Intelligent Educational System for Autistic Children Using Augmented Reality and Machine Learning

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Abstract. Autism is a severe disorder affecting 1 in 160 children globally. Autism comprises of several development disabilities such as social, communicational and behavioural challenges. Children being diagnosed by the autism mainly face a hard time studying curriculum in inclusive classrooms based on their IQ level and the autism levels. Although, different strategies and learning teaching tools are available to support autistic children, only few systems aid them in learning efficiently, and are not highly interactive. Thus, the proposed Intelligent Education System primarily focuses on providing interactive learning experience to the autistic children with IQ level >50% and efficient teaching assistance to their tutors using augmented reality and machine learning in both English and Arabic The capability of the education system to perform an action, allows the autistic child to interact with the playable sand and gain interest. In learning stage, once the child scribbles on the sandbox, Kinect 3D camera captures and recognizes the drawn image. After the refinement and recognition of the image using OpenCV and classification model, the stored set of real world object are projected on the canvas. Besides, a webcam captures the facial expression of the child, and emotion detection algorithm determines the reaction of the child. Based on the child's emotion, the current object is projected and pronounced three times to enforce better learning. Once the instructor chooses the language and character to be taught using the developed mobile application, the system displays it over the sandbox and further three objects that starts with the particular character are pronounced and projected. The system is tested rigorously with large set of users, and the results prove the efficiency of the system and happiness of the autistic children in better learning.

Keywords: Autism spectrum disorder · Autistic children · Education · Machine learning · Augmented reality · Image processing

1 Introduction

Autism or autism spectral disorder (ASD) is the most prevalent disability that the children of our generations are facing. According to recent research, autism now affects 1 in 160 children globally [1]. It is a complicated neurobehavioral disorder that

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includes impairment in interaction and communication skills combined with rigid, repetitive behaviours and obsessive interests. Autism is found in individual of every race, age, gender, etc. Often children with autism lack empathy and frequently involve in self-abusive behaviour; Biting one's hand or head-banging. There is a growth in the prevalence of the ASD globally. In 2011, Centres for disease control and prevention identified that 12 per 1,000 children are being diagnosed with the stated disorder. Estimated number of autistic disorder cases has increased massively, from 50% to 2000%, i.e. nearly about 67 million people around the globe [2]. The cross-sectional study conducted estimated about 1.4 out of 10,000 children aged 0–14, are found to be autistic in Oman [3]. 74.3% among those are boys. Hiding may be a potential reason for the low prevalence rate in Oman [4]. The families with an autistic child often tend to hide him/her from the outside world, which limits the child from attaining education and medical facilities. As per Dr. Said Al-Lamki, Director of Primary Healthcare, 1 out of 68 children in the sultanate of Oman are being diagnosed with autism [5]. With such high prevalence rate present globally, there is an urgent need to develop a system which can help in better management of kids with autistic symptoms. Several acts were passed to support the children with autism and development disabilities; No Child Left Behind and (2002) and Individuals with Disabilities Improvement Education Act (2004) [4].

Autism children face a hard time studying the curriculum along with other children, nowadays many of the schools have special classroom and a special attention is shown by the teachers for them. Though, the teaching techniques are still not productive and interactive. Several researchers have proposed different educational systems, to facilitate the better learning of autistic children using various methods and procedures. Decristofaro [6] recommends various evidence-based strategies for the tutors to proficiently educate the autistic children in inclusive classrooms, like peer-support, scribing, visual schedules, TRIBES Strategies. Two teachers claimed that adopting these strategies have improved the learning capability of the children in their classes. However, interviewing only two teachers may not be sufficient to gather précised information. A computer based program was developed, based on the daily activities performed during eating and playing, to determine the enhancement in the communication functionalities of the autistic child in a classroom. The system was implemented in a local special education school, by employing five autistic children, who are diagnosed with communication disabilities. Bernard-Opitz, Sriram and Nakhoda-Sapuan [7] idea of using pictures and animations was further enhanced, by developing a Virtual Environment of a café and bus to enhance social understanding among the autistic children. The study was carried out with the purpose of exploring the potential of using virtual environment to be used as an educational tool for autistic individuals.

