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A Monitoring System for Patients of Autism Spectrum Disorder Using Artificial Intelligence

Md. Hasan Al Banna[1], Tapotosh Ghosh[1], Kazi Abu Taher[1], M. Shamim Kaiser[2](✉), and Mufti Mahmud[3]

[1] Bangladesh University of Professionals, Dhaka, Bangladesh
alifhasan39@gmail.com, 16511038@student.bup.edu.bd, kataher@bup.edu.bd
[2] Institute of Information Technology, Jahangirnagar University, Savar, Dhaka 1342, Bangladesh
mskaiser@juniv.edu
[3] Nottingham Trent University, Clifton Campus, Nottingham NG11 8NS, UK
mufti.mahmud@ntu.ac.uk, mufti.mahmud@gmail.com

Abstract. When the world is suffering from the deadliest consequences of COVID-19, people with autism find themselves in the worst possible situation. The patients of autism lack social skills, and in many cases, show repetitive behavior. Many of them need outside support throughout their life. During the COVID-19 pandemic, as many of the places are in lockdown conditions, it is very tough for them to find help from their doctors and therapists. Suddenly, the caregivers and parents of the ASD patients find themselves in a strange situation. Therefore, we are proposing an artificial intelligence-based system that uses sensor data to monitor the patient's condition, and based on the emotion and facial expression of the patient, adjusts the learning method through exciting games and tasks. Whenever something goes wrong with the patient's behavior, the caregivers and the parents are alerted about it. We then presented how this AI-based system can help them during COVID-19 pandemic. This system can help the parents to adjust to the new situation and continue the mental growth of the patients.

Keywords: COVID-19 · Autism · Emotion Detection · Artificial intelligence

1 Introduction

The COVID-19 global pandemic is keeping its impact on every sector, taking away millions of lives. The world economy is collapsing, and healthcare providers face immense pressure to ensure health support to the help-seekers. People with

Md. H. A. Banna and T. Ghosh—These two authors contributed equally.

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autism spectrum disorder (ASD) need more attention during a regular period than anyone else. They follow strict routines, which keep their health in stable condition. Due to the COVID-19 pandemic, these routines are violated. This disruption leaves ASD patients in a more vulnerable position. Since the institutional help is not available, a new support system is needed to meet the demand for help.

ASD refers to the condition, where the patients face difficulties in social interactions and communication, show repetitive behavior, lack language skills, and perform a limited range of activities. Some patients do not understand pain, and therefore, when they are angry, they get involved in self-destructive activities. Worldwide 0.625% of the children are affected with ASD [10]. This situation is much worse in developing and underdeveloped countries. They usually face more domination and violence in the domestic environment than a healthy person [14]. During a lockdown, this situation worsens with an increase in these incidents [34]. The health condition of an ASD patient can be improved by providing constant care and appropriate therapies. These therapies involve some reinforcements to the patient, which can be some praising words or some privileges. Unfortunately, during the COVID-19 pandemic, since most of the places are in lockdown conditions, help from the clinicians and the therapist are challenging to get. The educational institutions are also closed because of the pandemic. Therefore, an alternative way needs to be created to solve these problems.

Artificial Intelligence (AI) is a technology that mimics the functionality of the human brain and is used in many applications as biological data mining [19,20], image analysis [5,22,23], anomaly detection [11,36] and expert system [15,21,25,31,33,39]. In the healthcare sector, AI is getting more popular and used for diagnosis purposes [6,7]. During the global pandemic, as the number of clinicians is small, and they cannot personally interact with the patient directly, an AI monitoring and response system can help. This AI system should take environmental parameters, patient's current situation, and uncommon situations as input to provide responses analyzing the data. This will help the parents and caregivers as an assistant and take better care of the patient.

Courtenay et al. [8] investigated how COVID-19 pandemic can impact on people with intellectual disabilities. He mentioned that these people have a weak immune system, which makes them vulnerable to this disease. He also mentioned that if anyone with intellectual disabilities is affected by COVID-19, they can face serious consequences. Lima et al. [27] assessed the risk factors of ASD during COVID-19. They said that ASD patients have cytokine dysregulation abnormal factors, and the COVID patients who faced complications also showed raise in cytokine. Therefore, they proposed to take special care for the ASD patients during this pandemic. Yarımkaya and Esentürk [38] emphasized exercise for ASD patients during COVID-19 as they tend to get weights quickly and show signs of obesity. They also described the exercise set, time duration, and the frequency in their study.

