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Capstone Project Phase B – 61999

ScribbleBoost

Enhancing handwriting using graphic tablet

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1. Abstract

Handwriting is an essential skill used in building self-esteem, academic achievement, accessible creativity, artistic opportunities, and daily task. Many children struggle with handwriting despite the fact that it is a necessary skill for academics and other professions. in order to assist and improve functional ability, there are occupational therapists who are skilled in helping children improve their handwriting.

Since technology has advanced, development of custom made adaptive digital technologies may offer fresh and newer ideas from the traditional methods like pencil and paper that are no longer efficient enough.

For occupational therapists treating elementary school-aged children with handwriting difficulties, we developed ScribbleBoost, a web-based program that utilizes graphic tablets to track and improve handwriting skills.

With the system, patients can perform writing exercises on the tablet, which are synchronized with what is done on the system's screen, providing positive and negative feedback in real time, while adjusting specific parameters such as marking the line at which the writing begins and the distance between the scribbles of a patient on a page.

As part of the system, therapists are able to view and track their patients' progress through a user management interface.

As a result of ScribbleBoost's unique capabilities, we believe it holds immense promise from two distinct angles. First, it provides a rich platform for researchers, enabling them to closely monitor patient progress. Secondly, it serves as a potent tool for enhancing performance, specifically directed at children who can significantly improve their handwriting abilities by utilizing this user-friendly system.

For their valuable contributions to the formulation of the project requirements, we would like to thank Romi Mirenburg, an occupational therapist, and Professor Sarah Rosenblum, Chair of the Doctoral Program in Occupational Therapy at Haifa University.

Please refer to the following link for the project code:

https://github.com/senderh55/enhancing-handwriting-project

2. Introduction

2.1 Motivation

Handwriting is the process of writing by hand, typically with a pen or pencil on paper. As the user must manually control the movements of their hand and fingers to produce written language. Handwriting is an important skill for children to learn, as it is a fundamental component of literacy and education. It is also important for adults to maintain good handwriting skills, as it can improve productivity and legibility. Some common challenges with handwriting include difficulty forming letters, illegible writing, and slow writing speed.

In general, poor handwriting is treated with a combination of educational support, such as specialized instruction and assistive technology, as well as occupational therapy to improve fine motor skills.

The purpose of our product is to help primary school children who are suffering from poor handwriting from various circumstances improve their handwriting as much as possible by using interactive software, and an interface that is friendly and not boring for them and that focuses on the Hebrew language.

The system is designed for occupational therapists who work with patients on their handwriting visibility problems so that they can use an intuitive registration system to register patients as profiles and access trainings that will provide an effective tool for providing feedback and monitoring patient progress.

It is both our personal experiences with handwriting difficulties from a young age that motivated us to develop this idea clearly.

Once we decided on the subject for the project, we contacted several professionals. As we searched, we found that the Hebrew language does not have enough satisfactory solutions, so we considered how to solve this problem

As a result, we need to combine hardware and software to meet our challenge. In our case, we design our software to work in conjunction with a graphic tablet that measures pen position, which then enables the software to respond appropriately to the input.

2.2 General Description

The ScribbleBoost system aims to provide occupational therapists with a tool for tracking handwriting practices. By utilizing the system, therapists can provide interactive handwriting practice and monitor their progress.

The system is divided into two parts, each of which complements the other:

The first part of the system is the user management system. Every user, aka the occupational therapist, registers with the system through a registration system that verifies the fields and encrypts the password so that the personal information is not saved in the system.

Moreover, confirmation of registration requires the user to enter a verification code sent to the email address used for registration.

In the user dashboard, users have access to profiles, that is, patients exclusively related to them, by opening them and displaying the information to them, as well as the ability to access any profile dashboard in their profile.

An overview of the profile dashboard includes options for starting a practice, monitoring the results of the practice filtered by parameters, and editing or deleting the profile

Handwriting practice is the second component of the system. The patient may write on a canvas that has been established into the system using a Wacom graphic tablet, and receive feedback regarding deviations from a line or from an extended distance as determined by the therapist.

While practicing, the system tracks the patient's handwriting speed and accuracy, and provides personalized feedback, along with a log file of every practice that includes a timestamp and coordination.

3. Review and Process Description

3.1 ScribbleBoost System Review

3.1.1 The Main Algorithm - writing practices

We are interested in creating a visual interface that makes the treatment process more enjoyable, rather than the cumbersome treatment process that exists today.

Since both of us have a programming training background, we recognized that graphic libraries are able to illustrate graphics on the screen in an intuitive and comfortable manner.

Among the programs, there is a p5.js library, which is described as follows: “p5.js is a JavaScript library for creative coding, with a focus on making coding accessible and inclusive for artists, designers, educators, beginners, and anyone else!” [2]

This graphic library has a unique draw function that allows the drawing to run continuously and be dynamic. Therefore, additional illustrations can be added and react in real-time to events.

In our case, the graphic tablet can be used in conjunction with the p5.js library to create interactive drawings and animations.

The tablet connects to the computer via USB and allows the user to draw on the tablet surface using a stylus, while the p5.js library captures the coordinates of the stylus and converts them into digital drawings on the computer screen.

Additionally, the p5.js library can be used to apply various effects and transformations to digital drawings, such as color, size, and rotation. This allows for a more natural and intuitive drawing experience compared to using a mouse or trackpad.

Handwriting organization practice is based on the concept that a patient should maintain the correct order on the page. In our case - the Hebrew language - we write from the top right to the bottom left.

The practice algorithm is based on the following principles:

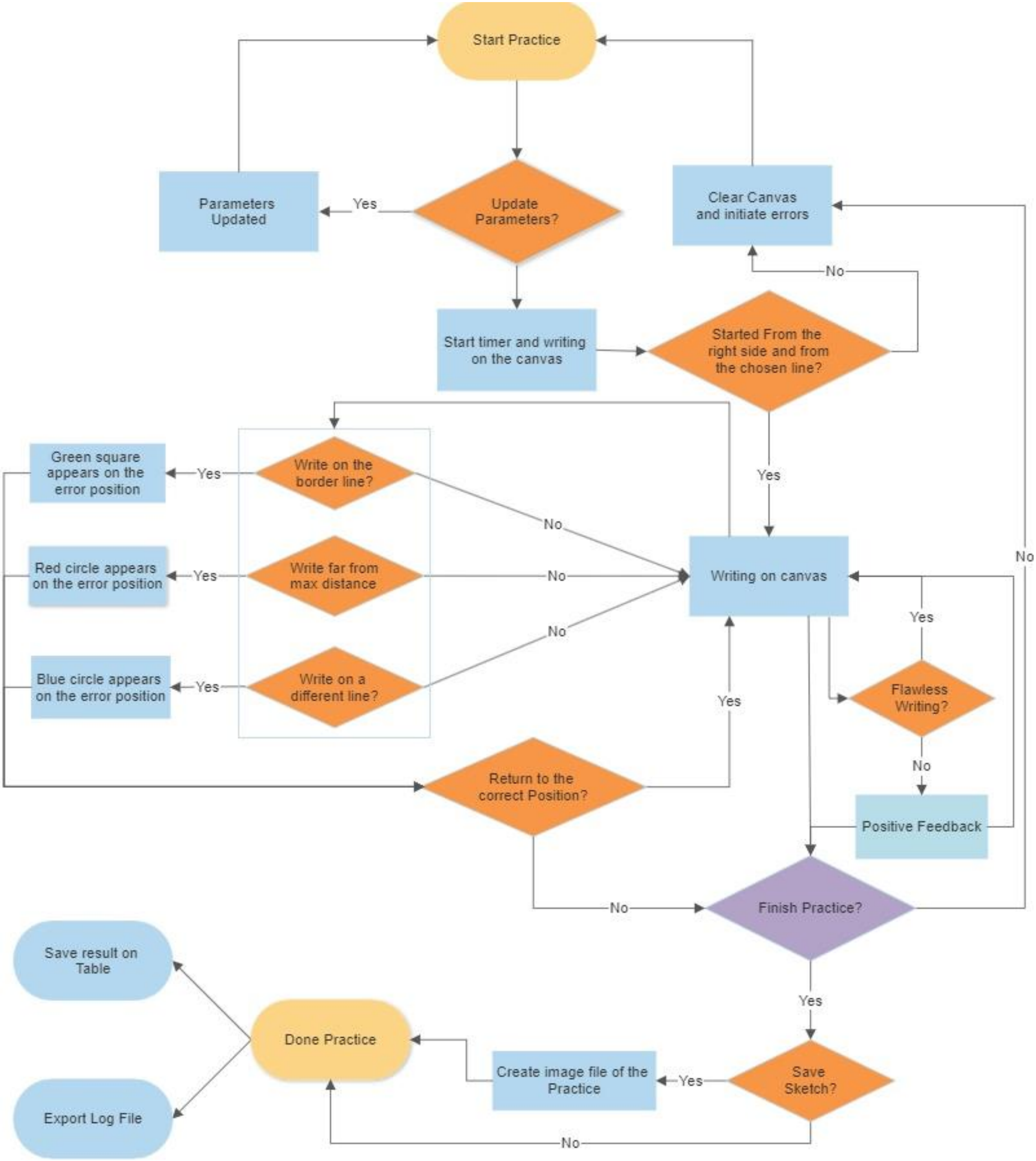
- Monitor the practice area: This step involves closely observing the process of writing from right to left throughout the entire line in order to ensure the consistency of writing direction.
- In boundary adhesion, the goal is to ensure that all writing fits within the allocated space and does not extend beyond it.
- Line Borders: Here, we are discussing when a writer reaches the end of a line. This event occurs when the end of the line is not reached and the patient begins writing on the next line.
- Writing that deviates from the line is when the pen or pencil drifts from the path of the line during the writing process.
- Defined Maximum Distance: This technique involves writing each new piece of handwriting at a defined maximum distance from the last.
- If none of the above errors are present and there is continuous writing, the patient will receive positive feedback in two stages: a successful end to a line and a continuation of the line.
- The writer receives real-time feedback as soon as positive feedback, deviations or errors are detected during the writing process.

Since the rate of writing is an important measure, we will use a timer during practice to measure the rate of writing, so the user can see and control his progress.

Data will be collected at the end of each practice- date, time, number of errors, and an option to take a screenshot. A dedicated page containing a table with export options will allow users to view these results.

In addition, a log file is created at the end of practice that contains the writing positions in terms of x and y coordinates as a function of the time
during the practice.

The diagram below illustrates how the practice flows


Start Practice
Update Parameters?
Yes
Parameters Updated
Start timer and writing on the canvas
Started From the right side and from the chosen line?
No
Clear Canvas and initiate errors
Yes
Writing on canvas
Write on the border line?
Yes
Green square appears on the error position
No
Write far from max distance
Yes
Red circle appears on the error position
No
Write on a different line?
Yes
Blue circle appears on the error position
No
Return to the correct Position?
Yes
No
Flawless Writing?
Yes
No
Positive Feedback
Finish Practice?
No
Yes
Save Sketch?
Yes
Create image file of the Practice
No
Done Practice
Save result on Table
Export Log File

3.1.2 User management system

Our web-based application includes a user management system that allows registered users to view their own profiles. Each profile will have access to the practice, and users can create and manage multiple profiles. The profiles include information about the patients, a description of their handwriting issue, and practice results.

The user management system also provides the ability to track progress and performance of users and profiles associated with them. This data can be used to generate detailed reports on user performance, which can be used to identify areas for improvement. In such a user management system, users (therapists) can monitor profiles (patients') progress in a centralized and organized manner.

The user management system has the following features:

- Registration and management of users: Therapists can register as users and create profiles for their patients, similar to a clinic where patients are associated with therapists.

- Authentication and isolation of data: Each user has access to only his profiles and receives only the information associated with him. Information cannot be shared or accessed by non-authenticated users.

- Profile management: Users can edit their profiles, add or remove information, and even remove them.

- Practice tracking: Users can track their progress of their practices by entering into their profile's results page. This data can be used to generate reports on user performance.

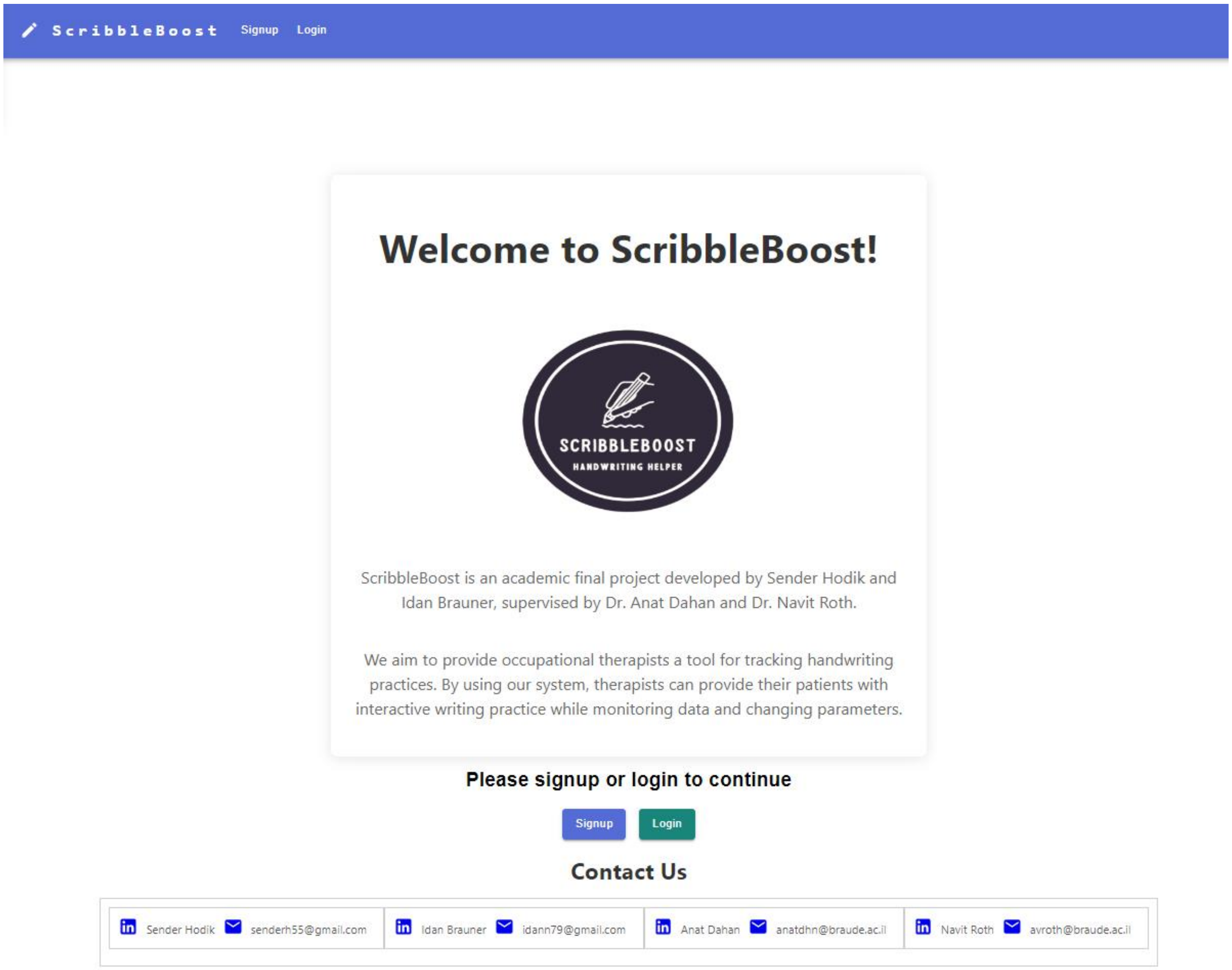
- Reporting: The system is capable of producing detailed reports on user performance. The information created in these reports can be used for various research purposes, including identifying areas for improvement and tracking progress over time.

From a therapist's perspective, the user management system plays a crucial role in streamlining and centralizing the monitoring process. Patients' profiles, progress, and development can be accessed conveniently by clinicians. A centralized approach ensures that therapists have access to accurate and up-to-date information so they can offer targeted guidance and support.

3.1.3 An overview of the system's screens

In this section, we are mainly concerned with understanding the user flow of the system, since it can provide an overview of how the various components interact with each other as well as how they work together as a system.

Here's the home page where information about the system is provided, as well as directions for logging in or registering



Welcome to ScribbleBoost!

ScribbleBoost is an academic final project developed by Sender Hodik and Idan Brauner, supervised by Dr. Anat Dahan and Dr. Navit Roth.

We aim to provide occupational therapists a tool for tracking handwriting practices. By using our system, therapists can provide their patients with interactive writing practice while monitoring data and changing parameters.

