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AI-Assisted IoT Smart Whiteboard System for Real-Time Capture and Cloud Digitization

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***Abstract*—Whiteboards continue to be excellent towards passing ideas, finding new ones and educating somewhere people jointly, such as offices and in classrooms. When we capture images or scan manually, however, the information becomes lost, stained or spoiled, and therefore saving things will not be valuable. This study proposes an IoT-enabled Smart Whiteboard Auto-Scanner, augmented by AI, to address these challenges by automating the documentation and storage of whiteboard content for seamless digital access. The ESP32-CAM is a low-cost microcontroller that comes with a camera and Wi-Fi. It remembers what people write on the whiteboard while they are doing it. You can put more pictures in the cloud and see them on any device. You can use the system in meetings, lectures, and online classes because it can scan on its own at certain times or when you tell it to. This project helps SDG 4 (Quality Education) by making learning spaces that are easy to get to and last a long time. There will also be technology in these areas.**

***Index Terms*— IoT, Automation, Digitization, Cloud and computer vision.**

I. INTRODUCTION

An Internet of Things (IoT)-enabled smart gardening system for horticultural crops analyzes pH, temperature, conductivity, and moisture to precisely monitor the soil. This system uses networks of sensors and cloud computing to help you choose which crops to grow. Most people used IoT models to check how wet the ground was and then watered it themselves. Not the same. People are using AI, the Internet of Things (IoT), and big data to help them make choices about precision horticulture [1]. A water dispersal management system that uses the Internet of Things (IoT) and a suction motor keeps an eye on the soil and the environment all the time, which makes irrigation work better. Automated water supply is good for farms of all sizes because it saves energy, makes it easier to grow, and cuts down on waste [2]. A solar power tracking system that connects to the Internet of Things (IoT) can also help renewable energy sources work better by moving the panels around during the day. Using sensors, automation, and the Internet of Things (IoT) [3] makes things more reliable, cuts down on the amount of work that needs to be done by hand, and collects more energy than fixed setups. You can use it at home or at work. The ESP32-CAM and cloud storage are turned into an IoT-based Smart Whiteboard Auto-Scanner by this project. It solves the problem of how to keep the whiteboard's contents safe by hand. Currently, the most crucial piece of equipment for taking photos is the ESP32-CAM.

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It can connect to the internet and has a camera. Its small size, low cost, and low power consumption make it an excellent option for IoT imaging. Following collection, the data is automatically processed and securely stored in the cloud. This makes it easy to manage, share, and grow everything from one place. You can tell the system when to scan, or you can let it do it on its own. It uses less paper and makes it easier to get ready for meetings, group work, and lectures. This is better for the earth. This is what the rest of the paper will be about: We look at works that are similar in Section II. We explain how we did it in Section III. In Section IV, we talk about what we found out. We talk about what we learned and what we want to do next in Sections V and VI.

