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DEVELOPMENT OF A MOBILE APPLICATION FOR TESTING FINE MOTOR SKILLS DISORDERS

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Abstract. *The purpose of this research is to develop a mobile application to identify fine motor disorders and help in their development. Many techniques are used to test fine motor skills, including drawing, cutting, folding, creating compositions from various materials, and more. However, using digital devices to test fine motor skills will be automatic, useful, and helpful. Digital devices such as sensor and graphic tablets, sensors, digitizers, and smartphones can provide accurate measurements of reaction times and movement speed, and allow real-time data to be recorded and analyzed. A cross-platform tool was developed to test basic graphic skills and level of fine motor skills development. The algorithm for the determination of the graphic abilities of users is based on the Frechette discrete distance formula, which allows measuring the deviation of an experimental figure from the etalon figure. Experimental results were conducted at the Laboratory of 3D Biomedical Technologies of the Department of Biomedical Engineering of Kharkiv National University of Radio Electronics. The application is designed to analyze graphic skills through a series of exercises that test various skills, such as drawing, shading, and coloring shapes.*

Keywords: healthcare, motor disorders detection, cross-platform development, digital healthcare tools, graphic motion analysis, mobile application

OPRACOWANIE APLIKACJI MOBILNEJ DO BADANIA ZABURZEŃ MOTORYKI PRECYZYJNEJ

Streszczenie. *Celem artykułu jest opracowanie aplikacji mobilnej do testowania umiejętności graficznych i określania zaburzeń zdolności motorycznych. Do testowania umiejętności motorycznych wykorzystywanych jest wiele technik, w tym rysowanie, wycinanie, składanie, tworzenie kompozycji z różnych materiałów i wiele innych. Jednak korzystanie z urządzeń cyfrowych do testowania umiejętności motorycznych będzie automatyczne, użyteczne i pomocne. Urządzenia cyfrowe, takie jak tablety sensoryczne i graficzne, czujniki, digitalizatory i smartfony mogą zapewnić dokładne pomiary czasu reakcji i prędkości ruchu oraz umożliwiają rejestrowanie i analizowanie danych w czasie rzeczywistym. Opracowano wieloplatformowe narzędzie do testowania podstawowych umiejętności graficznych i poziomu rozwoju umiejętności motorycznych. Algorytm określania zdolności graficznych użytkowników opiera się na formule dyskretnej odległości Frechette'a, która pozwala zmierzyć odchylenie figury eksperymentalnej od figury wzorcowej. Wyniki eksperymentalne przeprowadzono w Laboratorium Technologii Biomedycznych 3D Wydziału Inżynierii Biomedycznej Charkowskiego Narodowego Uniwersytetu Radioelektroniki. Aplikacja została zaprojektowana do analizy umiejętności graficznych poprzez serię ćwiczeń, które testują różne umiejętności, takie jak rysowanie, cieniowanie i kolorowanie kształtów.*

Słowa kluczowe: opieka zdrowotna, wykrywanie zaburzeń motorycznych, rozwój międzyplatformowy, cyfrowe narzędzia opieki zdrowotnej, graficzna analiza ruchu, aplikacja mobilna

Introduction

Physical rehabilitation after treatment of the neuromuscular system diseases involves the restoration of fine motor skills [3]. Fine motor skills refer to the ability to control small muscle movements, particularly those of the fingers, hands, and wrists. [12]. These skills are needed to execute several tasks, including writing, drawing, using appliances, and performing everyday activities such as buttoning and tying shoelaces etc. [9]. For children, it is crucial to detect fine motor skill disorders at an early age as it can lead to disorders in communication, information perception, mental development, mental retardation, etc. [13]. It is advisable to test children between the 3–5 ages. However, in modern realities, it is difficult to do this due to martial law in Ukraine. Therefore, an urgent task is to develop a mobile application to implement testing in a game form that parents can install on their smartphones or other gadgets [3, 9, 12]. The development of a program in the form of mobile applications is the best option since this type of software has better functionality, and allows to creation of the process at any convenient time and place, using various digital devices.

The purpose of this article is development of a portable, mobile, affordable, and easy-to-use tool for testing graphic skills and fine motor skills.