There were some researches, where the emotion of the ASD patients was detected using sensors. Heni and Hamam [13] proposed a facial emotion detection system and an automatic speech recognition system for emotion detection of ASD patients. They followed the rapid object detection system proposed by Viola and Jones [32]. Krysko and Rutherford [17] experimented with the ability of ASD patients to detect angry behavior. They found that the patients can successfully detect angry and happy faces but show difficulty in understanding discrepant images. Smitha and Vinod [26] proposed a real-time emotion detection procedure using principal component analysis (PCA). They extracted the face from the background and detected happy, sad, surprise, neutral, and angry expressions with reasonable accuracy. Afrin [1] et al. proposed an AI-based approach to recognize facial expression recognition of autism individuals. They at first, took the image as an input and removed noise from the image using a median filter. They segmented the filtered image. Then a simple CNN was introduced to classify the image [4]. They simulated the whole architecture and found that the architecture was successful in classifying facial expression.

Sumi et al. [28] proposed an assistance system for caregivers of ASD patients in the form of a smart wearable device that can detect position, heartbeat, sound, and movement of the patient. These sensors use wireless interface to transmit data to the parents, caregivers, and in an external repository. GPS sensor was used for location, and an accelerometer sensor was used for finding repetitive patterns in the patients. [2,3,6,16] proposed an assistive system for caregivers dealing with ASD patients in the form of a playing element [23,37].

In this research, we have proposed a system that can work as a substitute for the caregivers of ASD patients. We have proposed a wearable sensor-based device along with a camera-based monitoring system. Then we introduced a transfer learning-based CNN model for emotion recognition, which will be used to interact with ASD patients. To the best of the author's knowledge, no research has been done, which detects emotion of ASD patient using transfer learning and use that to maintain and teach them. This system can monitor the ASD patients without any contact of the caregivers. Therefore, when some of the family member is affected with COVID-19, this monitoring system can help a lot. Finally, we have discussed how this model can help the patients and their caregivers during this pandemic. We hope that this research will help take care of the ASD patients in this pandemic and relief their parents.

In the next section, we will discuss the world health organization's (WHO) guidelines for maintaining ASD patients. In Sect. 3, we will discuss our methodology. Section 4 will cover the results of this research. Section 5 will cover the usage of the proposed model during COVID-19, and in Sect. 6, the conclusion and future works will be discussed.

2 WHO on Autism

The symptoms of ASD are visible within ages 1 to 5, which continues to adolescence and adulthood [35]. In most cases, ASD is accompanied by attention deficit hyperactivity disorder, anxiety, and depression, making the situation much worse. The number of ASD patients is ever on the rise, possibly because of more reliable diagnostic tools and people being more conscious about the diagnosis. Although, they say that 0.625% of the world's population is suffering from this disease, the numbers from underdeveloped and developing countries are not available. The causes of ASD are environmental and genetic. Though many think that childhood vaccination is a cause of ASD, there was no evidence supporting it. To overcome the problem of communication and social behavior, skill training can help a lot. In many cases, they need consistent help from others throughout their life which can be a burden for their family. Therefore, rehabilitation programs should be arranged for them, and social, employment, and educational discrimination should be eradicated. This is not a stigma, and during situations like a pandemic, they should not be deprived of the health services just because the caregivers do not know how to handle them.

3 Methodology

3.1 Proposed System

In this work, we are proposing a system consisting of a smart wrist band (SWB), an interactive monitor, and a camera device attached to the monitor for monitoring ASD patients. These devices will be connected to a mobile application to continuously monitor and keep them in a learning environment all day long without caregivers.

The SWB consists of accelerometer, gyroscope, magnetometer, GPS tracker, heart rate sensor, pedometer, and temperature sensor. Accelerometer senses vibration to detect acceleration. Gyroscope is used for measuring angular movement, and a magnetometer is used to locate the position about the north pole. GPS is widely used to track a person by providing geological coordinates.

These sensors will be attached with a microcontroller, esp8266, and a sim card module. When wi-fi is available, esp8266's built-in wi-fi module will send sensor data to the mobile server. In the case of non availability of wi-fi, the GSM module will be used to transfer data to the mobile application. This device collects data from its inbuilt heart rate sensor, pedometer, and temperature sensor and will send the patient's condition to the mobile server. An ambient temperature sensor will be set up in the corner of the room for continuous monitoring of the room. There will be some toys and counting objects in the room. RFID will be attached to them to detect its touching.