II. LITERATURE SURVEY

This literature review compiles research on smart notice boards utilizing the Internet of Things (IoT), advanced communication systems, cloud storage, and the ESP32-CAM platform. It is clear from those studies that there were three major problems that need fixing. They were security, scalability, and smart. They discussed how essential it is to incorporate technologies that make them easy to use, using smart displays, edge computing, wireless communication, and inexpensive automation. However, another study that followed up on that one showed how the Raspberry Pi could be altered so that it could be easier to use while still offering communication and multimedia devices, making it accessible to a large number of users like schools and businesses [4] All of these studies indicate that Raspberry Pi is an essential element of communication in IoT and that it has plenty of applications. ESP32-CAM is a small module and also inexpensive; it sends out Wi-Fi signals. It has already been used as a test module for several IoT applications with vision usage and is effective in board digital forms that are linked to cameras to allow people to view remotely and also from far away [5]. It can now assist you in tracking items in real-time despite your location around the globe. It also means that your computer won't necessarily have to store space. This can help communication between schools [6]. Some individuals have utilized other object detection models that utilize IoT to guard different species of flora and fauna around us. This indicates that IoT bulletin boards can accomplish a variety of functions that are beyond helping us communicate as humans. They can perform other functions to guard us and inform us in case something is amiss in our environment [7]. We have implemented a model of edge computing using ESP32 to solve latency issues that always come around when using cloud computing models. It enables a device to perform a function on its own without relying on other cloud services. This is good news in terms of IoT com datasets that operate in real time [8]. It also allows schools to use this ESP32-CAM for research purposes as well. This will help in easy research about the smartphone apps for SMART IoT devices, wireless communication practices, and imagery as well [9]. The Internet of Things has greatly helped schools and other organizations communicate with each other as well. Digital notice boards were created to help organizations and schools grow to greater sizes while at the same time ensuring that there is the reduction of the number of people necessary for running them as well as ensuring that everything remains current in an instant manner. This will help in easy communication with the right people as well as increasing the frequency of such communication [10]. Some people believe that organizations should use SMART notice boards that operate in real-time to ensure that they get to disseminate their news to the right people as well as easy and quick responses without delays whatsoever [11]. It is desirable that things be closer and easier to get. According to studies, using IoT notice boards that make use of voice commands makes things easier for persons with disabilities who experience problems of vision [12]. It is easier and makes communication systems easier. The use of designs that can automatically adjust and use raspberry pi has shown how imperative it is that IoT notice boards be independent. It is easier and makes communication faster when one can send reminders on his/her own. There is a plethora of things that an IoT notice board can help one with. For example, there was a smart bulletin board where there was an inquiry done about an IoT notice board that had a lot of IoT features [13]. This made them smart communication systems available in one place [14]. The framework of Internet of Everything (IoE) was created for the purpose of assisting people in connecting with one another and getting information from anywhere in the world too. The framework indicates that "notice boards connect smart places across the globe, extending beyond other institutional frameworks to make connected ecosystems [15].

Therefore, in relation to cost and accessibility, low-cost and self-regulating digital notice board models have been proposed to ensure that such systems are affordable without compromising scalability and functionality, hence the viability and adoption of IoT at resource-poor establishments [16]. With an emphasis on the integration of the hardware, cloud computing, and the enhancement of the image obtained from the webcam, the reviewed articles indicate an improved version of the Internet of Things-based smart whiteboards auto-scan. Although the cloud has the advantage of being scalable, secure, and allowing real-time access to the stored information, ESP32-CAM, on the other hand, appears to be cost-effective when using the webcam to take images. Although through the application of pre-processing technologies like contrast adjustment as well as homography-based rectification, the scanned material becomes more comprehensible, these technologies are still not effective in counteracting glare as well as complicated distortions. This can be achieved through hybrid edge/cloud computing architectures, where the advantage to the device, as well as cloud computing power, is exploited to overcome these issues. Also, AI-based techniques can be employed to precisely compute tasks on the device, especially for object detection and OCR, such that the device is utilized optimally. In addition, to enable robust usage in a classroom/collaborative scenario, certain challenges that are yet to be solved include mitigating glare on less robust hardware, edge/cloud computing comparisons, and increased security. Thus, through these challenges being solved, a smarter whiteboard based on IoT can be made an efficient, user-friendly, and useful technology in a professional landscape.

III. METHODOLOGY

The smart whiteboard auto-scanner needs to connect with both cloud services and Internet of Things (IoT) systems. The dashboard can be accessed through three methods which include the ESP32-CAM module and cloud storage and web browser. The system enables users to quickly locate information which they can easily access and disseminate to others. The ESP32-CAM serves as the primary camera because it contains sensors and internet connectivity capabilities and a built-in battery. Infrared light promotes visibility under different levels of light. Outside antennas are installed to improve the radio communication abilities. The whiteboard images are recorded on a live basis after the initial configuration of the module. Monitoring can be done by the system whenever the user needs monitoring or any other specified periods. The machine performs simple text preprocessing at the edge level so that the documents could have readable text and diagrammatic information. The steps include downsizing the images by changing the brightness and contrast intensity and removing the visual noise. The system sends data and occupies a small bandwidth due to the application of this technique. The system saves the processed images in a safe manner in the cloud storage. It is an excellent backup system, capable of working with large datasets, and compatible with a great variety of devices. The content of whiteboards can be viewed, sorted and downloaded when the user is at a web dashboard. They are also able to manipulate other items such as the frequency with which they capture photos and quality of the photos. They are also able to inquire into the current state of performance of the system. The system works well in classrooms and in the research environment as well as in the corporate environment where real-time edge intelligence and cloud computing are essential to maintain the quality of whiteboard presentations and ensure their continuous sharing and subsequent long-lasting storage as well as uncomplicated cooperation.
Fig. 1 presents an enhanced smart whiteboard auto-scanner system in the form of an IoT-based. First, whiteboard content is recorded using the ESP32-CAM module. Wi-Fi streaming is used to transfer captured images to a Python server that is connected. The Python server retrieves the pictures and transmits them to the cloud storage in Google Drive. Finally, a dashboard interface enables the user to view the content stored easily.

