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Facial Emotion Recognition Based Real Time Learner Engagement Detection System

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Abstract - Inthe wake ofthe COVID-19pandemic, onlineeducationhasgrownrapidly, butithasbrought challenges in maintaining student engagement.Unlike traditional classrooms,onlinelearninglacksphysical cues like body language and facial expressions, making it harder for teachers to gauge attention and involvement. To address this, the proposed Facial Emotion Recognition-Based Real-Time Learner Engagement Detection System uses deep learning to analyses students' facial expressions during online classes. By detecting emotions like happiness, sadness, surprise, and neutrality, the system calculates an Engagement Index (EI) to provide real-time feedback to educators.

State-of-the-art models such as Inception-V3, VGG19, and ResNet-50 are employed, with ResNet-50 achieving the highest accuracy of 92.3% on benchmark datasets. This system helps educators identify disengagedstudentspromptly, enhancing both the learning experience and academic

Keywords: Online Education, Student Engagement, Facial Emotion Recognition, Deep Learning Algorithms, Engagement Index (EI), Real-Time Feedback, ResNet-50

i. INTRODUCTION

The rapid and widespread adoption of online learningplatformsinrecentyearshasfundamentally reshaped the educational landscape. With the integration of digital technology into education, learning has become more accessible than ever before.Theseplatformshaveallowedstudentsfrom diverse geographical locations and varying time zones to access high-quality learning materials and instruction at their convenience. Thisflexibilityhas been especially valuable for those who might otherwise face obstacles to education such as workingprofessionals,individualsinremoteorrural areas, and students with disabilities or health concerns. As a result, online learning has emerged as a powerful tool for democratizing education and fostering lifelong learning.

However,whilethebenefitsofonlineeducationare significant,thisshiftawayfromtraditional,in- person classrooms has also brought with it a set of complexchallenges.Oneofthemostpressing concernsisthepotentialdeclineinthequality of teaching and learning experiences, particularly due toreducedopportunitiesforinterpersonalinteraction andreal-timefeedback.Inphysicalclassrooms, teachers and students share a dynamic environment where communication flows not only

through words but also through non-verbal cues. Facial expressions, gestures, posture, and other forms of body language play a critical role in the teaching-learning process.

Educators often rely on these subtle, non-verbal signals to assess students' understanding, emotional responses,andlevelsofengagement.Forinstance,a confused or puzzled look might promptateacher to revisit a concept or offer further explanation. Similarly, signs of boredom or distraction can lead aninstructortoadoptamoreinteractiveapproach— perhaps by initiating group discussions, asking questions,orincorporatingmultimediacontenttore- engage the class. These spontaneous adjustments contribute significantly to a more responsive and effective learning environment In contrast, online education often limits

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the visibility and availability of such cues. Even with video conferencing tools, many students choose to keep their cameras off, or video quality and internet connectivity issues may obscure facial expressions and gestures. Moreover, the sense of physical presence is inherently diminished in virtual settings, making it harder for teachersto"readtheroom."Thislack ofimmediate, informal feedback can hinder educators from accuratelygauginghowwellstudentsare following

along, whether they are motivated, or if they are struggling silently.

Consequently, the reduced capacity to monitor and respond to student engagement poses a risk to academic performance. When students feel unseen or disconnected, they may be less likely to participate actively, ask questions, or seek help when needed. Over time, this disengagement can lead to lower retention of information, decreased motivation,andevendropout.Assuch,whileonline learning platforms offer unprecedented access and convenience,theyalsocallfor innovativestrategies to bridge the gap in teacher-student interaction and ensurethatthehumanelementsofeducationarenot lost in the digital transition.

In sum, thetransformation brought about byonline learning is a double-edged sword—unlocking new opportunitieswhilesimultaneouslyintroducingnew hurdles. Addressing these challenges will require thoughtful design of digital learning environments, including the integration of tools that simulate in- person feedback, promote interaction, and support educators in maintaining a strong connection with their students. Only then can the full potential of onlineeducationberealized,withoutcompromising the quality and effectiveness of the learning experience.