Please signup or login to continue

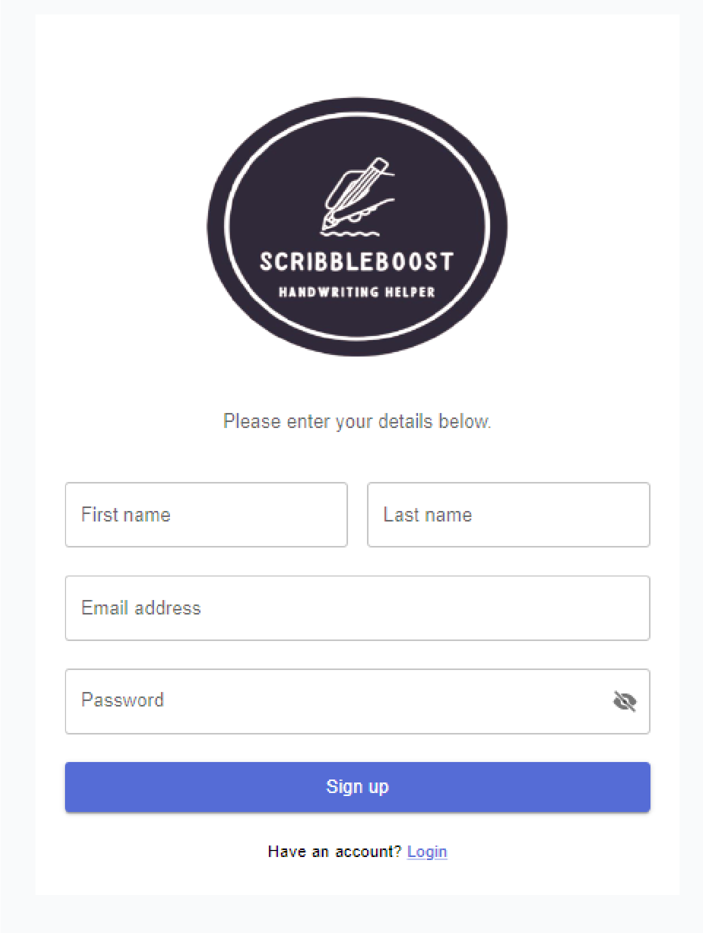
Contact Us

Sender Hodik senderh55@gmail.com	Idan Brauner idann79@gmail.com	Anat Dahan anatdhn@braude.ac.il	Navit Roth avroth@braude.ac.il

Note: The navigation bar above appears in each phase of the system, we will focus on each phase's unique functionality

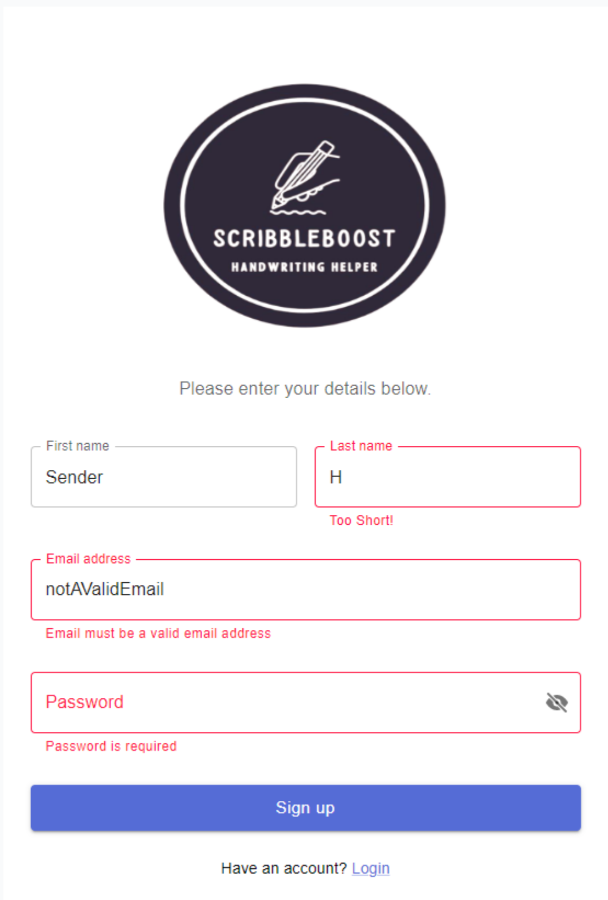
- The user registration page has a registration form that validates the data according to the field and the input

Note: In general, every form in the system includes input validation



Please enter your details below.

Have an account? Login



Please enter your details below.

First name: Sender

Last name: H

Too Short!

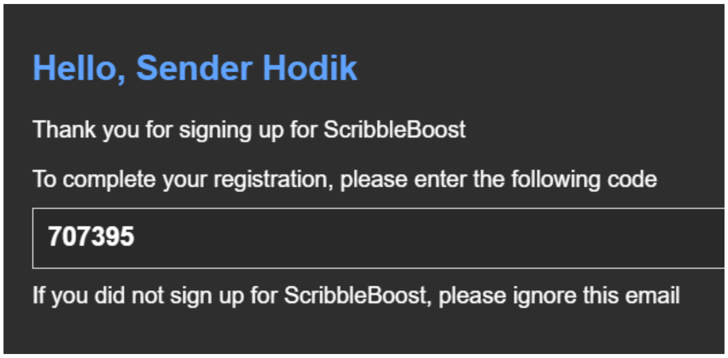
Email address: notAValidEmail

Email must be a valid email address

Password is required

Have an account? Login

- The user will receive an email with a verification code after registering successfully



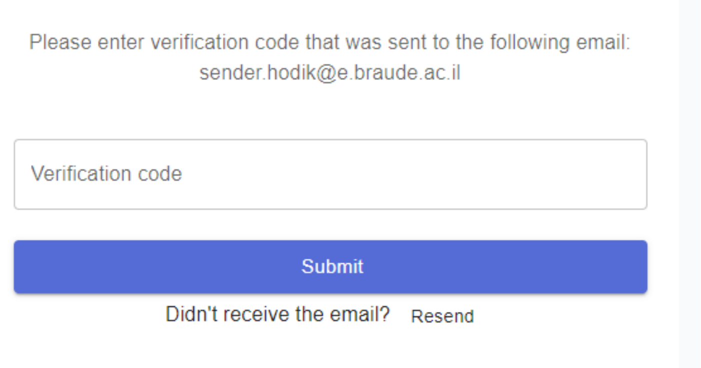
Hello, Sender Hodik

Thank you for signing up for ScribbleBoost

To complete your registration, please enter the following code

707395

If you did not sign up for ScribbleBoost, please ignore this email

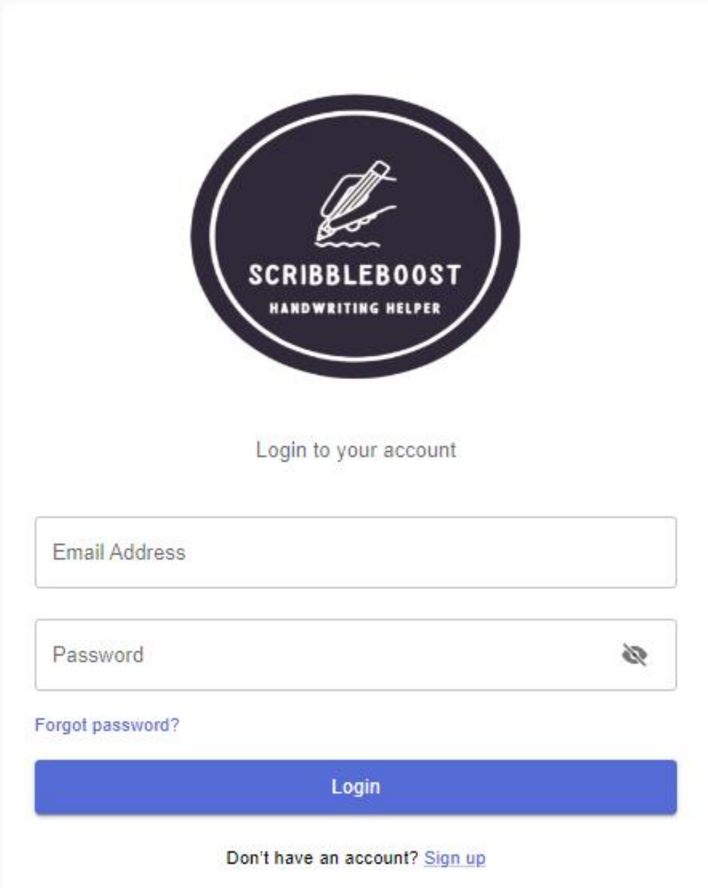


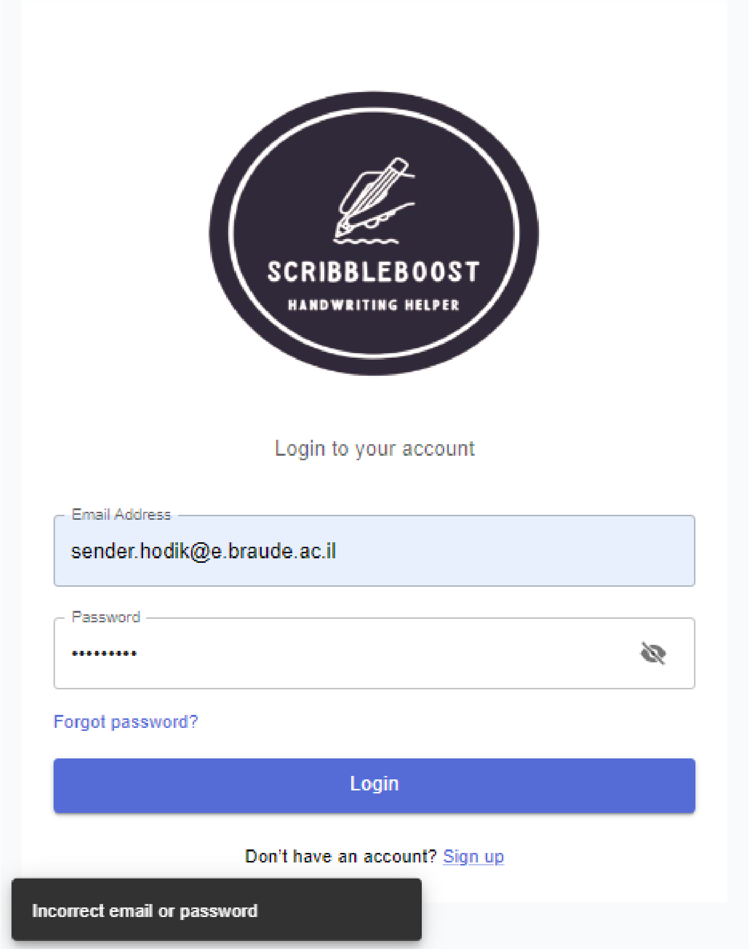
Please enter verification code that was sent to the following email: sender.hodik@e.braude.ac.il

Didn't receive the email? Resend

- After registering and verifying the user, access the login page and log in the user. A message will be displayed if the user does not exist or if the password is incorrect

  Note: The example message will also be displayed in various cases when there is a problem connecting to the server



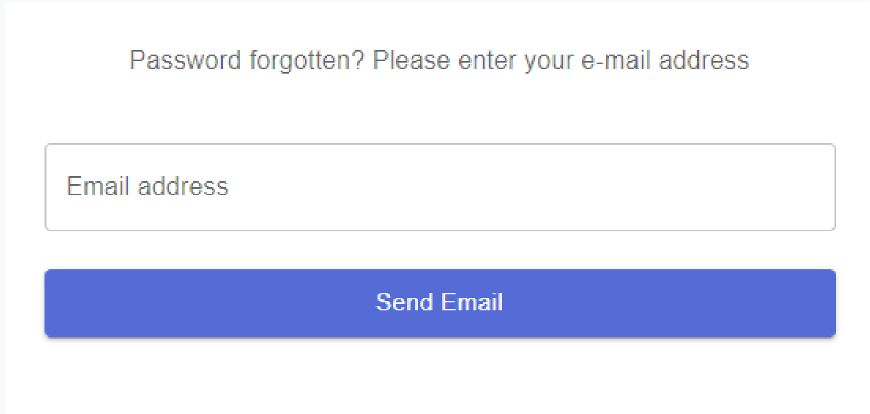


Email Address: sender.hodik@e.braude.ac.il

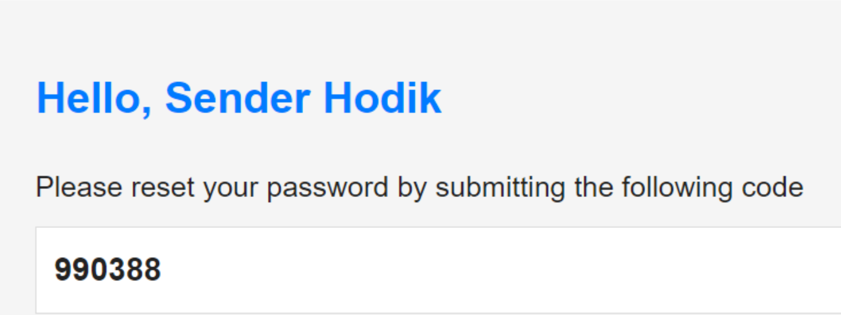
Password: •••••••••

Incorrect email or password

- A user whose password has been forgotten can use the I forgot my password functionality to receive an email along with a verification code



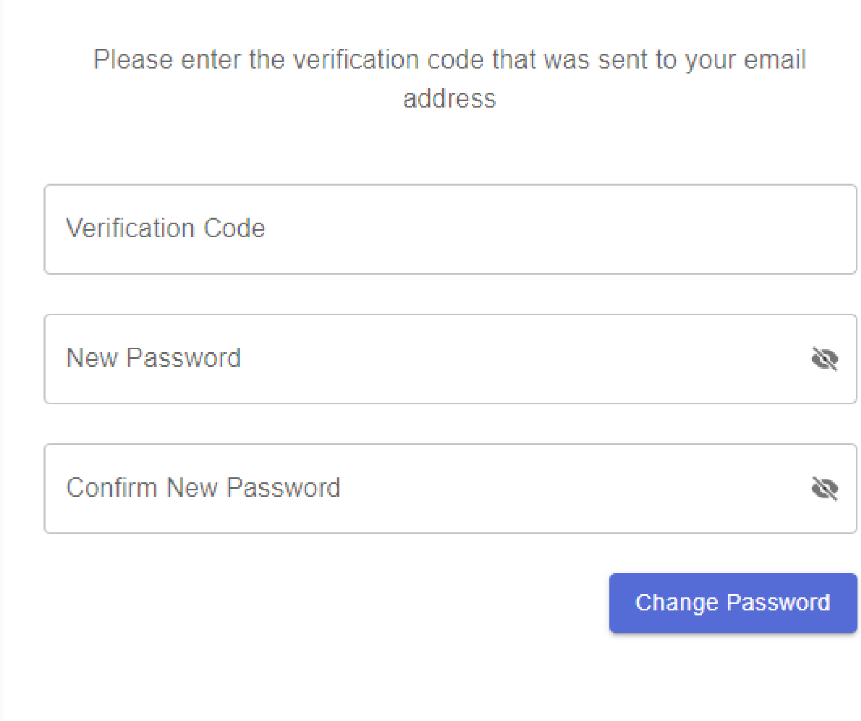
Password forgotten? Please enter your e-mail address



Hello, Sender Hodik

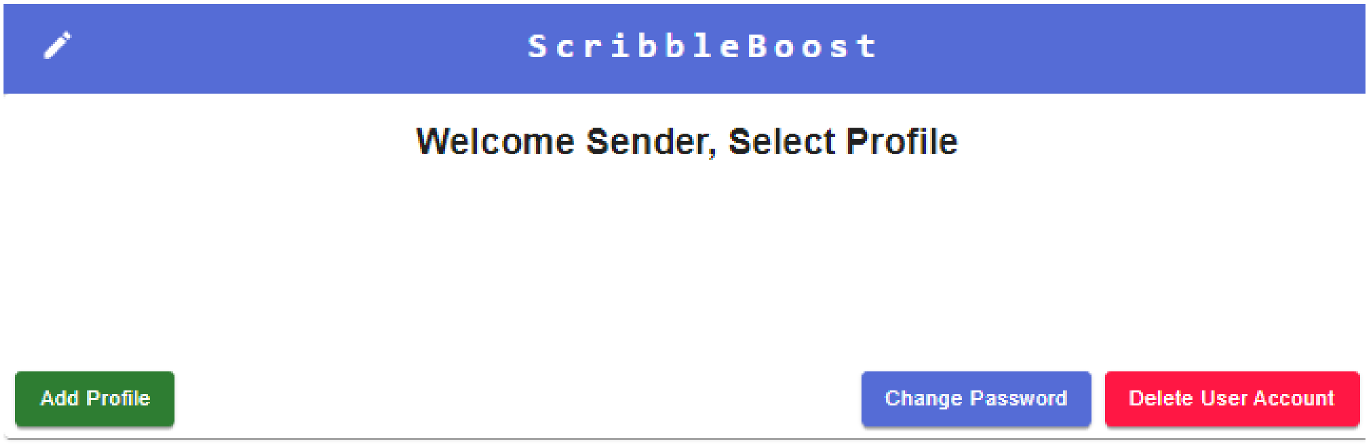
Please reset your password by submitting the following code

990388



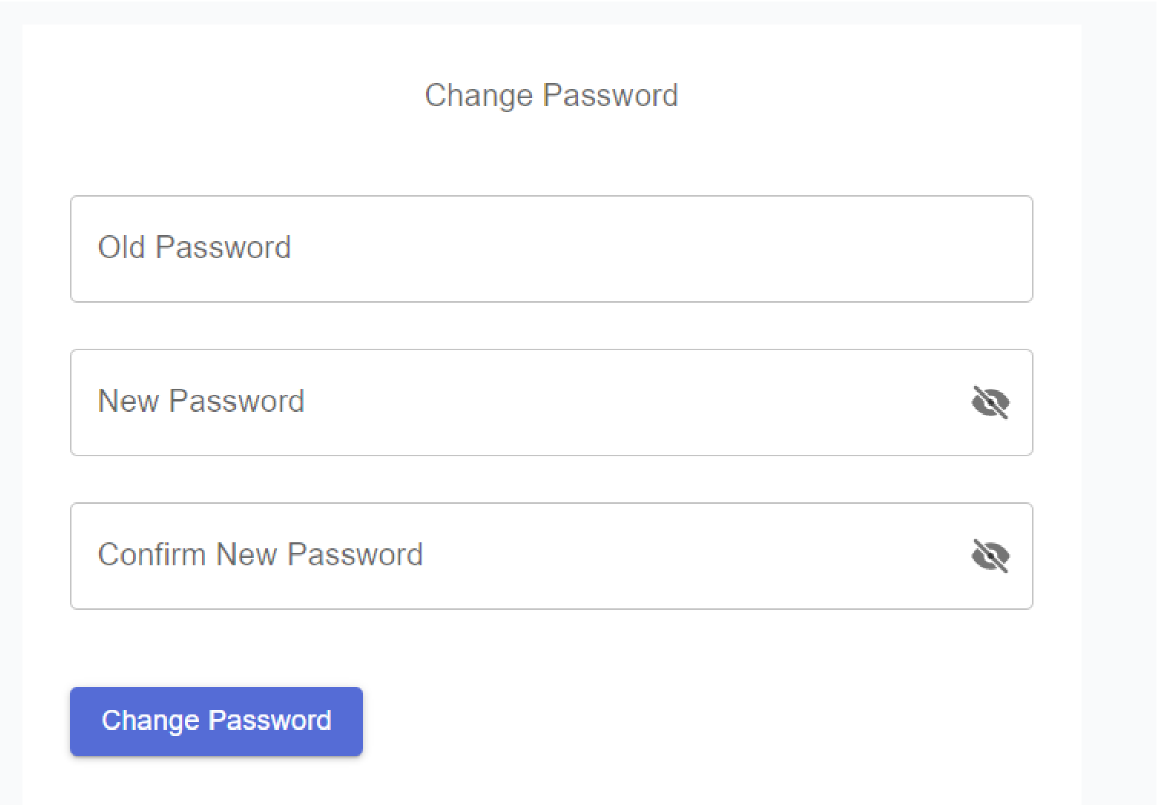
Please enter the verification code that was sent to your email address

- User dashboard options after successful login include choosing profile (if existing), opening a profile, changing a password, and deleting the user.