Fine motor testing can help identify developmental problems that may be related to a variety of conditions, including stroke, paralysis, dysarthria, dysgraphia, autism, cerebral palsy, etc. Many techniques are used to test fine motor skills, including drawing, cutting, folding, creating compositions from various materials, and more. However, using digital devices to test fine motor skills will be automatic, useful, and helpful [4].

Digital devices such as sensor and graphic tablets, sensors, digitizers, and smartphones can provide accurate measurements of reaction times and movement speed, and allow real-time data to be recorded and analyzed. This can help get a more accurate assessment of fine motor skills development [14].

In addition, the use of digital devices can make fine motor testing more interesting and engaging for children for example, which can improve their motivation and reduce stress levels during testing. This can be especially important for children who have learning difficulties or limited concentration. Thus, the implementation of mobile applications or applications in specialized educational institutions of preschool and school education, correctional schools, and medical institutions provides opportunities to automate the testing process and introduce new authors' ideas [5].

In reviewing the relevant literature, it is essential to highlight the contributions of Walla Mahmood and her findings [10], which underscore the critical need for a digital solution to address motor skill assessment. Key insights from Mahmood's work can be summarized as follows:

- Objective Measurement of Kinematics: Mahmood stresses the necessity of tools capable of objectively measuring motor activity and tracking the development of motor skills over time. Developing an application designed to analyze graphical movements and fine motor skills using digital devices enables real-time data collection, normalization, and analysis. This approach directly addresses Mahmood's call for more advanced and quantitative tools to evaluate motor deficits effectively.
- Early Detection of Motor Coordination Problems: Mahmood highlights the importance of early identification of motor skill deficits, particularly in children who struggle with functional and athletic motor tasks. A digital application offering tasks such as outlining, shading, and drawing can serve as a reliable screening and assessment tool for identifying delays in fine motor development, especially among young children.
- Affordable and Scalable Solutions: Mahmood's study identifies significant limitations in traditional motor skill assessments, which are often resource-intensive and impractical for large-scale implementation. In contrast, an affordable, digital solution deployed through mobile devices offers a practical

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alternative, facilitating broader access to motor skill evaluations.

- Support for Targeted Interventions: Mahmood also emphasizes the need for tools that consistently monitor motor activity to inform tailored interventions. A digital tool that provides continuous tracking of motor progress can assist educators, therapists, and parents in designing and adjusting interventions based on real-time data, addressing a critical gap in existing assessment methods.

1. Materials and methods

Development of the project should provide such opportunities as testing graphic skills and fine motor skills at home, as well as the possibility of disseminating the results to accredited persons (specialists) to diagnose disorders and develop an individual testing program. An expert must properly format the obtained data for transfer and further analysis.

The first step in the creation of the mobile application is to find relevant and proven approaches to testing graphic skills. One of them is a set of exercises that includes (examples are shown in Fig. 1):

- drawing;
- shading;
- drawing different lines in different directions;
- outlining the contours of an object (outlining a picture, connecting the dots, completing the drawing according to the principle of symmetry;
- tracing labyrinths, coloring shapes according to a pattern.

Modern smartphones equipped with artificial intelligence capabilities enable cross-platform development, which is a key requirement of this application. For example, Apple provides a unified API [6] to introduce ML components in its projects, but they are available only when developing native solutions, approximately the same opportunities but in the broader variant are also available on Android [2]. The result of the analysis was the idea of developing a basic algorithm that would allow determining with acceptable accuracy the presence of deviations in the development of fine motor skills, movement disorders and graphic skills.

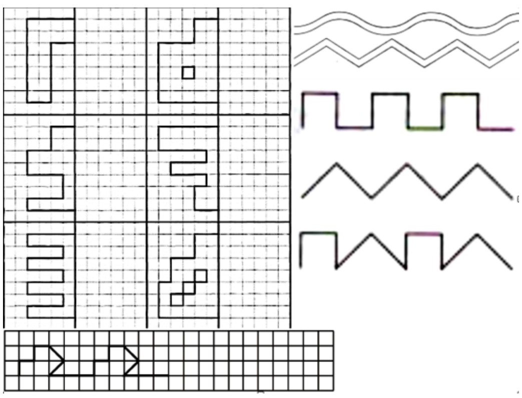

Fig. 1. Tests samples of graphic skills testing

The next requirement is that the accuracy of the algorithm must not decrease as the device configuration changes. Conventionally speaking, the algorithm should give acceptable results on 412x732 screens (Google Pixel) and on 428x926 screens (iPhone 12 ProMax).

