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Internet of Things Based Cradle Monitoring

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Abstract: This cradle monitoring integrates cutting-edge technology to provide anall-inclusive solution for busy parents. This cradle is fortified with an array of sensors that regularly monitor the baby's welfare. The cradle gathers real-time data, and offers parents treasuredinsights into their child's health and well-being . Remote access is provided to the cradle's functionalities, which allowsthem to observe various aspects of the baby's backgrounds and environment. This work aims toprovide better monitoring of the infant by utilizing Machine Learning models for the classification of the emotions of the infant as well as for intruder detection. Thisseamlessintegration of the cradle with IoT technology ensures that parents receive instant alerts and notifications in case of any anomalies, fostering a heightened sense of security.
Keywords: IoT, Machine Learning, Smart Cradle, Emotion Classification.

I. INTRODUCTION

Childcare is a huge challenge and hurdle for a working parent.Parentscannotalwayscarefortheirbabiesandspend time monitoring them due to other responsibilities. Keeping an eye on the infant and raising children in this present career-oriented worldisa difficult challenge.In today'sfast- paced world, parents often face challenges in ensuring the optimal well-being of their infants, especially during sleep and rest periods. There are a lot of security concerns that parents have with various daycare facilities and caregivers. The continuous dedicated monitoring of the baby expected by the parents cannot be fulfilled due to the lack of time.

Traditional baby cribs lack advanced monitoring and interactioncapabilities,leavingparentsconcernedabouttheir baby's safety, health, and overall comfort. Additionally, the demands of modern lifestyles require parents to balance childcarewithotherresponsibilities,makingitchallengingtoprovidecontinuous,real-timeattentiontotheirinfants.

Thus, weproposedanIoT-basedsmart cradletoconnectthebabies and parents in a safe environment. In today's world, we can observe a rise in systems that apply the concept of the Internet of Things(IoT). The main attraction of this technologyliesintheconnection of“Things”totheInternet. These include various sensors, actuators, and other smart objects. This allows us to convert all physical environment parameters into digital values for monitoring and analysis. IoT also allows the introduction and encouragement of varioussmartindustries.IoTcaneasilybefoundinour environmentinhealthcare,houses,cities,agriculturaland transportation industries to name a few.

Along with IoT, we can also observe the emergence of Machine Learning to enhance the IoT functionalities. The progressin thesetechnologieshashelped uspropose an IoT- based baby monitoring system. This system uses machine learning for emotion classification and intruder detection. Theaim isto overcometheissues faced by working parents.

A. Aim

In an era where technology seamlessly intertwines with every facet of our lives, ushering in a new wave of convenience and connectivity, we introduce SmartNest—an innovative IoT-based Smart Cradle designed to redefine infant care.

SmartNestintroducesaharmoniousblendofcutting-edge technology and nurturing comfort. Leveraging the power of RaspberryPi, thisproject representsa paradigm shift in how we perceive and safeguard the well-being of our tiniest familymembers.Thesmartcradlewillincorporateadvanced sensors and connectivity features to provide real-time monitoring and data analysis. These sensors allow us to measure various vital parameters that influence the comfort of the baby. We also have a web camera attached for better monitoring and also make use of this feed for emotion classification. The parents can receive alerts about the baby and monitor their baby's surroundings on their mobile phones.

The proposed system is equipped with a Raspberry Pi3 B+, a web camera, a sound sensor module, a heartbeat module, a speaker, a DHT11 sensor for reading temperature and humidity parameters to monitor the condition of the infant, and a DC Motor. All these components comprise the controlsystemoftheSmartcradle.Thesesensorsareusedto measure the environment of the infant. The read values are verifiedandaccordingly, telegrammessagesaresent,incase of any abnormal conditions, to alert the parents. Further, the system classifies the real-time emotion of the baby and detects intruders using CNN.

B. Data

We use an open-source dataset containing images of infants.Thedataisopensourceandlabeled,witheachimage being described as one of the seven classes - happy, sad, surprised, angry, disgusted, scared, and neutral.

II. RELATED WORK

This section discusses some of the relevant work in the domain of IoT-based Smart Cradle Systems.