Artificial Intelligence (AI), is a way of developing intelligent machines or a software, similar to humans. AI continuous to be a major trend in digital transformation in 2018, by affecting every industry and business with rapid advancements in technology [8]. AI has contributed a lot in the field of education, as a report suggests, an increase of AI in education sector will be 47.5% during the year 2017–2021 in United States [9]. A research has been carried out by Smith et al. [10], which discusses about blending human with the artificial intelligence, in order to aid the autistic children through the development of several AI powered tools. The research emphased on the technology

named, ECHOES, to enhance social interaction skills of the autistic children. ECHOES was deployed and tested. Children with or without autism were able to interact and perform the activities. However, the results may not be generalised and applied to all autistic individuals due to limitations in each person's highly diverse non-uniform qualities and comorbidity.

As prevalence rate of autism in Oman is increasing from time to time and only a few special need schools and facilities are provided for the education of the autistic children and most of the families are not interested to send their children to those schools. Furthermore, the analysis of the previous literature encouraged the idea of the intelligent education system, as the results of the previously used strategies were impressive. However, the previous system does not allow the child to freely represent their thoughts in an interactive playable environment for the purpose of learning. The Educational System will certainly help the autistic children to learn independently by being at homes, and will support the parents and caretakers of the child to teach the children effectively in both Arabic and English without any distress at low cost.

The remaining part of this research paper is organized as follows. Section 2 discusses about the overall design of the proposed Intelligent Educational System for Autistic Children (IESAC). Section 3 explains the design and methodology adopted in developing the system. Further, a Sect. 4 discusses the implementation details and Sect. 5 covers the result analysis followed by conclusion in Sect. 6.

2 Design

This chapter provides an overview about the design of the proposed system, including flowchart and a 3D model.

2.1 Flowchart

In order to initiate the intelligent autistic learning system, the system must be switched on and the autistic child must be positioned in the right place before carrying any further operations on the system. Once the system is calibrated, all the inputs provided to the intelligent autistic system are captured using the web application. The system then initiated either the teaching or learning process based on the input provided. If the teaching module of the project is initiated then the user must select an object from the drop down list provided on the web application to be displayed on the sand along with the respective audio (Refer to Fig. 1).

Moreover, if the learning module is initiated then the system is as kept on hold, waiting for the autistic child to scribble on the sandbox and raise their hand. Meanwhile, the webcam facing towards the child captures the hand gestures of the child. Once the child raises their hand, the Kinect camera would measure the depth of the play sand within the sandbox, to determine the shape scribbled by the autistic kid. Further processing would be done through image processing, to refine the image and extract the foreground from the background. The processed image is then fed into the machine learning model, through an API call to predict the object.

