting wide disparities between their minimum and maximum pressures. This could suggest variability in motor control and consistency in pressure application, potentially indicating underlying neurological or developmental factors. The wide range of pressures in certain subjects also highlights the diversity in motor skills among the test population.

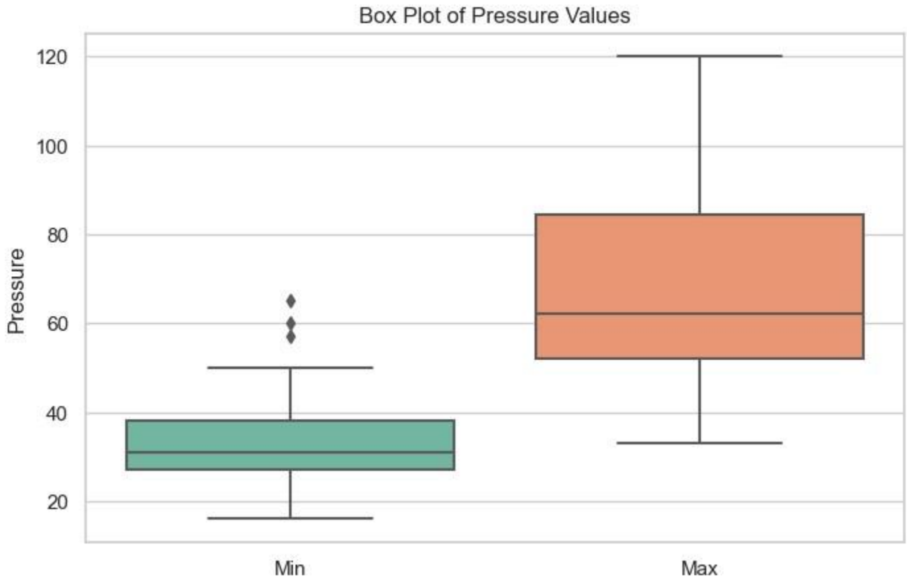

Fig.4: Box Plot of Pressure Values

The graph in *Fig.4* shows box plots of the minimum and maximum pressure values among test subjects, highlighting the variation in pressure application. The maximum pressure box plot displays a wider spread, indicating greater variability in pressure exertion, with a median below 60. This suggests that most subjects, particularly those without dysgraphia, apply moderate pressure when writing. For students with dysgraphia, the higher maximum pressures observed indicate challenges in motor control, underscoring the need for targeted interventions to help them manage pressure more effectively. By focusing on pressure control techniques, educators and therapists can support these students in improving their writing skills and legibility.

