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Machine Learning based Solution for Predicting the Affective State of Children with Autism

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***Abstract*—Autism, or autism spectrum disorder (ASD), is a development disorder characterized by difficulties in communication and speech and it cannot be cured entirely. The hardest part for individuals with autism is to express their feelings and emotions towards others. This paper describes a mobile application developed using machine learning algorithms for multiclass image classification that needs as input just children's drawings. The solution is dedicated specially to children between 2 and 5 years old and predicts their emotional state. The application has been proved to be robust, providing a 80.6% accuracy of emotional identification, using Firebase AutoML.**

Keywords—autism, neurodevelopmental disorder, machine learning, image classification.

I. INTRODUCTION

Autism is a neurodevelopmental disorder and for people diagnosed with it, integration in a group, communication or expressing their feelings are very difficult to do. In 2018, approximately 1 in 59 children were diagnosed with ASD - Autism Spectrum Disorder - (as informs Centers for Disease Control). Boys are four times more likely to have ASD than girls. Most children are being diagnosed after age 4, though autism can be diagnosed as early as age 2 [1]. There is no cure for ASD, but early detection (from 6 months to 3 years) help children learn different skills as communication and social skills and help control their repetitive behavior. This study is focused on children between 2-4 years. Many studies concluded that children can express their feelings through their drawings. Parents try to understand their kids and find out what they really need or why are they upset. Of course, parents are not psychologists, and they also do not have time to document about "reading" their children's drawings.

Drawings can tell how a child interprets the world around him. So a simple drawing can express a child's social behavior, the relationship between his parents and other relatives, level of intelligence and perception, areas of interest, also if a child is sad, frightened or insecure and introvert.

Michael Wimmer [2] divides the evolution of the children's drawing in three stages: "Stage 1 - Spontaneous Scribbling", "Stage2 - Structured Scribbling", and "Stage 3 - Pre-Schemtatic Stage". Stage 1 refers to children's drawings of age 1 year and 6 months and of 2 years and 6 months, stage 2 - ages between 2 and a half years and 3 and a half years, and stage 3 - ages between 3 years and a half and 4 and a half years.

In stage one you do not really understand too much of the child's drawings, because it consists mostly of random lines, geometric forms, irregular shapes. In stage 2, their drawings begin to make more sense, so they can draw circles and human figures in their perception. In stage 3, children begin to draw flowers, human figures, making connection with their relatives, their pets, cars, their home and so on.

Color "red" symbolizes strength, enthusiasm, energy, but also danger. Children are keen to use this color in many drawings, so those who draw too often with red, are believed to be extroverted, and they love to be in the center of attention all the time. Blue is the color of peace and in children's drawings signifies good social skills. Green color is also used often in toddlers' sketches, for nature representation and means they learn quick, and they need to be left to express themselves as they wish.

Children usually have a favorite color. For example, a little girl was asked by her mother about her favorite color, and she responded she liked "all the colors in the world ". Michael Wimmer analyzes this response in her book, and tells the parent that she is very intelligent and the fact that in her drawing (Figure 1) used different colors as: yellow, blue, green, and red, means she is curious, and she must stay learn new things and get challenged intellectually.

Fig. 1. Child drawings with multiple colors

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Children with good social skills are considered to draw shapes closed to each other, the figures have the same colors that are prevailing and there exists an interaction between elements from the drawing. Very detailed drawings represent a sign that the child is pushed to work very hard, bold strokes means that they are stressed, broken lines can tell that the child is insecure or hesitating, and by contrast continuous, thickened lines can show you that the child is very confident [3].

The intellectual level of children can be measured by their drawings [4]. Children draw what they think of; from their imagination, they transpose their consciousness on paper, on the sketch, and various psychological aspects can be analyzed from there.

II. MOBILE APPLICATION DETAILS

"PandaSays" is a mobile application destined to children with autism and also to their parents and tutors to help them improving their communication. The application uses machine learning for label recognition, recognizing various objects (Fig. 2). All the details of the application can be found in [5]. The "Google Text-To-Speech" feature is created also for children that are susceptible to aphasia or they have other speech problems.

