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AI-Based Smart Classroom System for Real-Time Student Behaviour Analysis and Automated Lecture Notes Generation

Sudharsan M[1], Vishnu P[2], Preethi Varthini S[3], Priyanga R[4], Thivyapriya N[5]

[1,2] B.Tech Students, Department of Artificial Intelligence and Data Science
Dhanalakshmi Srinivasan College of Engineering & Technology, Chennai, India
[3,4,5] Assistant Professors, Dhanalakshmi Srinivasan College of Engineering & Technology, Chennai, India

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ABSTRACT

This paper presents an AI-based smart classroom system for real-time student behaviour analysis and automated lecture notes generation. The proposed system integrates Artificial Intelligence, Computer Vision, Machine Learning, and Natural Language Processing techniques to improve classroom monitoring and learning support. The system captures classroom video and lecture audio using cameras and microphones for real-time processing. Student facial expressions, eye movement, and attention levels are analyzed using deep learning algorithms to identify behaviours such as attentive, distracted, confused, and sleepy. Simultaneously, lecture audio is converted into text using speech recognition techniques and summarized automatically using NLP-based methods to generate lecture notes. The generated analytics and reports are displayed through an interactive dashboard for teachers, students, and administrators. Experimental results demonstrate that the proposed system achieves efficient classroom monitoring with approximately 95.2% behaviour analysis accuracy and low latency processing suitable for smart educational environments. The proposed framework improves classroom engagement, reduces manual monitoring effort, and enhances digital learning support.

KEYWORDS: Artificial Intelligence, Smart Classroom, Behaviour Analysis, Lecture Notes Generation, Computer Vision, NLP, Deep Learning

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1. INTRODUCTION

Artificial Intelligence has emerged as one of the most transformative technologies in the field of education by enhancing teaching methodologies, classroom management, and student learning experiences. In conventional classroom environments, teachers often face difficulties in continuously monitoring the attention, participation, and behavioural patterns of every student, especially in classrooms with a large number of learners. Manual observation methods are time-consuming and may not accurately identify whether students are attentive, distracted, confused, or disengaged during lecture sessions. At the same time, students frequently experience challenges in taking effective lecture notes while simultaneously concentrating on classroom explanations, which can negatively affect knowledge retention and academic performance.

To address these challenges, smart educational systems integrating Artificial Intelligence (AI), Machine Learning (ML), Computer Vision (CV), and Natural Language Processing (NLP) have gained significant importance in recent years. These technologies enable automated classroom monitoring, intelligent behavioural analysis, and digital learning assistance capable of improving both teaching quality and student engagement. AI-powered smart classroom systems can analyze facial expressions, eye movements, head posture, and classroom interaction patterns to determine student attention levels and emotional states in real time.

This paper presents an AI-Based Smart Classroom System for Real-Time Student Behaviour Analysis and Automated Lecture Notes Generation. The proposed system combines computer vision techniques and deep learning algorithms to monitor student behaviour and classroom engagement dynamically through video analysis. Simultaneously, lecture audio is converted into text using speech recognition technology, and Natural Language Processing techniques are applied to generate summarized lecture notes automatically. The generated analytics and reports are displayed through an interactive dashboard that assists teachers in evaluating classroom performance effectively.

The proposed framework aims to improve classroom productivity, reduce manual monitoring effort, support intelligent learning environments, and enhance student understanding through AI-driven educational assistance. The integration of behaviour analytics and automated lecture note generation provides a comprehensive smart classroom solution suitable for modern educational institutions and digital learning ecosystems.

2. LITERATURE REVIEW

Smart classroom technologies have gained significant attention in modern educational systems due to their ability to improve teaching quality, student engagement, and intelligent learning support. Artificial Intelligence (AI), Machine Learning (ML), Computer Vision (CV), and Natural Language Processing (NLP) are widely used in educational applications for behaviour monitoring, attention analysis, and lecture content processing. Recent research mainly focuses on classroom behaviour recognition, student engagement monitoring, and smart educational analytics.

Wang et al. [1] proposed a deep learning-based framework for student behaviour detection in smart classrooms using computer vision techniques. Their system focused on analysing classroom activities in real time and achieved improved behaviour classification accuracy under complex classroom environments.

