



DESIGN AND DEVELOPMENT OF RESOLDEPMIRROR: A SMART MIRROR FOR RESOLVING DEPRESSION

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Abstract

Health is a precious gift from God. Both physical and mental health is equally important for living a quality life. Negligence towards mental health creates a lot of serious health problems affecting the both physical health and society. Mental health is associated with better performance, high efficiency, and lesser work environment mishaps. Internet of Things technologies can possibly create smart products that can react to human needs and improve the quality of life and can make traditional environments more favourable and intelligent. One such internet of things solution is the design and development of smart mirrors. The opportunity to apply smart technology to healthcare to foresee and monitor aspects of mental health is a natural but mostly underdeveloped idea. Although several smart mirror solutions have been proposed for different purposes, it has not been developed for the treatment of depression. We believe that smart mirrors involving a combination of hardware and software could identify depression as well as offer feedback for corrective measures and remedial activities. This paper examines the potential use of a smart mirror in healthcare and examines how this technology might benefit users in resolving depression. We present the design and development of a smart mirror that can diagnose and provide digitized treatment to resolve depression. The developed mirror is tested on humans, and from the obtained results, it is concluded that the developed mirror is more accurate and inexpensive as compared to existing smart mirrors.

Keywords: Smart Mirror, Depression, Cognitive Behavior Therapy, Convolution Neural Network, Internet of Things

I. Introduction

Mental health is as essential as physical health. It includes psychological, emotional, and social well-being. Mental health can affect how we behave, think, feel, and act. It also controls how we handle stress and makes choices and decisions. Mental health is important at every stage of life, from childhood to old age. Due to its importance, governments usually assigned proper financial budgets and human resources for promoting mental health and controlling mental disorders. The investment in mental health can give huge effective outcomes by reducing the ratio of disability and premature death [XXIX]. Still, about 450 million people are suffering from different mental health disorders, according to the WHO (World Health Organization) [XVIII]. Among them, depression is one of the leading psychological disorders [III]. Currently, about 322 million people are suffering from depression throughout the world [I]. Psychological depression is “a mood or emotional state that is marked by feelings of low self-worth or guilt and reduced the ability to enjoy life¹”. The symptoms of depression are sadness, disturbed sleep, poor concentration, feeling angry, thinking about sad things [XXXI, XIX]. The most common treatment of depression is medication and psychotherapy [XXVIII], in which the depressed people physically visit a psychiatrist. In most cases, the psychiatrist prescribes medication to cure the symptoms of depression. Depending on the patient’s condition, the medication is given for one week or month. However, taking medication have side effects such as fever, changing mood, anxiety, addiction, physical dependence on the drug, and even increase suicidal thoughts [XXVIII]. The psychiatrist also engaged the patient by giving therapy i.e., Psychotherapy. Psychotherapy is a talking therapy in which psychiatrists discuss the patient about their condition and issues professionally [XXVIII]. The well-known effective therapies for reducing depression are:

- 1) Cognitive Behavior Therapy (CBT): The CBT therapy detects the negative thoughts and behavior patterns in the patient which cause depression and built positive thoughts in the patient through different techniques [XXI].
- 2) Interpersonal Therapy (IPT): The IPT therapy builds social skills and a healthy relationship among the people to cure depression symptoms and life stress [XXI].

Alternatively, digital techniques can be used for reducing depression. For instance, an ICT based solution for conducting online face-to-face therapy is used in [XXVIII]. Also, several software applications are available, which are described in Table 1. Most of these applications are based on CBT, which addresses both anxiety and low mood while providing mental health information [VIII]. The problem with these applications is that they need too much input from the patient, which is already depressed. It means that some intelligent devices are needed which can detect depression automatically and provide a better solution to reduce it. Smart Mirror is an emerging intelligent device that can be used for the automatic detection of depression and to provide some solution for its cure. A smart mirror is a digital screen covered with a semitransparent reflective glass sheet. This screen is connected with a bunch of sensors and a micro-controller for data input and processing respectively [XXIV].