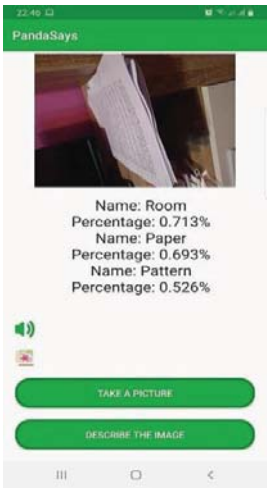

Fig. 2. Mobile application screenshot, representing object recognition

In the Drawing Module, the child has the possibility to draw in the application as seen in Fig. 3 and save the drawing. The Text-to-Speech Module, plays aloud what the child writes and Label Recognition Module consists in taking a picture and recognizing the objects in it.

The application is written in Java and Kotlin Programming languages and follows the MVP architecture (Model-View-Presenter). The models contains the data that is displayed to the user, views represent what the user sees on the screen, and the presenter handles the updates of the UI, according to the modifications of the data model (Fig. 4).

Fig. 3. Mobile application screenshot, representing drawing module

The application has 4 modules: Drawing Module, Label Recognition Module, Text-to-Speech Module, and Communication with the Robot module.

The communication with the Alpha 1P/1E is realized through Bluetooth Communication Protocols and the code is written in Python.

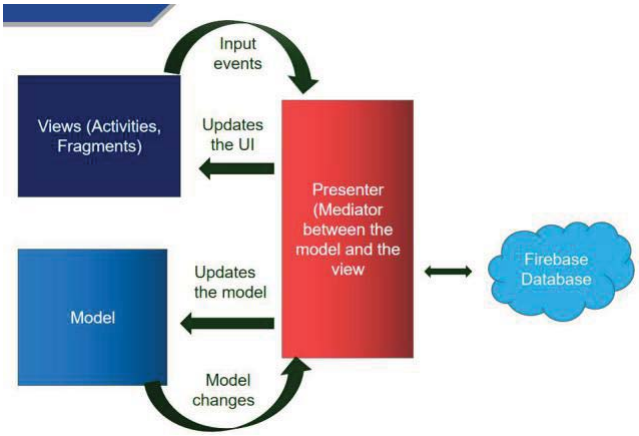

Fig. 4. Mobile application MVP architecture

III. DATA AND METHODS USED IN THE MOBILE APPLICATION

The mobile application is dedicated to children with ages between 2 and 5 years. It is called "PandaSays" [5] and it is a work in progress. The application has its own database of images. Firebase Database has been used for storing a large set of images, but the users can also upload their own drawing. The dataset of drawings contains 597 images. The problem is a multiclass one, because the dataset has five classes, representing the children's emotional state. The classes are: happy (167 images), sad (152), insecure (81), fear (102), and

angry (95). The representation is shown in Figure 5. It is noticed that the "happy" class has the highest number of pictures (167).

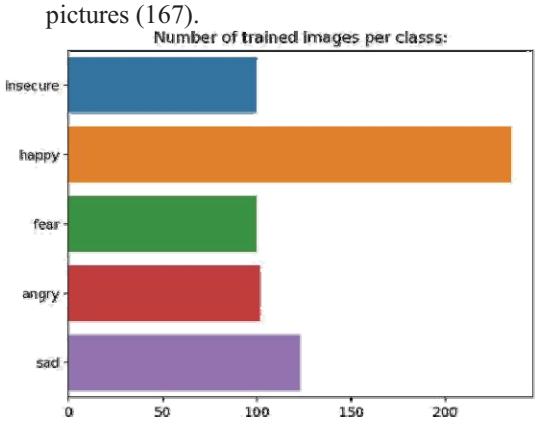

Fig. 5. Visual representation of trained images

For training the model, it was used initially AutoML Vision Edge [6], which is a Google product that helps building the machine learning model. The model is trained in Google Cloud. The metrics analyzed were precision and recall. For a threshold score of 0.5, the average precision of the model was 59.41%, the precision 62.26% and recall — 36.67%, which is not very high and means that are enough false negatives (Fig. 7). If we maximize the threshold score to 0.7, the model has a precision of 79.31% and a recall of 25.56%, so it is obtained a lower number of false positives, but the number of false negatives increases.

