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Interactive Data Acquisition System based on Hand Tracking to evaluate Children's Cognitive Abilities

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Abstract

Autism (ASD) is a mental disorder characterized by a pronounced deficit in personal, social, speech, and other aspects of development and communication skills. Since autism is a complex developmental disorder that requires a lot of effort to recognize, this research was conducted to develop an interactive data Acquisition System and detect the first signs of ASD in children. The proposed system presents several variants of the tasks in an entertaining form, using hand tracking. Hand tracking is used to attract children's attention and interest them more to achieve more accurate results. The creation of the system is based on such libraries as OpenCV, PyGame, TensorFlow, and Mediapipe. The ultimate goal of the paper is to obtain data on the disease of autism in children for use in further diagnosis by medical experts.

Keywords: *Interactive System, Data Acquisition, Hand Tracking, Cognitive Abilities*

1. Introduction

Children with autism spectrum disorder often need special support, but they also have fairly high intelligence and can solve quite complex problems. However, they often cannot speak normally. They understand speech but do not have the ability to use speech as a means of communication. Moreover, children with ASD have problems in society. That is, autistic children rarely play with their peers, they prefer to play alone, as society scares them. In such cases, there are already applications that allow children with ASD to communicate with the outside world, play, and develop. Medical specialists are already using these applications in their work to work with children with autism. It's much more interesting than playing with ordinary cards on the table. Moreover, classes with different applications show a completely different level of effectiveness [1].

Currently, there are already many applications for children with ASD. All of them are divided into different groups depending on the purpose [2]. These are programs that introduce the child to the world around them and help to master this or that material: for example, letters and numbers. There are many such applications, for example, Language Therapy for Kids – MITA.

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This app for language and cognitive abilities has gone through clinical studies and helped over 8,000 children learn how to speak confidently and achieve language development milestones. It's available in different languages [3].

These are applications that are focused on reproducing real-life situations and helping a child with autism adapt to society. One such application is Social Story Creation. This application allows you to create stories from pictures, thereby helping children prepare for various situations in real life [4].

There are also communication application apps. These apps help children with ASD, and other developmental disabilities, learn and connect with people. The app helps children with autistic spectrum disorders and other developmental disabilities learn and connect with people. One of the most popular applications of this type is Proloquo2Go. Proloquo2Go is an app specifically designed for people who are nonverbal. It promotes language development and allows people to communicate through the use of pictures. It presents users with images they're most likely to use and has a level-based system for basic to advanced vocabularies [5].

The above applications are good for developing the abilities of children with autism. However, all these applications are made in 2D format. The idea of the proposed system is to create an application using alternative resources such as hand tracking. This is done in order to interest the kids and attract their attention. Thus, children will be interested in playing games and at the same time, this application will help in the development of their abilities.

2. Proposed System

As mentioned above, the main idea of this project is to create an application for gathering interactive data on autism assessment. However, the main distinguishing feature of this application is the interactivity of the games. Since the main symptom of this mental disorder is the inability to communicate and the fear of society, this application will help the child relax and calmly pass the test game. Thus, it can be assumed that the results will be more accurate. In this application, during the game, children will use only their hands (without touching any screens and keyboards) and they will see themselves on the screen. This will avoid unnecessary panic and discomfort for a child with ASD. After completing all three tasks of the game form, the data on the results of the games will be saved in the dataset. After that, the medical expert can easily display the results of the child on the screen.

2.1 Snake Game

The first game that is offered to a child with ASD is the Snake game. The essence of the game is to control a long and thin creature resembling a snake, which crawls along the plane.

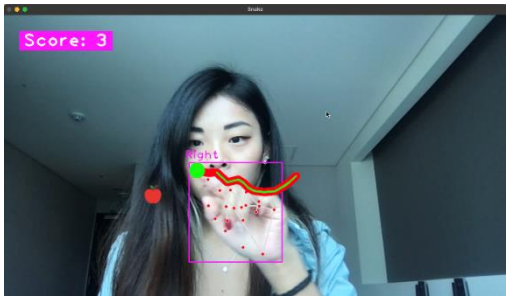

Figure 1. Snake Game Process

In this case, the children use only their hands, namely the index finger. With the help of "Mediapipe's hand landmark", we have set the head of the "snake" to point #8 [INDEX_FINGER_TIP]. The main task of the child is to collect food (in our case, these are apples), avoiding collision with the snake's own tail and the edges of the playing field, that is, the camera's visibility zone, since the program does not recognize the position of the hand. Each time the snake eats a piece of food, it becomes longer, which gradually makes the game more difficult as shown in Fig. 1.

The main reason for choosing this game was that children with ASD are more likely to show poor results. The fact is that autistic children have a repetitive and stereotyped games, their games are characterized by limitations, and they repeat the same actions.

In Fig. 2 one can see a schematic of the snake from the game we have implemented. It will consist of lines and points where green dots are points and the first point is the head. There are also distances between points, when the code is run there are a list of points and a list of distances. This is necessary for indicating distances, keeping track of the length of the snake, and adding the length in case the player "ate the apple". There are also variables called the current length that let us add them up for the total distances. Total length is the value that is allowed for the snake to be at the maximum.