The testing process for fine motor skills involves the following steps (*):

1. Initializing the test, displaying the test on the screen.
2. Collecting test data for further analysis (testing itself).
3. Normalization of the data obtained because of testing.
4. Analyzing the information, displaying the results of the analysis to the user.
5. Saving the information.

Steps 3 and 4 deserve special attention.

In order to save server space and lossless scaling of the test image, the application uses a vector image format (SVG).

The curve by which the subject's movements are checked is stored as a set of points (sets of coordinates), which are sorted by the order in which they are added to the test. These coordinates correspond to the coordinates that were obtained when the test was created, so to scale the test, the original screen size on which the test was created is entered.

Considering this, the collation curve and images are scaled using the following formula:

$$c(0) = (width = \frac{0.width}{w}, height = \frac{0.height}{h})$$

where: *o* – screen comfit of current device, *w*, and *h* – screen width and height, accordingly.

After the data have been normalized, to need proceed to the analysis phase of the data using next formulas:

First, if the number of points obtained exceeds the number of points that were in the original line, then you need to reduce their number using the Douglas-Pecker algorithm, one of its components is a formula for calculating the perpendicular distance between the point and the line.

$$d(p, vw) = \frac{|(w-v)\cdot(p-v)|}{\|w-v\|}$$

where: · dot denotes the dot product of two vectors, and || || denotes the norm of a vector.

The *d* function formula is responsible for determining the distance between two points.

$$d(p,q) = \sqrt{(q_x - p_x)^2 + (q_y - p_y)^2}$$

where: p_x p_y, are coordinates of point *p*, q_x q_y are coordinates of point *q*.

$$cP = \sum_{i=1}^{n} \left[d(\mathrm{I}_i, T_i) \le md \right]$$

where: *I* is the list of curve points, *T* is the list of curve points created by the user under test, *dist(p, q)* is the distance between *p* and *q* points, *n* is the number of points in the curves *I* and *T*, *md* is the maximum allowed distance between points.

$$ac = \frac{cP}{tP} \times 100$$

where: *cP* is the number of points that were drawn correctly; *tP* is the total number of points created by the user under test, *ac* – accuracy.

$$md = \sum_{i=1}^{n} \frac{d_i}{n}$$

where d_i is the distance between the *i-th* point of the figure and its corresponding *T* point, *n* is the number of points in the lists *I* and *T*, *md* – mean distance.

$$n(i,t) = \min_{I \in i} d(I,t)$$

where: *min* denotes the minimum value over all elements in the set, and *d(p,q)* is a separate function that calculates the distance between two points *p* and *q*, *n(i, t)* – function for finding the nearest point.

$$cm(I,T) = \begin{Bmatrix} true\ if\ (d(I_I, T_I) \le md\ and\ d(I_n, T_n) \le md \\ false\ if\ (d(I_I, T_I) \ge md\ or\ d(I_n, T_n) \ge md \end{Bmatrix}$$

where: *I* – initial line, *T* – target line, I_1 – first point of initial line, T_1 – first point of target line, T_n, I_n – last points, *md* is the maximum allowed distance between points, *cm* – completed, function that checks if the line ends match each other.

However, the above formulas represent the default analysis strategy, the test creators can write their own implementation of the algorithm for analyzing the test data obtained. Now there are tools available in the solution to create completely independent tests of fine motor skills with their own analysis metrics [11, 15].

The target study group for the test described above is children aged 3–5 years. Testing of fine motor skills includes a series of tasks designed to assess the skills of controlling small muscles of hands and fingers. An important condition of the test is that it should be administered regularly in order to more accurately assess fine motor development or to detect developmental abnormalities. During the test, an adult is needed to help ensure that the conditions of the test are met and to explain the conditions of the tasks to the subject.

