Multimedia Augmented Reality With Picture Exchange Communication System for Autism Spectrum Disorder

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Abstract
Autism or Autism Spectrum Disorders is a pervasive developmental disorder caused disruptions in thinking, feeling, hearing, speech and social interaction. For this reason, children with autism need special training to improve their ability to learn new skills and knowledge. This work aims to propose a new training system using augmented reality for the training techniques of Picture Exchange Communication System (PECS). This system helps in teaching children about new pictures or objects together with related keywords or phrases that fit the way deep with fast interaction. Basically, the system is responsible for teaching, monitor and strengthen or ask for actions that support their children to learn and repeat the correct behavior. Hardware setup consists of a projector, which can convert all the planar surface into a display device and a camera to monitor the actions of children by tracking their hands. This arrangement provides feedback on the virtual desk with the actual movement of the child's hand using hand visual detection and tracking algorithms.

Keywords
Augmented Reality, Autism Spectrum Disorder, Hand Detection and Tracking

I. Introduction

Autism Spectrum Disorder (ASD) is a general term for a group of complex brain disorder, which is characterized in varying degrees by difficulties in social interaction, verbal and nonverbal communication and repetitive behaviors. Autism can be associated with intellectual disability, difficulties in motor coordination, attention and physical health problems. It is necessary to decode the children's behavior to diagnose and treat disorders of behavior and development at an early stage. A detailed study of decoding the behavior of children is done by J.M. Rehg et al. [1], determines whether the children generate key behaviors (such as seeing partners, smiling and gesturing) and assessed the degree of involvement in a dyadic social interaction.

On the other hand, children with autism have a tendency to excel in music, mathematics, art and visual skills [1]. It is necessary to understand their superior skills and skills that require special training. Thus the training system should be essentially attract attention and interest. The fact that children with autism are quite interested in the device technology (eg computer, PDA, etc.) rather than conventional training tools such as pictograms [2], making work AR tool suitable for the training of ASD children. There has been a great effort from augmented reality and virtual communities in developing entertainment, training and analysis tools for ASD children.

Some ideas and new projects have been suggested to help ASD children to develop new skills and identify their deficiencies. For example, the use of AR has been proposed by Z.Bai, where children pretend to play with toys plus. This system uses a monitor screen to create content is added and the camera for motion detection marker in the work table [3]. Another study named Pictogram Room proposes a set of educational video game using Kinect for gesture recognition camera body and the monitor screen where the image is reflected by the number of players and music add graphic elements [4]. In order to guide the learning process exergame virtual reality to deep torso motion faster than autistic children studied [5]. The results reported that the children will practice more often with a high level of enjoyment if such games are available on a regular basis. These results indicate that the technology AR creates a positive improvement in terms of enjoyment, engagement and imaginative skills development and learning in children with autism.

Considerable effort has been spent of researchers around the world in the development of training techniques to help autistic children in teaching new skills that can improve their quality of life [6]. One of these techniques is Picture Exchange Communication System (PECS). The principle of this technique is based on the idea that every correct behavior is more likely to be repeated if it is followed by some sort of reward. One method is the most famous PECS discrete trial was introduced by Ivan Lovaas [7]. discrete trial has three main steps: (1) Instruct the task to the child, (2) Monitor child's response, (3) Strengthen measures or ask the child if necessary. Below the discrete trial training begins by showing a set of pictures or a real object that a child should learn/ acquire. Kids are asked to associate keywords with their images or objects. child monitored by encouraging or strengthening based / action done. These steps are repeated several times by shuffling the image or object and ask them to show key items. Recurrent training process along with prizes motivate children to learn and remember the key words associated with the image or object.

Learning methods can be improved by using AR that will help children improve their attention in the training process. In this paper, the AR system for training autistic children is proposed. in outline, the system involves the teacher and children with autism as a major role player. Children with autism interact with the system and the teacher guides the child. Parents of children with autism can also be involved in monitoring and aware of their progress. Researchers and psychologists are more interested in the data collected from these systems to improve training measures and to analyze the performance and behavior of children when they encounter a particular stimulus. It can help them decide on the type of training needed to improve the level of learning of children with autism. It is important to make the child comfortable and attentive to the system. On the other hand, teachers and researchers must have the proper tools to assess the performance and progress of the child. Therefore, it is necessary to have a training system for recording and reporting methods are good.