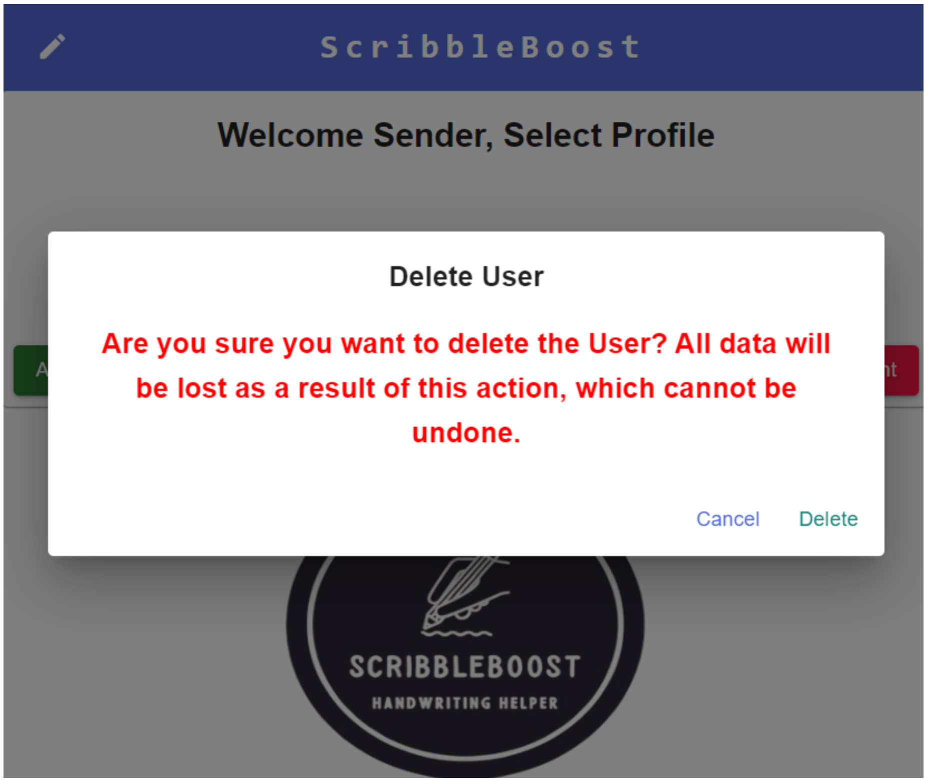


Welcome Sender, Select Profile

- Change Password option



- Delete User option

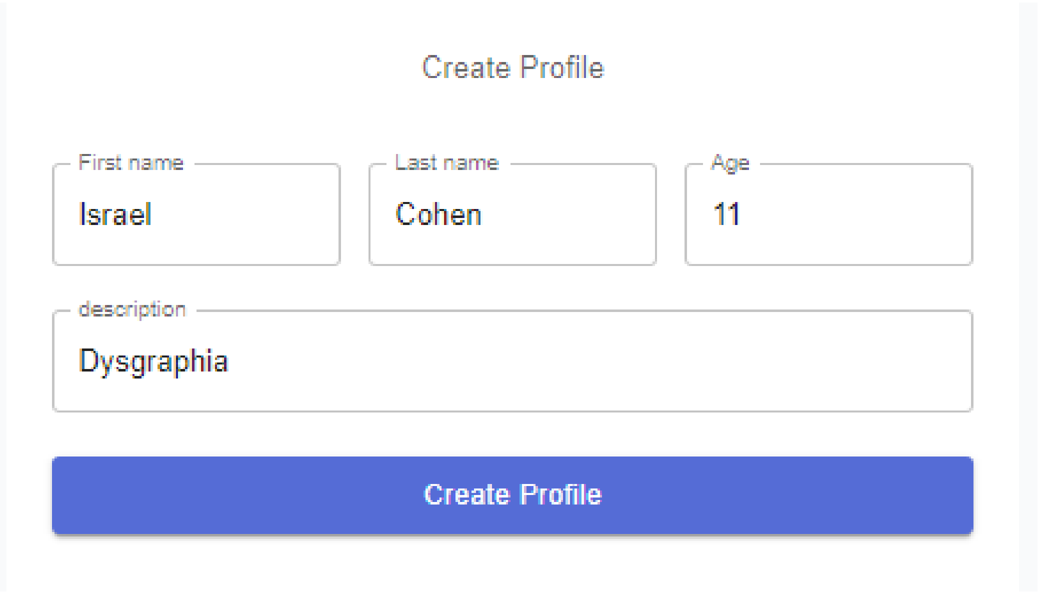


Welcome Sender, Select Profile

Delete User

Are you sure you want to delete the User? All data will be lost as a result of this action, which cannot be undone.

- Create Profile Option


Create Profile

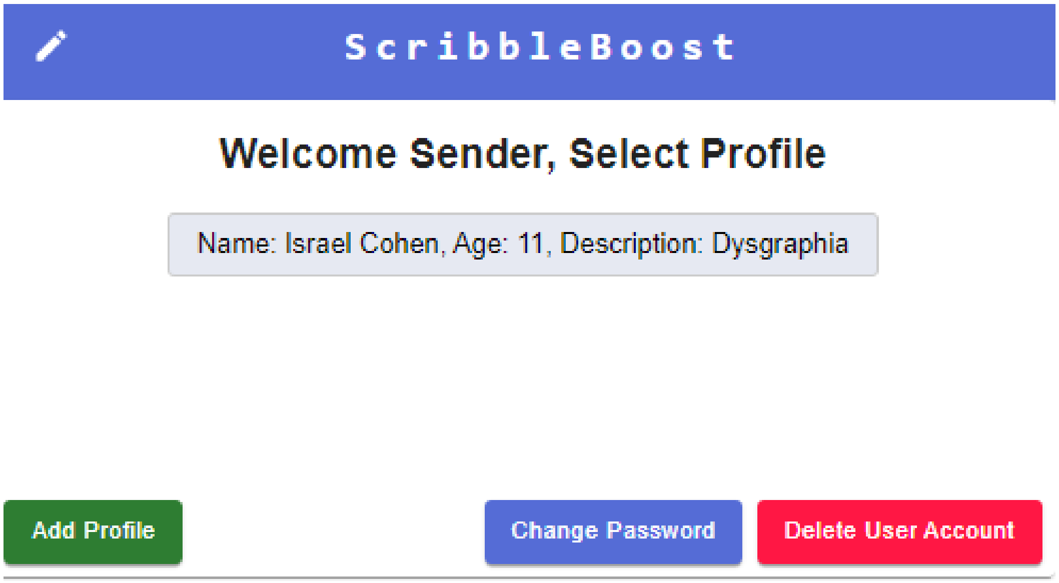
First name: Israel

Last name: Cohen

Age: 11

description: Dysgraphia

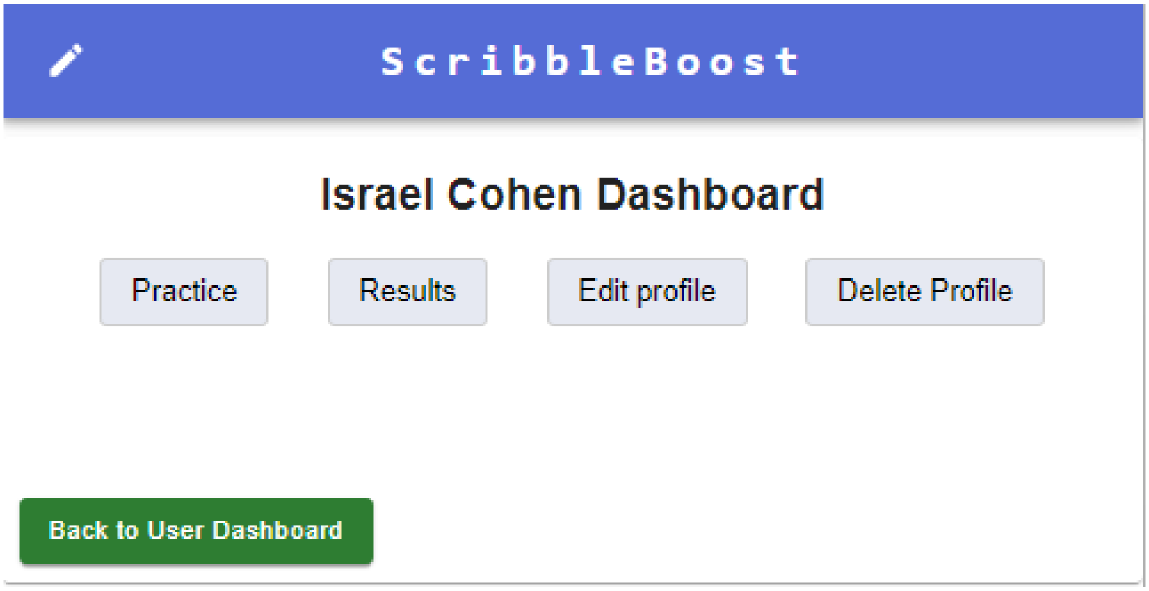
- As soon as a profile is created, it will appear in the dashboard where you can access its profile dashboard by clicking on it



ScribbleBoost

Welcome Sender, Select Profile

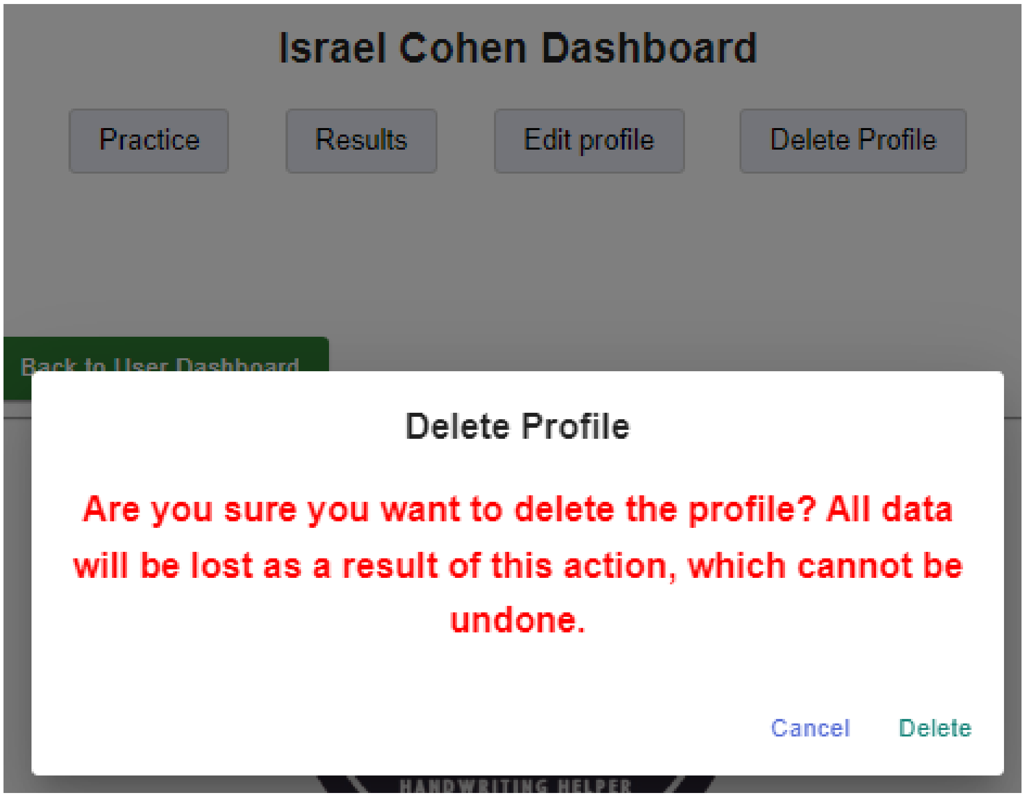
Name: Israel Cohen, Age: 11, Description: Dysgraphia



ScribbleBoost

Israel Cohen Dashboard

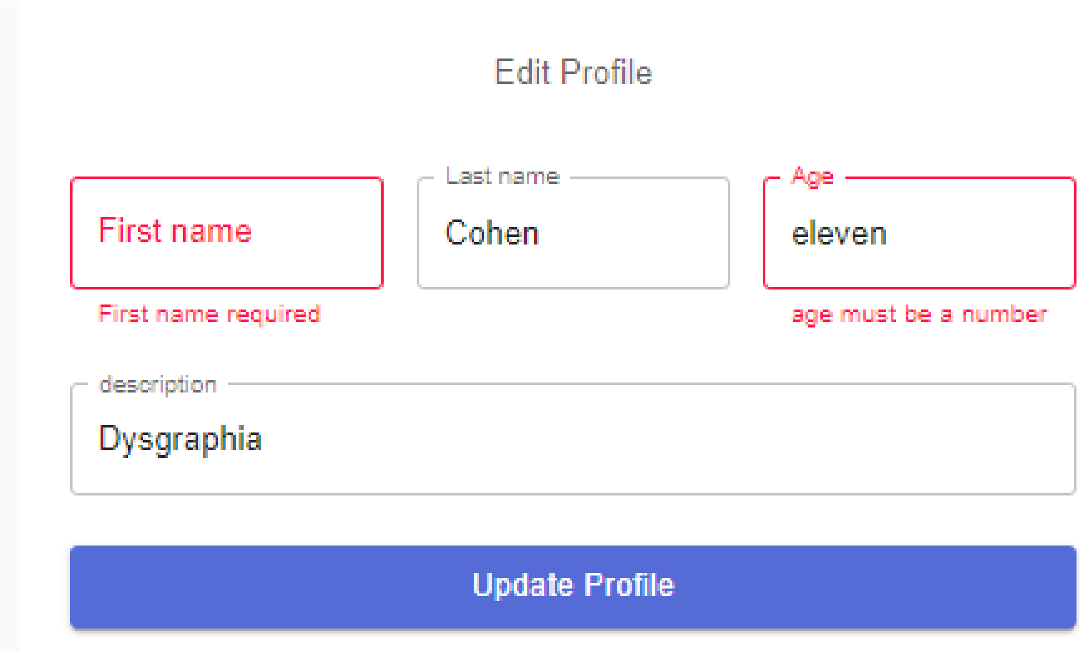
- Edit and delete profile options will provide similar functionality to user options, here we can also see input validation.



Israel Cohen Dashboard

Delete Profile

Are you sure you want to delete the profile? All data will be lost as a result of this action, which cannot be undone.