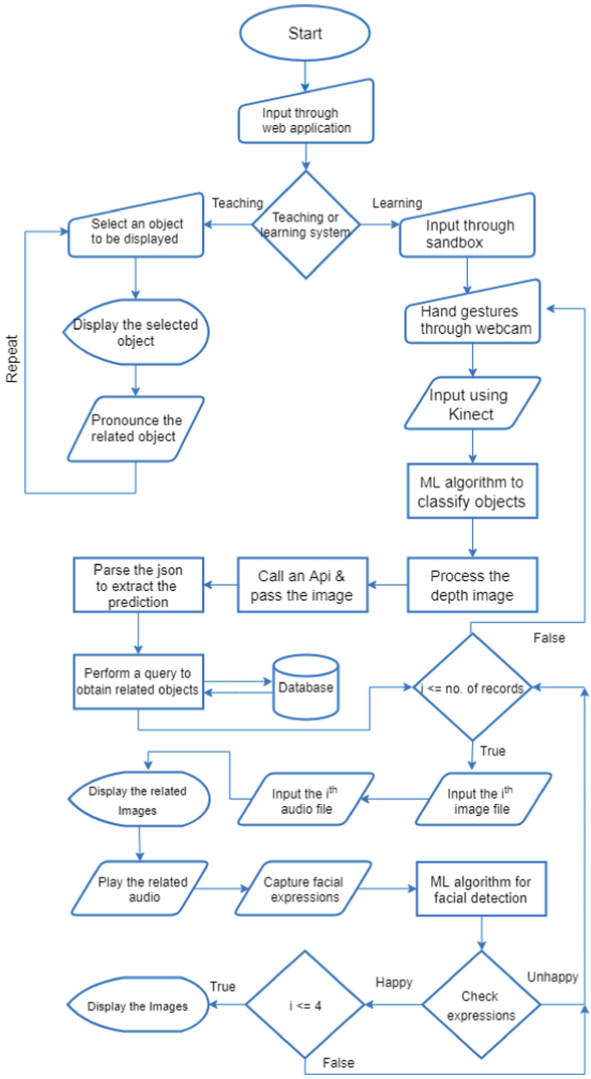

Fig. 1. Overall flow of the IESAC

Once the object is predicted, it is sent as a parameter in a database query to obtain the objects related to it. Each object is projected on the sand box using a projector and its respective audio is played. Further processing is based on the child's reaction on the prediction made by intelligent autistic learning system. A webcam is used to constantly capture and monitor the facial expressions of the autistic child and process it on a machine learning model to determine the emotions. If the projected object is of child's interest, positive emotion would be captured; therefore, the object will be displayed for a longer span of time. In case, if the captured reaction is against the child's preference, then next object from the database will be projected and the process would be repeated.

Once after the entire process has been completed, the system would jump back to the initial phase, to allow the child to scribble the object on the sandbox.

2.2 3D Design

This image demonstrated the 3D design of intelligent autistic learning system (Refer to Fig. 2). It showcases all the components that are used and attached in the intelligent autistic learning system. Starting from the main component of the system being the sandbox, which carries the entire sand. Attached to the sand box is the short throw project on top of the system, which is projecting all the images from the machine learning model onto the sand. Providing the augmented reality on the sandbox. Along with the projector, the Kinect 3D camera is also attached on top of the system, the Kinect 3D camera is used to perform image processing for autistic learning system. A small camera is attached on the centre of the system which is capturing the gestures and expression of the autistic child and makes the decisions accordingly.

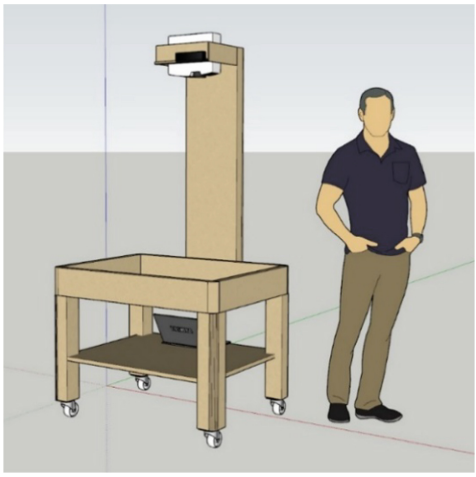

Fig. 2. 3-D design of the educational system

3 Methodology

In this chapter, the methodology adopted and the phases of implementation are clearly defined and illustrated, following a structure in which the tasks are undertaken.

3.1 Phase 1

Initially a deep research was done based on machine learning and artificial intelligent in the field of medicine. Many different research papers were reviewed in order to build an efficient and enhanced system without the limitations being faced by the previous systems in the same field. In order to better understand the issues being faced by the autistic child and in order to understand the autism spectrum disorder, different autistic learning centres were visited. Along with the visits, the teachers and students were interviewed in order to understand autism and build the optimum system to aid this disorder.

3.2 Phase 2

Secondly, a process of requirement analysis and gathered all the components was implemented for intelligent autistic learning system. In order to obtain an efficient and optimum solution, a detailed research on each component was done. The outcome of the detailed research concluded that the components that were used in the implementation of this project were the most suitable components for intelligent autistic learning system.