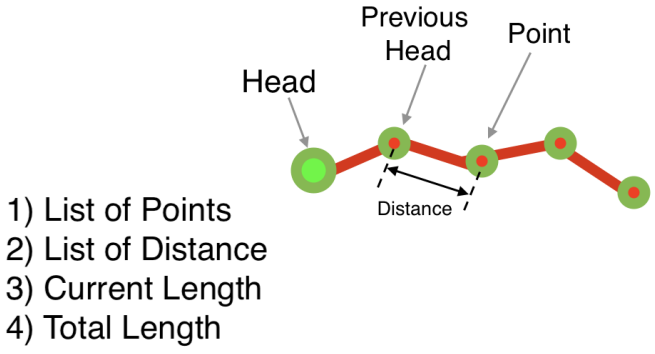

Figure 2. Schematic of the Snake

To reproduce the movements of the snake, we use the finger. With the movement of the finger, we create a point, while the task was to calculate the new length from the new point to the previous one, and then, based on it, remove several lines from the back of the snake as can be seen in Fig. 3

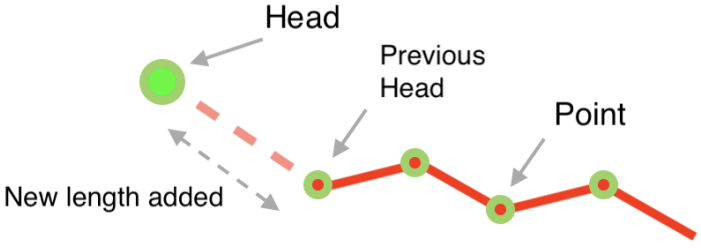

Figure 3. Schematic of the moving Snake

The next step is the length reduction of the snake. Assume that the total length of the snake after movement is 170, but the allowed length is 150. It means that at this moment the snake should be 150. However, by removing the last length of the snake, we still get more than the allowed length. Therefore, in this case, we remove the last two lengths of the snake, thereby making it shorter than the maximum allowed size as seen in Fig. 4.

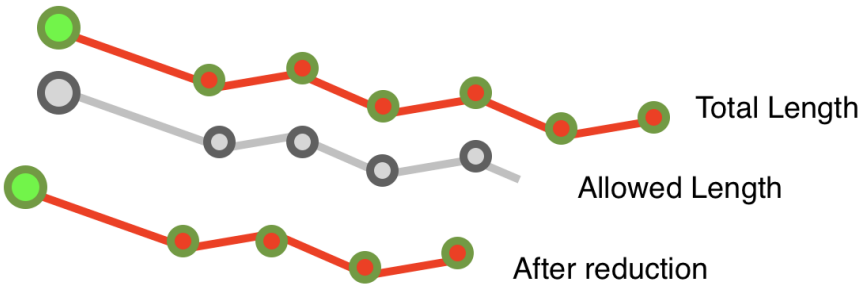

Figure 4. Length reduction

Next, we implemented the rules of the game, that is, we introduced the conditions for "Eating an apple" (Fig. 5) and the conditions for the "Game over".

```
88                  # Check if snake ate the Food
89                  rx, ry = self.foodPoint
90                  if rx - self.wFood // 2 < cx < rx + self.wFood // 2 and \
91                          ry - self.hFood // 2 < cy < ry + self.hFood // 2:
92                      self.randomFoodLocation()
93                      self.allowedLength += 50
94                      self.score += 1
95                      print(self.score)
```

Figure 5. Part of code for "Eating an apple"

The end of the game occurs when the head collides with the points of the snake's body. In order to recognize a collision, the distances from the point of the head to each point of the body were calculated, and if the distance from any point is less than the specified one, the program will recognize it as a collision and display a message on the screen about the end of the game as shown in Fig. 6. We uploaded a recorded video of the game on YouTube [6].

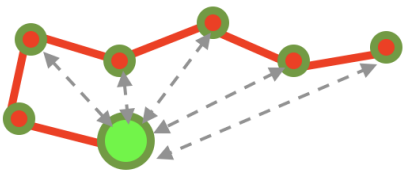

Figure 6. Schematic of checking for collision

2.2 Kohs Block design Test

The Kohs block design test is a technique that has been developed to measure intelligence in both children and adults. The American psychologist Samuel C. Kohs created such a technique.

Initially, cubes were used to diagnose the intelligence of a child. Using this technique, the mental abilities of children who had speech disorders or a delay in psychological development were analyzed. This technique is still used by psychologists and teachers.

The essence of the technique is for the child to fold patterns from blocks, relying on task cards. The child is given a card with a task (a certain pattern). Kid must fold the pattern from the upper faces of the cubes. The pattern must fully match the picture on the task card. Cards with tasks differ in the level of complexity, they should be issued in a certain sequence, from simple to complex. When diagnosing, they also pay attention to the time the task is completed.

In this work, the light level of this technique was used [Fig. 7 A, B, C]. A card with a task is displayed on the screen, consisting of four blocks, which are a definition pattern. And next to it are cubes of different colors. The task of the children is to transfer the cubes of different colors to a card with a pattern, while the pattern must match. The main distinguishing feature is that children use only their fingers to carry the blocks.