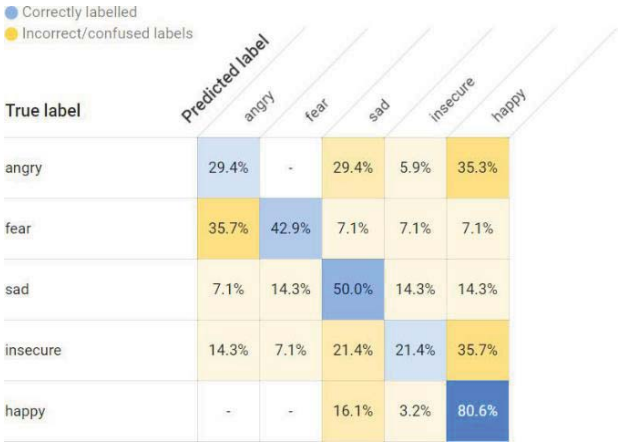

Fig. 6. Results of model classification with AutoML

As expected, "happy" class was labeled correctly with 80.6% accuracy, and the "insecure" class had the lowest accuracy - 21.4% (Fig. 6). The model has been tested with an image, representing "angry" state with 60.8% accuracy, as shown in Fig. 7. A Convolutional Neural Network model has been also built, that has total 426,340,605 parameters and 426,340,605 trainable parameters. Five convolutional layers were used for the model creation. Then Keras data augmentation has been applied by adding the following parameters:"rescale","shear_range","zoom_range","brightness_range","height_shift_range","width_shift_range" and "horizontal_flip".

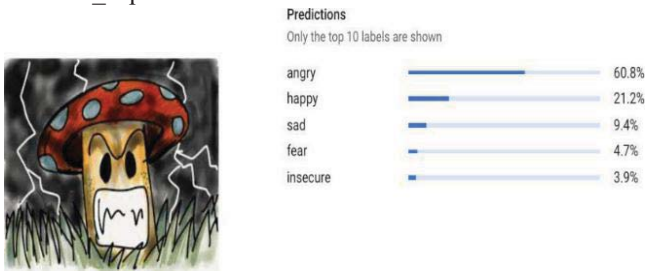

Fig. 7. Firebase AutoML Predictions results for angry state

The validation dataset and the test dataset represented 20% of the total set of images from the entire labeled data. The accuracy of the model prediction has been evaluated and results are shown in Fig. 8.

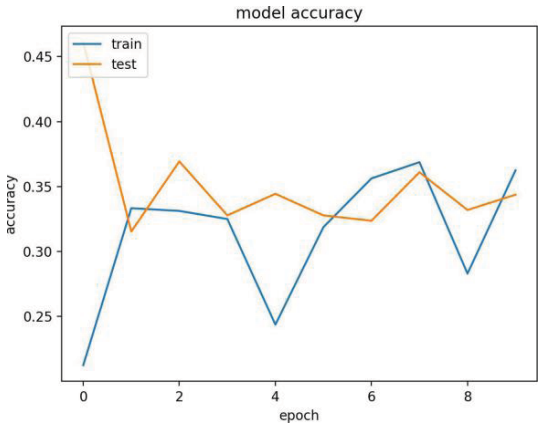

Fig. 8. Convolutional Neural Network model accuracy

The highest accuracy was approximately 50% for the test data with a number of 10 epochs (Fig. 8). The accuracy will be increased by adding more layers and more data. The model was tested with the same image (Fig. 6) as in Firebase model and the results were good - 96% predicted "angry":

- fear (0.000)
- happy (0.000)
- insecure (0.000)
- sad (0.034)
- angry (0.966)

For comparison with other machine learning algorithms, WEKA tool [7] was used. The algorithms chosen for the prediction were: SMO (sequential minimal optimization algorithm), J48 (a decision tree that consists of implementation of the Iterative Dichotomiser 3 algorithm), PART (a partial decision tree, that uses separate-and-conquer technique), NaiveBayes, Logisic-R (a class for building a multinomial logistic regression model) Function and IBk (K-nearest neighbours classifier). A 10-fold cross-validation was applied and a statistical significance of 0.5 (based on measures of training time, percent correct, and standard deviation). The results were weak, approximately 40% accuracy has been got.