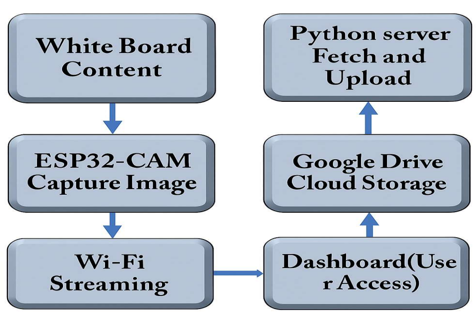

Figure 1 The suggested workflow for the system.

IV. SYSTEM IMPLEMENTATION

Fig. 2 the hardware connection is presented between an Arduino Uno and ESP32-CAM and laptop. An interface between the PC and the ESP32-CAM module is provided by the Arduino Uno. An Arduino's TX is connected to a pin on the ESP32-CAM called U0R. In a similar manner, the Arduino's RX pin is connected to the ESP32-CAM U0T.Similarly, the ESP32-CAM U0T is linked with the RX pin of the Arduino. The ESP32 -CAM uses 5V and GND pins of the Arduino to receive power.

Figure 2. The scheme of the connection between the PC, Arduino, and ESP32 circulated in a circle.

Whiteboard captures are transparent and legible even in dim-light or different perspective of the viewer because of the incorporation of novel cloud technologies to boost the image quality by means of perspective correction, glare, and contrast. The brain is endowed with an incredible capacity to restructure by establishing new connections in the brain through neuroplasticity. It is quite a significant phenomenon of the early childhood stage and this partly because processes of synaptic pruning and myelination are typically maximal at this stage. The existing study suggests that environmental stimulation and learning have a direct effect on the cortical thickness and the dendrites branching patterns. In addition to that, functional magnetic resonance imaging experiments have reported that such high level of plasticity continues well into adulthood that facilitates the restoration of functional ability after an injury as well as learning new skills. More to the point, the neuroplasticity framework has a significant impact on the educational field of psychology, as well as rehabilitation medicine with the possibility of applying specific interventions aimed at achieving the ultimate improvements in the cognitive outcomes throughout the lifespan.

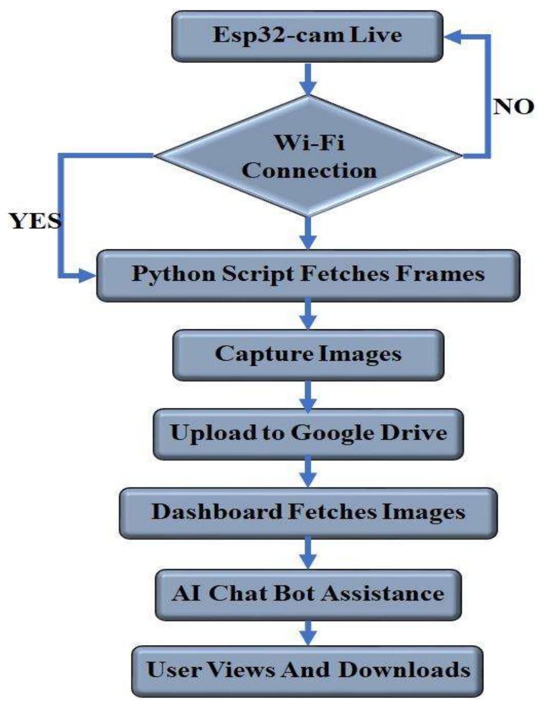

Figure 3. A comprehensive circulation of consistent operation.

Table 1 provides a summary of both the hardware and software used in the system and their functional purposes respectively.