Figure1FacialEmotionRecognition

ii. BACKGROUNDSTUDY

The transition to online education—accelerated dramatically by the COVID-19 pandemic—has fundamentally altered the way learning is delivered and experienced. Virtual classrooms have introduced a new level of flexibility and accessibility, allowing students from all over the worldtoparticipatein classeswithouttheconstraints of location or strict scheduling. This has been especially beneficial for those in remote areas, students with physical limitations, or individuals balancing work and study. However, despite these advantages, online learning has also introduced several critical challenges, the most prominent of which is maintaining student engagement.

In traditional face-to-face classrooms, teachers are abletocloselyobservestudents'behaviour, posture, and expressions to gauge their emotional state and levelofunderstanding.Forinstance,ateachermight noticepuzzledlooks,yawning,slouchedpostures,or enthusiastic nodding—all of which provide immediate,non-verbalfeedbackabouthowwell the lesson is being received. This feedback allows educators to adjust their teaching strategies in real time, whether it’s by slowing down, offering more explanations, or introducing interactive elements to re-capture students’ attention. These interactions help create a responsive and effective learning environment that supports student success.

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However, in online learningenvironments, manyof these physical cues are absent or significantly diminished.Studentsoftenkeeptheircamerasturned off,andevenwhenvisible,thesmallscreensizeand video quality may not allow teachers to clearly interpret facial expressionsor gestures. Additionally, mutedmicrophones andlimited verbalparticipation further reduce the opportunities for spontaneous interaction. As a result, educators often find themselves teaching without a clear sense of how their students are feeling or whether they are truly engaged with the material.

This disconnect can lead to several negative consequences. Without effective ways to assess engagement, teachers may miss signs of confusion or boredom. Students, in turn, may feel isolated, unmotivated, or reluctant to ask questions. Over time, this can contribute to reduced academic performance, lack of participation, and even increased dropout rates in online programs.

To address this issue, emerging technologies like Facial Emotion Recognition (FER) offer promising solutions. FER uses artificial intelligence and computer vision techniques to analyse facial expressions and identify emotional states such as happiness, sadness, anger, surprise, or neutrality. When integrated into online education platforms, FER systems can provide real-time emotional feedback to educators, offering insights into how studentsarereacting to the lesson. Thisinformation can then be used to adapt teaching methods dynamically—for example, by revisiting confusing topics,adjustingthepaceofinstruction,or

incorporating interactive elements to improve engagement.

The proposed project seeks toharness thepower of FER by employing advanced deep learning models—specifically, Inception-V3, VGG19, and ResNet-50. These models are known for their high accuracyinimageclassificationtasksandhavebeen successfully applied to emotion recognition using benchmark datasets like FER-2013 and RAF-DB. By training these models on diverse facial expression data, the system can accurately classify emotions in real-time during virtual classes.

This application of FER technology aims to bridge the gap created by the lack of physical presence in online education. By enabling teachers to better understand students' emotional states, it supports more adaptive, responsive, and personalized teaching strategies. Ultimately, such tools can enhance the online learning experience, making it notjustmoreaccessible,butalsomoreengagingand effective.

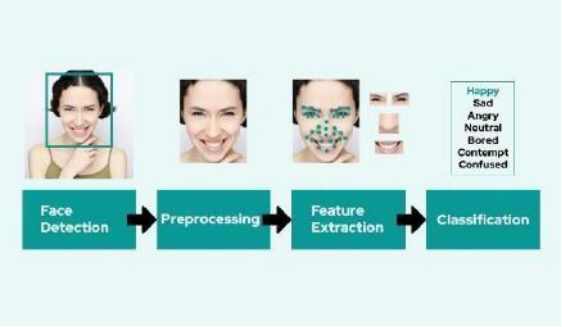

Figure2FaceRecognitionexpressfeeling

iii. PROPOSEDWORK

The development of a reliable Facial Emotion Recognition (FER) system relies heavily on the implementation of powerful and accurate deep learning models. These models must be capable of detecting and interpreting a wide range of human emotions across various real-world conditions. However,thistaskisfarfromstraightforward.Facial emotion recognition presents numerous challenges that can affect the system's performance. Factors such as inconsistent lighting, low-quality or varied- resolutioncamerainputs,differentfacialorientations (e.g., tilted heads or partially visible faces), occlusions (like glasses or hands), and the natural diversity of facial features among

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individuals all contributetothecomplexityofaccurateemotion detection.