Patil et.al. has previously built a cradle that monitors the activities of the infant. The cradle uses an Arduino and a GSM module. The cradle is also incorporated with the camera to track the baby but the major problem that was identified is that the messaging system is not present along with the absence of the machine learning which is being vanquished by our model.[1]

Jabbar et.al. have suggested using the concept of IoT with baby monitoring systems. It uses the MQTT server cloud and internet along with the Lullaby toy machine, but this model failed to incorporate the system with the Raspberry Pi and also the servo motor was being manually controlled by the parent this has been taken care of along with the machine learning aspect.[2]

This system uses sound sensors. They are used for cry detection. It measures the intensity of noise. This system madeuse of themobileapplication methanesensor to detect the smell of the diaper along with the GSM module. The major setback of this system is that it failed to use the sensors along with the microprocessor. The presence of the sensorsmakesSmart Nestanadvantageous Systemcompared to this system.[3]

Batool et.al. have emphasized theuse of the servo motor andthesensorstowatchanewborn for twoyears.Theuseof themanuallyactivated servomotor hasbeen observedalong with the alarm-sending capabilities, but the limitation of the system is that it only uses a microcontroller. The manual activation of the motor and that system communicates with the parents through an alarm message. All of these limitations have been achieved in our system.[4]

In a preceding study, a Wi-Fi camera's built-in smartphone app allows parents to view their child's status and speak with them by video monitoring. The major accomplishment ofthissystemisthatitusesan Arduinoand also uses the Blynk application, but the absence of the Raspberry Pi, motor, and machine learning algorithm made this system a demerit.[5]

The use of the cloud has been to store the data. The system makes use of various components to monitor the environment and activities of the infant including sensors and a servo motor. Additionally, the motor was driven by a microcontroller upon the cry detection. The hindrance that was observed in this system wastheabsence of themachine learningalgorithmandthatitonlyusedamicrocontroller.[6]

In another system, where a sensor for noise detection is used to detect the baby's cries or loud noises, as the mobile toy rotates. The system had an alarm activated for the wetnessdetection butthelackofawebcameraandthesound sensor modulemadeasetbackinthissystem whichhasbeen being achieved in the SmartNest.[7]

TheuseofBluetooth for Androidapplication controlhas also been used before. The quick response of the work is depicted using a flowchart. The presence of the Arduino, heart rate sensor, speaker facility, Raspberry Pi, and mobile notification has made the system advantageous over the systems previously mentioned but the absence of the machinelearningalgorithmalong withthehumidityand temperature sensor. SmartNest has incorporated the use of temperature and humidity sensors along with the machine learning aspect which made the system more efficient.[8]

Mahesh Kaluti, Kavana et.al., monitored the quality of the crib by observing the exceeded humidity levels, to send warnings. As in many other studies, the temperature and humidity of the room are also monitored. The use of Raspberry Pi and the Blynk server for notification of the baby's cry made this system beneficial but the absence of a web camera and machine learning algorithms made this system inefficient which is achieved in the SmartNest.[9]

III. METHODOLOGY

A. Internet of Things

The design of our work includes the use of various technologies including the Internet of Things (Sensors), Automatic Rocking Mechanism, CryDetecting Mechanism, Intruder Detection, Live Video Surveillance, etc.

For the monitoring of the activities of the infant, we make use of the various modules and sensors:

- DHT11 as a Temperature and Humidity sensing module.
- Wetness detection was performed using a soil moisturesensor.
- Crydetection usingasoundmodule.Thistriggersthe swinging of the cradle using a motor.
- Heartbeat sensing module to check the pulse of the infant.

- Speakertoplaythemother'svoiceuponcrydetection.

Web camera to facilitate live streaming for monitoring the infant. The images required for the emotion classification model and intruder detection model are obtained from this web camera.