Table- 1: List of applications developed to control/detect depression

Application	Description
Anxiety Coach	Controls the fear and worries using Cognitive Behavior therapy (CBT).
Breathe Experiment	Helps to relax and focus on breathing as well as remind and guide us to take deep breaths every day
DBT Diary Card	It helps us to solve the behavior problem that occurs due to some circumstances.
Healthy Mind	Problem-solving app to deal with emotion and overcome stress.
Mood Kit	It helps us to build self-awareness and a healthy attitude.
Mind Shift	Helps us to face a challenging situation and encourage us to change our life.
IMoodJournal	Analyze the daily feeling through the summary chart to detect the stress level rise and fall.

Several smart mirrors have been proposed for different purposes such as for self-monitoring [XX], managing and controlling different home appliances [XVI], monitoring children [XXVII], checking music beat and music [V], motivating our mood by offering different games [IX], physical exercises in the gym [I], and providing elder health information to their caretakers [XXI]. However, to the best of the authors' knowledge, no smart mirror exists which can automatically detect and resolve depression based on human emotions. To this end, this work presents the design and development of a smart mirror named **ResolDepMirror**.

ResolDepMirror is a smart mirror that detects and resolves depression by monitoring the emotions of the patient. Also as a treatment, it provides Quranic and mindfulness therapies for mental relaxation and to build positive thinking. This paper presents the details of designing and developing **ResolDepMirror**, a smart mirror to control depression. This includes how the hardware and software components are integrated to develop **ResolDepMirror**. The software side is based on neural networks to make **ResolDepMirror** intelligent and allow it to make decisions like a human brain. In particular, Convolution Neural Network, a technique of deep learning, is used for training in this work. The user emotions are detected from a camera using the haar cascade classifier and the trained model. The results show that **ResolDepMirror** can accurately detect user emotions and provide solutions to cure depression. In comparison with existing smart mirrors, **ResolDepMirror** is one of its kind smart mirror used for controlling depression. It is easy to set up and is affordable in terms of cost.

II. Literature Review

From a psychological perspective, depression is the condition where a person thinks more negative thoughts than positive ones. This can be controlled using CBT, which is effective for long term depression disorder [VI, VII, X, XII, XIII, XVII, XXV]. In the following, a review of different CBT based methods and existing smart mirrors are provided.

CBT based Methods

Medication is an effective method used for the treatment of depression in the U.S.A, but it has some drawbacks such as an increased rate of cardiotoxicity and suicides, etc. Therefore, psychotherapy using CBT is considered a long-term treatment of controlling depression. However, the result shows that psychotherapy is the least effective than medication [X]. On the other side, mindfulness therapy (i.e., Yoga, tai chi, breathing exercises) is used for decades in Buddhism as a practice. In the Western world, it is also considered the most effective therapy for controlling depression. Because mindfulness therapy decreases negative thoughts, relaxes the body, improves memory, and is also good for human neural mechanisms [VI]. In contrast, music therapy is another way of controlling depression. In [XII], it is shown that music therapy gives high results compared to self-care. However, music therapy is not good in every situation and music creates noise and signals [VII]. Likewise, Quran therapy

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(i.e., listening to the Quran, the holy book of Muslims) has produced amazing results. This therapy is applied to control depression of 12 patients in a hospital [XXV]. As a result, the female felt better after the experiment. Similarly, to detect the emotion of Muslims and non-Muslim while listening to the Quran, a study is performed [XVII] using EEG to crop the feature and brain waves. The result shows that the Quran recitation gives a positive impact on both Muslims and non-Muslim even they understand the Arabic language or not. Therefore, listening to Quran recitation can be included as a medical treatment to control stress and depression [XVII].