Edit Profile

First name

First name required

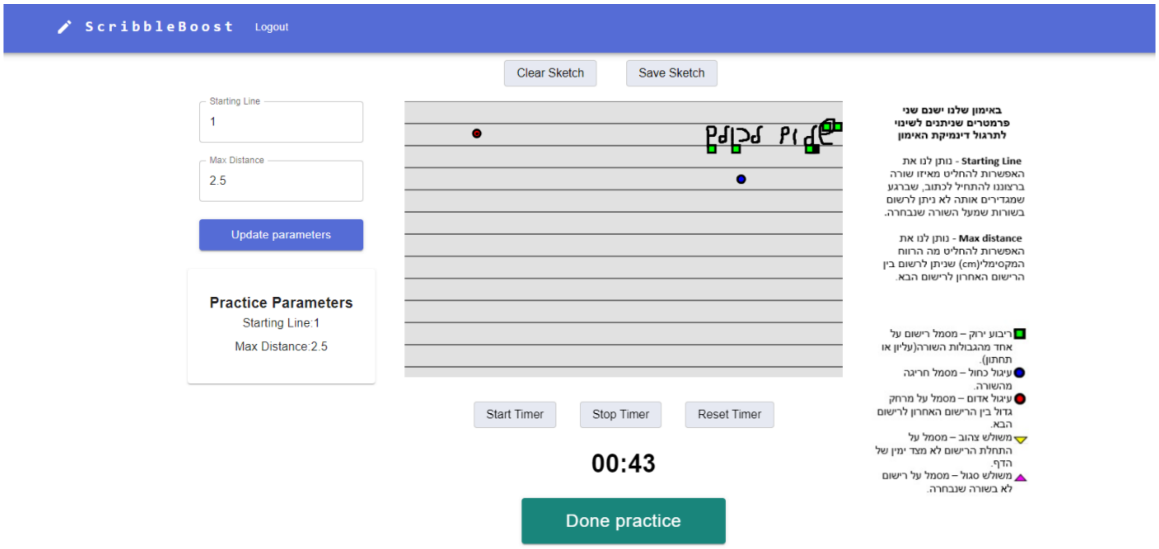
Last name: Cohen

Age: eleven

age must be a number

description: Dysgraphia

- <u>**Now, we'll examine the practice operation and its results**</u>



Starting Line: 1

Max Distance: 2.5

Practice Parameters
Starting Line:1
Max Distance:2.5

00:43

באימון שלנו ישנם שני
פרמטרים שניתנים לשינוי
לתרגול דינמיקת האימון

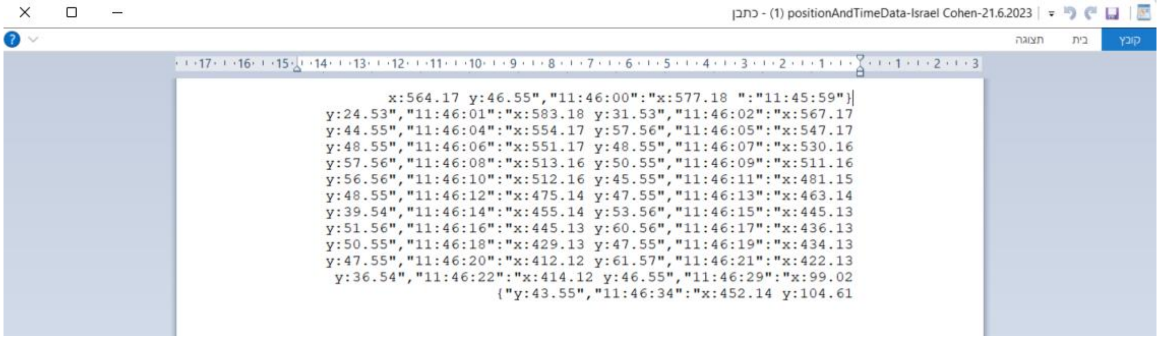
Starting Line - נותן לנו את
האפשרות להחליט מאיזו שורה
ברצוננו להתחיל לכתוב, שברגע
שמגדירים אותה לא ניתן לרשום
בשורות שמעל השורה שנבחרה.

Max distance - נותן לנו את
האפשרות להחליט מה הרווח
המקסימלי(cm) שניתן לרשום בין
הרישום האחרון לרישום הבא.

🟩 ריבוע ירוק – מסמל רישום על
אחד מהגבולות השורה(עליון או
תחתון).
● עיגול כחול – מסמל חריגה
מהשורה.
● עיגול אדום – מסמל על מרחק
גדול בין הרישום האחרון לרישום
הבא.
▽ משולש צהוב – מסמל על
התחלת הרישום לא מצד ימין של
הדף.
△ משולש סגול – מסמל על רישום
לא בשורה שנבחרה.

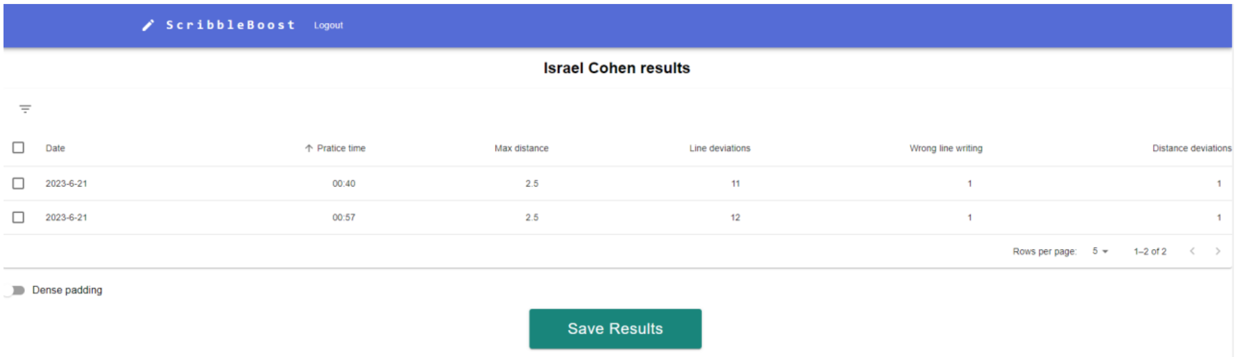
Once we finished the practice and press "Done practice" we will get two things:

1. We will automatically get a log text file that contains every x-axis and y-axis point of the writing practice at every moment in the exercise.



```
           x:564.17 y:46.55","11:46:00":"x:577.18 ":"11:45:59"}
y:24.53","11:46:01":"x:583.18 y:31.53","11:46:02":"x:567.17
y:44.55","11:46:04":"x:554.17 y:57.56","11:46:05":"x:547.17
y:48.55","11:46:06":"x:551.17 y:48.55","11:46:07":"x:530.16
y:57.56","11:46:08":"x:513.16 y:50.55","11:46:09":"x:511.16
y:56.56","11:46:10":"x:512.16 y:45.55","11:46:11":"x:481.15
y:48.55","11:46:12":"x:475.14 y:47.55","11:46:13":"x:463.14
y:39.54","11:46:14":"x:455.14 y:53.56","11:46:15":"x:445.13
y:51.56","11:46:16":"x:445.13 y:60.56","11:46:17":"x:436.13
y:50.55","11:46:18":"x:429.13 y:47.55","11:46:19":"x:434.13
y:47.55","11:46:20":"x:412.12 y:61.57","11:46:21":"x:422.13
 y:36.54","11:46:22":"x:414.12 y:46.55","11:46:29":"x:99.02
                     {"y:43.55","11:46:34":"x:452.14 y:104.61
```

2. ScribbleBoost will direct us automatically to a table page of the profile show us the latest practice errors and time sessions as well as the older practices he did before.



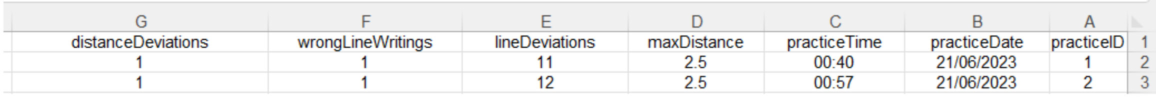
Israel Cohen results

□	Date	↑ Pratice time	Max distance	Line deviations	Wrong line writing	Distance deviations
□	2023-6-21	00:40	2.5	11	1	1
□	2023-6-21	00:57	2.5	12	1	1

Rows per page: 5 1–2 of 2

3. Upon pressing "Save Results," the therapist has the option of saving these results as an CSV file containing the profile's details.

- The columns provide information about the practice, including the practice id number, the duration of the practice according to the built-in timer, as well as the maximum distance and errors.



G	F	E	D	C	B	A	
distanceDeviations	wrongLineWritings	lineDeviations	maxDistance	practiceTime	practiceDate	practiceID	1
1	1	11	2.5	00:40	21/06/2023	1	2
1	1	12	2.5	00:57	21/06/2023	2	3

3.2 Engineering Process

Our engineering process began with brainstorming with an aspiration to characterize difficulties we experienced from a young age and to be able to offer them a technological solution, focusing on the medical psychological aspect.

After finding that we both had difficulties with writing, we began to delve into this topic.

We realized that the subject consists of many fields and we decided to publish a post on Facebook in an occupational therapy group that includes a survey, in order to receive help and guidance from professional sources in the field.

As a response to the post, we received a referral to Prof. Sarah Rosenblum, chair of the doctoral program in the Department of Healing and Occupation at the University of Haifa. We contacted Prof. Rosenblum who directed us to studies that clarified which subfield of the manuscript we should focus on, diagnosis or treatment.

After the review of the studies and a referral from Prof. Rosenblum to Dr. Navit Roth from the mechanical engineering department at Braude Academic College, with whom she did an in-depth study on hand tremors. We shared our findings with our supervisor, Dr. Anat Dahan, who joined us as a co-supervisor.

With the help of Navit and Anat's guidance, we made contact with an occupational therapist named Ms. Romi Mirenburg who helped us focus on a technological solution that would support the treatment of handwriting difficulties while focusing on one of three main parameters - speed, organization or directionality, real-time feedback and tracking of practice data will be provided by the system's core.

Having discussed initial goals with Romi, we held a follow-up consultation with Professor Sarah Rosenblum. We were advised by Professor Rosenblum to emphasize both positive and negative feedback, such as deviations from the line, while focusing on practice measured in time without transition restrictions.

Tracking practice results is also a vital part of the system, whether it is issuing a report showing the writing position on a page over time or monitoring training results through error and time calculations.

The next step was to define the requirements for our system. At first, we had to envision how our system will be visualized and what hardware would be needed to show handwriting on a screen. We also investigated the handwriting process, challenges, and existing treatments.

The method for getting inputs from our graphic tablet and transferring them to the browser was discussed. During this process, we planned our basic algorithm and the functionality of our system. An architecture scheme was created then followed by use case and activity diagrams.

As soon as we had gathered most of the information we needed about our system, we began designing the prototype (based on all the information we had collected) and planning the testing.

To overcome the following challenges, we realized we needed to learn new software environments and programming languages:

- The system should be web-based: using JavaScript programming language, the front-end is built using the React library, and the back-end is built using the NodeJS runtime environment.
- p5.js library will enable us to create interactive practice and graphic experiences such as real-time feedback based on the user's input
- Our database will store user data and properties, such as personal details and information for the related work. For that, we will use MongoDB, a no-SQL database that integrates well with NodeJS.

Using these new technologies, we will be able to create a system that is both user-friendly and efficient.

3.2.1 Graphic Tablets

Graphic tablets, also known as pen tablets or drawing tablets, are input devices that are used to capture digital images. They consist of a flat, pressure-sensitive surface, on which the user can draw or write using a special pen or stylus. Graphic tablets are commonly used by artists and designers to create digital artwork and are also used in a variety of other applications, such as handwriting recognition and data entry. Unlike a traditional mouse, which only has two degrees of freedom (x and y movement).

Wacom Intuos Pro

Wacom tablets can be connected to a computer via USB or Bluetooth, and are compatible with a wide range of creative software, including Adobe Photoshop, Illustrator, etc.

The Wacom Intuos Pro is considered to be one of the best graphic tablets on the market and is widely used by professional artists and designers.

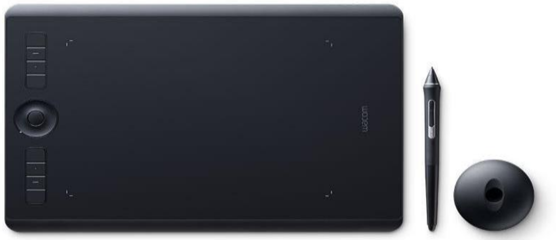


Figure 1. Wacom Intuos pro [1]

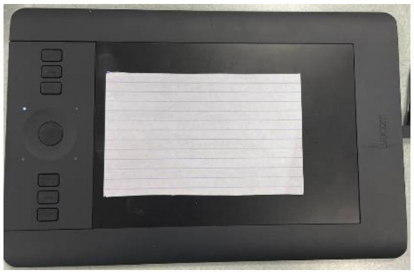


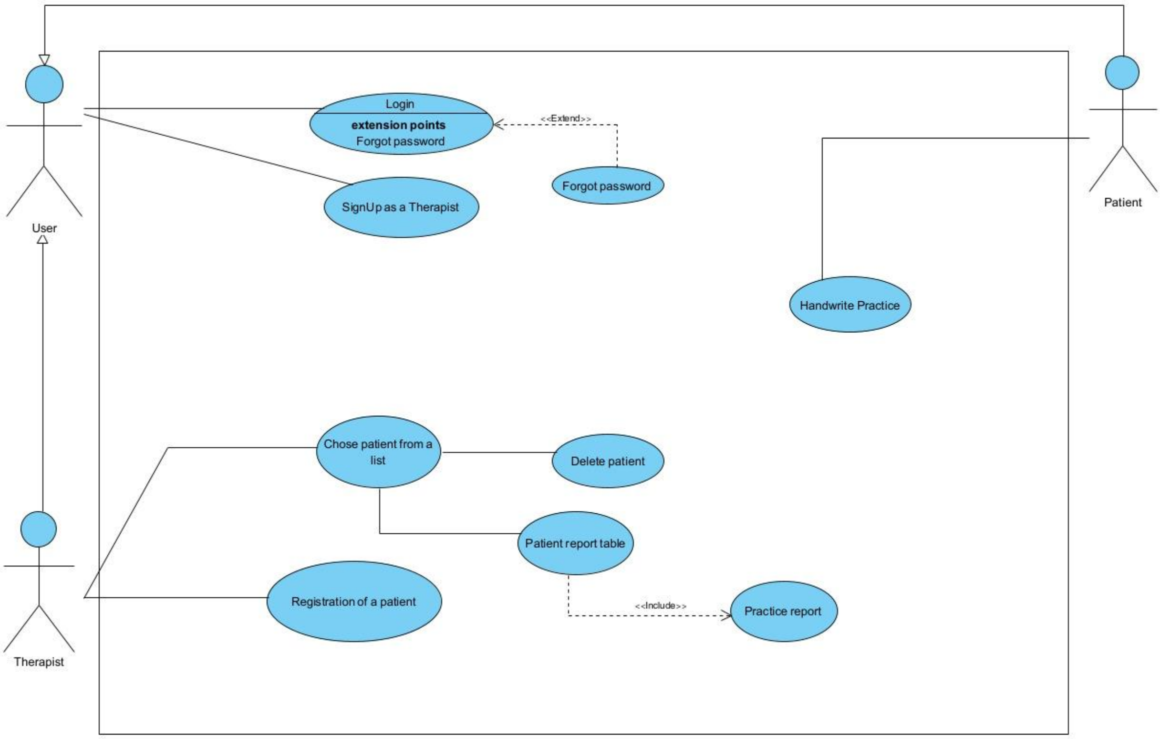
Figure 2. Wacom Intuos pro small with paper

The Wacom Intuos Pro paper edition can attach a paper that is a variant of the regular Wacom Intuos Pro graphic tablet that comes with a special paper clip, which allows the user to draw on paper and have their work digitized in real time. The paper clip attaches to the edge of a piece of paper, and uses a combination of sensors to track the position of the pen on the paper. This allows the user to draw on paper as they normally would, and have their work automatically converted into a digital format and saved to their computer

3.2.2 Structure of the system

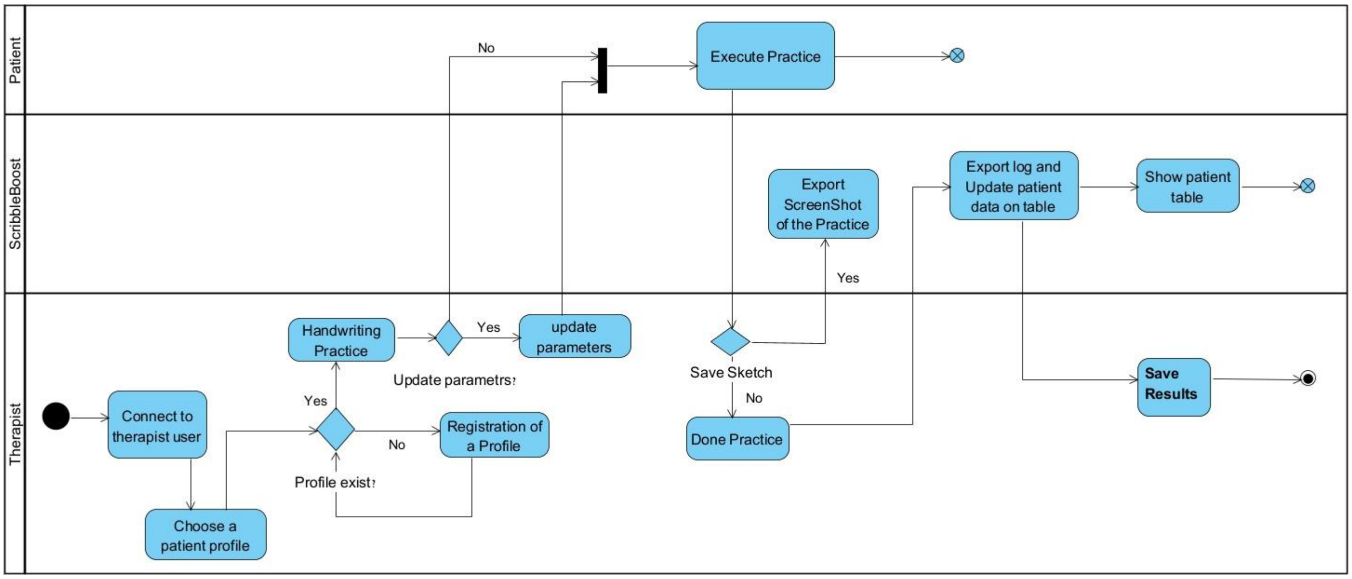
Use Case diagram

The diagram illustrates the interaction between therapists and patients, capturing various functionalities and use cases associated with Scribbleboost.