3.3 Phase 3

After gathering all the equipment that are suitable to carry out the implementation process of this project. Implementation phase was started of the project, where each and every component was integrated with the system; this process was a one by one process, in order to test the components integration. Along with the integration of components, the python libraries and code were written to execute machine learning and augmented reality of intelligent autistic learning system. The implementation of this project is done in two languages which was challenging as the objects of both the languages were often similar in nature, which challenged the performance and prediction of the machine learning model. This issue was mitigated by using more datasets of both the languages and often the dataset was captures by drawing the object on the sandbox. It was a long procedure of enhancing the machine learning model in order to make the system intelligent enough for its deployment.

3.4 Phase 4

Upon the completion of integration process of intelligent autistic learning system. The crucial process of testing and debugging was executed where the system was deployed in autistic learning centres and the testing procedures were carried out. This process included the hand on experience of intelligent autistic system with teachers as well as autistic children. This phase enhanced the system by using the approach of trial and error. Different issues were encountered by having real time deployment of the project and the working principles. These issues were then resolved by enhancing the python code and using excessive amount of dataset in order to optimize the machine learning predictions of the system. As, the lack of training data resulted in lower accuracy of the prediction.

The phase of data capturing was repeated several times to gather excessive amount of dataset. Alongside, the scribbles by the autistic child were recoded for the purpose of research and enhancement of the model [11].

4 Implementation

To extract the Kinet Camera frames it was programmed in python with the necessary libraries for the component. Then the kinect captures 3 different streams, namely, color, depth and IR. Through SyncMultiFrameListener the computer receives the frames of

the 3 streams. Mainly the depth frame was used to comprehend the diagram on the sand. Kinect camera was operated through Libfreenect2 library. For example, to close/open camera.

The stored frames from the Kinect streams, hence, each frame was processed against an image processing to extract a meaningful image. Set of pre-defined functions in the OpenCV library were utilized to convert the depth frames in a numpy data type, before applying the equalizeHist() function to adjust the colour contrast of the frames. The frame is later masked to set the background pixel values to zero, and further the threshold effect is applied on the frame. Number of frames were extracted on a continuous loop every 3 s and alongside, the sand was scribbled continuously forming different set of images (Refer to Fig. 3). The images were further refined and classified manually before training the model. The classification model was trained employing a third party application, named as Ximilar App. Within the Ximilar app, a new task is created which has a unique ID and Token. Within each task, several categories of images can be defined and the images can be uploaded separately for each. Each category needs be labelled with tags. Once after the categories are defined, other options needs to be configured, to optimize the model. Finally, the model would be deployed, which is later called trough the API calls. After the deployment of trained model, the processed image is passed through API call. An authorization token and taskID is required in API header to pass API. The response of API is in JSON format is parsed to obtain the prediction.

Fig. 3. Processed image

A web application was developed to control the flow of the system by the tutor, such as start/stop the system, display specific objects, etc. Therefore, to design the web application, a readymade bootstrap template was implemented. Moreover, a local database server was configured in the system. Set of related objects were gather and manually stored into the table to perform a query, with the prediction as a where clause. Numbers of records were obtained against each query, which were processed one at a time. The web application has been developed into a fully functional unit by implementing the server-side codes. A python library named as Flask was implemented in this phase, to execute the server side codes during run-time.

Alongside, the Emotion Detection model was obtained from GitHub and was than trained with the dataset. The dataset consist of 35887 greyscale images of size 48 × 48, with total of seven emotions; angry, disgusted, fearful, happy, neutral, sad and surprised. The model was developed using tensorflow, tflearn and keras libraries. Finally, the system was taken for the acceptance testing by the tutors and verification was done by the set of students, 10 + college staff members and the autistic kids.

5 Testing

Throughout the development of the system, it has undergone several types of testing. Several types of testing methodologies and readily available CASE tools are used to test the computer based systems depending on the type and complexity of the system. The Intelligent educational system was divided into two major phases, the functioning of object classification and the functioning of emotion detector model. Therefore, two system tests were performed, each with the gap of 2 months. The interaction of the tutor was required, as no such requirement document was maintained.