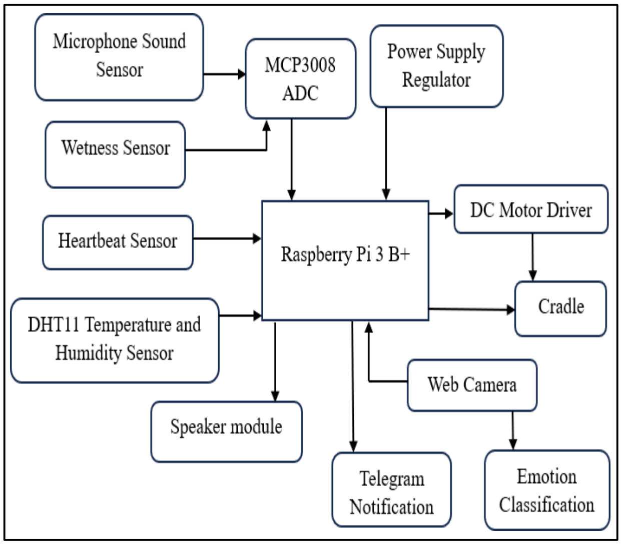

Fig.1.BlockDiagram

B. System Architecture

Conduction of a thorough analysis and study of the system requirements to identify potential challenges, assess the viability of the proposed system, and ensure completion of the project.

Sensor requirements are analyzed along with its integrationanddataprocessingcapabilities.Compatibilityof theRaspberryPi tohandleprocessing isstudied. Along with these technical requirements, hardware availability is analyzed. Resources required include hardware components and the various software libraries and packages. Assess the functionalityofthehardware components. Studythe various algorithmsforemotionclassification.Computetheestimated cost of the project.

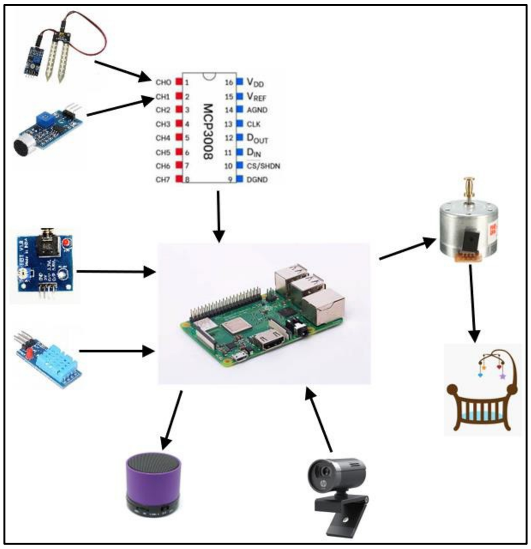

Fig.2.SystemArchitecture

1) RaspberryPi3B+

Raspberry Pi3 B+ has the below new features for enhancement of its functionality. A few of the specs of the new model are:
Quad-core64-bitprocessorclockedat1.4GHz 1GB LPDDR2 SRAM
Dual-band2.4GHzand5GHzwirelessLAN Bluetooth 4.2 / BLE

Higherspeedethernetupto300Mbps
Power-over-Ethernetcapability(viaaseparate PoEHAT)

2) DataFlow

The flow of data begins with the temperature and humidity values that are measured using DHT11 and this data is sent to the parents via telegram. It also alerts parents when the value of the temperature increases the given threshold. Further, the wetness sensor detects the values to determine the wetness of the clothes or diaper of the infant. Accordingly, the parent is notified.

Next, data from the heartbeat sensor is checked and the value is sent to the parent. The data from the sound sensor cannot be utilized in its current form. Thus, we first use an ADC to convert it into digital data and if the sound level exceeds the given threshold it indicates that the baby is crying.Uponthisdiscovery,atelegrammessageissentto notify the parent and we also play music using the speaker. Also,themotorattachedtothecradlerotatesandthedelayis set such that it causesthe cradle to swing at a safe angle.

Data from the web camera is used to interpret the emotion and to detect the presence of unknown individuals.