The proposed system works in the following way; The first begins by displaying a series of pictures and then instruct children with keywords must be related to the rendered image. Child action was monitored using detection algorithm hand and right action strengthened to motivate and encourage them to respond in the same way again. In the case of a time out or show a wrong answer, the system will ask to highlight the image until the child asked to

do it right. This will make a positive reinforcement for children to imitate and respond to the challenge. This system also records the action of the child and the time required to complete a training session for the purpose of analysis and research.

The rest of the paper describing the proposed AR system and details of its implementation with all components, hand detection and tracking algorithms. Finally, the experimental results in terms of detection and tracking algorithms hands will be evaluated the performance of the prototype AR system developed.

II. Augmented Reality System Overview

The main objective is to develop a user-friendly AR system that can assist ASD children in learning new skills. This training system stimulates the child to imitate, interact, and respond to the basic request such as keyword association and matching sentence to a picture or an object. It is a well established fact that any equipment that is to be used by children must be robust enough to withstand their abuse, something that becomes even more important in the case of children with ASD. Thus it is preferable to have a system that provides all the training information sparingly to them without any intrusive hardware interactions. Additionally, the system must be user-friendly with the augmentation on the real scene with real object. All the aspect mentioned before, make the use of PDAs, Tablets and other handheld devices unsuitable for this application. On the other hand, a projector as display interface would satisfy these requirements as it allows converting child's usual working table into a display interface.

Following the common practice in discrete trial training, we propose to use a table as working area where query pictures are displayed or real objects are placed. A camera is used as a natural user interface to monitor the child's action by detecting and tracking hand. Thus, the system provides a visual feedback on the table by tangible hand movements with no barrier between the child and the system. This can make it easy for the child to interact effortlessly without any requirement to practicing the new system.

The system setup works in the following ways: (1) the projector starts by displaying three pictures on a conventional table, after which the child is instructed by the system to point out at one of the projected pictures; (2) the child starts to move hand to point out the queried image; (3) the system examines the child action for its correctness and then reinforce or prompt based on the evaluation.

III. Augmented Reality System Implementation

The AR system implementation details can be seen at each of the steps involved in training for ASD children.

Instruct - The system uses a projector to convert any table into a virtual display area where a set of pictures or objects are displayed. The system instructs the task to complete at each training session. The projector helps the child to interact on his/her normal working table with the minimal change due to the virtual display content. For this purpose, a short throw table projector is used in the proposed system.

A. Monitor

The system uses a camera to monitor and track the action performed by the child. In most cases, children do not like to attach fiducial markers or color gloves on their hands. They may either remove or get distracted from their task. Hence, it is important to have a natural interface between the child and the system. Therefore the hand is considered as a major cue to detect their action. Another important task involved in this matter is the transformation of hand position from camera or pixel coordinate system to the projector or table coordinate system so that appropriate content can be properly augmented or highlighted. In this work, homography based transformation is used that makes the system simple and fast to initialize.

B. Reinforce or Prompt

It is very important to reward or highlight the correct answer that will help them to learn. In this AR system, the correct action is accomplished by rewarding the child with verbal praise and also by playing music of their desire. The system also realizes any delayed or incorrect action performed and prompts by highlighting the correct answer to the child.

During a survey of the training for autism and after some discussion with the psychologist, the need to log all information during the session. Such information is vital that effective and appropriate training can be tailored to each child's needs and their evolution. The proposed system also records information about the child's profile, achievements, as well as the actions taken by the child during the sessions for analysis. Hand movements were recorded and the track can also help psychologists to analyze the behavior of the child. In the following section, details of the implementation of the hand detection and tracking algorithms in detail.

The child action is tracked using hand detection techniques to analyze the correctness of response, to identify any random behavior and to store the hand trajectory information in the database for later use. It is also well known that the children with ASD perform unwanted hand movements to elude from answering the question. Also, the psychologists are more interested in analyzing the hand trajectory information which in turn helps them to understand the progress of child's learning rate. This makes hand detection and tracking algorithm to be a crucial element in our system.

There are several methods available for the hand detection, starting from the skin color based detection to advanced supervised and unsupervised learning methods [8]. All these methods fall under three categories: Invariant feature based approaches, Template matching and appearance based approaches [9]. Global appearance based adaboost-learning algorithm with Haar-like features hassuccessfully demonstrated to accomplish real time face and other object detections task.

The available hand detection techniques are influenced by the different hand gestures, complex hand motions and environmental variations such as lighting, occlusion and cluttered background. Under these conditions, the detection algorithm can fail to give any result. It is always preferred to have a tracking algorithm that can ake use of previous detection to predict the hand position in the current frame. Also, these tracking algorithms are defined to estimate the trajectory of the hand in an image as the child moves hand around the table. There are three major types of tracking: point, kernel and silhouette tracking. The hand detection in consecutive frames can be represented by points and thus it falls under the point tracking category. This work adopts filter, the statistical method for hand tracking.