Emotion detection using deep neural network

Emotion is important from a psychological perspective and it is also used for detecting mental health disorders [II]. Emotion can be recognized through seven facial expressions that are sad, angry, neutral, surprise, happy, fear, and disgusted. A lot of work has been done on emotion detection through deep learning using a convolution neural network (CNN) with different models and frameworks. For instance, Xu et al. [XXX] have developed a framework for emotion recognition from scratch. The data sets are collected manually, processed, and trained using VGG's model. Although this method provides 82 % accuracy, VGG's model is old and is less reliable than the Mobile net model. Similarly, Tripathi et al. [XXX] have made a technique for the identification of males and females through the Mobile net model. The result proved that the Mobile net is more reliable than the VGG model [XXX].

Review of existing Smart Mirrors

MagicMirror is an open-source code mirror, which shows date, time, weather, complement, and calendar. It also has a customized module that can be accessed by installing the plug-in. Moreover, it provides a guideline for the developer to create their module. Basically, this mirror is based on an Electron application and a web server. However, some of the customized modules are not accessible due to the finite amount of knowledge about installing plug-in, code, and issues in the code. Aware Mirror [XIV] is another similar smart mirror that displays information (such as date, time, weather, etc.) according to a person's interest. It recognizes the person through a toothbrush, using a proximity sensor attached to the brush. However, this mirror does not have any fancy interface and it displays only basic information (i.e., date, time, etc.).

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Samsung Hair salon mirror is a 55-inch mirror, made by Samsung, for hair salons that displays information about the latest haircuts, color, and other information related to hair. To achieve these tasks, it used a 3D sensor camera. This mirror is used in Korea, but this mirror can only be used in hair salons. Similarly, Smart Makeup Mirror [XI] provides ease to females in doing their makeup easily by providing automatic zoom in/out feature, showing face from multiple angles, and saving the makeup image in their profile using high and low-resolution cameras and proximity and range sensors. However, this mirror can only be used for makeup purposes.

Smart Mirrors for emotion detection

There also exist some smart mirrors which can detect emotions. For example, Magic Mirror Table [XXXIV] is a furniture designed mirror that recognizes the positive and negative emotions of the viewer using Back Propagation Neural Network (BPNN). This mirror plays the viewer's favourite song and displays encouraging quotes when the viewer is detected with negative emotions i.e., sad, scared, and disgusted. Since anger is not considered a negative emotion in this mirror, it does not perform any operation to control that emotion. However, anger is one of the strong psychological negative emotions that should be handled to control mental health disorders. Similarly, WizeMirror [XXIII] can measure height, weight, heart rate, body mass index, and even our mood. This all is done without any contact, i.e., now wrist band or other wearables are used. However, this mirror only focuses on monitoring physical health and is not effective to solve mental health issues. FitMirror [IX] improves the mood of the viewer and motivates by offering different exercise games. It recognizes the face and emotion of the viewer using Microsoft Kinect V2, a Wii balance board. However, this mirror cannot recognize the positive and negative emotions of the viewer separately. Moreover, it doesn't focus on the negative emotion of the viewer at all. Interactive Mirror [VIII] can detect emotion or analyze health, and provides event reminders. According to user feedback, face recognition is not good in this mirror. Multi-users can access this mirror but it does not provide the functionality of controlling and finding depression. On the same note, Mirror that talks [III] is built for decreasing the rate of depression in people. It provides virtual therapy using Remotion and Eliza' natural languages. This mirror controls the depression, by giving talking therapy as a solution to depression but it is not effective in all situations. Moreover, the validation of results and conclusions are not provided in [III].

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Smart Mirror Architecture

The hardware and software architecture of a smart mirror is proposed in [XV], for home automation communication. The hardware architecture comprises the mirror, frame, driver board, GIPO, electronic control module, speaker, camera, microphone, and infrared induction module. The smart mirror first recognizes the human face using the GPIO library and Baidu voice API. On proper authentication, it allows the person to perform a specific task using voice commands (e.g., switch on the light, etc.). Similarly, the hardware and software architectures are proposed for a smart mirror [XXVIII] that examines and recognizes the face and emotion of the viewer. It uses a Multitask learning approach based on CNN, where the model is trained on the Affect Net database. But this mirror only recognizes the face and emotion of the viewer and does not perform any action after detecting the emotion. In [IV], the authors have proposed hardware and software architectures to build a secure smart mirror. For this purpose, they are using face recognition and artificial intelligence. Therefore, the software architecture consists of OpenCV, QT, and Local binary pattern histogram algorithm for face recognition.