The output device will be a sound box and a computer screen, which will contain a camera to take the images of the patient for emotion analysis in every 5 min. All the devices described in this system will send data to the mobile server, and data will be stored for around 20 days. The processed data will be sent to the server from the mobile device. Our AI models will analyze the health condition of the autistic individual and operate through some visuals and sounds. Figure 1 depicts the proposed AI-based system for the ASD patients.

The children will have a routine for playing, learning, and sleeping. The AI-powered application will be installed on the mobile. It will produce some relaxation music during sleeping, show visuals during teaching, and help them

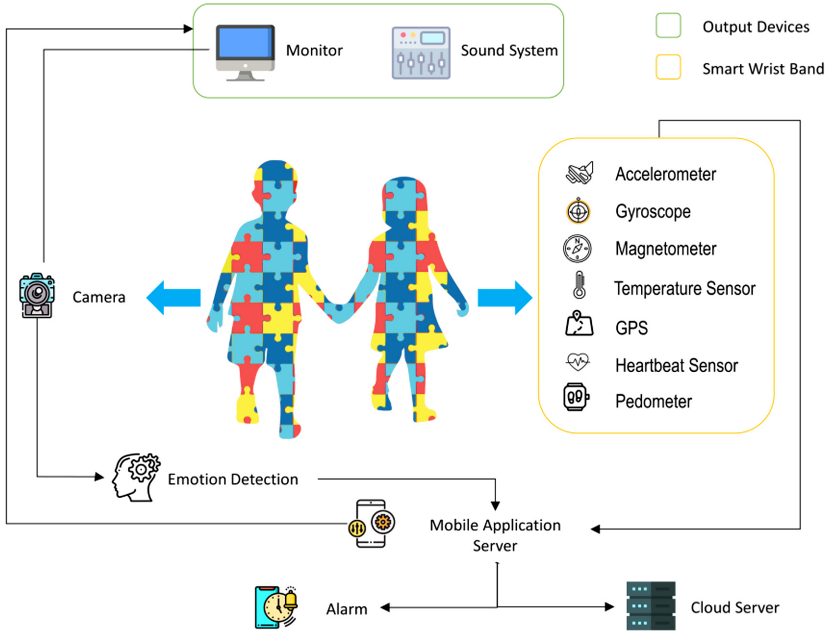

Fig. 1. An AI-based autism monitoring system. There are sensor elements such as accelerometer, gyroscope, magnetometer, temperature sensor, GPS, heartbeat sensor, pedometer, and a camera attached to the monitor, which shows visuals based on the mobile application decision. The camera output is used to detect the emotion of the ASD patient. When some unusual event happens, an alarm signal is sent to the care-givers. The mobile application takes the decision and sends it to the server.

play based on their emotion. We have proposed an Inception-ResNetV2 based model for emotion recognition from camera images. It can detect the positive, negative, and neutral state of a person.

If the child is in a positive mental state during the time of the study, the mobile application will show him some alphabets, pictures for teaching counting, or contents according to the school's guidelines on the screen. It will also provide sound to keep him attracted to this lesson. If his mindset becomes negative, the application will try to relax him by showing cartoons or some relaxation songs, which will make him ready to study again. The whole emotion state will be controlled through the proposed CNN model using images taken by attached camera in the monitor screen.

During playing, the software will give him the command to do something. If he is trying to play Lego, it will provide instruction in a language that the child can understand. RFID attached to the toys will detect the child's touch on it and will prompt the monitor to show the child a visual and a sound related to the visual. If he successfully does something, the application will praise him and take him to more laborious tasks. If the child is touching a dirty object, RFID will detect it, and the application will play visuals and sound so that the child can learn that he should not move the dirty objects.

The ambient temperature sensor will try to alarm the other members when the room temperature gets too hot or too cold. The attached heart rate sensor and temperature sensor in the smart band will provide a way of monitoring his health status. An AI model will be deployed to analyze his sleeping pattern, heart rate data, and temperature data collected from the band. It will then alarm parents through a text message and app notification. If the child goes outside without telling anyone, he can easily be found out using the location tracked by the GPS attached in the SWB.