The images need more processing and it needs to be worked on a better feature extraction.

IV. EVALUATION OF MOBILE APPLICATION

The performance of "PandaSays" application was measured using Performance Monitoring SDK. The app start trace was 545 ms on Google Emulator, 408 ms on Samsung Galaxy S10+, 498 ms on Samsung Galaxy Note 9 and 437 ms on Samsung Galaxy S9. app in foreground trace was recorded at 495 ms and in the background at 3.53 s. The maximum usage of User CPU, representing the time spent on running the mobile app in the user space is 77.58%. The memory allocated for the application for now is 5.9 MB. For testing the app it was used Robo Test from Firebase Console, in order to analyse the app's UI and to check if it crashes. The tests were performed on the following mobile devices: Pixel 4, Pixel 3, Asus ZenFone Max Pro M1, Asus ZenFone 4, and Huawei Mate RS. The tests all passed and there were no crushes. Time to initial display was 164ms on Pixel 4 and the highest time to display was achieved on Asus ZenFone Max Pro M1- 454ms. The frame rate was 18 fps and the CPU usage was 35.89%. The application was tested using a custom model build with VGG-16 convolutional neural network model and also with ResNet101V2, getting a 65% accuracy for state prediction on drawings.

V. CONCLUSIONS

Drawings represent important assets for gathering data about children's affective state and play an important role in helping children with autism integrate easier in society and start building connections with others from childhood. As it was presented in the previous sections, "PandaSays" was developed as a mobile application destined to children with autism and their parents as a virtual friend for improving their communication. The application is a work in progress and it will be improved further as it is shown in the next section. The dataset is not very large at this moment and this is reflected in the accuracy of model prediction. The image dataset will be increased to at least 3000 images for better accuracy in prediction, and also other machine learning algorithms will be applied.

VI. FUTURE WORK

It is known that robots help children communicate better what they feel. The mobile application will predict the emotional state of children with autism. After the state is predicted, the output will be sent to the humanoid robot (NAO or ALPHA 1P, 1E Ubtech Robots) and then, the robots will perform some actions in order to make the child feel better. If he is sad,for example, the robot dances, tells a joke, makes them laugh and so on. Fig. 8 presents the communication with the robots.

NAO robot is designed by SoftBank Robotics, and it can be programmed in Python and C++. It is also used in Healthcare industry. It has the following sensors: FSRs (Force Sensitive Sensors), Inertial unit, Sonars, Joint position sensors, Contact and tactile sensors, and also LEDs, camera, microphones and loudspeakers [8], [9].

Alpha 1P (Pro) is created by Ubtech and is a programmable humanoid robot also used in education. The robot has 16 servo joints, 3D visual programming software and PRP (Pose, Record & Playback) function. The Ubtech robots have android and iOS mobile applications [10]. In order to program Alpha 1P robot, a client-server communication will be established using Bluetooth Communication Protocol and Raspberry Pi 4.

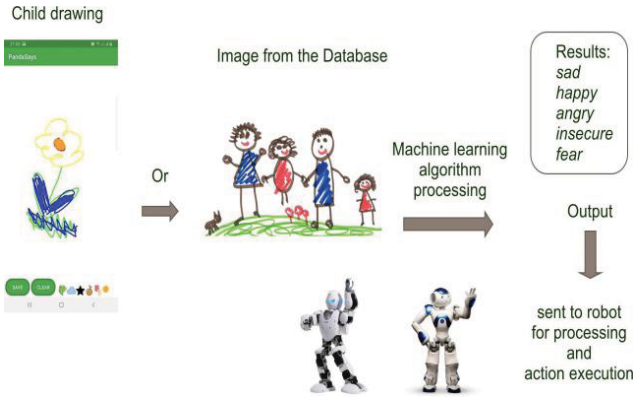

Fig. 9. Communication between mobile application and robots

Another module that will be implemented will be dedicated to an augmented reality game for children. The game will have a user-friendly interface and its main goal is to increase children communication skills and learn to express their feelings. For this module it will be used ARCore and OpenGL, for rendering 2d and 3d vector graphics. ARCore is created by Google for developing augmented reality applications [11].

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