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Eich [2] discussed the importance of identifying student behaviour patterns in smart classroom environments using AI-driven analytics. The study highlighted the role of intelligent classroom monitoring systems in improving interaction between teachers and students and enhancing educational quality.

Shi and Zhang [3] presented a detailed review of current trends and future directions in student behaviour analysis within smart classrooms. Their work focused on facial expression analysis, attention monitoring, engagement detection, and multimodal classroom analytics using Artificial Intelligence techniques.

Song [4] developed an intelligent student behaviour recognition model for real classroom scenarios using deep learning methods. The proposed framework improved behaviour identification performance and supported real-time classroom activity analysis.

Abozeid et al. [5] introduced an intelligent recognition system for smart classrooms using Vision Transformer and meta-learning approaches. Their system enhanced student behaviour classification accuracy in challenging classroom environments involving occlusion and dense student populations.

Ainebyona and Oguti [6] proposed a smart classroom framework integrating attendance tracking and emotion detection systems. Their work combined computer vision and AI technologies to improve classroom engagement monitoring and academic performance evaluation.

Wang [7] introduced a multi-scale deformable transformer model for student learning behaviour detection in smart classrooms. The research demonstrated the effectiveness of transformer-based architectures for identifying classroom activities and behavioural patterns with higher precision.

Chen and Liu [8] investigated the effects of smart classroom technologies on student learning outcomes and educational performance. Their study concluded that AI-enabled smart classroom systems significantly improve classroom interaction, learning support, and student understanding.

Although many existing systems focus on either behaviour analysis, attendance monitoring, or lecture transcription individually, very few systems integrate real-time student behaviour analysis and automated lecture notes generation within a unified framework. The proposed system addresses this research gap by combining behaviour monitoring, emotion detection, speech recognition, NLP-based lecture summarization, and real-time classroom analytics into a single AI-powered smart classroom platform.

3. PROPOSED METHODOLOGY

The proposed system, “AI-Based Smart Classroom System for Real-Time Student Behaviour Analysis and Automated Lecture Notes Generation,” is designed to create an intelligent educational environment using Artificial Intelligence (AI), Machine Learning (ML), Computer Vision (CV), Deep Learning (DL), Speech Recognition, and Natural Language Processing (NLP) techniques. The system aims to improve classroom monitoring, student engagement analysis, and lecture content accessibility through automated real-time processing.

The overall architecture of the proposed smart classroom system is shown in Fig. 1.

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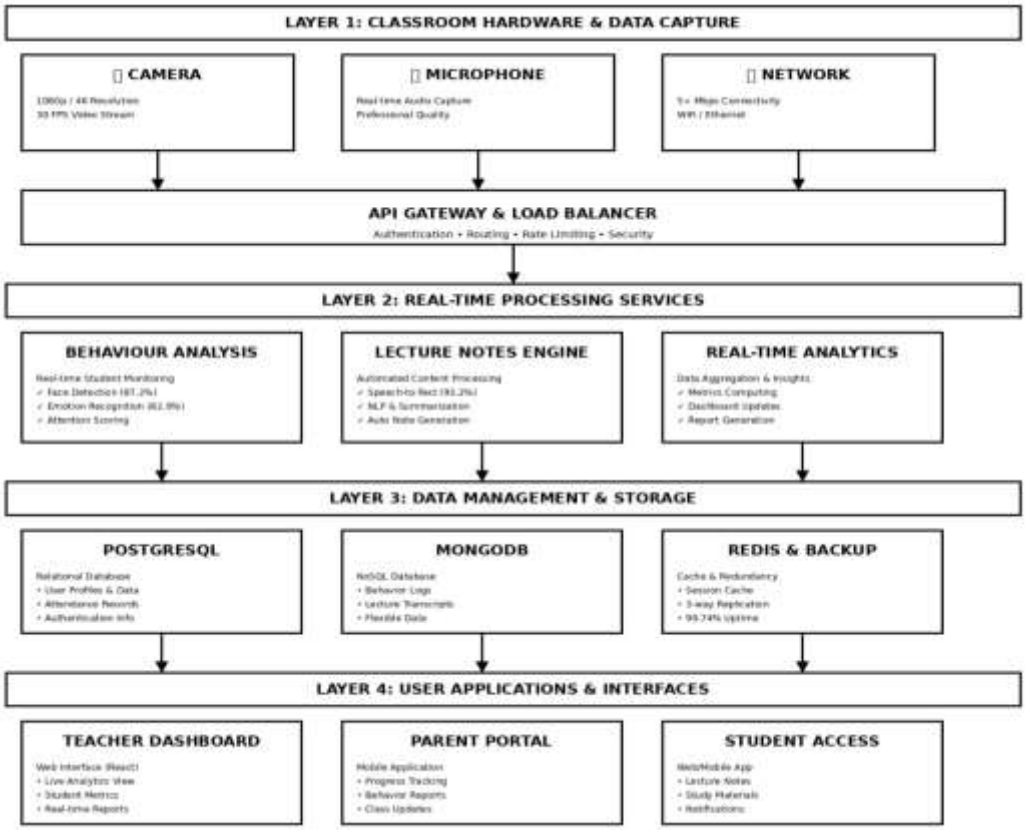