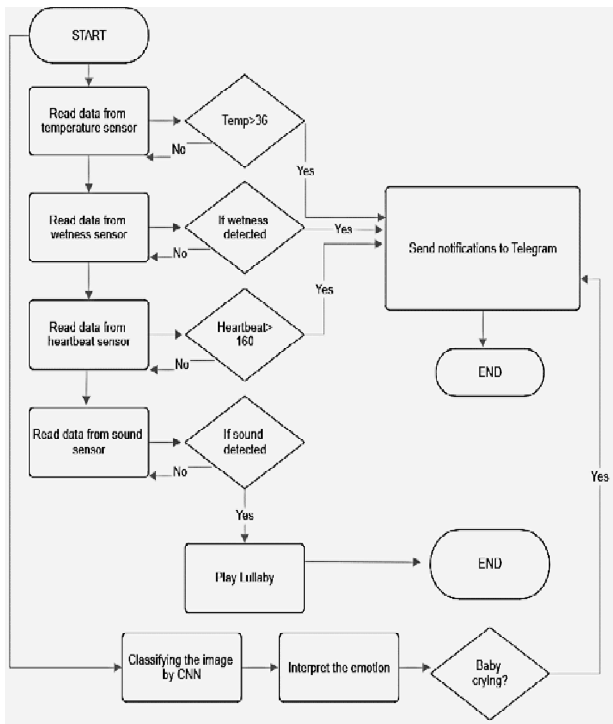

Fig.3.DataFlowChart

C. Emotion Classification

The emotion classification machine learning model follows a supervised learning approach, utilizing images showcasing various facial expressions for training and testing.Theprocess begins withimageacquisition,followed by face detection and preprocessing. The Facial Landmark Detection algorithm is then used to identify crucial facial features, which are subsequently extracted for recognition and classification purposes. Face detection and feature extraction are carried out on facial images, ultimately classifying them into one of seven emotion classes.

1) ImageAcquisition

The data used for training and testing are static images. For training we use an open-source data set, for testing, we make use of images captured using our web camera. The training data is a dataset of facial images labeled with the corresponding emotions. The labeled emotions are “angry”, “disgust”, “scared”, “happy”, “sad”, “surprised” and “neutral”. This is defined in our “EMOTIONS” list for programming requirements.

Our pre-trained model is of CNN architecture trained on thefacialexpressiondatasets.Loadingthispre-trainedmodel is achieved using TensorFlow/Keras.

2) Face Detection

Face Detectioniscarriedoutinthetrainingdataset using the Viola-Jones face detection algorithm, implemented through the Haar cascade classifier provided by OpenCV. Thisencodesthedifferencesintheaverageintensityof various sections of the image. It divides the sections into black-and-white connected rectangles with different pixel values in each region.

The video frames are captured from the webcam using OpenCV. It detects the faces in each frame using the Haar cascade classifier and processes only the region of interest corresponding to the detected face.

3) DataPreprocessing

Preprocessing includes resizing the face ROI to 64X64 pixels and normalizing the pixel values to be in the range [0,1].Thisstepisessential topreparetheobtainedimages as input for our emotion classification model. We perform the elimination of noise and normalization against the variation of brightness and pixel positions. The two normalizations used are

- ColorNormalization
- HistogramNormalization

4) FacialLandmark Detection

We use facial landmark detection algorithms to identify keyfacial landmarkssuch aseyes, nose,andmouth. Wecan the n extract features based on the position and geometry of these landmarks to capture the facial expression effectively.

5) FeatureExtraction

Next, we move on to select the feature vector. This processhasvariousparameterstoconsider.Thisincludesthe pose of the subject, the scale, translation, and also the diversity in the illumination levels. This process includes passing the pre-processed face ROI through the loaded model to get predictions for each emotion. The model outputs probabilities for each class indicating the likelihood that the input face expresses that particular emotion. The accuracy of this machine-learning model is 93%.

Based on this likelihood, we determine the emotion and check if it is necessary to notify the parents and send a Telegram message accordingly. For these messages, we use the Telepot Library to use the Telegram Bot API.

D. Facial Recognition

We utilized OpenCV for facial recognition. It captures video frames from the camera and detects faces using the Haar cascade classifier. The detected faces are then used as input to predict the identity of the faces using LBPH face recognition.

We procure the frames of a user from the webcam and assign them an ID. The users are saved in a separate folder. To train our model, the face images and labels previously saved are detected and face samples along with their correspondingIDsarecollected. Wetrainedthemodel using the LBPH face recognizer and collected data.