Toeffectivelyaddressthesechallenges,theproposed system incorporates state-of-the-art Convolutional Neural Network (CNN) architectures that have demonstrated high performance in image analysis and classification tasks. These models are specifically chosen for their ability to extract meaningful features from complex image data and their robustness in dealing with variability in visual input. The three primary models utilized in this system include Inception-V3, VGG19, and ResNet- 50, each offering distinct advantages:

- Inception-V3: This architecture is known for its ability to extract features efficiently while maintaining lower computational requirements compared to similarly deep networks. Inception-V3 utilizes inception modules that process the input at multiple scales simultaneously, which is especially useful for identifying subtle variations in facial expressions. Its design enables the model to focus on fine-grained features without overfitting, making it ideal for detecting nuanced emotional states even in thepresenceofminordistortionsornoisein the image.
- VGG19: As a deeper version of the VGG family, VGG19 consists of 19 layers, primarily made up of small (3x3) convolutional filters stacked sequentially. This structure allows the model to develop a strong hierarchical representation of image features, gradually capturing more abstractanddetailedpatternsfromthefacial data. VGG19 is particularly effective at learningintricatetexturesandshapes,which are crucial for distinguishing between similar emotional expressions, such as sadnessanddisappointmentor surpriseand fear.
- ResNet-50: Short for Residual Network, ResNet-50 introduces the concept of "skip connections"orresidualblocks,whichhelp the model learn deeper representations withoutencounteringthevanishinggradient problem common in deep neural networks. Theseconnectionsenablethemodeltopass information across layers more effectively, allowing it to learn complex, high-level features from detailed facial images. ResNet-50 is well-suited for emotion detection in high-resolution images, where subtle facial cues can be key to accurate classification.

By integrating these three advanced CNN models into the system, the project aims to achieve high accuracy and reliability in real-time emotion detection.Eachmodelcontributescomplementary

strengths—Inception-V3's efficiency, VGG19’s depth and feature richness, and ResNet-50’s ability to handle very deep learning tasks—resulting in a robust FERsystem thatcan adapttoa widerangeof environmental and individual variations.

Ultimately, the use of these deep learning architectures enhances the system’s ability to support educators in online learning environments, by providing accurate insights into students' emotional engagement. This makes it possible to create more responsive and emotionally intelligent virtual classrooms, whereteachingstrategiescan be adapted based on students’ real-time emotional feedback.

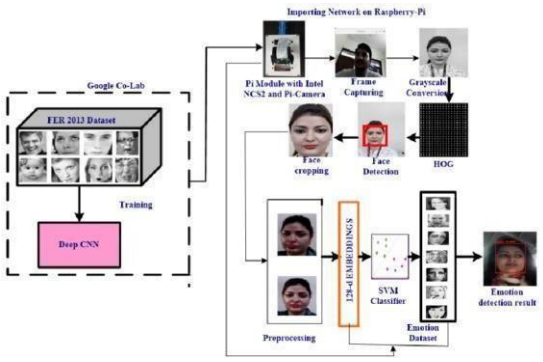

Figure3ArchitectureforFaceRecognition

Thesemodelswillbetrainedandtestedonextensive datasets, such as FER2013 and Affect Net, which include diverse facial expressions across various conditions. Real-time emotion detection will be achieved through optimized algorithms that ensure low latency, preserving the interactive nature of online classes. The implementation of this system has the potential to revolutionize online education byaddressingoneofitsmost critical shortcomings. Real-time engagement monitoring empowers educators with insights that were previously unattainable in virtual settings, helping them to:

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1. **Enhance Student Engagement**: By identifying disengaged students, teachers canintervenepromptlyandre-engagethem before their attention wanes further.
2. **Improve Learning Outcomes**: Personalized and adaptive teaching strategies ensure that students remain actively involved, fostering deeper understandingandretentionofthematerial.

iv. **Support Inclusive Learning**: The system can adapt to diverse student needs by identifying individuals who may require additional support, thereby promoting equity in education.

v. CONCLUSIONANDFUTURE SCOPE

Thewidespreadshifttoonlineeducationhasbrought about transformative changes in the waylearning is delivered, offering unparalleled flexibility and access. However, it has also introduced a range of challenges, among which maintaining student engagement stands out as one of the most critical. Engagement is a key predictor of learning success, influencing how well students absorb, retain, and applyknowledge.Intraditionalclassrooms,teachers naturallymonitorstudentengagementthroughdirect observation, using visual and behavioural cues to assess attentiveness, confusion, or disinterest. In virtualsettings,however,suchcuesareoftenmissing or limited,makingit difficult for educatorstoassess students'emotionalandcognitiveinvolvementinthe learning process.

To address this issue, the **Facial Emotion Recognition-Based Real-Time Learner Engagement Detection System** has been proposed as an innovativesolution.This system leverages the capabilities of advanced deep learning models to analyze students' facial expressions inreal timeand interpret their emotional states. Byprocessing these emotional cues, the system calculates an **Engagement Index (EI)**—a quantitative measure thatreflectsthelevelofstudentengagementduringa session. This real-time index serves as a powerful feedbackmechanismforeducators,enablingthemto detect when a student becomes disengaged, distracted, or frustrated. With this insight, teachers cantaketimelycorrectiveactions,suchasmodifying their teaching pace, introducing interactive content, or reaching out to students individually to offer support.

The core value of this system lies in its ability to bridge the gap between the responsive nature of physical classrooms and the often-passive experience of virtual learning. By reintroducing a layer of emotional awareness into online education, the system significantly enhances the effectiveness ofteaching.Itenablesamore**personalizedlearning experience**, whereinstruction can be adapted based on individual students' emotional responses, thus improvingmotivation, participation, and ultimately, academic performance. In this way, the project representsamajor stepforwardinaddressingoneof the most pressing limitations of online education.

Looking ahead, the future development of this system holds immense potential for innovation and expansion. Integrating the engagement detection system into Learning Management Systems (LMS) wouldallowforseamlessmonitoringofengagement

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across various learning modules and activities, automatingtheprocessandmakingitmorescalable. Moreover, enhancing the system with multimodal analysis—by incorporating additional data sources suchasvoicetoneanalysis,eyemovementtracking, and behavioural interaction logs—could provide a richer, more holistic view of student engagement. This would deepen educators' understanding of learners' cognitive and emotional states beyond facial expressions alone.

Further research and development could also focus on improving the scalability and adaptability of the system to function efficiently across diverse environments. This includes optimizing it for low- bandwidth settings or devices with limited processing capabilities, ensuring that students in under-resourced or remote areas can also benefit. Another critical area of advancement involves personalization and inclusivity. By allowing the system to be customized based on individual differences in facial expression, cultural variations in emotional display, and diverse learning styles, it can become more sensitive and student-cantered.

At the same time, the ethical implications of facial recognitiontechnologymustbecarefullyaddressed. Emphasis should be placed on enhancing privacy protections, securing student data, and establishing transparentandethicalusagepolicies.Implementing clear consent protocols, anonymizing data when possible, and ensuring compliance with global privacy standards will be essential to build trust among users and educational institutions.

In conclusion, the proposed engagement detection system opensup exciting possibilitiesfor thefuture ofdigitaleducation.Itnotonlyaddressesthecurrent shortcomings of online learning but also paves the way for intelligent, emotionally responsive, and adaptive educational environments. By making virtual classrooms more interactive and human- cantered,theprojectcontributesmeaningfullytothe evolution ofsmarter,moreconnected, and effective online education experiences.

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