The testing procedure consists of the following steps:

1. Preparation for the test. The test child takes a sitting position at the table in such a way as to minimize the influence of external factors on the subject's hand motor skills. During test preparation, it is necessary to make sure that the subject is not under stress and has no visual problems that would affect the cleanliness of the test.
2. Initialization of the test. The test is started on the screen of the device where the graphic task is displayed.
3. Conducting the test in accordance with the conditions described in the test (*).
4. Data collection. While performing the tasks, the coordinates of finger or stylus movements, as well as reaction speed and accuracy of movements are collected. If the accuracy calculated after performing the test for 3 test attempts exceeds 90%, the test is considered to be successfully passed.

2. Experimental results

Experimental results were conducted at the laboratory of 3D biomedical technologies of the Department of Biomedical Engineering of Kharkiv National University of Radio Electronics. The project was tested on Xiaomi Redmi 9, Xiaomi Redmi 9a, Xiaomi Redmi 7, Xiaomi Redmi Note 10T, iPhone SE (3rd generation). Fig. 2 shows a diagram of the test device.

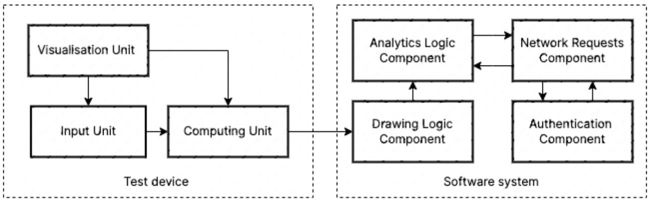

Fig. 2. A block diagram of the device for testing graphic skills and fine motor skills

Fig. 3 shows the testing process and the appearance of one of the tests.

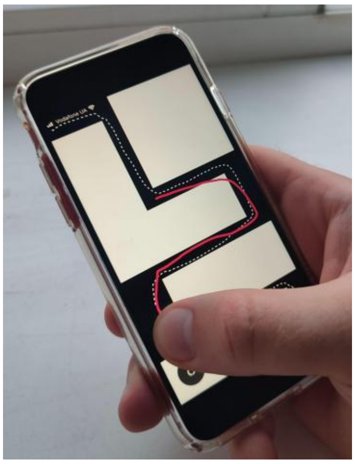

Fig. 3. An example of taking a test

The user experience is organized into three main tabs: 'Tests', 'Analytics', and 'Settings'.

The "Tests" tab contains the available tests, which can be run and re-run. The items presented on the tab are divided into two types:

- comprehensive tests;
- single test.

After the test is finished, quick analytics on the test is displayed (is shown in Fig. 4), the results of the tests are automatically saved.

The tab "Analytics" contains the results of the tests passed, as well as general analytics on them, there is a possibility to export them to PDF, as well as copy them as a link to share complete data (it is shown on Figure 5).

