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[1]Sumbul Alam*
[2]S Pravinth Raja

Predicting meltdown situation in Autism and ADHD in real-time through camera using deep learning algorithm.

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Abstract: - Neurodevelopmental issues such as Autism spectrum disorder (ASD) and Attention deficit hyperactive disorders (ADHD) are quite prevalent in small children detecting and differentiating them at a very early stage is necessary for the future of the affected children and their parents or care giver. This may require 24 hours of surveillance in level 3 cases in which the affected may experience meltdown situation. It is well known by clinical psychologist that sudden meltdowns are common in autistic children, which makes the situation difficult for the parents or care givers and is also a physical threat to the affected children and people around them as they most likely injure themselves. Research has shown that children diagnosed with autism spectrum disorder display specific behaviors that allow us to predict their violent outbursts. Our aim is to develop a CNN-based system that can identify these kinds of behaviors using real time camera.

In our study, we are trying to make a model that can perform Human Activity Recognition (HAR) in real time. Based on the available training data we have trained our model on a few common pre meltdown actions or gestures creating two classes of dataset. but in future we may take huge number of video frame of different types of gestures (using HMBD51 datasets) to train the algorithm so that it can practically identify the situation in real time and alarm the caregiver before they enter the meltdown situation, this will save the patients from self-inflicted injuries and panic attacks not just in the above mentioned two cases but many other brain disorders. The present model has achieved a training accuracy of 100% ,a satisfactory FPS(Frame processed per Second) and the validation accuracy is slightly increasing in each epoch.

Keywords: Meltdown Situation, Autism Spectrum Disorder (ASD), Human Activity Recognition (HAR), CNN, Brain Disorders.

I. INTRODUCTION

There are different types of neurodevelopmental disorders in children but the most prevalent among them are ASD and ADHD. According to Centre for Disease Control and prevention (CDC), there has been a significant growth in the number of children suffering from ASD over a period of time. The graph below in figure 1, depicts the rate of growth in three decades.

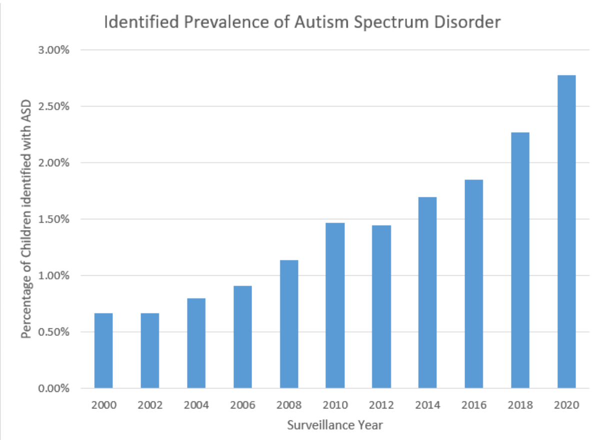


Figure 1. Graph depicting increase in occurrences of ASD over 2 decades

The facts and survey data for the chart above is fetched from (https://www.cdc.gov/ncbddd/autism/data.html).

[1] *Corresponding author: Department of Computer Science Engineering, Presidency University, Bengaluru-560064, Karnataka, India

[2] Author 2 Affiliation: Department of computer Science and IS. Presidency University, Bengaluru-560064, Karnataka, India

In this study we're going to deal with autism meltdown which is an intense and complex neurological response often caused due to overwhelming sensory or emotional flux of experiences. Most of the time these meltdowns are usually considered as tantrums but it's not the same, it is important to differentiate between them as meltdown is a type of physiological response to stress that is incredibly challenging for an individual while they are experiencing it. Therefore for parents or caregivers it is crucial to understand the factors that triggers the affected person such as social anxiety while interacting with others, changes in routine specially while traveling by air or using public transport, sensory overload etc. Now to detect meltdown situation it is important for us to know how meltdown in autism/ADHD looks like.

Practically there are numerous things that can set off an autistic meltdown, so it's critical to identify the warning indicators that someone may be on the verge of losing their control. Typical indicators to watch out include: crying or screaming, heightened anxiousness exhibited by pacing or fidgeting, increased sensitivity to sensory input, as demonstrated by squinting or closing their ears, having trouble clearly expressing or articulating, becoming angry or annoyed easily, banging on doors or walls, hyperventilating, committing routine actions more often than usual, throwing away things around them and many more. From the above indicators we can conclude that not all of them will be easy to be detected by a real time camera. Some of the pre meltdown symptoms such as becoming angry and hyperventilating may be confusing too therefore for this study we are going to consider indicators such as crying/screaming, hands on head and hands on ear.