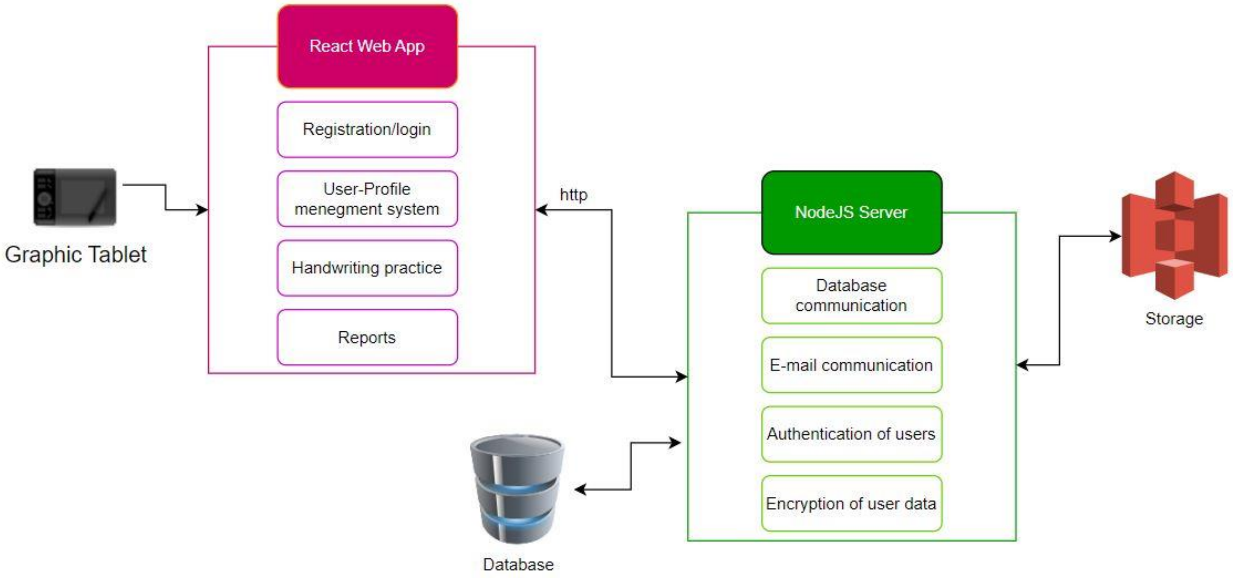
Activity diagram

The activity diagram the workflow of activities undertaken by the therapist, the patient, and the ScribbleBoost system.



<u>ScribbleBoost architecture</u>

Described above is the system's architecture as a combination of client and server components



3.2.3 Challenges

- Identify the technological tools we need to realize our planning
  We encountered challenges during our development process when it came to understanding and implementing web development systems and user interface libraries, specifically creating effective user interfaces.

  Despite the fact that React was the foundation for our user interfaces, we also needed a framework to streamline styling and enhance visual appeal. We chose Material-UI, a widely used UI framework that offers pre-designed components and styling options to overcome the challenge of creating visually appealing components. Using Material-UI's extensive library, we were able to develop aesthetically appealing components more efficiently and quickly.

  As a server-side challenge, we were challenged to construct a robust server architecture using Node.js and Express. Although we were familiar with JavaScript and Node.js, it was challenging to build a scalable and efficient server application. Nevertheless, the Node.js Express framework provided the necessary tools for routing, middleware, and handling requests and responses. Using Express, we structured our server-side code and ensured seamless communication between the front-end and back-end.

  We extensively used self-learning resources, such as tutorials, documentation, and community forums, to overcome these challenges. A clear understanding and direction were gained by referring to comprehensive diagrams and tutorials that visually represented various technologies and their best practices. By regularly consulting these resources, we were able to align our code with the intended architecture and make informed decisions throughout the implementation process.

- Developing efficient and friendly practice that meets the research requirements
  In order to provide effective learning experiences for children, it is necessary to develop an efficient and friendly practice that meets the requirements that arose during the research on system design requirements. Particularly, children may find traditional methods unengaging and monotonous, such as writing on a page with a regular pen.

  The task of developing a friendly and effective practice was both challenging as well as invaluable. Navigating through the distinct language and perspectives of occupational therapists, engineers, and other professionals was challenging. As each profession has its own jargon, we initially encountered unfamiliar therapy terminology.

Adapting the system to cater to children's unique characteristics is crucial to maintaining enthusiasm and motivation. Making learning more interactive and stimulating might involve integrating interactive and multimedia elements. Gamification techniques, like rewards and challenges, can make the practice more fun and engaging for children. In addition, the system should allow children to express themselves in various ways, fostering their individuality and creativity. Children's engagement and knowledge retention can be maximized by creating an effective and child-friendly practice aligned with research requirements.

As educators and tutors of teenagers on programming and math topics, we approached this challenge based on our experience in conveying content. During the training there were both negative and positive feedbacks.

Feedbacks are colorful, different, and contain sounds to attract the eye and encourage patients to succeed.

As a result of interdisciplinary collaboration, we learned how to view problems from multiple perspectives and how diverse perspectives lead to more robust and inclusive solutions.

- Analyzing pen location to detect writing coordinates on screen

  In order to accurately identify writing coordinates on the screen, we need to analyze the location of the pen using a graphic tablet equipped with sensors. As soon as the pen's location is captured, it must be processed and transmitted to a computer in real-time for analysis and display.
  We need software that can receive and process pen coordinates from the graphic tablet to tackle this challenge.

  Dedicated software drivers support Wacom tablets to ensure seamless communication with computers. By enabling the transmission of pen data in real-time, the driver enables the definition of the tablet's operation area on the screen, ensuring the tablet's operation only progresses in the practice area.
  Using the combination of Wacom hardware and software technologies, in addition to HTML and P5 library functionality, the location of the pen on the tablet surface can be accurately determined. As a result of the pen's

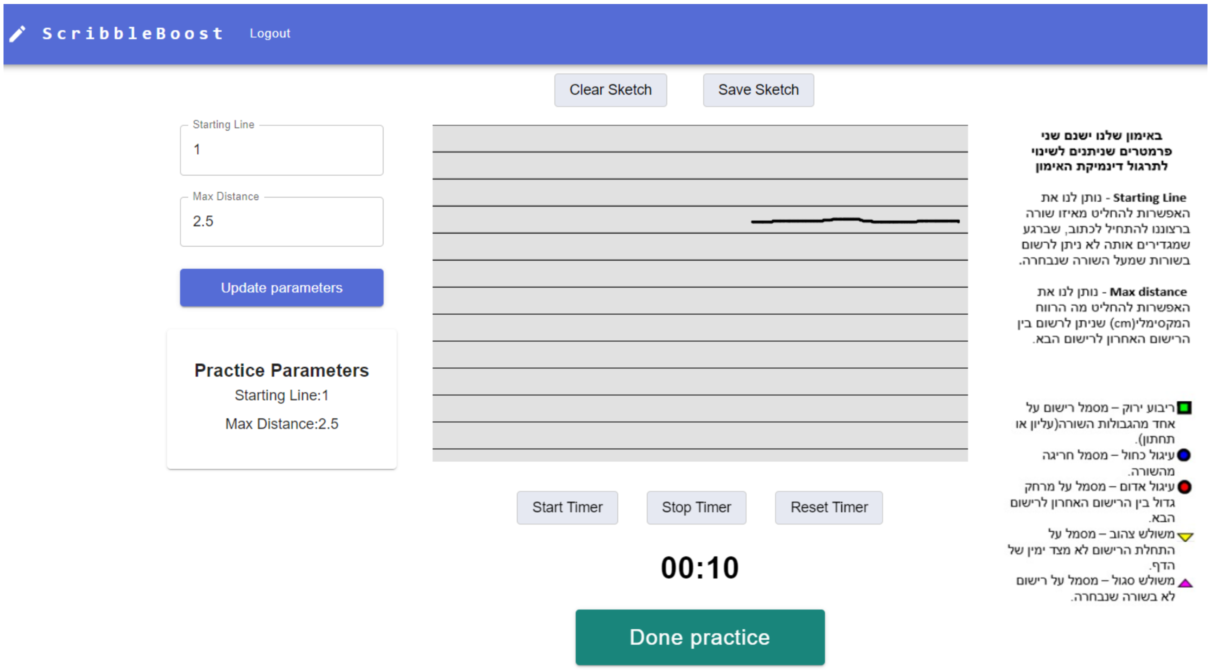
interaction with the tablet, the pen keeps its position, tracks and checks the order of writing.

3.3 Testing Process

Testing is divided into two phases – Validation and Functional testing.
One focuses on the practice itself and the other on all the features of the shell, including the user management system and the buttons associated with the practice.

3.3.1 Validation Testing

1. When we started thinking about the training, we decided to break it down into several components based on real-time experiences:
A constant check on the location of the writing that checks whether we are writing within the frame of the canvas. By checking the limits, we get constant feedback on the screen from the moment the patient starts writing.



Starting Line: 1

Max Distance: 2.5

Practice Parameters
Starting Line:1
Max Distance:2.5

00:10

באימון שלנו ישנם שני
פרמטרים שניתנים לשינוי
לתרגול דינמיקת האימון

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ברצוננו להתחיל לכתוב, שברגע
שמגדירים אותה לא ניתן לרשום
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המקסימלי(cm) שניתן לרשום בין
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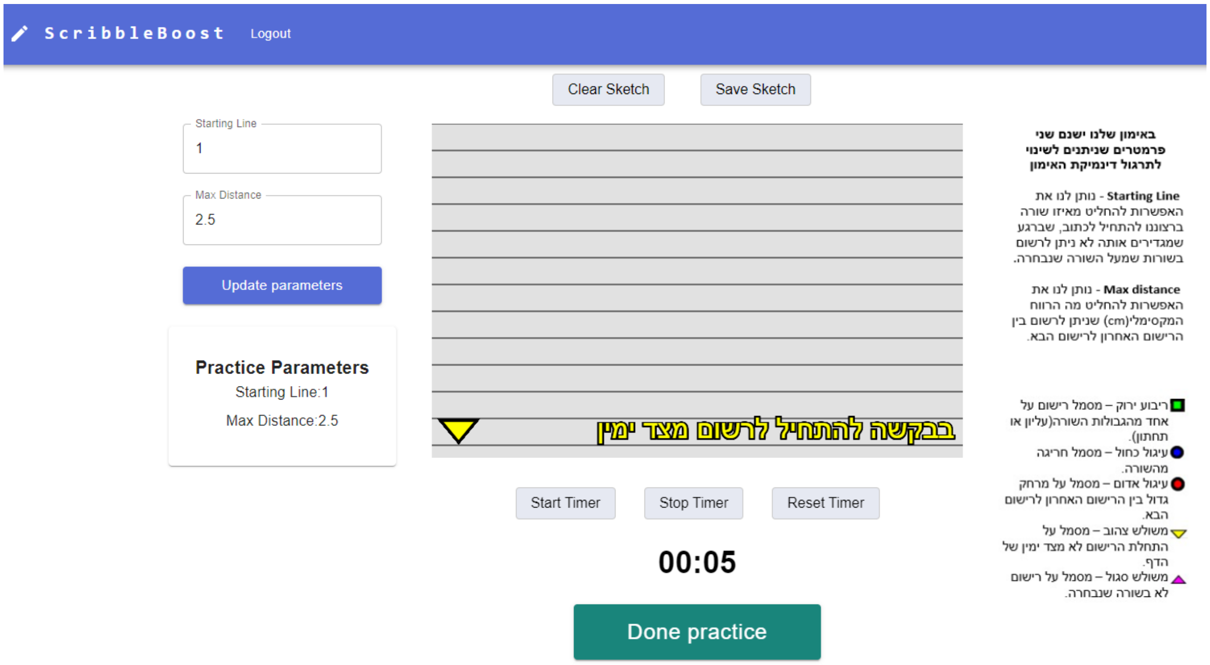
גדול בין הרישום האחרון לרישום
הבא.
▽ משולש צהוב – מסמל על
התחלת הרישום לא מצד ימין של
הדף.
▲ משולש סגול – מסמל על רישום
לא בשורה שנבחרה.

2. Checking writing from right to left. Because our training is based on the Hebrew language, it was important to us that the writing be done from right to left. Using a test on the right border of the canvas in the initial writing we gave a reasonable writing range for the beginning of writing.



Starting Line: 1

Max Distance: 2.5

Practice Parameters

Starting Line:1

Max Distance:2.5

00:05

באימון שלנו ישנם שני פרמטרים שניתנים לשינוי לתרגול דינמיקת האימון

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Max distance - נותן לנו את האפשרות להחליט מה הרווח המקסימלי(cm) שניתן לרשום בין הרישום האחרון לרישום הבא.

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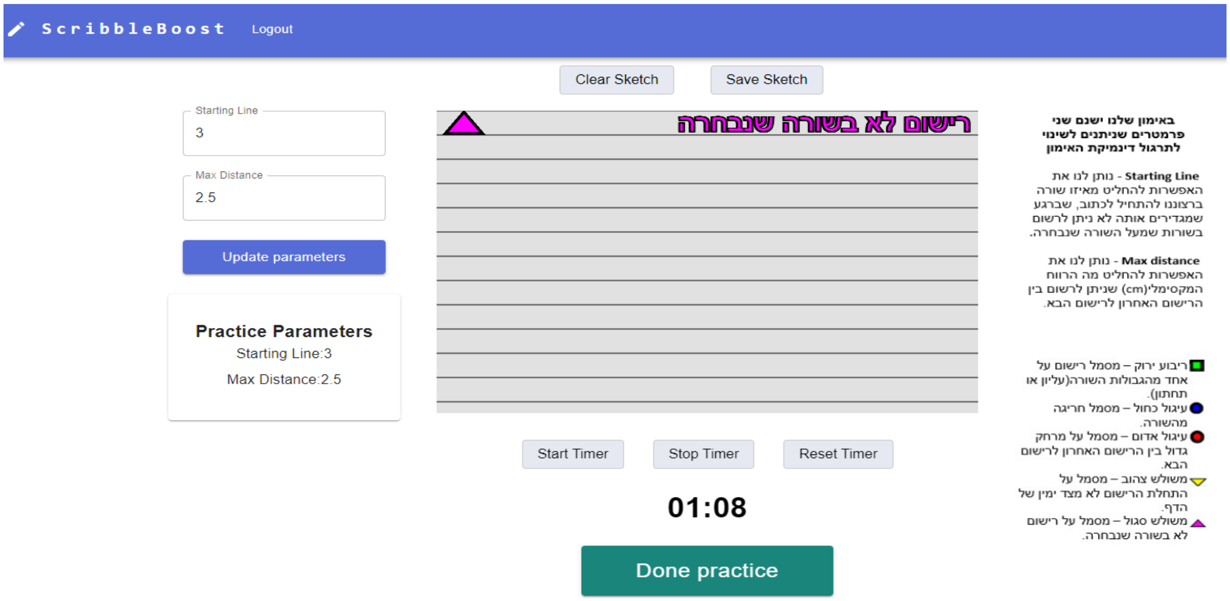
△משולש סגול – מסמל על רישום לא בשורה שנבחרה.

3. Determining a starting line according to the therapist's choice. As part of the practice, the therapist will be able to perform a writing test from the page prompt by updating the line parameter, when the patient writes above the selected line, real-time feedback will pop up alerting them to this.



Starting Line: 3

Max Distance: 2.5

Practice Parameters

Starting Line:3

Max Distance:2.5

01:08

באימון שלנו ישנם שני פרמטרים שניתנים לשינוי לתרגול דינמיקת האימון

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Max distance - נותן לנו את האפשרות להחליט מה הרווח המקסימלי(cm) שניתן לרשום בין הרישום האחרון לרישום הבא.

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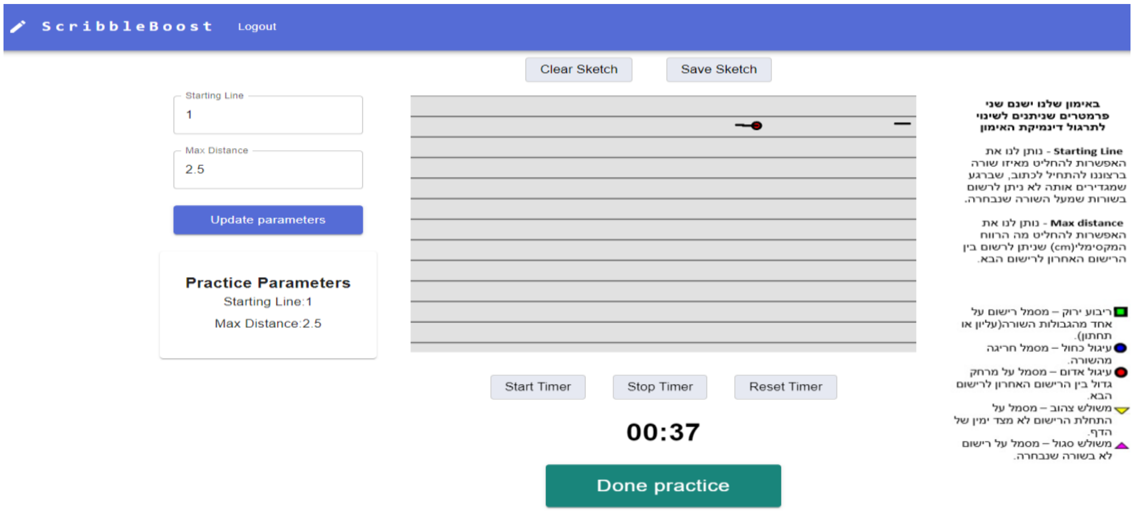
4. Determining the distance between point to point on the x-axis according to the therapist's choice, following the line selection, the therapist has the option to determine a gap between two writing points. Similar to instructional letters, feedback will be given in real time in the form of a red circle on the screen if there is a deviation from the distance defined by the therapist. To see if we have exceeded the defined distance, we compared the distance between the last point recorded and the point before it using the distance formula, Distance = $\sqrt{(\boldsymbol{x2}-\boldsymbol{x1})^2+(\boldsymbol{y2}-\boldsymbol{y1})^2}$ which is part of the p5 library(p5.dist), when we reset the y-axis points because we are checking the distance of that row only, so we end up using the distance formula as Distance = $\sqrt{(\boldsymbol{y2}-\boldsymbol{y1})^2}$.