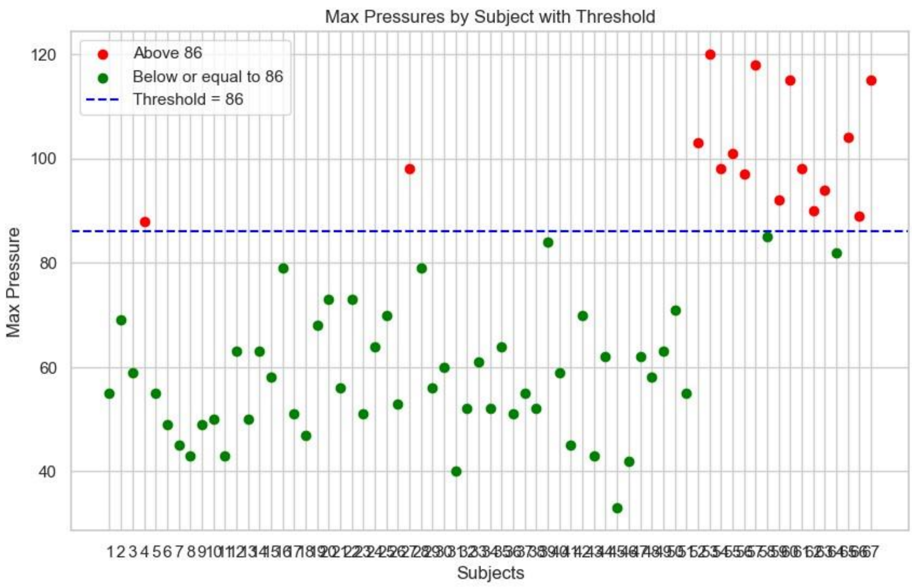

Fig.5: Max pressure with Threshold

The graph in *Fig.5* illustrates the maximum pressure readings of individual subjects, highlighting those exceeding a threshold of 86 Pascal(Pa). This threshold was established based on the pressure readings of students with dysgraphia, following consultation with a psychologist. The plot effectively identifies outliers, with points above the threshold marked in red, indicating subjects exerting higher than typical pressure. This distinction helps in isolating cases that may require further attention or intervention. After analysis of identified dysgraphic subjects and subjects without dysgraphia, this study came to a threshold pressure value of 86 Pa that differentiates the writing pressures of potential dysgraphic subjects and non-dysgraphic subjects using which the signals of reducing pressure values were given to the students for improving fine motor skills.

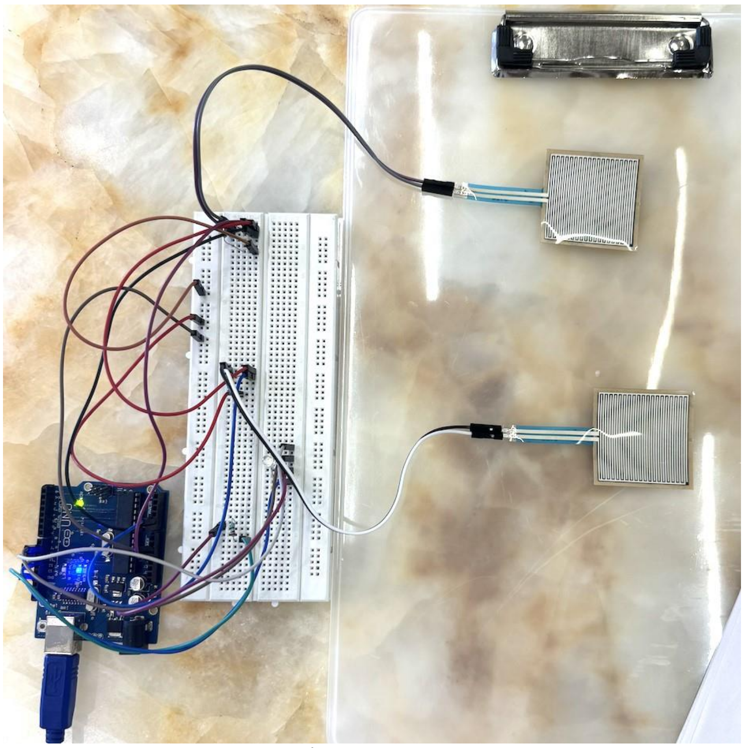

Fig.6: Setup

As mentioned earlier in the circuit setup the actual working prototype shown in *Fig.6* includes an Arduino Uno connected to two force-sensitive resistors which are placed over a writing board. A couple of papers are then placed to get the pressure readings. This work utilizes a code written in C language to find the minimum pressure and maximum pressure on the sensor placed above as seen in the *Fig.6*. The code gives the minimum pressure value, which is greater than 20 in order to neglect the unwritten or ideal pressure readings ranging from 0 to 20, and the maximum pressure value for a given time frame of 10 seconds. The test subjects were asked to draw lines or write their names according to the practices done in educational classes of students to improve their fine motor skills. The subjects were also asked to do so with their usual speed and pressure. The value 20 was taken as the values below 20 would mean a very light writing or no writing, furthermore maximum pressure values are the more important values. The minimum pressure values help in analyzing the correctness of the maximum pressure values and nothing more. So the analysis done is majorly on the maximum pressure value.