All the above-mentioned smart mirrors are developed to achieve a specific goal and cannot be used for monitoring mental health disorders. Therefore, an alternate system is needed that can automatically detect depression without any human interaction by focusing on the psychological emotion of the person. Unfortunately, no such smart mirror is developed, which can do these types of activities. Moreover, the hardware and software architecture presented in [XII, IV] are too specific and cannot be used in another context. In the works described above [III, XXVII, XXIV, IX, XXIX], all of the smart mirrors cannot control the depression. This research work is focused on two negative emotions (sad and angry) at the same time and provides a novel and better solution to control them.

III. Methodology

The design of **ResolDepMirror** comprises the software and hardware parts. Both of these components are configured based on the requirements and drawbacks extracted from the analysis of existing smart mirrors [III, V, IX, XVI, XX, XXV, XXI, XIV, XXXIV, XXIV]. The software configuration includes the installation of useful software required to set up a smart mirror and for emotion detection. For emotion detection, the data is collected in two ways. The primary data comprise of a customized

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set of images collected manually, whereas the secondary data is collected from the Kaggle face data-set. As **ResolDepMirror** is focused on detecting two emotions (sad, angry), the data is kept in two directories i.e., sad emotion images and angry emotion images. These primary and secondary data sets are then trained using tensor flow framework, and deep learning techniques i.e., CNN and mobile net model version 224-1.4. The emotions are extracted from the data sets through the haar cascade frontal face classifier and the trained model. The basic programming code of emotion detection is taken from the open-source GitHub which is then updated by adding Tkinter and gTTs APIs in it. The gTTs API is an online API, which is used to speak the text. **ResolDepMirror** is tested in the real-world and it involves humans in collecting the result. Therefore, all human ethics are considered. Finally, **ResolDepMirror** is compared with an existing mirror via checking functional non-functional attributes. The complete methodology of designing and developing of **ResolDepMirror** is shown in Figure 1.

IV. The Proposed Smart Mirror – ResolDepMirror

The hardware and software design of the proposed **ResolDepMirror** is presented below.

Hardware architecture

The hardware of the proposed mirror consists of a two-way mirror, LCD screen, camera attached to raspberry pi, and speaker as shown in Figure 2. The two-way mirror has a transparent and reflective surface. The LCD screen monitor is enclosed inside a rectangular wooden box to make the digital mirror interface and to hide the hardware complexity from the users.