Starting Line: 1

Max Distance: 2.5

Practice Parameters
Starting Line:1
Max Distance:2.5

00:37

באימון שלנו ישנם שני
פרמטרים שניתנים לשינוי
לתרגול דינמיקת האימון

Starting Line - נותן לנו את
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ברצוננו להתחיל לכתוב, שברגע
שמגדירים אותה לא ניתן לרשום
בשורות שמעל השורה שנבחרה.

Max distance - נותן לנו את
האפשרות להחליט מה הרווח
המקסימלי(cm) שניתן לרשום בין
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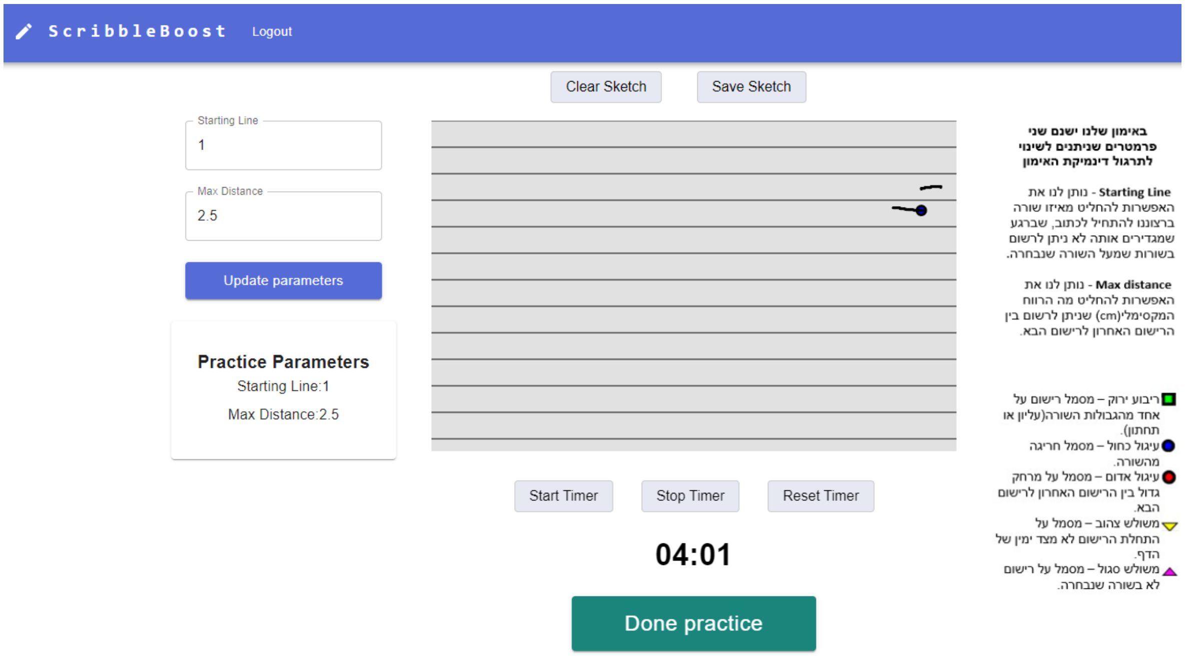
לא בשורה שנבחרה.

5. Checking writing on the wrong line, when the patient writes down and receives feedback, which appears in the form of a blue circle that pops up on the screen, the patient probably deviated and went down or up from the line on which he started writing the sentence.
By comparing distances with a downward rounding of the lines we were able to see if we are writing in the same line or if we have deviated from it.



Starting Line
1

Max Distance
2.5

Practice Parameters

Starting Line:1

Max Distance:2.5

04:01

באימון שלנו ישנם שני
פרמטרים שניתנים לשינוי
לתרגול דינמיקת האימון

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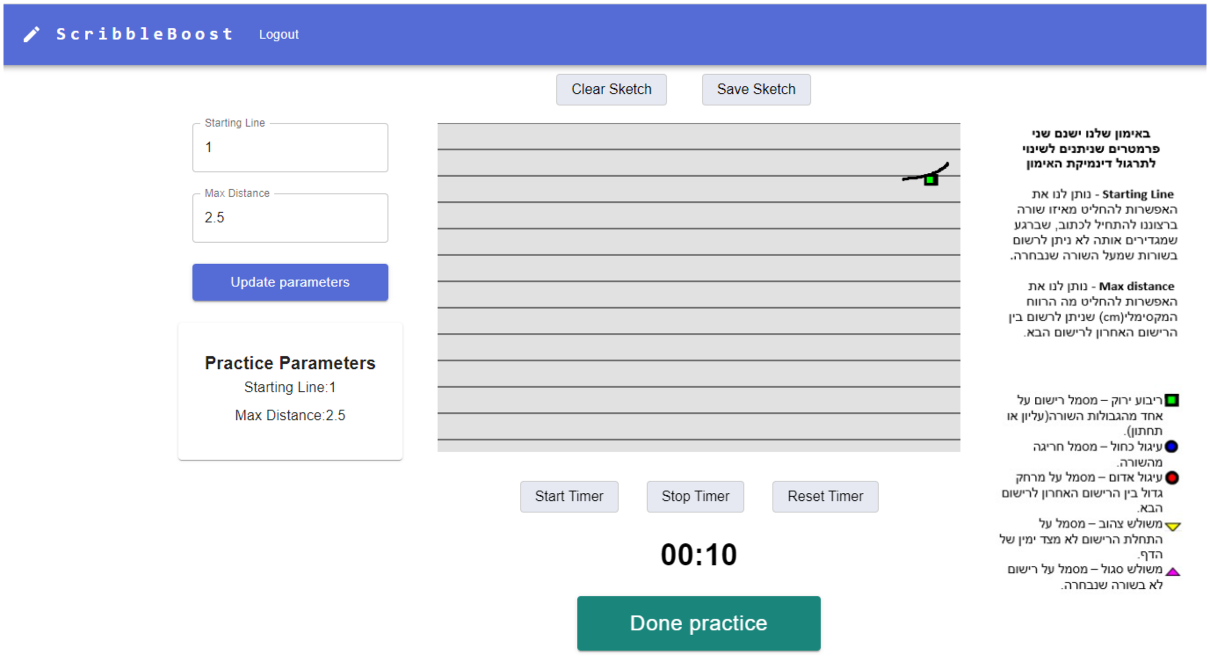
6. Deviation on a line test, when the patient writes on the defined line structure, a green square is received on the screen showing the deviation from the line, when a constant check on the line checks if the accordance with the writing is between the line border and if the points of the x and y axes have collided with the point of the line.



Starting Line
1

Max Distance
2.5

Practice Parameters

Starting Line:1

Max Distance:2.5

00:10

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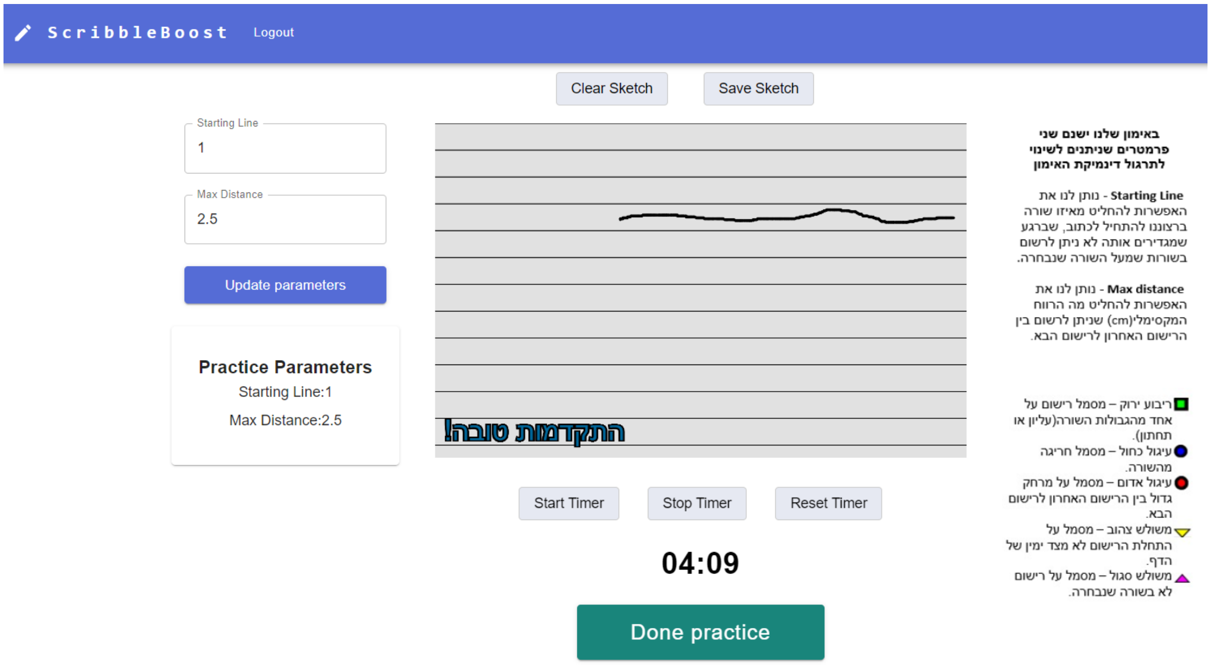
7. Positive feedbacks, as part of the practice experience we added feedbacks aimed at showing the patient's progress and giving him the feeling that his persistence and effort have results. Providing the positive feedbacks appear every middle of a line without a single error and every end of a line with a drop of a new line and every complete line without errors.



Starting Line: 1

Max Distance: 2.5

Practice Parameters

Starting Line:1

Max Distance:2.5

04:09

באימון שלנו ישנם שני פרמטרים שניתנים לשינוי לתרגול דינמיקת האימון

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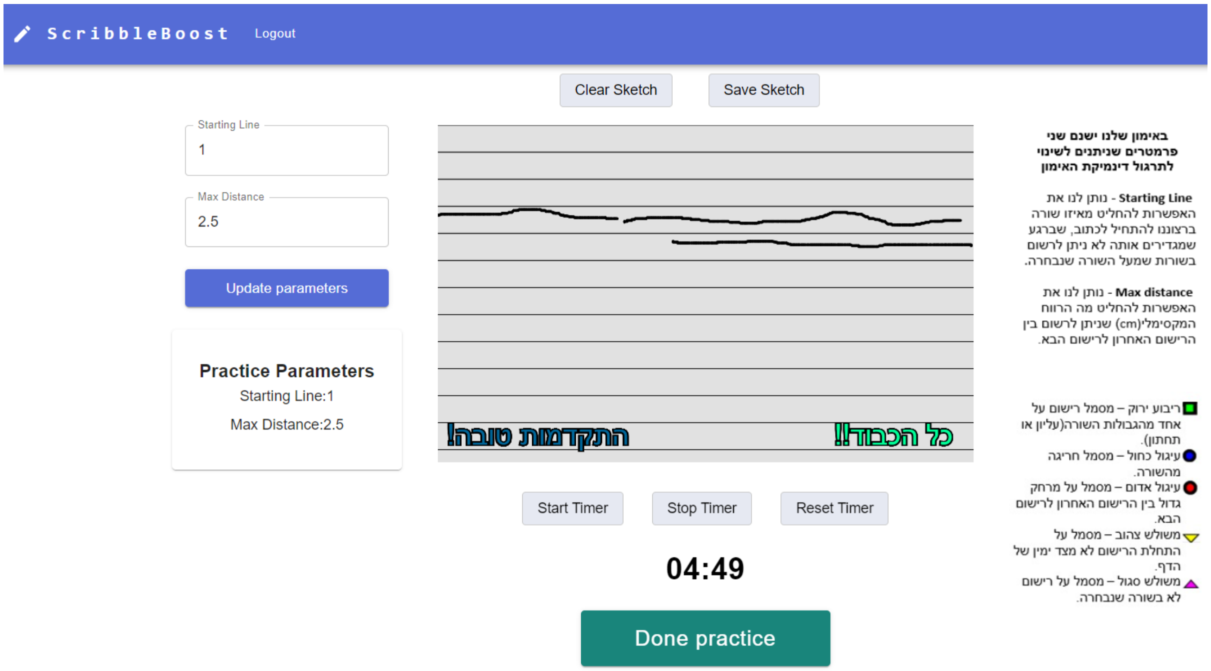

Starting Line: 1

Max Distance: 2.5

Practice Parameters

Starting Line:1

Max Distance:2.5

04:49

באימון שלנו ישנם שני פרמטרים שניתנים לשינוי לתרגול דינמיקת האימון

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3.3.2 Functional Testing

The reliability and effectiveness of software applications are crucially dependent on functional testing. To determine if a system or component meets the desired functionality and functions correctly, it evaluates its behavior in light of specified requirements. A common approach to functional testing is to use GUI (Graphical User Interface) tests, which examine the user interface and interactions of the application.

To validate that the software responds appropriately and produces the expected outcomes, GUI tests simulate user actions, such as clicking buttons, entering data, and navigating through screens. We present a comprehensive set of functional tests conducted through GUI testing in the following table, providing information on the specific test cases executed and the results obtained.

	Test Scenario	Description	Expected Result	Comments	Test passed
#1	**Navigation bar**	From the navigation bar, click the login button	Redirect to login page	Login form displayed	V
#2		From the navigation bar, click the signup button	Redirect to signup page	Signup form displayed	V
A1	**Registration**	On the homepage, click the signup button	Redirect to signup page	Signup form displayed	V
A2		The sign-up form has been successfully completed	Move to the user verification screen	Database entry for a new user has been created	V
A3		Clicking the signup button when there is an empty field in one or more of the signup fields	The empty fields will be surrounded by a red message	This validation prevents an invalid request from being sent to the server	V
A4		Clicking the signup button	A message displayed	In a similar fashion to the	V

		when email is invalid	around the email field that states: must be a valid email address .	previous test, this is a part of the validation process on the client side	
A5		Clicking the signup button when the password has fewer than seven characters	A message displayed around the email field that states: Too Short! please use at least 7 characters .	In a similar fashion to the previous test, this is a part of the validation process on the client side	V
B1	**User Verification**	Clicking on submit button after entering a valid verification code after receiving it by email	The user is redirected to the login page and a successful verification message is displayed	Login form displayed	V
B2		Entering no code when clicking the submit button	Display a message requesting a verification code from the user	Part of the validation process on the client side	V
B3		An incorrect verification code is entered when the submit button is clicked	A message indicating that the code is incorrect is displayed to the user	Part of the validation process on the client side	V
B4		Clicking on Resend button	An email with a new verification code is sent to the registered user		V

C1		On the homepage, click the login button	Redirect to login page	Login form displayed	V
C2		Login form successfully submitted	Redirect to user dashboard page		V
C3		Clicking the login button when there is an empty field in one or more of the login fields	The empty fields will be surrounded by a red message	This validation prevents an invalid request from being sent to the server	V
C4		Clicking the login button when email is invalid	A message displayed around the email field that states: must be a valid email address .	In a similar fashion to the previous test, this is a part of the validation process on the client side	V
C5		Invalid email name or password entered when clicking the login button	A message displayed around the email field that states: Incorrect email or password .	In a similar fashion to the previous test, this is a part of the validation process on the client side	V

C6		Clicking the Forgot Password button	Redirect to forgot password page	Resetting the password can be done via email and verification code	V
D1	**Forgot password**	Clicking on submit button after entering a valid Email address	Redirect to reset password form	An email with a verification code is sent to the registered user	V
D2		Entering no code when clicking the submit button	Display a message requesting a verification code from the user	Part of the validation process on the client side	V
D3		Clicking the signup button when email is invalid	a message displayed around the email field that states: must be a valid email address	In a similar fashion to the previous test, this is a part of the validation process on the client side	V
D4		Clicking the signup button when email not exist in the database	A message displayed around the email field that states: user not found .		V
E1	**Reset Password**	Reset password form successfully submitted	The user is redirected to the login page and a successful reset password	The new password has been hashed and stored in the database	V

			message is displayed		
E2		Clicking the change password button when there is an empty field in one or more of the reset password fields	The empty fields will be surrounded by a red message	Part of the validation process on the client side	V
E3		Clicking the change password button when the password has fewer than seven characters	A message displayed around the email field that states: Too Short! please use at least 7 characters .	Part of the validation process on the client side	V
E4		An incorrect verification code is entered when the change password button is clicked	A message indicating that the code is incorrect is displayed to the user	Part of the validation process on the client side	V
E5		There is a difference between the new password entered in the upper field and the new password entered in the lower verification field when the change password button is clicked	Surrounded by a red message: the passwords must match	Part of the validation process on the client side	V