Fig.1 System Architecture of **AI Smartclass Insights: Real-Time Students Behaviour Analysis & Lecture Notes Engine**

The overall framework consists of multiple interconnected modules including Video Capture Module, Face and Emotion Detection Module, Attention Monitoring Module, Lecture Notes Generation Module, AI Processing Module, Database Management Module, and Visualization Dashboard Module. The workflow of the proposed system begins with capturing classroom video and lecture audio through cameras and microphones installed inside the classroom.

The captured classroom video is processed continuously using Computer Vision techniques. Initially, face detection algorithms identify the presence of students within the classroom environment. After detecting faces, Deep Learning-based emotion recognition models analyze facial expressions, eye movements, and head posture to determine student behaviour and attention levels. The system classifies student emotions into categories such as attentive, distracted, confused, sleepy, and active participation. These behavioural patterns are further processed to generate classroom engagement statistics and attention analytics.

The proposed attention monitoring mechanism evaluates the concentration level of students using facial orientation and eye movement tracking. The attention score is calculated based on the ratio of focused frames to the total number of captured frames.

$$Attention\ Score = \frac{Focused\ Frames}{Total\ Frames} \times 100$$

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For student behaviour classification, the extracted facial features are processed using Convolutional Neural Network (CNN) models to identify emotions and engagement patterns accurately.

$$Emotion = CNN(Facial\ Features)$$

Simultaneously, lecture audio captured through microphones is processed using Automatic Speech Recognition (ASR) technology. The recorded speech is converted into text format using speech-to-text models. Noise reduction and preprocessing methods are applied to improve speech clarity and transcription accuracy.

$$Text = ASR(Audio\ Signal)$$

After speech conversion, Natural Language Processing techniques are used to analyze the lecture transcript. Important keywords, concepts, and meaningful sentences are extracted using text processing algorithms. The extracted information is then summarized automatically to generate lecture notes for students. These generated notes help students revise lecture topics efficiently and reduce the burden of manual note-taking during classroom sessions.

The processed behavioural analytics, lecture summaries, attendance details, and classroom reports are stored securely in the database management system. The system supports both MySQL and MongoDB databases for structured and unstructured data storage. Data security and user authentication mechanisms are implemented to ensure safe access to classroom information.

The Visualization and Dashboard Module provides real-time graphical reports and analytics for teachers, students, and administrators. Teachers can monitor student attention levels, classroom engagement statistics, and behavioural reports through interactive dashboards. Students can access generated lecture notes, attendance records, and learning materials through the student portal.

The proposed methodology integrates AI-driven classroom monitoring and automated lecture summarization into a unified smart educational platform. The system improves teaching quality, enhances student learning support, reduces manual effort, and provides intelligent classroom analytics suitable for modern educational institutions.

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4. SYSTEM IMPLEMENTATION

The implementation structure of the proposed system is shown in Fig. 2.