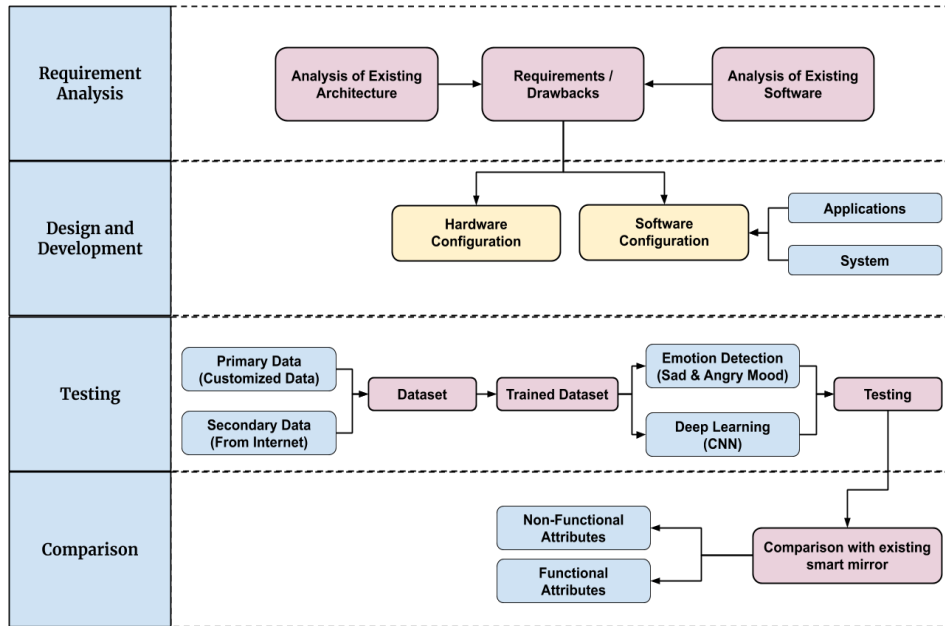


Fig 1. Methodology to develop **ResolDepMirror**

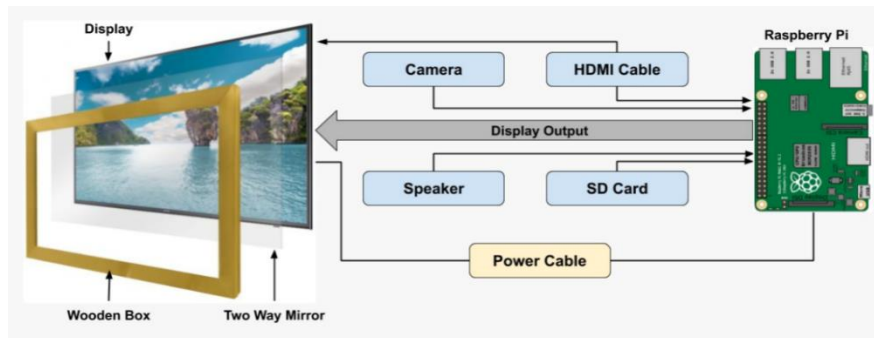


Fig 2. Hardware Architecture of **ResolDepMirror**

To detect and recognize the emotion of a person, **ResolDepMirror** contains a 12MP camera and a speaker to produce audio output. For saving of Open CV libraries, tensor flow, and operating systems, a 32GB SD card is used in the raspberry pi. To connect raspberry pi with an LCD screen, an HDMI cable is used to show the display on the screen. To provide power to raspberry pi, a 5VUSB charger cable is used, whereas a normal monitor power cable is used to switch on the LCD screen.

Software Design

The software part of the proposed design is composed of computer vision (i.e., Open CV) libraries and deep learning techniques for the training of models. In this

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work, two types of data sets are used i.e., customized data-sets (primary data) and facial expression data-sets (secondary data) from Kaggle face data-set. Customized data sets contain the images of facial expressions of two different emotional expressions (angry, sad) of eight persons; whereas, Kaggle datasets are the open-access data sets that are available on the Internet. Consequently, the data set comprises a total of 270 images. The images are extracted from the data sets through the haar cascade frontal face classifier. Haar cascade classifier uses the machine learning algorithm for accuracy, in which a small amount of important feature is selected from a large data set to give an accurate and efficient result. The classifier takes three features of the face i.e., nose, eyes, and mouth as a face model. Also, computer vision open-source libraries are used for object detection, recognition, and so on. The mobile Net model is used for training data sets because of its advantages over other models. It is a lightweight architecture of the depth-wise CNN. This model is designed for tensor flow to provide a high accuracy rate (70.9 – 89.9%). Figure 3 provides a pictorial representation of software configuration done to setup **ResolDepMirror**.

Working of ResolDepMirror

When a user is standing in front of **ResolDepMirror** for 30 seconds, it starts checking his mood. Once a user is detected “sad”, **ResolDepMirror** marks the emotion with a yellow rectangle, as shown in Figure 4. It then starts Quranic therapy by displaying and pronouncing Quranic verse as shown in Figure 5. Also, the English translation of the Holy verse is displayed as a subtitle. On the other hand, if the mirror detects the user in an angry mood then it will be marked the user’s face by a red rectangle, as depicted in Figure 6. In this case, **ResolDepMirror** will start mindfulness therapy (breathing exercise) as shown in Figure 7. The mirror also produces audio and textual commands regarding breathing exercises to relax the viewer from angry emotion.