If the predicted ID is less than 60 and the ID matches a predefined valuethen theperson present is known. Ifthe ID is greater than 60 and doesn't match a telegram message is sent to alert the parents of an unknown intruder.

E. Implementation

1) Convolution Neural Network(CNN) with ResNetArchitecture

Classification is used to decrease the magnitude and varietyofdata.Thisisduetotheveryhighdimensionality presentinourfeatureextractionmethod.Weperform classification using CNN.

Facial Expression Recognition and classification can be performed using multiple models including decision trees and neural networks. Studies show that the Convolution Neural Network (CNN) model is the most accurate. Due to thebetter capturing featuresof CNN,itishighlysuitable for image classification. This high capturing capability arises from the large number of filters being used.

For our emotion classification model, we have used a CNNmodelwithResNetarchitecture.TheCNNarchitecture used in the pre-trained model includes convolutional layers consisting of filters to extract the features. Activation functionslikeRectifiedLinear Unit(ReLU) areemployed to establish non-linearity and increase model expressiveness. The complexitiesareabstracted using the pre-trainedmodel. The CNN processes the facial ROI to predict the emotion label based on learned features.

2) Maxpooling

Max-pooling is a common technique used in CNN to down-sample feature maps, reducing their spatial dimensions. This allows to capture the most relevant

features while discarding unnecessary details. It contributes to the efficiency and effectiveness of the CNN model by reducing computational complexity and allows to focus on the important special information.

3) LBPHFaceRecognizer

Local Binary Patterns Histograms is an algorithm used for face recognition. The algorithm divides the face image into small regions and for each region, computes a local binary pattern histogram.

The histograms are integrated to construct the required featurevector.Thesefeaturevectorsareusedtorepresentthe faces. We make use of this algorithm for the intruder detection feature of our smart cradle system. It captures video frames from the camera, detects faces using the Haar cascade classifier, and predicts the identity of the face using the LBPH face recognizer.

IV. RESULTS AND DISCUSSION

We have successfully connected all sensors to our RaspberryPi 3 B+. Weutilizethesesensors' datatoperform the actions of cradle swinging by activating the motor, Playing the mother's voice or music using the speaker, and alsosendingnotificationsin caseofencounteringextremeor harmfulparametervalues.Wehaveincorporatedtheemotion classification model successfully and accordingly send telegram notifications for emotions like happy, sad, and scared.

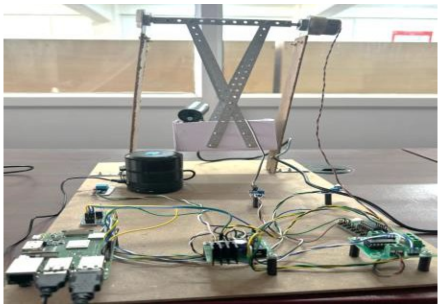

Fig.4.SmartCradle

The real-time values of the temperature and humidity sensor were monitored, and telegram messages were sent if they exceeded the set threshold. Cry detection functionality was examined by playing a video of a crying baby. The sound sensor module captured the sound level from this cryingaudio,baseduponwhichanotificationwassenttothe parent using telegram messages, the motor attached to the cradlewasactivatedandresultedin thesoothingswingingof thecradletocomfortheinfant.Alongwiththis,themother's voice was alsoplayed on thespeaker tocreatea comfortable and familiar environment for the infant.

TABLEI.
SENSORRANGEANDTHRESHOLD

Sensor/Actuator	DependantParameter	Range	Threshold
Temperature	Temperature	36.1- 37.9°C	38°C
Humidity	Humidity	50-60%	60%
Sound	Frequency	75-1000	130
Moisture	WaterContent	400-600	650
Heartbeat	Heartrate	60-120beastspm	78bpm

Thebelowfigures showthetelegrammessages sent with the values measured by the sensors.