F1	**User Dashboard**	The patient profile has been successfully created by the user	An associated profile will be added to the database, and a confirmation message will be sent to the user		V
F2		Clicking the Create profile button when there is an empty field in one or more of the login fields	The empty fields will be surrounded by a red message	Part of the validation process on the client side	V
F3		The user has been successfully deleted from the system by Clicking on Delete user account button	There is a warning message that all information associated with the user will be deleted when the user is deleted	In order to avoid errors, the deletion record of the user is double-verified	V
F4		By clicking the Change Password button, the user wishes to change his password	User redirect to change password page		V
		Using the user's profile list, a patient profile is selected	Redirect to profile dashboard of the selected profile		V
G1	**Change Password**	Change password form successfully submitted	The user is redirected to the login page and a successful changed	The new password has been hashed and stored in the database	V

			password message is displayed		
G2		Clicking the change password button when there is an empty field in one or more of the change password form fields	The empty fields will be surrounded by a red message	Part of the validation process on the client side	V
G3		Clicking the signup button when the password has fewer than seven characters	a message displayed around the email field that states: Too Short! please use at least 7 characters	Part of the validation process on the client side	V
G4		An incorrect old password is entered when the change password button is clicked	A message indicating that the code is incorrect is displayed to the user	Part of the validation process on the client side	V
G5		There is a difference between the new password entered in the upper field and the new password entered in the lower verification field when the change password button is clicked	surrounded by a red message: the passwords must match	Part of the validation process on the client side	V

G6		There is a No difference between the new password entered and the old password	A message indicating that new password must be different from old password		V
H1	**Profile Dashboard**	Clicking the update profile button when there is an empty field in one or more of the edit profile form fields	The empty fields will be surrounded by a red message	Part of the validation process on the client side	V
H2		Start the practice associated with your profile by clicking on the practice button	Redirect to practice page		V
H3		The profile has been successfully deleted from the system by Clicking on Delete Profile button	There is a warning message that all information associated with the user will be deleted when the user is deleted	In order to avoid errors, the deletion record of the user is double-verified	V
H4		Changing the profile information by clicking on the edit profile button	Redirect to edit profile page		V
H5		The patient profile has been successfully edited	Redirect to the user dashboard page	the associated profile will be updated in the database	V
H6		By clicking the result button, see the results	Redirect to results page	Results are retrieved from the database	V

		history of the profile practices			
I1	**Practice**	By clicking on update parameters, the practice parameters will be changed	There is a change in the parameter data in the information window		V
I2		Clear the practice page by clicking the clear sketch button	The practice page has been cleaned and is ready for use	Logic changes behind the scenes when the button is pressed	V
I3		Save the practice screenshot by clicking the save sketch button	The screenshot of the practice is saved, and the practice continues as usual	PNG format is used for the screenshot	V
I4		By clicking on the start, stop, and reset buttons on the timer controller	Controlling the timer, starting, stopping, and restarting it		V
I5		Ending the profile practice by clicking the button for done practice	The results page is redirected, and the log file is created and downloaded	X.Y coordinates of handwriting locations over time are recorded in a log file	V
J1	**Results**	A sorting option is available by clicking the table titles	Each title (parameter) can be sorted by clicking on it.	Parameters are sorted ascending or descending according to the user's preference	V

J2		By clicking Save results, results will be saved as a local file	The table of the practice result is saved on the computer,	CSV format is used for the results file	V
&1	**Log out**	From the navigation bar, click the logout button	Redirect to home page	The user will not be able to access information until he reconnects the user will not be able to access information until he reconnects	V

3.4 Results and Conclusions

Our early planning led to the successful implementation of the system. This resulted in the following results:

- User management system that separates information based on users and profiles: The project incorporates a user management system that is ready to use and secure. In this system, data and access privileges are separated and controlled appropriately based on individual users and their respective profiles, enhancing security and privacy
  .
- This project is designed to take into account the size of the tablet used in the laboratory setting, with positive or negative real-time feedback: The project's design takes into account the tablet's size. The practice or activity being performed on the tablet is tailored to suit its dimensions. Moreover, the system provides real-time feedback to users, offering prompt information on the progress they are making. Positive reinforcement is provided in response to correct actions e.g., continuous handwriting on the same line, while negative feedback is given to address errors or inaccuracies such as line deviation.

- A comprehensive result tracking system, location log files based on training time and results based on x, y pixel parameters on screen: The project implements a comprehensive result tracking system. Using this system, users' performance and progress are recorded and monitored. It generates location log files that capture training time and correlate it with specific results. A graphical interface allows for precise evaluation and analysis of user performance based on x and y pixel parameters.

We realized that it is essential to plan the system in advance in order to know which technological tools to use. This saved us a great deal of time and we began implementing the system at the beginning of the semester.

The division of tasks is also critical to the project's success, especially in the limited amount of time available. Both members of the team must be professional, self-motivated and committed to the work process, where at least once a week specific tasks must be defined for each team member, along with a schedule for completion of those tasks.

It is our firm belief that ScribbleBoost has tremendous potential, both in terms of a research perspective, where researchers may examine patient progress, as well as a performance perspective, where patients, particularly children, are able to improve their handwriting skills through the use of a user-friendly system.

3.5 Feature suggestions for the future

There are many features that can be added to the system to give the system depth, here are a few suggestions for future enhancements.

- Adjusting the dynamic canvas size based on the type of graphic tablet used
- Addition of additional training parameters, such as writing direction.
- Visualizing the information with graphs and generating recommendations accordingly.
- A cloud infrastructure will be used to save the training images and results on servers that can be accessed from any device with Internet access
- In order to maximize the training experience, some of the Hebrew letters must be excluded, such as the letter "ל" or the final letters "ף","ץ" so that we do not get the writing error on the margin of the line.
- In our training, we are currently checking the text sequentially from beginning to end and sometimes we will want to practice writing a summary that requires a different organization on the page, so one of the improvements that can be taken into account is the possibility of setting a space between the lines for writing paragraphs.

4. User Documentation

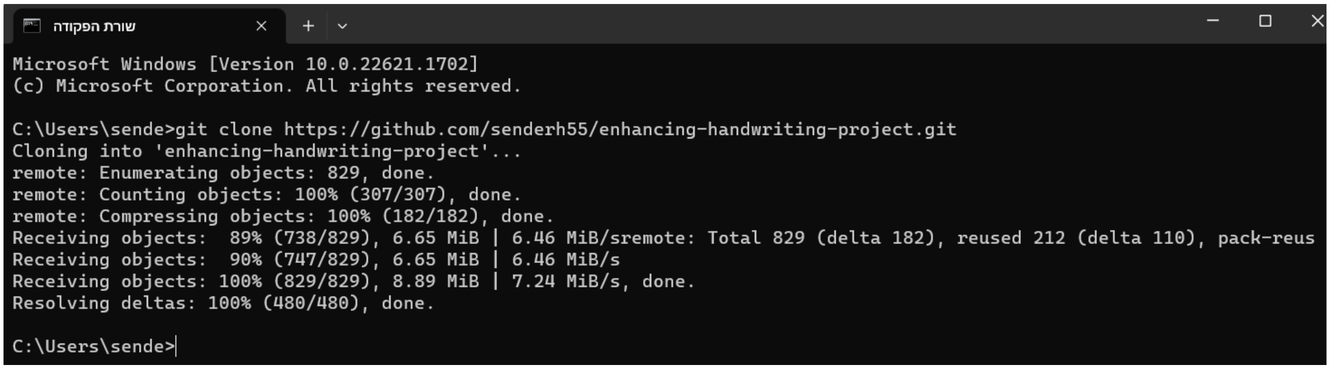
4.1 User's Guide Operating Instructions

As the system is a JavaScript-based web application and most operations are performed on the server and require a connection to a database, certain preliminary steps must be taken before it can be operated locally.

It is also necessary to download and adjust separate settings in order to optimize the use of the system with the Wacom graphic tablet.

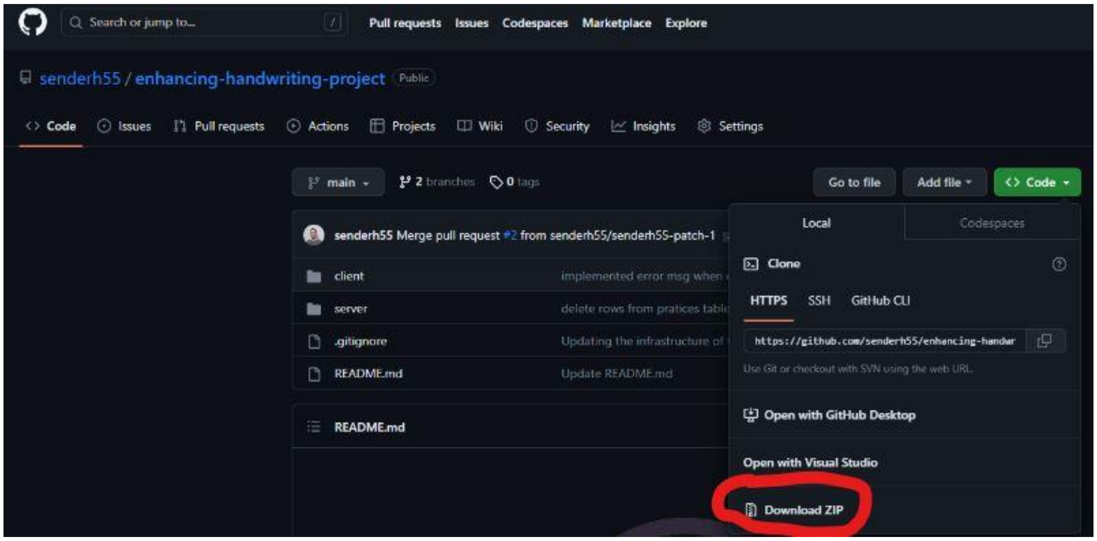
- Software Environment
  - Visual Studio Code [3]
  - Node.js – a JavaScript runtime environment [4]
  - Git – version control system [5]
  - Wacom tablet driver [6]
  - MongoDB database [7] and MongoDB GUI [8]

- Running Instructions
  - Choose one of these options to clone the GitHub repository [9]:
    - Run the following commands in the command line window of your operating system:
      git clone https://github.com/senderh55/enhancing-handwriting-project.git



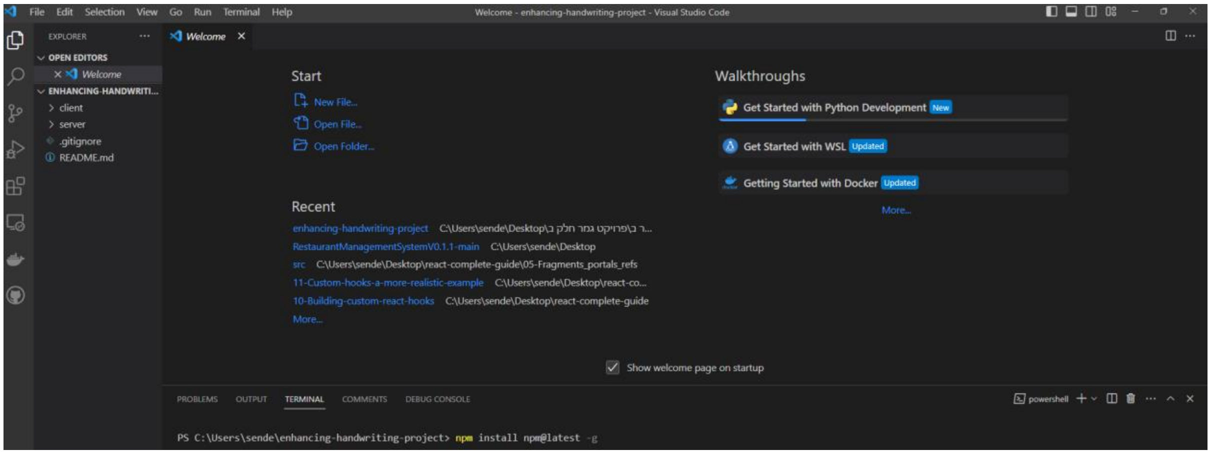
```
Microsoft Windows [Version 10.0.22621.1702]
(c) Microsoft Corporation. All rights reserved.

C:\Users\sende>git clone https://github.com/senderh55/enhancing-handwriting-project.git
Cloning into 'enhancing-handwriting-project'...
remote: Enumerating objects: 829, done.
remote: Counting objects: 100% (307/307), done.
remote: Compressing objects: 100% (182/182), done.
Receiving objects:  89% (738/829), 6.65 MiB | 6.46 MiB/sremote: Total 829 (delta 182), reused 212 (delta 110), pack-reus
Receiving objects:  90% (747/829), 6.65 MiB | 6.46 MiB/s
Receiving objects: 100% (829/829), 8.89 MiB | 7.24 MiB/s, done.
Resolving deltas: 100% (480/480), done.

C:\Users\sende>
```

- Alternatively, you can manually download and unzip the GitHub repository.



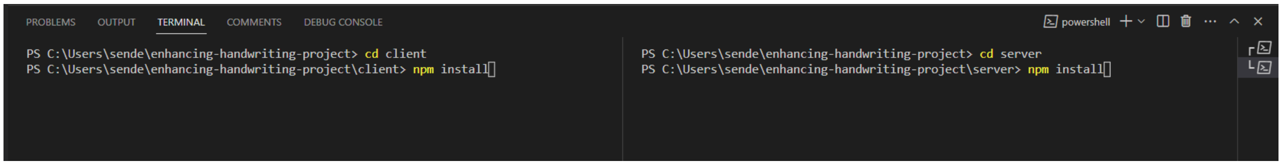
```
https://github.com/senderh55/enhancing-handwr
```

- Open Visual Studio Code and open the project folder
  - After opening the terminal, execute the following command to install the system dependencies: npm install npm@latest -g



```
PS C:\Users\sende\enhancing-handwriting-project> npm install npm@latest -g
```

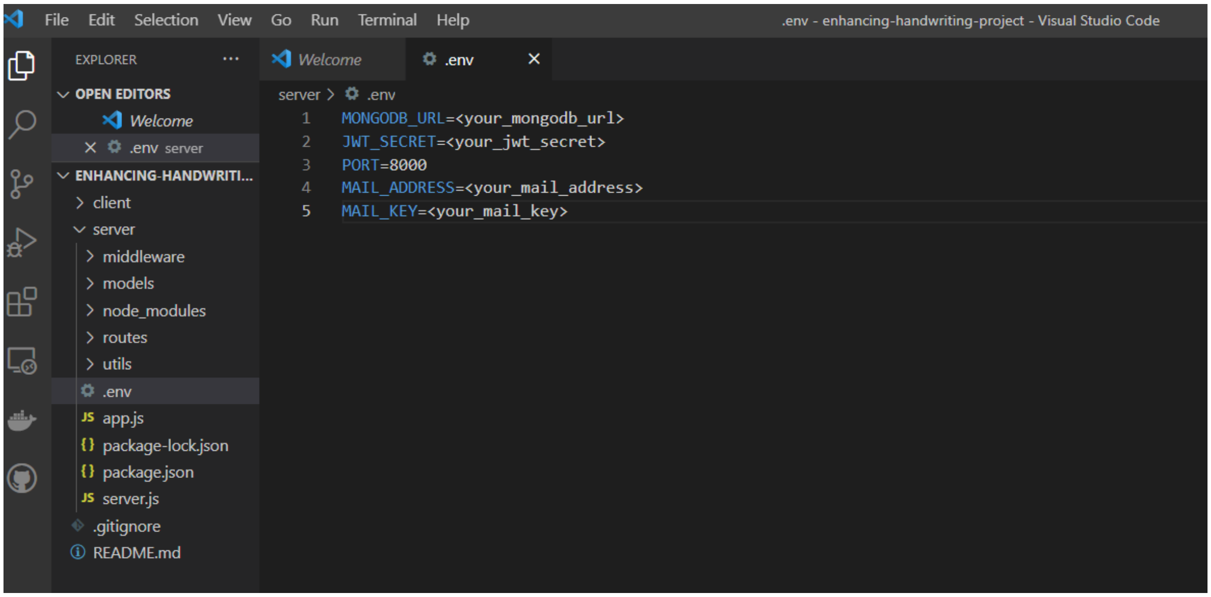
  - Split the terminal and Install NPM packages separately in server and client folders using the commands:
    - cd client   cd server
    - npm install   npm install



```
PS C:\Users\sende\enhancing-handwriting-project> cd client
PS C:\Users\sende\enhancing-handwriting-project\client> npm install
```

```
PS C:\Users\sende\enhancing-handwriting-project> cd server
PS C:\Users\sende\enhancing-handwriting-project\server> npm install
```

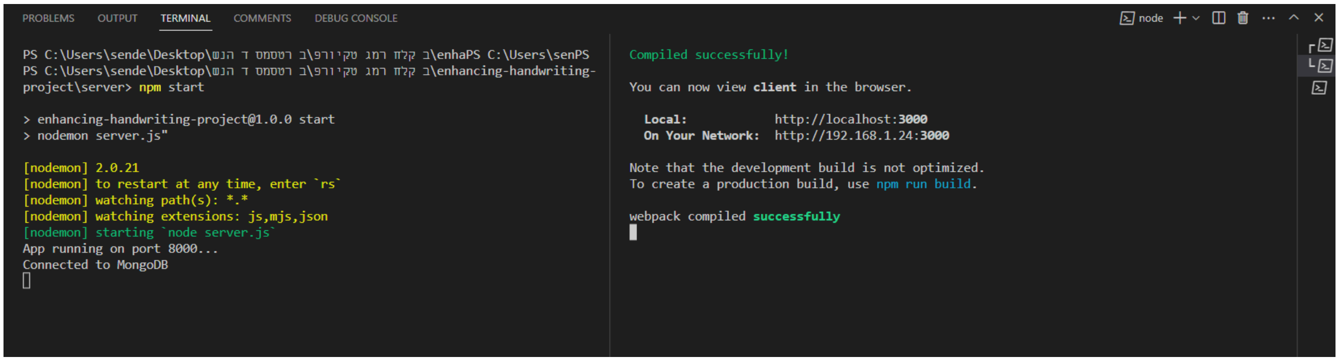
- In the server folder, create an environment variable file called ".env" with the following contents:
    - MONGODB_URL=<your_mongodb_url>
    - JWT_SECRET=<your_jwt_secret>
    - PORT=8000
    - MAIL_ADDRESS=<your_mail_address>
    - MAIL_KEY=<your_mail_key>



```
MONGODB_URL=<your_mongodb_url>
JWT_SECRET=<your_jwt_secret>
PORT=8000
MAIL_ADDRESS=<your_mail_address>
MAIL_KEY=<your_mail_key>
```

- You should provide a personal system environment variable according to your settings, your database address (local or cloud), a JWT key for encrypting your passwords, as well as an e-mail address and password to configure the system to send notifications of the user management system.