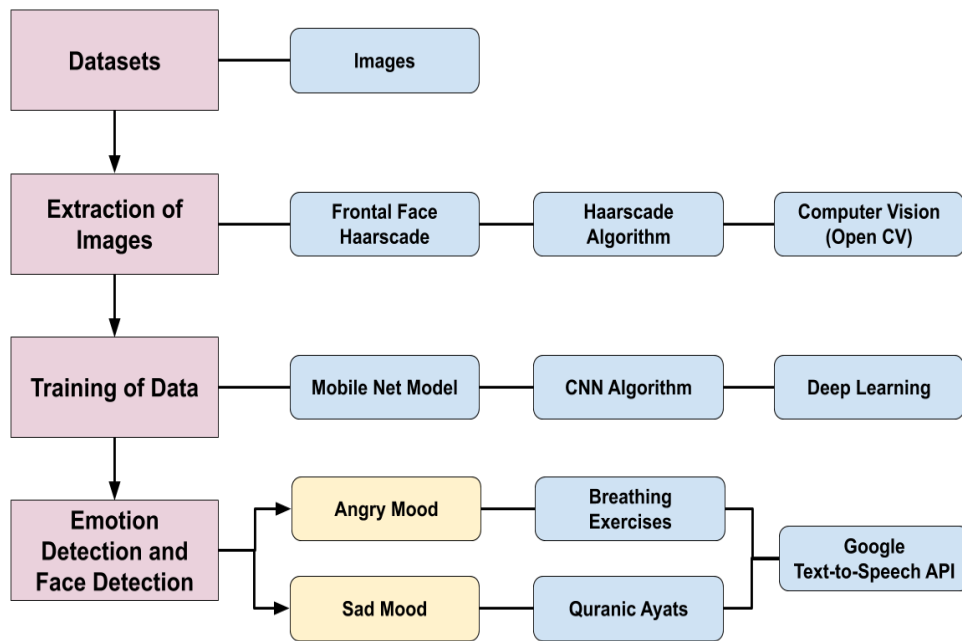


Fig 3. Software configuration of **ResolDepMirror**



Fig 4. The test case of sad emotion detection

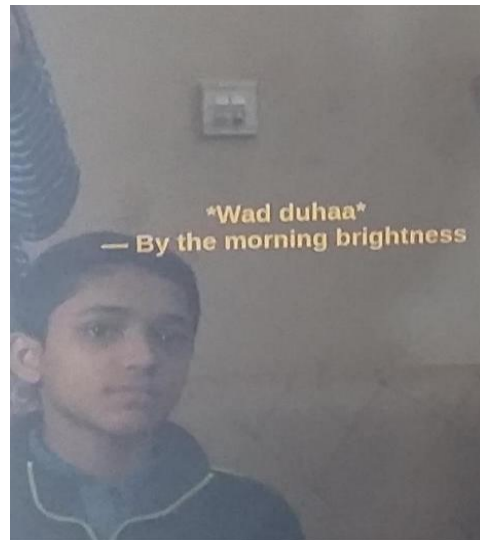


Fig 5. Example of Quranic therapy provided by **ResolDepMirror**



Fig 6. The test case of angry emotion detection

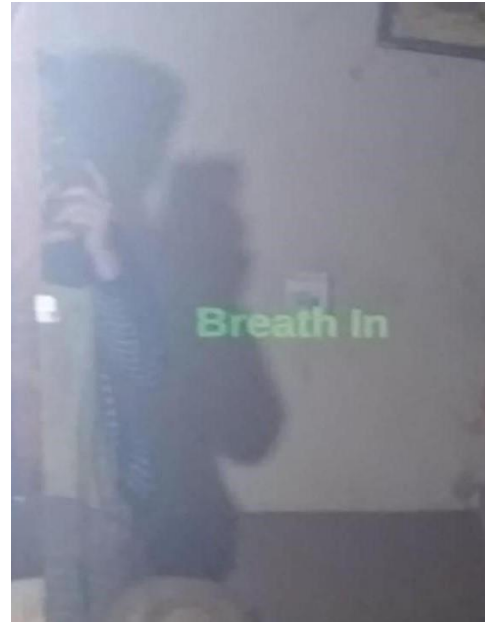


Fig 7. Example of Mindfulness therapy provided by **ResolDepMirror**

V. Results and Discussion

ResolDepMirror was tested on ten people, of which four were female and six were male. During the test, it was found that **ResolDepMirror** also recognizes the emotion of untrained persons. The accuracy of **ResolDepMirror** was measured in terms of face and emotions detection, and display of Quranic Verses and breathing exercises. The results recorded during these experiments are shown in Table 2. It can be observed that the accuracy of sad emotion is more than angry. This is due to the use of large data set of sad emotions. The average overall accuracy is 79.5 %. **ResolDepMirror** has a list of other advantages over traditional psychotherapy such as cost-saving, reduction of burden on the psychiatrist, and no human interaction, etc. In addition, **ResolDepMirror** is compared with other existing smart mirrors [III, IX]. The results of the comparison are shown in Table 3. It is clear that **ResolDepMirror** provides 79.5 % accuracy, whereas the Mirror That Talks [III] does not provide any validation results. On the other side, Fit Mirror [IX] does not control depression. It only motivates the mood of the user using different exercises.

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Table- 2: Lists of applications developed for controlling the detecting depression

Task	Accuracy
Detection of face	90%
Detection of emotion	70%
Sad emotion	80%
Angry emotion	77%
Display Quranic Ayat (sad mood)	80%
Display Breathing exercise	80%
Average result	79.5%

Table- 3: Comparison of **ResolDepMirror** with other smart mirrors

Mirrors	Accuracy	Controlling depression	Detection of emotion
ResolDepMirror	79.5%	Yes	Yes
FitMirror [IX]	36.58%	No	No
The Mirror that Talks [III]	No results available	Yes	Yes

VI. Conclusion