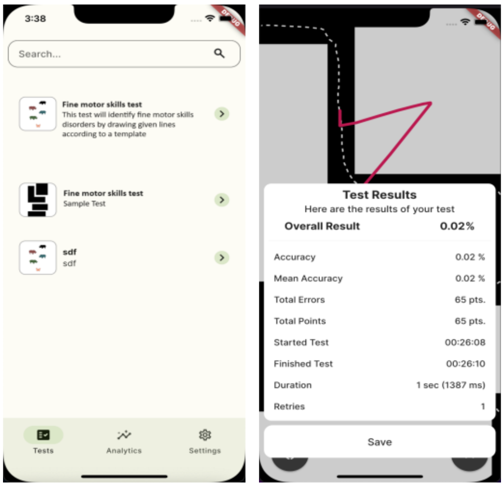

Fig. 4. Experimental results of tests and analytics

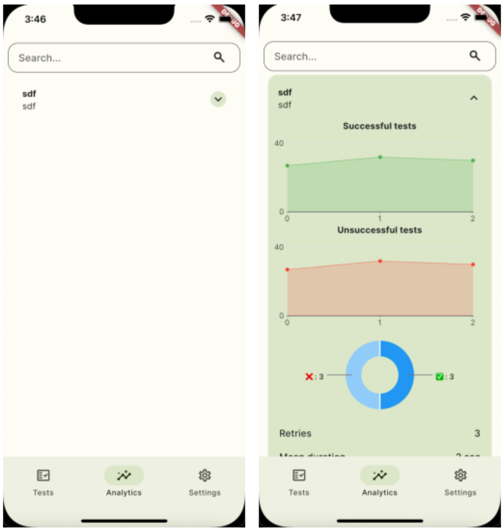

Fig. 5. "Analytics" Tab

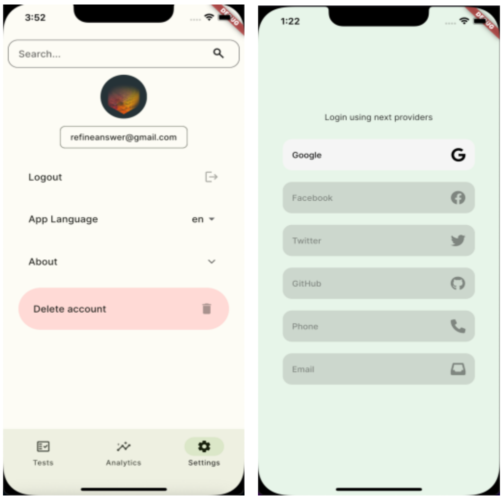

Fig. 6."Settings" Tab and authorization page

The settings tab allows you to sign out of the account used in the application, as well as change the current language of the application. The settings will be applied after opening the application again (it is shown on Figure 6).

A Google account is used as the primary account for interacting with the application. The account is needed to link the user and its data on different devices, to store test results and to allow sharing with other users. The app does not share this data with third parties, by clicking the "Share link" button its consent to the third parties (it is sharing the link) viewing the linked data. The application collects data about errors in its operation, in order to further improve the quality of its use. In case is not satisfied with this fact, it can build the necessary version of the application using its source code.

In future releases, it is planned to use a more extensive list of authorization providers, under the conditions described above.

The application is implemented on the Flutter technology, which allows you to use it on both Android and iOS, there is an opportunity to run it in a browser, but this possibility has not yet been properly tested [1, 7, 8].

All screen sizes and ratios are supported, but due to the limited number of devices available for testing now, this possibility has not been tested as well.

The application logic is very easy to customize thanks to the "CLEAN" approach in the architecture design [11].

There are many similar applications on iOS, almost all of them are paid, but their quality is noticeably higher than that of similar applications on Android:

- "Quick test of fine motor quality" – a great app for testing fine motor skills, but it lacks English localization, it looks outdated, but it is completely free. Android only [1].
- "Fine Motor Skills Practice" is a fine motor skills training app, priced at 99.9 UAH on the Play Store or 4.99 UAH on the App Store. It lacks the ability to share data and perform detailed analytics [9].
- "KanDo: Fine Motor Skills Measurement Tool" is a great app for testing fine motor skills. Only for iOS. It lacks the ability to share data (Figure 7 shows one of the tests) [4].

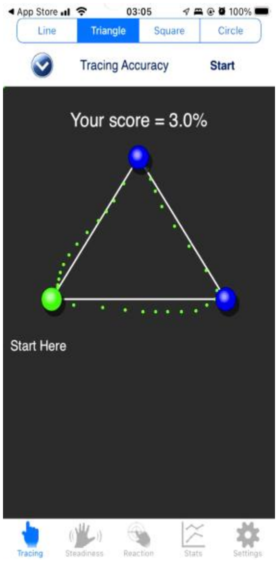

Fig. 7."KanDo: A Tool for Measuring Fine Motor Skills"

The advantages of this developed application is that it: is completely free; available on both mobile platforms; open source; a convenient platform for further development in the direction of fine motor testing.

3. Conclusions

This study presents the development of a cross-platform application designed to assess fine motor skills and detect movement disorders. The application is designed to analyze graphic skills through a series of exercises that test various skills, such as drawing, shading, and coloring shapes. This scientific work discusses the challenges of developing the application on different devices and the importance of normalizing data and analyzing the information obtained from testing. The use of a vector image format helps to save server space and enables lossless scaling of the test image [5, 16].

The project provides formulas for data normalization and analysis, which can be used as a default analysis strategy or the test creators, can write own implementation of the algorithm for analyzing the test data obtained .

Overall, the developed application provides an effective and user-friendly tool for assessing fine motor skills and movement disorders, the analysis generated from the data obtained can be used to create a report that can be shared later. The authors also highlight the prospect of adding new features to the application and developing a community, which would positively influence the application's quality and contribute to the continued improvement of the tool. In summary, the article offers a practical approach to testing fine motor skills and provides valuable insights into the development of cross-platform applications for educational purposes.

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