The calibration between camera and table plays an important role in augmenting appropriate content at correct location on the table. It is required to relate the hand detection in pixel coordinate system to the projector or table coordinate system using a transformation matrix. Since the table is a 2D planar surface, the homography transformation is used for easy and fast calibration. This homography transformation helps in fast calibration and system initialization aiding towards converting

any planar surface into a display.
The homography transformation matrix is used to convert the hand detection result from the camera coordinate system to the table coordinate system which is then compared to see any overlapping within the query images. If it is lying in the query image asked to the child then the action is rewarded. Otherwise, the system will highlight the query image to make the child learn. Either the child action is correct or not; a plot showing centroid of the hand gesture is saved for later analysis.

IV. Experimental Demonstration

The hand detection training is a critical point for the success of the detection results. To carry out this training, it is necessary to have a set of positive and negative (background) samples. A small dataset of children hand images was created for this reason. The hand dataset consist of 1800 images from five children (aged between 5 to 12 years) taken under different lighting conditions and view. The background dataset consists of images where tables of different textures, lighting and projector on condition were used. The cascade was trained with the 15 stages and the resulting trained cascade is used for hand detection in remaining part of the paper.

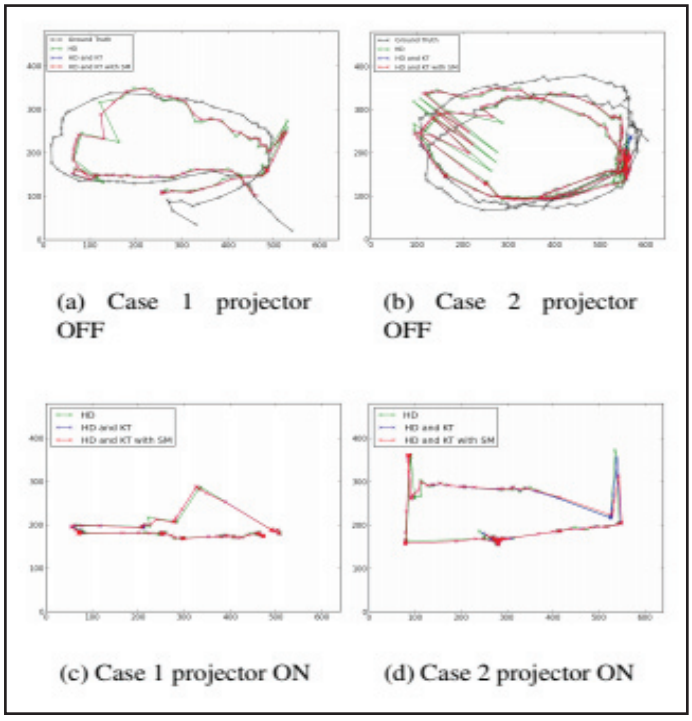

Fig. 1: Results From Hand Detection

The performance of hand detection is shown in fig. 1. These plots show the hand track in four video sequences with projector OFF and ON. In the projector ON case, three images as shown in fig. 2 was displayed. The total no. of frames considered at each case with the no. of frames that has hand inside and results obtained from different algorithms with projector OFF and ON condition is summarized in Table 1. The hand detection performs very well when the projector is OFF wherein the improvement produced by the tracking algorithm is not appealing. It is clearly seen from the Figure 1 and Table 1 that the hand detection results decline drastically between the projector OFF and ON scenarios. Also, there is a notable amount of increase in false positive using only hand detection. In this scenario, the tracking evidences a significant improvement in the overall system performance.

In spite of the improvement created by the tracking algorithm, there is always a high level of possibility to have false positives. This is evidenced in Table 1 by comparing frames where the hand is present, the tracking results and its false positive in terms of numbers.