Now coming to the procedure, as with any other field nowadays deep learning as well as machine learning procedures have gained a foothold in the detection of neurological disorder [1]. Numerous neurological disorders have general symptoms and behaviors that are now started being recognized through automated and machine learning-based models [2]. Two major behavioral disorders in this regard are Attention-Deficit/Hyperactivity Disorder (ADHD) and Autism Spectrum Disorder (ASD). Autism and ADHD are a kind of neurodevelopmental disability that causes social, communication, and behavioral challenges [3]. “ADHD is one of the most common neurodevelopmental disorders of childhood. It is usually first diagnosed in childhood and often lasts into adulthood. Children with ADHD may have trouble paying attention, controlling impulsive behaviors (may act without thinking about what the result will be), or be overly active” [4].

Children with ASD and ADHD often experience sudden meltdowns, which makes the situation tough for the caretakers/parents it also makes the children offend themselves physically [5, 6 and 7]. Studies have revealed that children with ASD and ADHD exhibit certain actions through which we can anticipate mutilating meltdowns in them [8, 9]. The presence of machine learning and deep learning based detection systems is vital in this regard as it has the potential of timely analysis and recognition of meltdown behavior that assists the parents or caretakers in perceiving the situation and hence handling it efficiently before it gets more extreme[10]. Hence, the implications of early diagnosing drew the consideration of researchers to use different machine learning-based techniques [11]. Multiple analyses are done using deep learning (DL) Algorithms for Human Activity Recognition (HAR) but till date HAR dataset has not been applied to foresee meltdowns in children affected by ASD and ADHD. However several machine learning Algorithms such as “Support Vector Machines, Random Forests, Naive Bayes, K-nearest Neighbors, and many more has been applied” [12,13] to this context using Image data set. The current study intends to join forces with the body of knowledge in this regard by attempting to design a deep-learning model for detecting meltdowns in real-time by camera as deep learning can be a feasible solution to differentiate different types of gestures a child may show before entering a meltdown phase.

II. Research Aim

The present work is principally intended to design a deep learning-based prediction model for the recognition of meltdown behavior in patients suffering from ADHD, ASD or both. The prime incentive is to propose a simple and efficient system architecture that can timely detect and alarm in the event of a meltdown in a live scenario with efficiency and accuracy by using Convolution Neural Network.

III. Related works

With the rapid progression of machine learning approaches in every domain of life, the detection and diagnosis of medical disorders have also opened up to these methodologies. Numerous research scholars have conducted studies involving a myriad of machine-learning approaches for the detection and diagnosis of medical and neurological disorders. For instance, Karim et al. (2021) conducted a review study concerning the machine learning-based prediction of Autism Spectrum Disorder (ASD) meltdown[13]. The researcher analysed over 80 studies concerning the implementation of machine learning in detecting ASD. The outcomes of their study gave a detailed insight into the machine learning trends in predicting meltdowns and outlined several areas for the future researchers to work on.

Patnam et al. (2017) used a “deep learning-based recognition system for detecting meltdown behaviour in autistic children” [10]. The researchers used deep learning regions with Recurrent Convolutional Neural Networks (RCNNs) and trained the system using a classifier on images collected from reliable resources and videos that contained the most predictive gestures to detect meltdowns. The accuracy of their model was 93%, accompanied by a loss/train classifier having a minimal 0.4% loss. For conducting functional testing, the deep neural network was fed with certain actions that, as a result, gave 92% accuracy for each individual case hence ensuring the system's real-time usage.

Based on a deep learning architecture, Rad and Furlanello (2016) proposed an automatic Stereotypical Motor Movements (SMMs) detection system associated with meltdown situations in a real-world setting[14]. The model surrounds multi-sensor accelerometer signals. The results of their work for convolutional neural networks validated the generation of accurate SMM detection results in regard to feature learning and transferred learning embedded in deep architectures for longitudinal scenarios.

Alsaade and Alzahrani [15] proposed a system designed for detecting ASD on social media and face recognition. The authors did not use a deep learning method owing to the need for precise technologies to extract and produce proper patterns of facial features. Rather, the authors used a deep learning-based system of convolutional neural networks. The transfer learning and the flask framework were used. A number of pre-trained models like NASNETMobile, Visual Geometry Group Network (VGG19), and Xception were employed for classifications. The Kaggle platform was used for extracting the dataset comprising 2,940 face images. After evaluating the preliminary metrics, i.e., accuracy, specificity, and sensitivity, the authors reported that out of all three models, Xception attained the highest level of accuracy (91%), whereas the other two models achieved an accuracy level of 80% for VGG19 and 78% for NASNETMobile. The outcomes of this study were valuable as they offered a detailed comparison of three models against each other.