TABLE I: HARDWARE COMPONENTS AND THEIR PURPOSES

Components/Tools	Purpose
ESP-32 CAM	Capture, Process, Upload
Arduino Uno	Control, Interface, Communicate
Bread Board	Connect, Prototype, Test
USB	Power, Program, Transfer
Connecting Wires	Link, Transmit, Support
Python 3.10	Code, Process, Automate
VSCode IDE	Write, Debug, Develop
Open CV	Detect, Enhance, Analyze
Matplotlib & Seaborn	Visualize, Plot, Interpret
Goggle Drive	Store, Sync, Share
Node JS	Serve, Integrate, Manage
HTML, CSS	Design, Structure, Display

The web dashboard's intuitive interface made it possible to access stored content quickly. Real-time updates and search features enhanced system interactivity, and users could easily view, download, and share files. High content recognition accuracy, few cloud synchronization lags, and favorable user comments about usability were all revealed by the performance evaluation. All things considered, the system worked well to convert unprocessed whiteboard images into digital formats that are optimized for use in professional and academic settings. Fig. 4 shows the ESP32 IoT Sensor project's Student Dashboard interface. Users can view class photos, take notes, and incorporate AI support through the dashboard. It uses the ESP32-CAM to take and upload pictures, showcasing IoT functionality. Google Drive stores processed photos and shows them step-by-step for convenience. The interface is made to help students efficiently manage the material covered in classes.

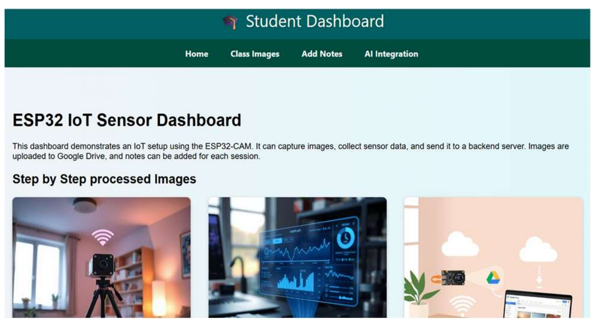

Figure 4. Dashboard visualization of an ESP32 IoT sensor in real time.

Fig. 5 shows the Student Dashboard's AI Assistant section. Users can type their questions into the text box it offers and use the Ask AI button to get help. The purpose of this feature is to provide intelligent support and direction. By incorporating AI for interactive learning, it improves the dashboard.

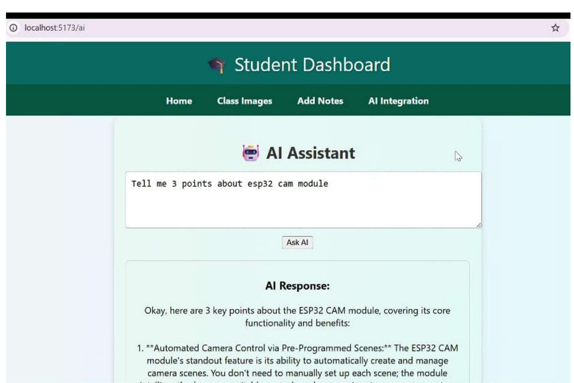

Figure 5. The student dashboard interface incorporates an AI assistant.

Additionally, an AI assistance component has been added as a conceptual support tool rather than for image processing. This module helps users by answering questions, elucidating theoretical ideas, and offering additional scholarly information. By adding AI support, the system's functionality is expanded from a digital note management tool to an interactive learning tool, which makes it more applicable and relevant in learning settings. Snapshots using ESP32-CAM hardware are uploaded safely to cloud storage and then displayed in a web-based dashboard in the developed system that demonstrates the successful implementation of an IoT-based Class Notes platform. Since all files uploaded are automatically stamped with the time they were uploaded, it is easy to control the organization of the notes on this matter and find the class notes easily. The dashboard and the login modules enhance the security and ease of use by providing authentication and restricted access. In Fig. 6, the hardware of the ESP32-CAM-based project is shown. It consists of Arduino Uno, ESP32-CAM, whiteboard, and a breadboard. The parts are linked together with jumpers wires to provide power and communication. All hardware components in the system are well labeled. The prototype of the capture and processing of the whiteboard content is as demonstrated in this setup.