Table 1: Results From Hand Detection

Case	Total No. of frames	No. of frames with hand	HD			HD & KT		
			Tot.	FP	FN	Tot.	FP	FN
With Projector OFF								
Case 1	98	78	70	3	10	84	11	4
Case 2	177	168	152	2	20	177	16	5
With Projector ON								
Case 1	195	167	54	4	121	187	32	23
Case 2	135	122	50	2	85	120	19	14

In order to reduce the number of false positive, the similarity measure between the current frame and the previous frame with hand detection output is used. The similarity measure aims to reject the frame where there are huge variations with the higher possibility of hand being moved out from that location or even out of that frame. The performance evaluation of this approach has indicated a decrease in number of false positive and false negative, as in Table 1. Further, by comparing the results from tracking with similarity measure and frames with hand inside (see in Table 1) significantly shows that there is a correspondence in terms of numbers. This strongly suggests the usage of hand detection and tracking with similarity measure for the proposed AR system.
The proposed AR system setup with a camera, projector and working table arrangement in the laboratory environment. At first, the system allots 3 seconds to complete the task by moving the hand over the queried image or object. Whenever the child moves hand over the query image, the system acknowledges the correct action by rewarding them with verbal praise or by playing their desired music. If there is no hand detected on the query image within 3 seconds, the system prompts by highlighting after which the child is again given with 3 seconds to complete. All hand action performed during this session will be saved to facilitate the analysis of the child's learning progress by teachers and psychologists. Also the correctness is evaluated not by just considering one frame over the queried image, i.e. the child has to keep hand continuously over it for at least 1 second. This helps in avoiding the wavy and unwanted hand movements made by the child.

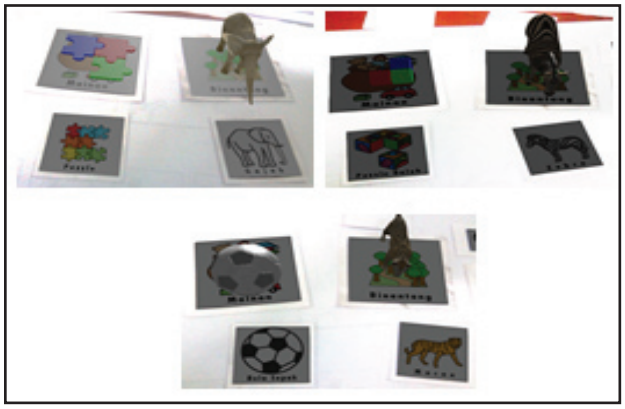

Fig. 2: The System's Working By Displaying Three Images and asks the Child to Associate With a Keyword

The testing was carried out with children that do not suffer from autism to verify and validate the algorithm working. Firstly, the child was asked to show an elephant image out of the three displayed images (Fig. 2(a)). The child selects wrong image (apple in this case) and the system prompts the correct answer as in fig. 2(b). The system rewards the correct action by showing cartoon and verbal praise or playing music as in fig. 2(c). Similar to Fig. 2, the child was asked to show an elephant toy (see Fig. 3). The correct answer is reinforced or highlighted based on the child action. The effect of shadow, projector lighting and textured hand due to content display can be very clearly seen in fig. 2 and 3. Tracking with similarity measure helps to overcome this by predicting the hand position using previous detection results. Overall, the proposed system performs very well under the laboratory conditions.

Fig. 2: Three Real Objects are Placed on the Table and System Asks the Child to Associate With a Keyword

V. System Evaluation

The AR system was demonstrated to the ASD psychologists and teachers to have their constructive feedback. They were satisfied to know about this system which will immerse the child's attention and will help them learn new things without their knowledge. From the teachers' and the psychologists' point of view, the proposed system will help the child in developing, (1) Identification and recognition capability, (2) Ability to associate keyword and sentence to a picture, (3) Other competencies. The psychologists were pleased to see the monitoring and reinforcing capability of the system together with the recorded information of the child's hand action trajectories. Also, they highlighted the system's interface as very natural, simple and friendly with no fiducial marker. Further, there is a plan to test the system with several autistic children and also to obtain feedback from parents, teachers and psychologist to see its usefulness.

VI. Conclusion

The paper proposed an augmented reality system meant for discrete trial autistic children training. The three major steps in discrete trial training namely, instruct, monitor and reinforce or prompt were implemented successfully. The system interaction was made natural with the hand detection and tracking algorithm. It was noticed that the hand detection results degrades significantly with the projector ON condition. This was overcome by using similarity measure based tracking and the performance seems to be consistent both with projector OFF and ON scenarios. The proposed system was assessed in the laboratory environment to validate its working principle and performance. The results of hand detection and tracking along with the display content illustrated its functionality very well.

As a further step, we plan to assist the psychologist and teachers to evaluate the system with ASD children to study its usefulness in terms of interaction and learning. Also, the proposed AR system will be demonstrated to collect feedback from parents (in terms of usefulness to the child), teachers (to study the difficulty level to teach the child or to use the system) and the psychologist (in the assessment of the child's progress).

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