Mental health is equally important to physical health in everyone's lives. Due to a lack of awareness about mental health, a lot of people face serious problems that not only affect their physical health but the whole society. Due to a lack of resources, developing countries cannot provide proper budgets and funds for a mental health cure. This research is about providing digitized treatment as a cure for one of the mental health disorders i.e., depression. Different psychotherapy and mobile apps are present for the treatment of depression. However, **ResolDepMirror** provides a new interactive interface as a mirror to resolve depression.

ResolDepMirror is a smart mirror that detects the psychological emotions of its viewer and provides Quranic, mindfulness therapy according to the viewer's emotions. In this work, the hardware and software design of a smart mirror is presented that will be used for controlling depression. As existing smart mirrors are developed for specific purposes, they cannot be used for this purpose. The developed mirror is tested using several test cases to check its validity. Also, **ResolDepMirror** is compared with existing mirrors to check its accuracy. The results showed that **ResolDepMirror**

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provides the highest accuracy rate i.e., 79.5 %. In the future, it can also be used as a counseling technique by providing a list of the psychiatric session based on profile data. It could also be used in the detection of physical health problems such as early detection of cancer from a mammography graph using a deep learning approach and MRI (Magnetic resonance) diagnosing using deep learning.

VII. Compliance with Ethical Standards

Funding: The authors did not receive support from any organization for the submitted work.

Conflict of Interest: The authors have no conflicts of interest to declare that are relevant to the content of this article.

Ethical approval: All procedures performed in studies involving human participants were by the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent: Informed consent was obtained from all individual participants included in the study.

Conflict of Interest:

All authors have no conflict of interest

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