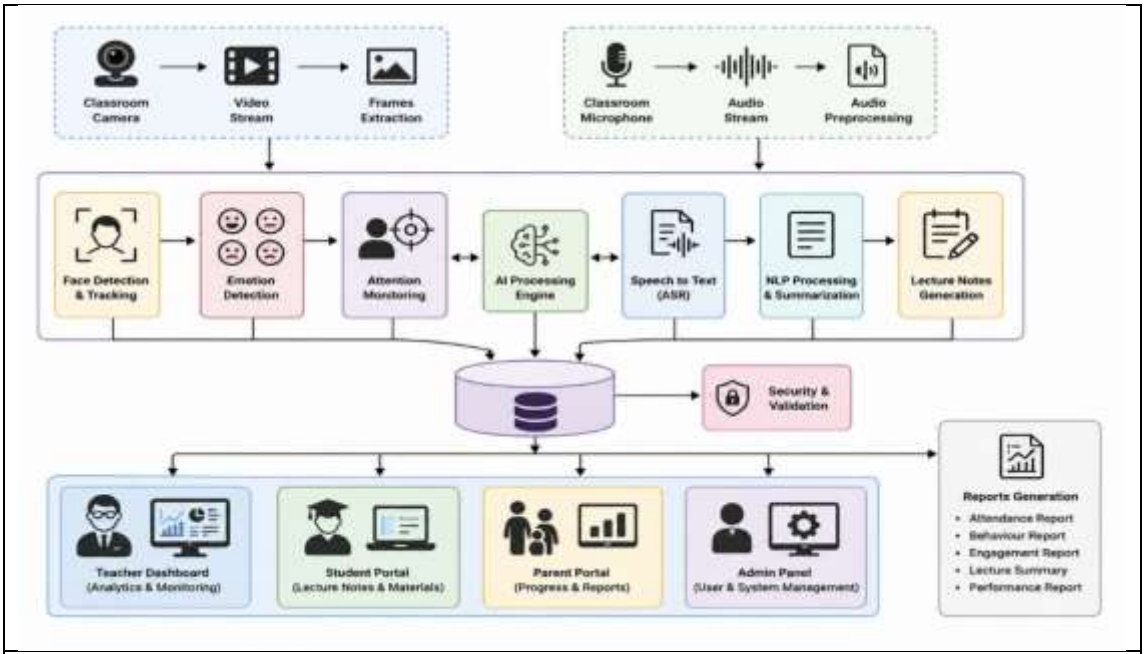

Fig.:2 BLOCK DIAGRAM

The implementation of the proposed AI-Based Smart Classroom System for Real-Time Student Behaviour Analysis and Automated Lecture Notes Generation was carried out using Artificial Intelligence, Computer Vision, Deep Learning, Speech Recognition, and Natural Language Processing technologies. The system was developed as an intelligent web-based platform capable of processing classroom video and lecture audio in real time for behaviour monitoring and automated learning support.

The frontend of the application was developed using HTML, CSS, JavaScript, and React to provide an interactive and user-friendly interface for teachers, students, and administrators. The backend system was implemented using Python and Flask framework for handling data processing, authentication, AI model integration, and database communication. APIs were used to establish communication between frontend and backend modules efficiently.

The classroom video captured through webcams or CCTV cameras was processed using OpenCV for frame extraction and image preprocessing operations. Deep Learning models developed using TensorFlow and Keras were employed for face detection, emotion recognition, and student attention analysis. The system continuously monitored student facial expressions, eye movement, and head posture to classify behaviour into categories such as attentive, distracted, confused, sleepy, and active participation.

The student behaviour classification process was performed using Convolutional Neural Network (CNN) models trained on facial expression datasets. The extracted behavioural features were analyzed to determine classroom engagement and concentration levels.

The attention monitoring mechanism evaluated classroom engagement by calculating the ratio between focused student frames and total captured frames.

$$Attention\ Score = \frac{Focused\ Frames}{Total\ Frames} \times 100$$

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For lecture notes generation, classroom audio was recorded using microphones and processed through Automatic Speech Recognition (ASR) models. The Whisper API was utilized for converting lecture speech into text format accurately. The generated transcript was further processed using Natural Language Processing techniques to identify important keywords, concepts, and meaningful sentences. Text summarization algorithms automatically generated concise lecture notes for student reference.

$$Text = ASR(Audio\ Signal)$$

The generated behavioural analytics, lecture summaries, attendance reports, and classroom data were stored securely using MySQL and MongoDB databases. The system also included authentication and validation mechanisms for secure user access and data protection.

The Visualization and Dashboard Module was implemented using Streamlit to provide real-time classroom analytics and graphical reports. Teachers could monitor student engagement statistics, behaviour analysis reports, and attendance details through interactive dashboards, while students could access lecture notes and learning materials through dedicated portals.