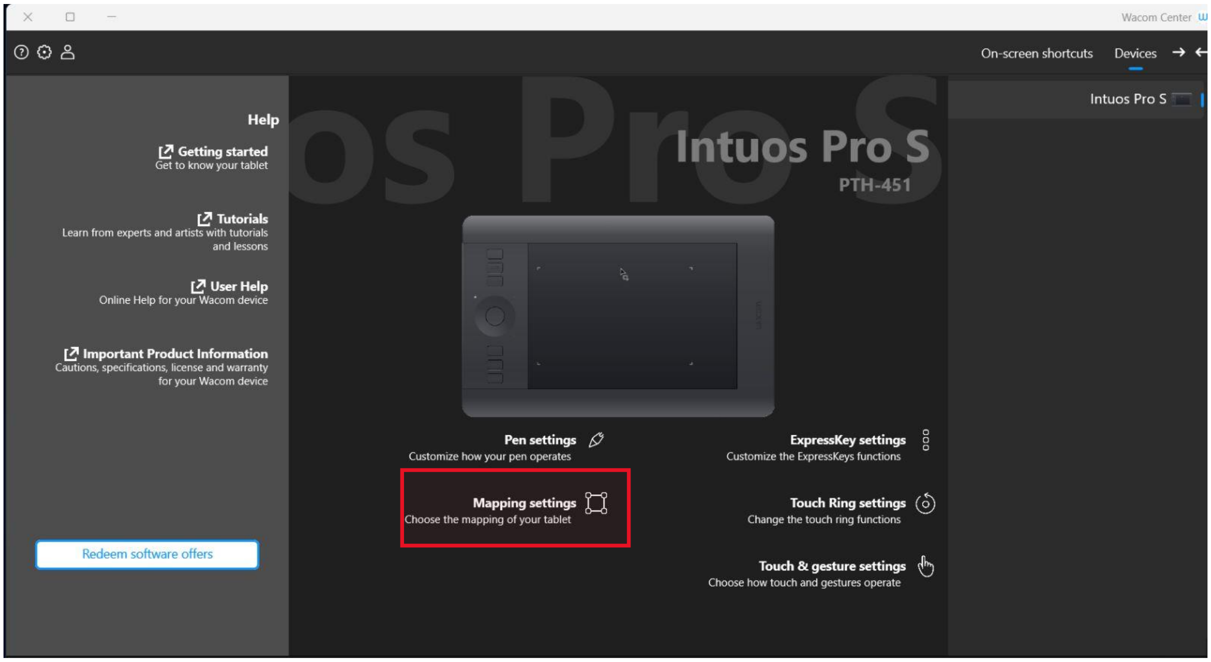
- For each of the folders, client and server, enter the command npm start



```
PS C:\Users\sende\Desktop\שנה ד סמסטר ב\פרויקט גמר חלק ב\enhaPS C:\Users\senPS
PS C:\Users\sende\Desktop\שנה ד סמסטר ב\פרויקט גמר חלק ב\enhancing-handwriting-
project\server> npm start

> enhancing-handwriting-project@1.0.0 start
> nodemon server.js"

[nodemon] 2.0.21
[nodemon] to restart at any time, enter `rs`
[nodemon] watching path(s): *.*
[nodemon] watching extensions: js,mjs,json
[nodemon] starting `node server.js`
App running on port 8000...
Connected to MongoDB
```

```
Compiled successfully!

You can now view client in the browser.

  Local:            http://localhost:3000
  On Your Network:  http://192.168.1.24:3000

Note that the development build is not optimized.
To create a production build, use npm run build.

webpack compiled successfully
```

Wacom driver configuration is required to realize the system's purpose



Wacom Center

On-screen shortcuts Devices

Intuos Pro S

Help

Getting started
Get to know your tablet

Tutorials
Learn from experts and artists with tutorials and lessons

User Help
Online Help for your Wacom device

Important Product Information
Cautions, specifications, license and warranty for your Wacom device

Redeem software offers

Intuos Pro S
PTH-451

Pen settings
Customize how your pen operates

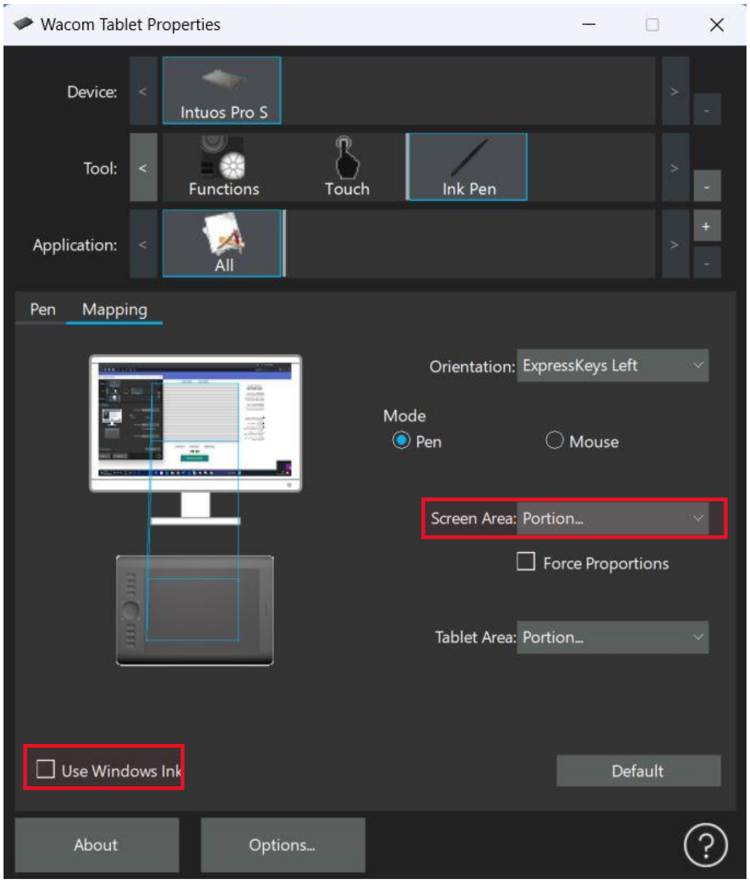
ExpressKey settings
Customize the ExpressKeys functions

Mapping settings
Choose the mapping of your tablet

Touch Ring settings
Change the touch ring functions

Touch & gesture settings
Choose how touch and gestures operate

- Ensure that the box for using Windows Ink is unchecked after selecting mapping settings
- Select the portion of the screen where the practice canvas will be displayed



Wacom Tablet Properties

Device: Intuos Pro S

Tool: Functions Touch Ink Pen

Application: All

Pen Mapping

Orientation: ExpressKeys Left

Mode
● Pen ○ Mouse

Screen Area: Portion...

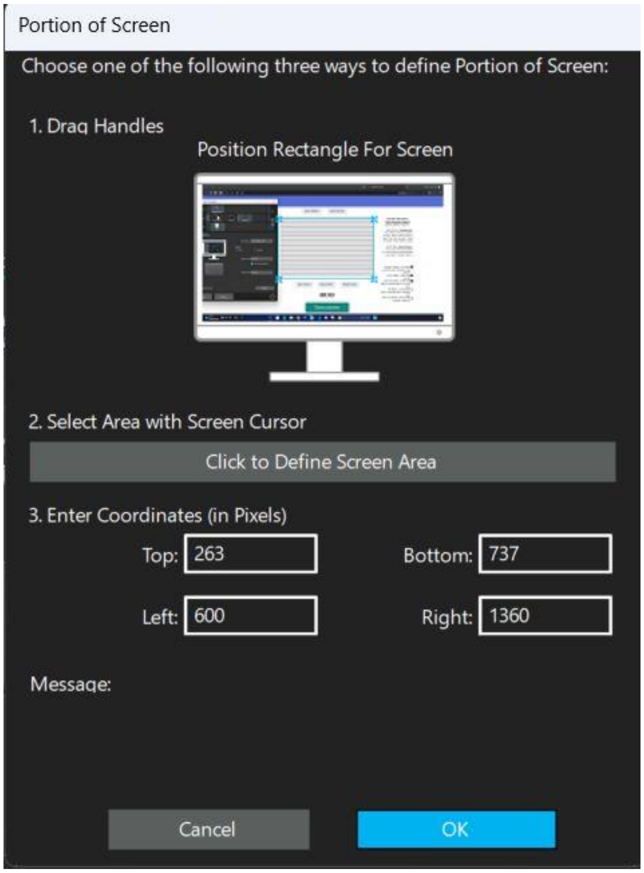
□ Force Proportions

Tablet Area: Portion...

□ Use Windows Ink

Default

About Options...



Portion of Screen

Choose one of the following three ways to define Portion of Screen:

1. Drag Handles

Position Rectangle For Screen

2. Select Area with Screen Cursor

Click to Define Screen Area

3. Enter Coordinates (in Pixels)

Top:	263	Bottom:	737
Left:	600	Right:	1360

Message:

Cancel OK

4.2 Maintenance Guide

JavaScript is used by both the client and the server; we examine each side in more detail

4.2.1 Client side – ReactJS

File\ Folder Name	Description
package.json	This file contains information about the react app, such as its name, version, and dependencies.
app.js	This file is the main entry point for the react application
src	This folder contains the source code for the application.
src/pages	This folder contains the pages for the application.
src/components	This folder contains the React components for the application.
src/assets	This folder contains the audio and images of the application (mostly for practice).
src/context	This folder contains the React context file (authContext.js).
src/utils	This folder contains utility functions for the application (api.js)
theme.js	All common Material UI designs of the system are contained in theme.js

On the client-side, there are three main parts that play a vital role in the system's functionality and aesthetics. A variety of interactive practices are implemented using p5.js, allowing the users to interact with the system in an immersive and dynamic manner.

Material UI is utilized to enhance the overall design, ensuring a visually appealing and intuitive user interface.

Lastly, ReactJS is extensively used to implement all aspects of the user interface, providing a robust framework for efficient component rendering.

In terms of the training process itself, activities such as drawing the canvas heavily rely on the p5.js library. With its wide range of features and capabilities, it provides seamless drawing experiences for its users. In the React framework, the integration of p5.js is handled exclusively through the practice.js file, which contains the necessary components and functions to enable the smooth interaction between React and p5.js.

Several key concepts within React are required to maintain the client side of the system. These concepts include:

- **useState**: This concept enables the creation and management of state variables within functional components. By utilizing useState, the system can dynamically update and track the state of various UI elements, facilitating real-time changes and user interactivity.
- **useEffect**: The useEffect hook allows the system to perform side effects in response to changes in specific variables or when certain conditions are met. It is essential for handling tasks such as fetching data from the server, updating the DOM, or subscribing to events.
- **useContext**: With the useContext hook, the system can access shared data or functions across multiple components without having to pass props explicitly. It simplifies the process of managing global states and facilitates effective communication between different parts of the application. AuthContext.js centralizes all shared data in the system.
- **react-router-dom**: This library provides a collection of components and utilities for handling client-side routing within a React application. By utilizing react-router-dom, the system can navigate between different pages or views without the need for a full page reload, enhancing the overall user experience and application responsiveness.

  App.js contains all routes and their assignments to relevant pages.

The client-side of the system can be efficiently maintained by understanding and employing these React key concepts, ensuring optimal performance.

4.2.3 Client-backend communication using api.js

api.js is the **<u>only</u>** file that have functions that interacts with the server. It makes requests and handles responses.

Axios is a JavaScript library that makes it easy to make HTTP requests. The api.js file defines functions such as: login, signup, and userEmailVerification.

Using the login function as an example, the login function takes two parameters: email and password. It makes a POST request to the server at the URL /users/login with the email and password as the body.

In api.js, errors are handled by checking the status code of the server response. If the status code is 401, the login function throws an error stating "Incorrect email or password." If the status code is 404, the login function throws an error stating "User not found". The signup function throws an error stating "Email already in use". The login function throws an error with the message "Something went wrong, please try again later" if the status code is not 401, 404, or 400.

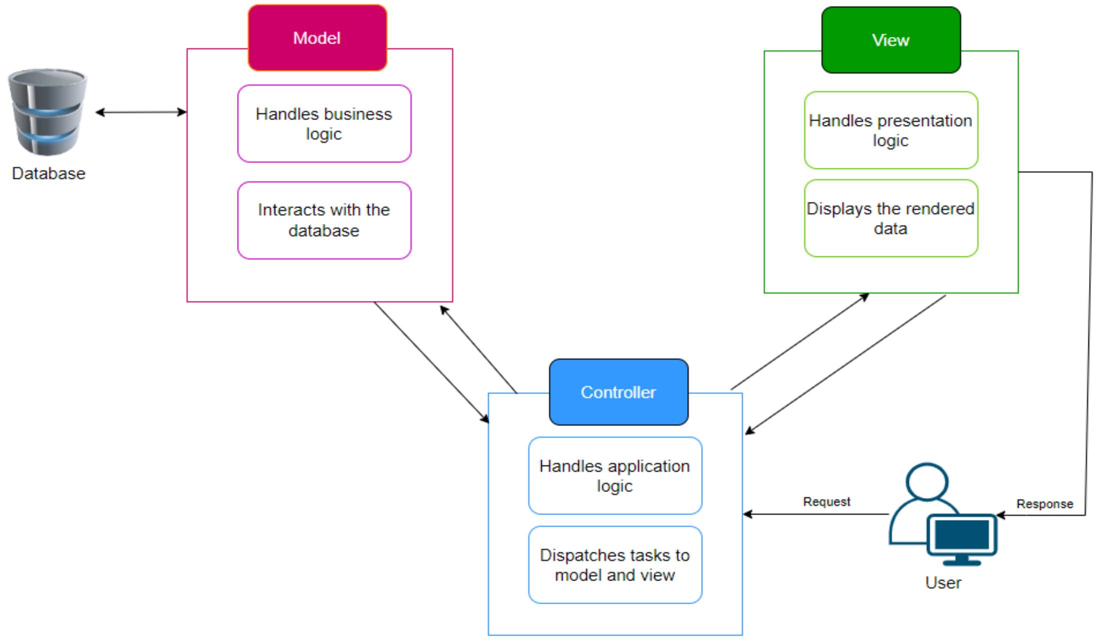
Note: Since most requests require shared information, authcontext.js accounts for a significant number of calls to api.js.

4.2.4 Server side – Node.JS

File\ Folder Name	Description
package.json	This file contains information about the Node.JS app, such as its name, version, and dependencies.
server.js	As the main entry point for the NodeJS app, this file provides a connection to the database and runs app.js
app.js	This file creates an Express application that allows to interact with a user and profile routes that makes the database communication.
utils	This folder contains utility functions for the application (email.js)
middleware	Middleware folders contain functions that can log, authenticate, and authorize before or after a route receives a request (auth.js).
routes	Routes folder contains routes files that have functions that are executed when a request is made to a specific path. A route handles requests for different pages or resources.
models	Models folder contains the data models or schemas that define how the data will interact with the MongoDB database.

The system based on Model-view-controller architecture that separates the user interface from the business logic. This allows for easier development and maintenance, as changes to the interface can be made without affecting the underlying code. It also makes it easier to add new features, as the code is already separated into distinct components.

Following is the diagram that illustrates the division of responsibilities among the components of the architecture as well as how it is implemented in our system in accordance with the following description.


Model
Handles business logic
Interacts with the database
View
Handles presentation logic
Displays the rendered data
Database
Controller
Handles application logic
Dispatches tasks to model and view
Request
Response
User

The models are:

- The user model represents an individual user of the application and contain information such as the user's username, email, password, and other relevant data such as associated profiles. It also contains methods for authentication and authorization, such as checking if a user's password matches the stored hash or determining if a user has a certain role or permission (tokens).

- The profile model represents a user's profile and would contain information such the profile name, age, bio, and practices history. Profiles are owned by users when there is a one-to-many relationship between a user and a profile.

The routes(controllers) are:

- userRoutes.js route handles requests related to users such as login, signup, reset password, etc. It is responsible for authenticating users and ensuring that they have access to the features they are authorized to use. It also handles requests related to user data, such as updating user profile information or retrieving user data.

- ProfileRoutes.js manages profiles, including adding new profiles, editing existing profiles, storing practice data, and more.

HTTP requests are sent to the server and are then routed through Routes. The server handles the request and responds with the appropriate data or an error message if anything goes wrong.

Additionally, there are files related to authentication (auth.js) and emailing (email.js).

Third-party libraries such as nodemailer and jsonwebtoken were used to implement these functionalities.

5. References

[1] https://www.wacom.com/en-us/products/pen-tablets/wacom-intuos-pro

[2] https://p5js.org/

[3] https://code.visualstudio.com/

[4] https://nodejs.org/en

[5] https://git-scm.com/

[6]https://cdn.wacom.com/u/productsupport/drivers/win/professional/WacomTablet_6.4.2-3.exe

[7] https://www.mongodb.com/

[8] https://www.mongodb.com/products/compass

[9] https://github.com/senderh55/enhancing-handwriting-project