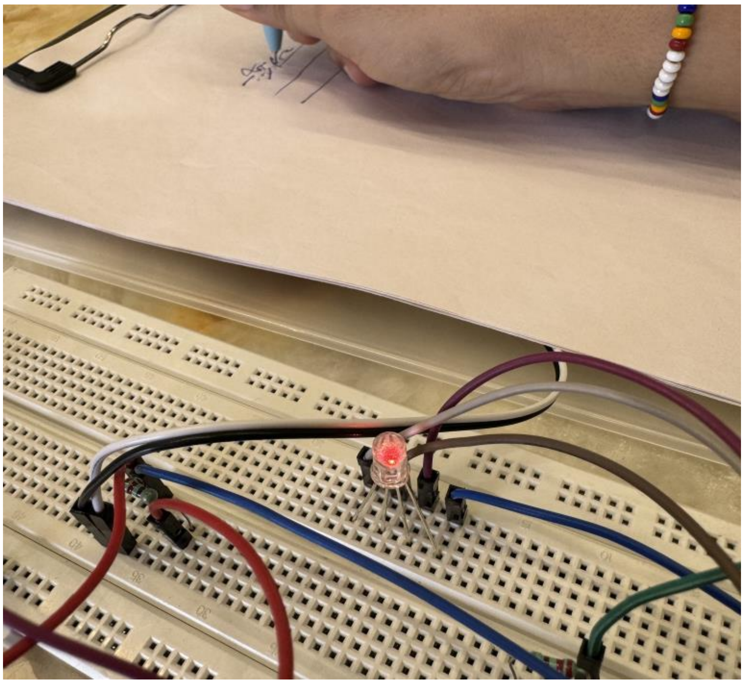

Fig.7: High Pressure

As shown in *Fig.7* when the subject having dysgraphia writes on the board with paper placed on it and the pressure value goes above 86 Pa which is the threshold then the red LED starts glowing which is a visual indication to the user to lower down the pressure applied which The threshold value of 86 Pa in the code was used to identify high pressure by lighting the LED red. This threshold was carefully selected through calibration experiments to distinguish between typical and excessive pressure levels accurately.
This real-time feedback is crucial for users, particularly when engaging in activities that require precise pressure control, such as writing or drawing. By visually signaling when the applied pressure is too high, users can quickly adjust their technique. For example, they may reduce the force they are applying or modify the angle at which they hold the writing instrument. This adjustment is demonstrated in *Fig.7*.
The activation of the red light serves as a direct prompt for users to correct their pressure levels, thereby aiding in the development of better fine motor skills. By providing this immediate feedback, users are encouraged to practice and refine their motor control, leading to improved writing habits and reduced strain during writing tasks. This approach not only enhances the user's writing experience but also contributes to their overall skill development.

5 Conclusion

The study presents an innovative approach to improve fine motor skills for students with dysgraphia through the use of pressure sensors. This device, connected to an Arduino, provides immediate visual feedback to help regulate writing pressure, which is crucial for children struggling with dysgraphia. The threshold was calculated through analysis of test subjects under normal conditions for various students with different age categories and was evaluated to be 86 Pa. This was further used to give signals to students with dysgraphia for improvement of their fine motor skills. The research also highlights the correlation between fine motor skills and handwriting assessments. By incorporating this pressure threshold technique, children can improve their writing abilities, which in turn may cure some of the challenges associated with dysgraphia which was verified by psychiatrists. Helping students with such technology-aid tools may change their future.

6 Future Scope

The result of the current study gives valuable information to the specified area of assessment and subsequent enhancement of dysgraphia, which in turn opens up a myriad of research studies in this field. This was a working prototype of the assessment board, the future scope includes integrating the board with electronic devices such as phones and e-boards to make it accessible to more people and validate the approach. Secondly, collaborating with schools and medical organizations for students with dyslexia to get more data and curate the threshold as accurately as possible. Creating a mobile application for end-to-end help of students with Dysgraphia including awareness about the condition, text-to-speech and parent control as the features.

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