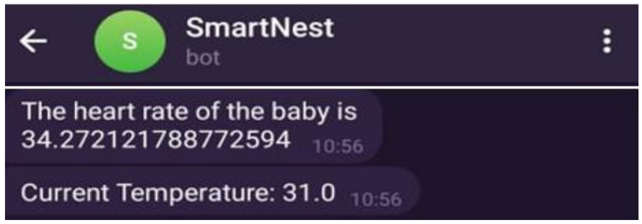

Fig. 5. Telegram message to send values of heartbeat and temperaturesensor

Fig.6.TelegramMessagestonotifyparentswhenbabycriesandwetness of baby clothes

We also make use of an external web camera to be able to view live streaming. Thishelps the parents to monitor the infant at any given time. The algorithm implemented for emotion classification helps to classify the emotions of the baby with the help of the images captured by the web camera.

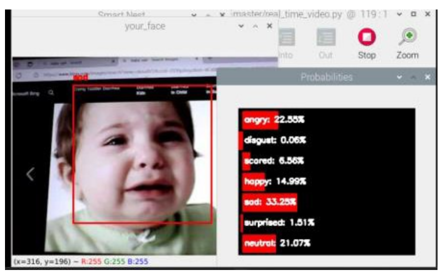

Fig.7.Emotionclassifiedassad

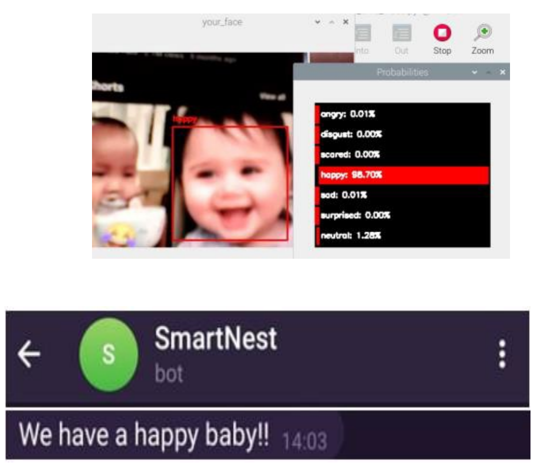

Fig.8.Emotionclassifiedashappyandcorrespondingtelegrammessage

The footage of the external web camera is used to perform intruder detection. Ithelpsto identifytheusers, and ifthefaceisunknown,thenatelegrammessageissenttothe parent.

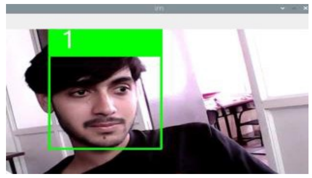

Fig.9.Registeredpersondetected

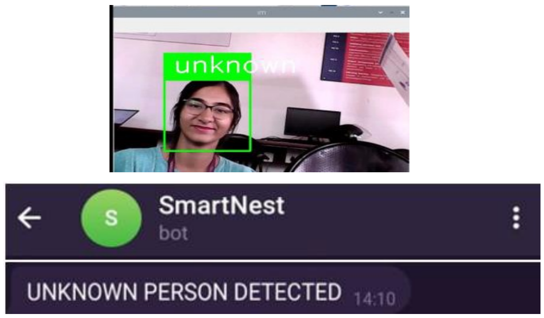

Fig.10.Unknownpersondetectedandcorrespondingtelegrammessage

V. CONCLUSION AND FUTURE SCOPE

We, therefore, consider our work to be a step forward in the better care of thenewer generation. Our work allows the working parents to better monitor and care for the infant whilealsobeingabletomanagetheir careers.Thiswillbeof greatassistance. Ourfeaturesofsensorsformanagingthe environment and various parameters like the wetness of the baby'sclothesand monitoring theemotion softhebabyallow us to provide timely notifications for the parents. The live streaming feature also allows the parents to check on the baby at any time from anywhere. This allows the remote monitoring of the baby. We do, however, recognize that various other needs of the infant are too complex for our machinestohandle.Theresultsofour emotion classification model and intruder detection model hinge entirely on our trainingdata.Thequalityandquantityofthedatasetmust be adequate to ensure the right decisions are made. Regular maintenance of our system is required to ensure that it does not hinder the parents in the future. Further, we can also allowdeployingthesensor datatothecloud.Usingthecloud to storeand manage our data would be a better utilization of resources. Along with the present sensors, we can also include other sensors like PIR for movement and Methane sensorsfor smell. Wecanalsocreateamobileapplicationto display all the sensor data.