The whole architecture will monitor the child's concentration, health condition, and activity continuously. If it finds something unusual, it will send messages to the parents immediately. It will also generate a report every week, including the child's daily activity, performance in games, mental state, activity log, progress in learning, and health condition. The parents can easily find the growth of their child through it and send it to the doctor.

3.2 Emotion Detection Model

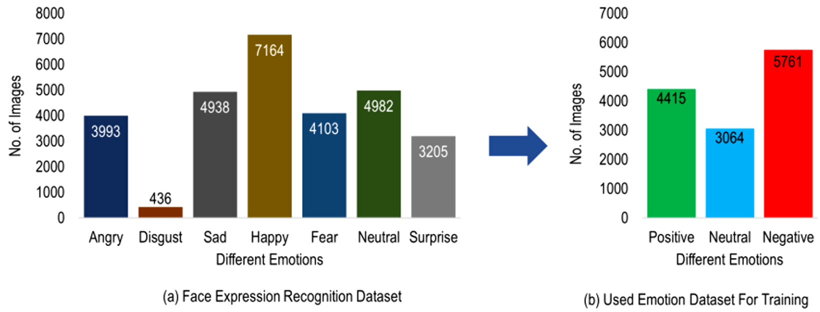

Fig. 2. (a) Distribution of images to seven different classes in the face recognition dataset. The class labeled "Happy" contains the highest number of images (7,164) and "Disgust" contains the least number of images (436) (b) Distribution of images after removing, shuffling, and re-labeling images from the face recognition dataset. Images of seven classes in the Face recognition dataset were distributed to three classes (Positive, Negative, Neutral). The negative class contains the highest number of images (5,761), and the neutral class contains the least number of images (3,064).

The emotion of ASD patient can be detected from real-time images. For training and testing the emotion recognition model, we have used a facial expression recognition dataset that is publicly available at Kaggle [24]. This dataset contains a total of 35,887 images divided into training and testing folders. This dataset contains images of 7 facial expressions: happy, sad, anger, disgust, surprise, sad, and neutral. The dimension of these images is 48×48 in grey-scaled form. In this work, we have divided the dataset into three classes: positive, neutral, and negative. We have considered the images labeled happy as positive, neutral labeled images were considered as neutral, and sad, disgust, and anger tagged images were labeled as the negative class. After removing, shuffling, and re-labeling images, we took 21,513 samples for training, testing, and validation. For training purposes, we have kept 13,240 samples, and 3,254 were used as a validation set. A set of 5,019 images were kept aside for testing the performance of the model.

We have also used a facial expression recognition dataset named CK+48 [18] for cross-validating the model. This dataset contained images of 7 facial expressions: happy, sad, anger, disgust, surprise, fear, and neutral. We converted it to 3 classes (positive, negative, neutral), where we did not consider the images of fear and surprise. The positive class contained images labeled as happy, the neutral class had the images labeled as neutral, and the negative class was a collection of images labeled as anger, disgust, and sad. Figure 2 presents how emotion recognition dataset was created from the Kaggle dataset. Figure 2(a) shows the number of samples in each class of the Kaggle dataset. Figure 2(b) shows the distribution of number samples in each class in the converted dataset.

Inception-ResNet [30] architecture is a state-of-the-art CNN architecture, a combination of InceptionNet [29] and ResNet [12]. These two architectures are capable of acquiring high precision in lower epochs in case of image classification. Inception-ResnetV2 combines the power of these two models. It contains 164 layers, which is trained with the ImageNet [9] dataset containing 1,000 classes. In this architecture, the Inception block is combined with a 1×1 convolution layer without activation for scaling up filter bank dimensionality. Convolution is done by multiplying filters with the image pixels to find new features. It is also necessary to match dimensionality with input block as it is mandatory to have the same dimension in input and output for residual operation. As the number of filters increases, residual networks tend to die. So, residual activation is scaled to in between 0.1 and 0.3 in Inception-ResNetV2. The total number of parameters in the Inception-ResnetV2 model is 55,873,736, and the size of the architecture is 215 MB.