To perform the acceptance testing of the intelligent educational system, a visit to an autistic centre was arranged on 29th May, 2019, to allow the autistic kids use the system. Total of 6 participants were involved in the testing of the system. 4 out of 6 participants were male students, within the age group of 5–9. Whereas, the female participants were 4–8 years old. As per the teacher, the kids were not taught English, and only knew the Arabic alphabets and numbers.

The autism level indicated in the Table 1 below, was provided by the tutor and was reported to be obtained using the Childhood Autism Rating Scale (CARS). CARS is an autism assessment tool, to diagnose the autism in children and scale it [12].

Table 1. List of participant along with autism level

Name	Age	Autism level
Participant 1	7	27
Participant 2	9	35
Participant 3	4	30
Participant 4	5	37
Participant 5	7	31
Participant 6	9	30

6 Result Analysis

The improvement in the learning of the autistic kids through the use of educational system is evident. The results achieved by the development of this project bring positivity and motivation to further enhance the project. The intelligent educational system is developed to aid in the learning of the autistic kids, enhance their skill set and build their sense of touch. To ensure the efficient learning of the autistic kids, the system should run smoothly and predicted accurate results, within optimal time duration.

Whereas, in the learning phase, the child should interact with the system. Outcome of the implemented system is successful, as demonstrated in the Figs. 4 and 5. The child scribbled the desired object and the webcam was simultaneously capturing the hand gestures. The emotion detection model was concurrently running in the local machine to capture and store the emotions of the child. However, it was difficult to capture the emotion data, as the child is not expected to be within the frame at all times.

To gain more experience regarding autism and autistic behaviors through interaction with the autistic kids, the autism centre was visited several times.

Fig. 4. Teaching phase with participant 1 in English

The visit to the autistic centre was not only for the purpose of testing, it was to gain more experience regarding autism through the interaction. However, during the testing phase, the emotions of each of the kid were recorded for the purpose of analysis. Participants with less autism level, were the only participants to move to the learning phase within the system, after completion of the teaching phase. They were able to scribble the objects shown on the sand, and was able to name the objects clearly. Moreover, they were able to scribble 2 out of 3 objects dictated by the tutor during the learning phase [13].

Few participants were comparatively not scared to interact initially. They took a little more time to scribble in the sand as compared to others. One of the participants was piling up the sand on the object shown, instead of digging down. Although, the system is designed to work on the depth of the sand, thus this would be a point of further research, to understand the behaviour of the child. Participant with extremely high level of autism were scared of the loud audio, due to which they did not interact with the sand much. Yet, they were excited to see the displayed objects and was able to repeatedly pronounce the words.

Fig. 5. Teaching phase with participant 1 in Arabic

As per the tutor, "This is a good project! There are some children that will be attracted to the project and even without me saying anything; you have seen how the children were happy and interacting with the project. So yeah it will be a new thing and it will not only cover the academic learning only, it will also increase their knowledge and sense of feel (because they play with sand) so it will be a very good project."

On an average, 4 out of 6 participants took 2–3 min to get comfortable with the system, and get involved in scribbling the sand. Fearfulness was observed in 2 out of 6 participants, due to the loud audio or the display of frightful objects such as ants & insects. This required some time for the kids to get used to of the audio; however, 5 out of 6 kids were able to speak out the alphabets by listening to the audio within the first 3–5 min of interaction.

7 Conclusion

In conclusion, the detailed study about autism, the prevalence worldwide and prevalence within Oman is discussed. The problems faced in managing the autistic children were emphasized and the number of strategies and tools available were further discussed in detail. The procedures, findings and limitations were highlighted for each. By keeping in mind the major limitations in the existing education systems for autistic children, an intelligent education system has been designed and developed which aids the interactive teaching and learning of tutors and children.

The developed system was tested by autistic children in a local autism centre, Muscat. The results of the test showed a clear positive impact on the children because the children showed an interest on the project, and they have engaged in learning through the system. However, the centre mentioned that the proposed system will have a higher impact on the autistic children in Oman. Furthermore, the instructors at the centre commented that the proposed system would help the autistic children in the academic learning as well as increase in the sense of feel and overall attention and hence the main aim of the project is successfully accomplished.

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