For predicting meltdown in ASD, Karim et al. proposed a novel "fuzziness-based semi-supervised learning (SSL) strategy" by employing the mislabelled data alongside training labelled data for increasing the reliability of the model[16]. Using the given method, the prediction performance exhibited significant advancements in increasing the results of the classifier as against other classification approaches, i.e., Naive Bayes, Fuzzy MinMax Classifier, Random tree, ZeroR, Fuzzy Data Mining, and so forth. The study was significant as it integrated huge volumes of unlabelled and labelled data for producing a robust classification model.

Researchers have also inspected the involvement of machine learning-based projects during meltdown situations. For example, Alhaddad et al. [17] investigated the head impact severity measures for small social robots thrown during the meltdown in autism. The authors intended to identify the potential harmful scenarios that may occur between a child and a social robot as a result of behaviour meltdown owing to autism. The findings of their work revealed that the overall levels of harm (on the basis of the indices they specified in their work) were comparatively low than their respective thresholds. However, it was also reported that throwing objects can lead to serious injuries in tissues as well as concussive and sub concussive events. Therefore, it was recommended that such behaviours should be taken into account while designing interactive social robots intended for autistic children.

To find the severity of multisite meltdown in children suffering from ASD, LSTM integrated Convolution Neural Network was used. In this study to improve the image quality, “Segment anything model for segmentation” and PCA for feature extraction were applied [18], to isolate and pin point certain regions containing specific meltdown related feature within a child’s image .The model showed a promising result but more diverse dataset was needed for a real-time application.

For recognising micro-expressions of complex emotion in autistic children during meltdown S.K. Jarraya et al. [19] developed a predictive model using different feature selection methods such as Feed- Forward (FF), Cascade Feed Forward, RNN and LSTM, for the purpose of building a sensor that would detect meltdown. But the proposed approach covered a wide range of issues as they used a set of films that were captured using a Kinect camera kept at a distance ranging from 0.5 to 1 metre, which is not very practical for patients to remain under the mentioned proximity.

As a whole, it can be asserted that the researchers have explored the issue of early detection and diagnosis of ASD and ADHD via machine learning from various aspects and have reviewed and proposed several models. The current study also takes a step forward in this paradigm by incorporating ASD and ADHD into a single model for the joint detection of meltdown in both cases under practical situations.

IV. Material and methodology

This method offers holistic approach to detect meltdown in real time. Due to the recent advancement in technology different types of surveillance cameras are used. Most of them are easily available and affordable. We have used EZVIZ C6W, smart Wi-Fi home camera, to capture the pre meltdown indicator used for testing our algorithm.

A. Convulation Layer

In this study we are simply going to track movement of a child using object tracking with the help of image convolution in real time. For this purpose the pivotal element of our architecture is CNN. CNNs are most widely used for image classification jobs because of their capacity for autonomous feature extraction and learning. In image classification applications, CNNs have achieved state-of-the-art performance, frequently surpassing conventional machine learning techniques. This is due to CNNs' ability to recognize intricate details in pictures, such as textures, edges, and corners, without the requirement for explicit feature engineering.

Here by the help of tensor flow class in real time we are going to detect the object and visualize tracker line. The X and Y coordinates of the current object under surveillance will be found.

B. Pending Layer:

First of all in this step the colored images(BGR) are converted to gray for implementing max pooling operation to gray images .Fine hyper parameters and number of strides are decided in this step ,for example if the width and height of the spatial input image is 1080 x 720 then the output image after pooling will be as follow:
Height = (720-2)/2+1=360
Width = (1020-2)/2+1=510, here 2 is the step for sliding
These processes improves the generalization capacity of the model [20]

C. Sobel Filter

The edges in the image can be detected using different filters such as Laplacian filter, Prewitt filter and sobel filter, but here in this case we are using Sobel filter as it works best because the background of the input image is sometime almost the same as the object itself. Certain amount of noise can also be detected occasionally which can be later rectified. Here the values of the sobel filter are weights by which the convolution will be performed.1-chanelled 3x3 Sobel filter is set up for the edge detection, as it has higher edge pixel intensity as compared with other filters. Here sobel filter is used to detect vertical changes on image.