The Inception-ResNetV2 model was trained and tested using the above mentioned facial expression recognition dataset. The model took images as input, converted it to a tensor of $299 \times 299 \times 3$, and was given input to the model's input layer. The model was trained using an adam optimizer, where the learning rate was set to 0.001. It was trained for 20 epochs. The model was then tested using a separated testing set of facial expression recognition. We have cross-validated the trained model using the CK+48 dataset. The images of this dataset were at first converted to $299 \times 299 \times 3$ as InceptionResNetV2 can take images of $299 \times 299 \times 3$ as input. Then they were given input to the trained model for predicting their class. We have removed the last layer from the original Inception-ResNetv2 and tried several combinations of fully connected layers and activation functions (Softmax, Sigmoid, Tanh). We have tried to improve the model's performance by changing learning rate (0.1, 0.01, 0.001, 0.0001). The best model is presented in this study (Fig. 3).

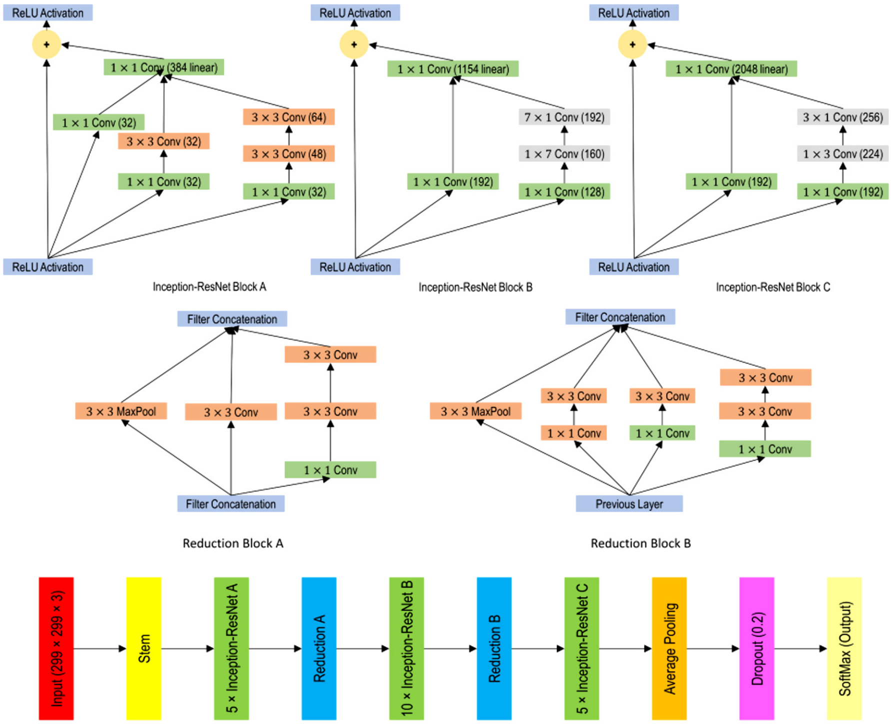

Fig. 3. The architecture of Inception-ResNetV2. There are three inception blocks where each of them has an additional 1×1 convolutional layer for scaling up the dimensionality. Reduction blocks are introduced to change tensor's height and width. The stem takes a $299 \times 299 \times 3$ image as input and performs some operations. After that, Inception blocks and reduction blocks extract significant features for classifying images.

4 Result Analysis

The Inception-ResNetV2 architecture achieved 78.56% accuracy in emotion recognition from facial images. It has classified 3961 out of 5019 images successfully into three different classes. Figure 4(a) shows the confusion matrix of the proposed model. This architecture was most successful in classifying positive emotions. It has successfully recognized emotion from 1,521 out of 1,978 samples in negative class, 884 out of 1,216 images from neutral class, and 1,556 out of 1,825 samples in positive class. Figure 4(b) shows the prediction ability of the model for classifying different emotions. The model was also cross-validated using a publicly available CK+48 dataset, where this model achieved an accuracy of 76.70%. The images of this dataset were not used for training purposes. So, it proves that the model is very much efficient in recognizing emotion from facial expression image. Figure 5(a) shows the comparison of the achieved testing accuracy of the model in the two different datasets.

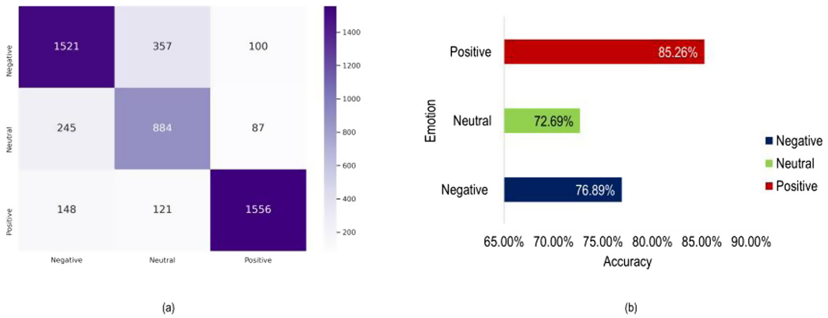

Fig. 4. (a) The confusion matrix of the emotion detection model. (b) Accuracy of the InceptionResNetV2 model to classify positive, negative, and neutral emotions.