VI. ACKNOWLEDGMENT

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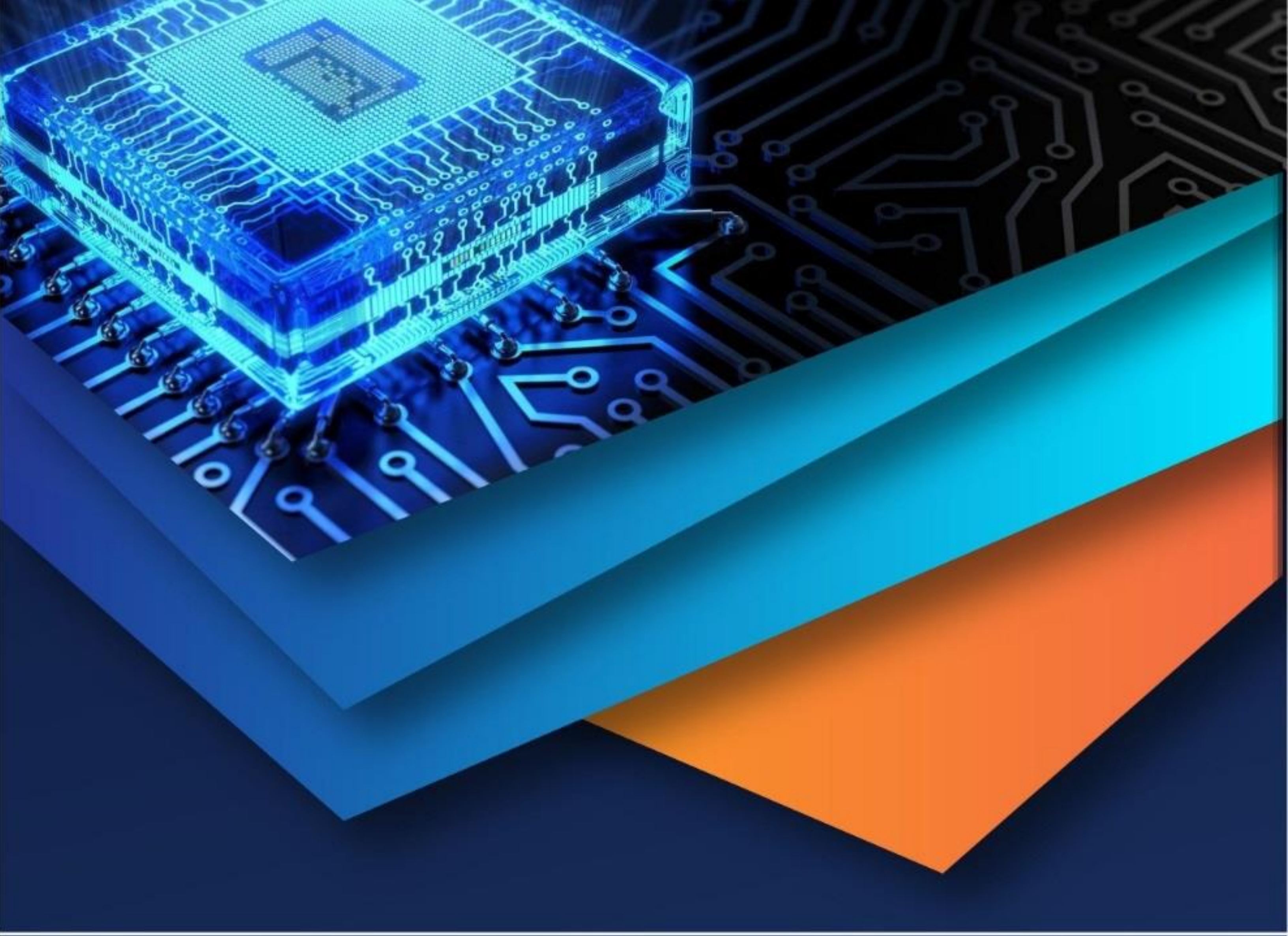

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