D. Activation Function

There are various type of activation functions used in neural networks, depending on the requirements such as sigmoid, Tanh, softmax etc. but here we will be using Rectified linear unit function(ReLu) : f(x) = max(0, x). This means that all the negative values will be replaced by 0.

E. Drawing bounding box with label around it

The frames of the child under observation are read one-by-one from the camera and a 2D convolution layer is initialized with the help of Tensor flow. On every output of the convolution we draw bounding box and label around the bounding box. The tracker line is implemented along with the X and Y coordinates as the movement of the child is detected in the room.

F. Calculate FPS (Frames Processed per second)

Time needed to apply convolution to every single frame is calculated. Number of frames processed per second is calculated after that counter for frames is updated to get new time point to start new calculation for FPS.
To implement this algorithm, sobel filter is used to detect vertical changes on image. Open CV window has been used to show current view from camera in real time, to find the contour and to show the cut fragments the windows are resizable. The process starts with reading frames from camera in the loop, variables are prepared for the spatial dimension of the captured frames.

Algorithm 1: convolution in real time by camera using sobel filter

Input: video frames of the child under surveillance

Output: Open CV windows with different results

Process

Train ()

Preprocessing of training images ()

Defining one channel kernel size= (3 x 3) filter for detecting the edges

Initializing and preparing open CV windows to show the results

Reading frames from camera in the loop

Initializing conv2D layer for Gray input

Implementing 2D convolution to the captured video frame

Activation function=ReLu ()

Drawing bounding box around the detection (crying, screaming, hands on head or ears) label

Draw tracker line (X=: Y=:)

Cutting detected fragments

Showing open CV windows with results

Calculating FPS rate ()

V. DATASET FOR TRAINING MODEL

Based on the results gained from the assessment of previous studies, a number of symptoms of meltdown behaviors in children with ASD and ADHD were accumulated. These behaviors included crying, screaming, yelling, biting, abnormally laughing, hitting, withdrawing, throwing objects, covering ears or head with hands, shivering/shaking, stimming or any other self-harm.

In this study we are considering only three gestures for now i.e. crying/screaming, hands on head and hands on ears. The selection criteria were high-quality images that best represented the situation and were pertinent for each gesture. These images were then fed into the system, for the purpose of training our model.

Initially the model was trained with the help of available data which we collected through reliable sources from Internet, Kaggle data repository and a few while interviewing the parent with their consent along with their autistic child. These images were first preprocessed, background was removed and the images were converted to RGB and then categorized in two different classes for the purpose of training as shown below in Figure 2.then fed into the system and a set of networks was designed.

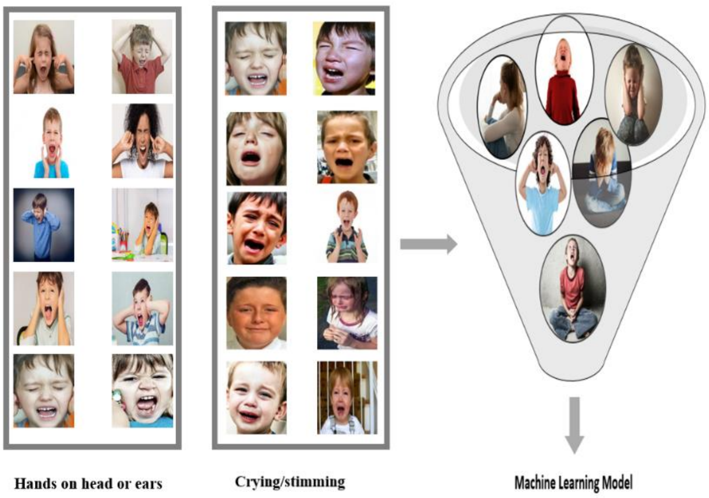


Figure 2. Insertion of the dataset for Training the model

VI. SIGNAL PROCESSING

The system was trained for signal processing following Patnam et al.'s (2017) approach, which they termed as the "Waterfall Model". This approach was adopted as it deemed the most straightforward and convenient method to incorporate into the current research design and similarity with the aim of our work. Consequently, the signal processing architecture was composed of four steps:

- First: The camera will detect the behavior.
- Second: The video frames/images will be sent to the computer.
- Third: In the computer, the automated machine learning model will detect the behavior of a meltdown by comparing the symptoms from the training data set.
- Four: In case of detecting similar activity and confirming the event of meltdown, the system will then alarm the prediction of meltdown behavior using sensors.