Figure 5(b) shows the comparison between different ML algorithms and the Inception-ResNetV2 model for classifying emotions from a person's image. The ML models did not perform well with the data. Random forest (RF) and support vector machine (SVM) achieved accuracy around 57% mark, which is not very encouraging. On the other hand, our proposed transfer learning model achieved good accuracy for this job.

5 Utility of the Proposed Model During COVID-19 Pandemic

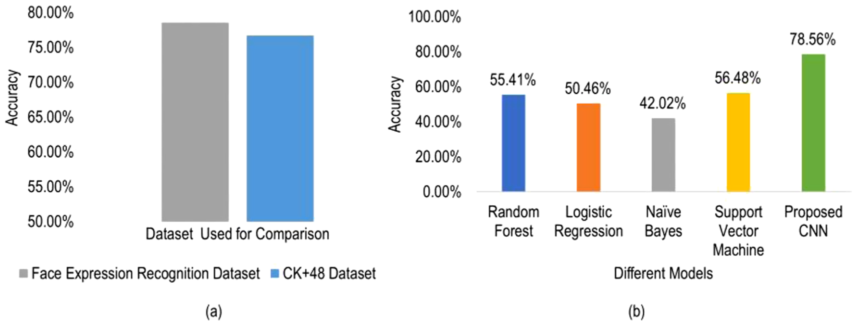

Fig. 5. (a) Comparison of testing accuracies for two different datasets for the proposed model. (c) Comparison of different ML models with the proposed CNN model. Among the ML algorithms, SVM performed better than the others, but the CNN model outperformed them.

Due to the Covid-19 pandemic, washing hands has become very important. Autistic children don't understand the importance of washing hands or putting on masks, and he cannot understand what he should do in this tough time.

The proposed application will show him visuals and make him washing hands every 2 h. It will also teach him through games and visuals that he should wear masks when he goes out. The games will have a few stages, and the child will be prompted to do some tasks in the virtual game for completing every steps. He will gather the understanding of COVID-19 through an interactive visual. If he is sitting for a very long time, the visuals and sounds will be played to make the child walk for sometimes. It will make them physically healthy, fit, and boost their immune system. If he is walking for a long time, it will try to make him rested for some time. The child will be prompted to do some easy physical activities such as hand raising, spreading, and so on. The system will keep the patient busy with engaging content and generate an alert in times of unusual behaviors. It will optimize the method of learning based on the patient's mood so that burden is not imposed on them. If the parents of the patient are affected by COVID-19, this system will help them maintain distance with the patient and maintain a healthy environment.

6 Conclusions

In recent years, technologies are offering considerable assistance to every sectors. AI has given some decision-making capabilities to electrical devices. Healthcare systems are adopting AI, so that they can assist the clinicians in monitoring and managing the patients. ASD patients need persistent assistance, which is tough to get during the COVID-19 pandemic. The availability of clinical help is limited, and emergency help is hard to get. A personalized monitoring and supporting system can help the ASD patients during this pandemic and afterward. This study proposes an automated AI-based control system which can not only monitor the patients but also give support with learning and therapy. The patients with ASD are mentally and physically unstable. Their response to any sudden event around them is extreme and this phenomenon needs proper attention. That is why environment near them should be as stable as possible. We are using an AI based emotion recognition system to evaluate their sudden change in emotional state and finding out the cause of it by using the proposed architecture's sensor data. We have proposed the use of different sensors that help the system to provide decisions accordingly. The emotion detection model offers a good indication of the mood and unusual behavior of the patient. Based on them, the level of the learning games and tasks are modified, and the reward system is developed. This way, the patients never get bored with the therapy. At last, we discussed how this proposed system could be used for maintaining the patients during COVID-19. This system can help the clueless parents in finding some space to get themselves sorted. In the future, more compact design and features like augmented reality will be incorporated with this proposed system. A human activity recognition model will be incorporated with this existing model as well.

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