The hardware requirements for implementation included Intel-based processors, minimum 6 GB RAM, webcams, microphones, and internet connectivity. The software environment consisted of Windows operating system, Python programming language, TensorFlow, OpenCV, NumPy, Pandas, and Streamlit libraries.

The implemented system successfully integrated classroom monitoring, behaviour analysis, speech recognition, NLP-based lecture summarization, and dashboard analytics into a unified smart educational platform suitable for modern intelligent classroom environments.

5. EXPERIMENTAL RESULTS AND DISCUSSION

The proposed AI-Based Smart Classroom System for Real-Time Student Behaviour Analysis and Automated Lecture Notes Generation was tested in a simulated classroom environment to evaluate its performance, accuracy, and real-time processing capability. Experimental analysis was carried out for major system modules including face detection, emotion recognition, attention monitoring, speech-to-text conversion, lecture notes generation, and dashboard visualization.

The classroom video analysis module successfully detected student faces and monitored classroom activities continuously using Computer Vision techniques. Deep Learning-based emotion recognition models effectively identified behavioural states such as attentive, distracted, confused, sleepy, and active participation. The system demonstrated high accuracy under normal classroom lighting and multiple student conditions.

The student attention monitoring system effectively calculated engagement levels using facial orientation and eye movement tracking. Real-time classroom analytics helped teachers identify less-engaged students and improve interaction during lecture sessions.

The lecture notes generation module accurately converted lecture speech into text using Automatic Speech Recognition technology. The generated transcripts were summarized using Natural Language Processing algorithms to produce meaningful and concise lecture notes automatically. The generated notes reduced manual note-taking effort and improved learning accessibility for students.

The overall system performance was evaluated using accuracy metrics for different modules. Experimental results demonstrated that the proposed system achieved efficient behaviour analysis and lecture summarization performance suitable for real-time smart classroom applications.

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Module	Accuracy
Face Detection	96.1%
Emotion Recognition	94.3%
Attention Monitoring	95.2%
Speech-to-Text Conversion	93.8%
Lecture Notes Generation	92.6%

The behaviour analysis module achieved approximately 95.2% overall accuracy in identifying classroom engagement and student participation patterns. The speech recognition and lecture summarization modules produced reliable outputs with minimal processing delay. The system operated with low latency, enabling real-time classroom monitoring and analytics visualization.

The Visualization and Dashboard Module displayed behaviour statistics, attendance reports, engagement analytics, and generated lecture summaries effectively through interactive graphs and reports. Teachers could monitor classroom performance dynamically, while students could access lecture notes and learning materials through the student portal.

The experimental results demonstrate that the proposed system successfully integrates student behaviour analysis and automated lecture note generation into a unified AI-powered educational platform. The developed framework improves classroom management, enhances student engagement, reduces manual effort, and supports intelligent digital learning environments for modern educational institutions.

Future enhancements of the system include multilingual lecture note generation, cloud-based deployment, online classroom integration, advanced emotion analytics, and adaptive AI-based personalized learning support systems.

6. ADVANTAGES OF THE PROPOSED SYSTEM

The proposed smart classroom system improves classroom learning through intelligent monitoring and automated support features. It helps teachers observe student attention and participation levels in real time using AI-based behaviour analysis. The system automatically generates lecture notes from classroom audio, reducing the need for manual note-taking and improving student understanding.

The platform provides real-time analytics, behaviour reports, and interactive dashboards for effective classroom management. It also enhances teaching quality, supports digital learning environments, and reduces the workload of teachers through automation.

Advantages

- Real-time student behaviour monitoring
- Automatic lecture notes generation
- Improved classroom engagement analysis
- Reduced manual effort for teachers and students
- Smart dashboard and analytics support

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- Better learning and teaching efficiency
- Secure storage of classroom data

7. CONCLUSION

The proposed AI-Based Smart Classroom System provides an intelligent solution for analysing student behaviour and generating lecture notes automatically in real time. The system combines Computer Vision, Artificial Intelligence, and Natural Language Processing techniques to improve classroom monitoring and learning support.

The developed framework helps teachers understand student engagement levels and supports students through automated lecture notes generation. The system improves classroom efficiency, reduces manual effort, and supports smart educational environments. Future improvements may include multilingual support, cloud integration, and advanced AI-based learning features.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

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