A. System Architecture

After training the model as per the signal processing steps adopted from Patnam et al. (2017),[10] as enlightened above, the final system architecture is as depicted in Figure 3.

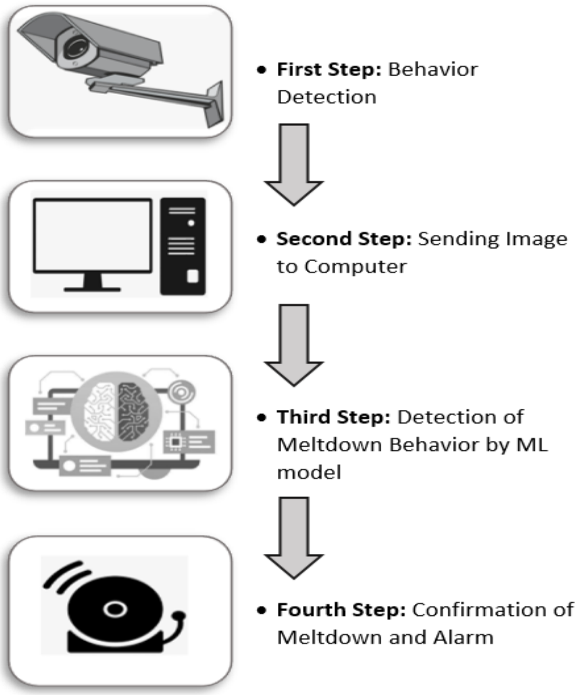


Figure 3. System Architecture of the Proposed Model

VII. DATASET AND MODEL

The dataset that was first entered into the model was composed of images and signs of meltdown, which were fed to the system in the prior step for training the model. Then as per the proposed machine learning model depicted in figure 4. CNN was used for step by step processing of the real time video.

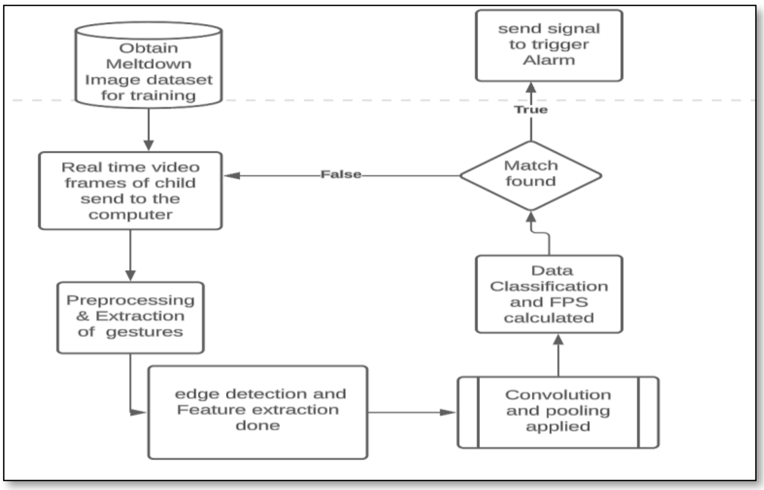


Figure 4. A flowchart of the testing phase for pre trained Data

VIII. RESULTS

In this section the result of the performed experiment is analyzed. We load model by specifying the folder name and file from our directories .This study used a HPTM Envy 14-eb0xxx notebook with NVIDIA GeForce GTX 1650 Ti graphic card.