Table 1. Standards for assessing passing Kohs block test

Tasks	Points				
	7	6	5	4	2-1-0
A					45”
B					45”
C					45”
1	1-10”	11-15”	16-20”	21-75”	
2	1-10”	11-15”	16-20”	21-75”	
3	1-15”	16-20”	21-25”	26-75”	
4	1-10”	11-15”	16-20”	21-75”	
5	1-35”	36-45”	46-65”	66-150”	
6	1-55”	56-65”	66-80”	81-150”	
7	1-55”	56-65”	66-90”	91-150”	

Table 1. **Standards for assessing passing Kohs block test**

shows the grades and time limits for passing Kohs block design test. As you can see from the table, items A, B, and C are scored based on attempts. If the child completed the task on the 1st attempt, then he is assigned 2 points, if on the 2nd - 1 point. However, these tasks have a time limit of 45 seconds. While tasks from 1-7 are evaluated solely depending on the time of execution [7].

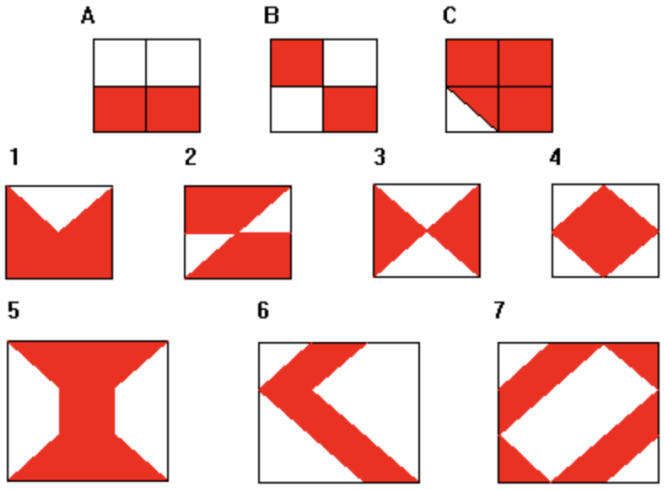

Figure 7. Task cards of Kohs Block test

2.3 Quiz

Visual support is the use of pictures or other visual objects to convey information to a child who has difficulty understanding and using speech. Photographs, drawings, three-dimensional objects, written words, or written lists can be used as visual support. Studies have shown the high effectiveness of visual support in autism. Visual support for children with autism spectrum disorders (ASD) is used for two main reasons. It facilitates communication and helps in teaching social rules [8].

It is for this purpose that the application Quiz was included in this work. This game presented questions and 4 possible answers to them. The child answers the questions by clicking on one of the answer options, when pressed, the child only needs to move his fingers as shown in Fig. 8. In our case, there are #4 (THUMB_TIP) and #8 (INDEX_FINGER_TIP).

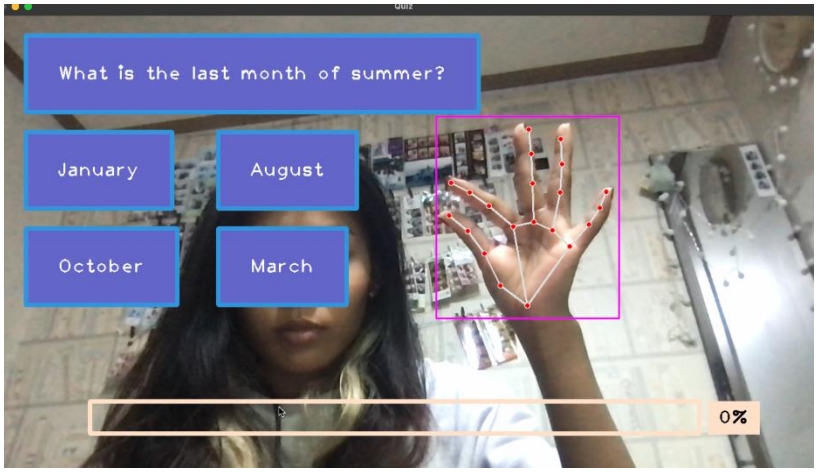

Figure 8. Quiz application

3. Conclusion

This work presents the process and testing of developing of Interactive data acquisition system based on Hand Tracking for children's cognitive abilities. The system is designed to automate and simplify the identification of ASD symptoms in children. In the course of the work, both advantages and disadvantages of this project were identified. The main advantage of this system is the saving time and resources for identifying signs of children's autism. Moreover, medical specialists can work with the received database without prolonged interaction with children, in order not to create a stressful environment for the child. The next important advantage is interactivity. Since in this work, Hand Tracking was used and the playful way of tests, children can enjoy testing. It will also help to focus the attention of the child and force him/her to concentrate on taking the test. However, the main disadvantage of this work is that a medical expert did not take part in the development of this application, therefore there is no opportunity to test this application on children with signs of an autistic disorder. Consequently, this work is expected to be continued for further research from a medical point of view. In the future, it is possible to correct the code and program interface of this application.

Acknowledgement

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