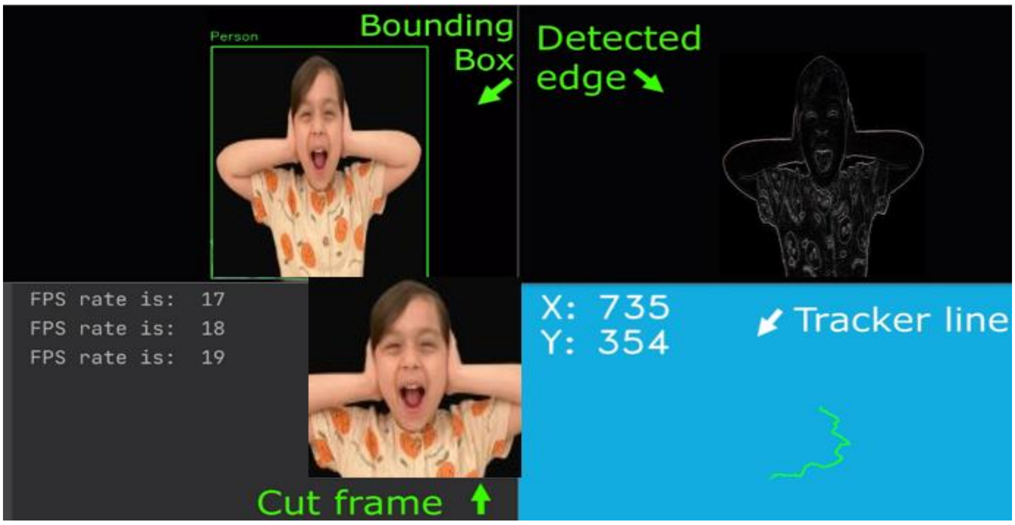
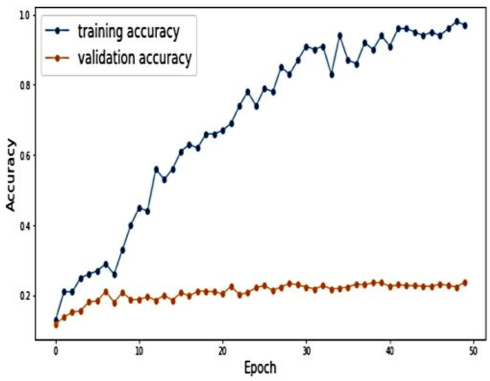


Figure 5: Output Window in OpenCV

With the intention of testing the accuracy and efficacy of the model, several estimations were made. The precision of the model, time taken and accuracy of detection of gestures were assessed.

The Frame Rate per Second (FPS) obtained is 19 for a 5-10 sec video. FPS directly depends on the quality of video recording camera and the GPU of the machine on which the codes are run. Ideal frame rate of security cameras are in the range of 15-30 so the FPS of the testing video is satisfactory.

As we know Accuracy is a very extensively used metric in the task of classification that measures the proportion of correctly categorized data out of the total number of instances. Figure 6 shows the training and validation accuracy of the model.



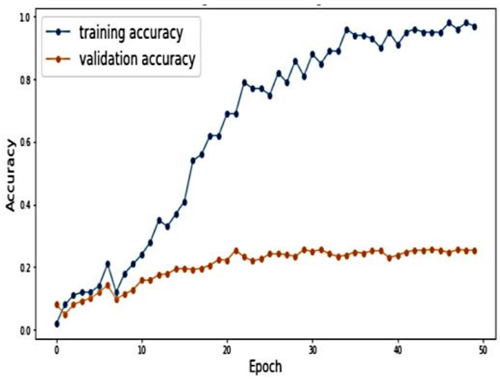


Figure 6: Training and validation accuracy of the proposed model

Training Accuracy =0.9800 Validation accuracy =0.25600 in the other iteration further

Training Accuracy =1.0000 Validation accuracy =0.3820

We observe that the model reached the training accuracy of 100% but the validation accuracy almost remained the same, this means that the model can classify around all the images that were used for training but can rarely classify any other images this is due to overfitting.

IX. Discussion

As we observe that the training accuracy kept on increasing showing that the model can predict those limited number of images that were used in training but the validation accuracy curve showed an insignificant growth that means rarely a new image can be classified correctly. This means it is vital to have huge number of images or video frames for training this predictive model. The above explained issues can be solved by simplifying the designed model and including large number of data used for training the model. This can be done by using Human activity recognition (HAR) algorithms and for training the model, we will be using HMDB51 data set. There has been many recent work done on these model with improved accuracy but the utilization of HAR with HMDB 51 data which is a large Human Motion Data base comprising of 7000 clips and divided in 51 different classes of actions [21] will be a novel approach if applied in the field of healthcare. Thus saving millions around the world who can be intervened and calmed down during meltdowns and panic attacks.

X. Conclusion

To sum up, we designed a model for the detection of meltdown situation in children or adult suffering from ASD and ADHD in real time using surveillance camera and machine learning CNN-based algorithm. When compared with the different work done in this field the idea is novel in application to this field but the performance needs to improve. The training accuracy reached 100% but validation did not show satisfactory growth. In future we will implement the same idea but the training dataset will be changed to HMDB51.We expect a much more advanced algorithms such as ResNet 3D will give a much better results that could be practically used not just for the detection of meltdown in ASD but many other neurological disorders such as Parkinson's disease, schizophrenia and epilepsy [21] as they exhibit similar gestures that can be identified by real-time cameras using deep CNNs.
Deep learning can be a feasible solution to differentiate different types of gestures a child may show before entering a meltdown phase.

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