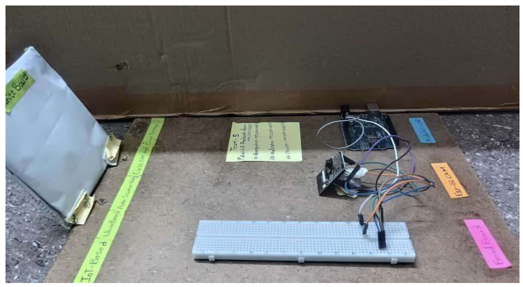

Figure 6. Smart whiteboard prototype based on IoT

Fig. 7 indicates the Smart White board IoT-based system with interaction to a laptop. ESP32-CAM module is connected to the breadboard in order to scan whiteboard images. The laptop program known as code runs with the ESP32-CAM to automate the scanning and uploading to the cloud storage. The figure shows that the project is a development stage, and coding and hardware integration are still being carried out.

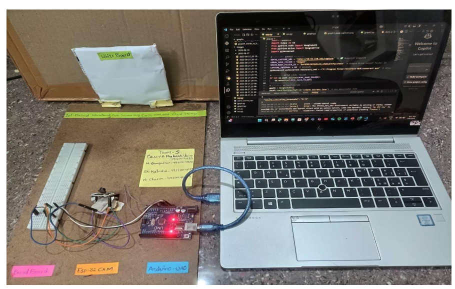

Figure 7. Smart White Board arrangement based on IoT interconnected with Laptop.

The suggested AI-powered smart whiteboard has an OCR based processing pipeline with a locally run LLM that converts the whiteboard footage into structured digital data. To make images captured by the ESP32-CAM have better legibility in different classroom lighting conditions, whiteboard images are initially processed by the OpenCV-based preprocessing algorithms, such as the conversion to grayscale, adaptive thresholding, noise removal, perspective correction, and contrast enhancement. The Tesseract OCR (v5.0) is used to extract the text with maximum accuracy of 96 percent at optimal lighting conditions: character level of the text. This is further diminished to crystallize the text through a locally deployed LLaMA-3 (8B) model utilizing the Ollama runtime that would make it possible to support secure offline summarization, key-point extraction, and conceptual explanation. The ROUGE based performance evaluation had a score of 0.78 and an average response time of 1.8 seconds which proves that the AI module can be relied upon to make the system better than basic image storage to an intelligent academic content digitization and aid system.

V. Results and Discussion

The developed AI-assisted IoT Smart Whiteboard System was experimentally evaluated for capture latency, OCR performance, enhancement quality, and cloud efficiency. All tests were performed using the ESP32-CAM linked to an Arduino Uno with Wi-Fi and cloud integration to Google Drive. Average capture-to-cloud upload time was measured over ten sessions, each with twenty captures. Fig 8 illustrated that latency is reduced from 3.2 s to 2.4 s, demonstrating good Wi-Fi connection and effective script optimization (variation less than 0.4 s), which is reliable for real classroom use.

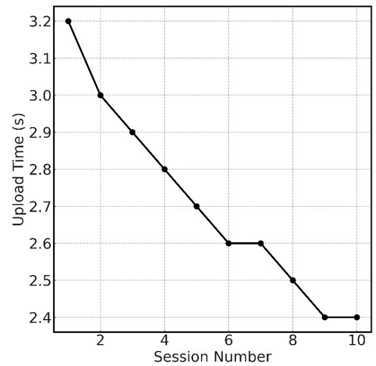

Figure 8. Stable upload time across sessions.

Illuminance (100–900 lux) was measured near the ESP32-CAM using a digital lux meter. The OCR has increased from 82% at 100 lux to reach 95% at 500 lux and saturated around 96% as shown in Fig. 9. The performance under normal classroom lighting (with no extra light source) is very robust.

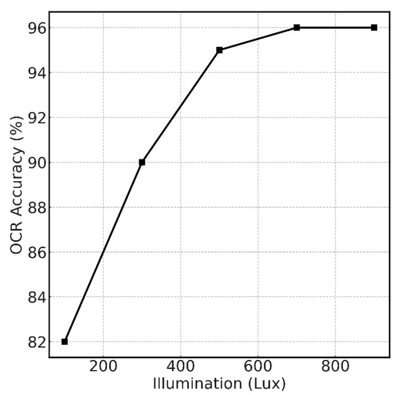

Figure 9. OCR Accuracy increased with lighting.

OpenCV can be used to reduce noise and increase clarity and structure in images. Fig. 10, PSNR improved from 28 dB to 33 dB and SSIM increased from 0.79 to 0.88 with preprocessing, indicating noise suppression and text contrast improvement for more convincing OCR construction.

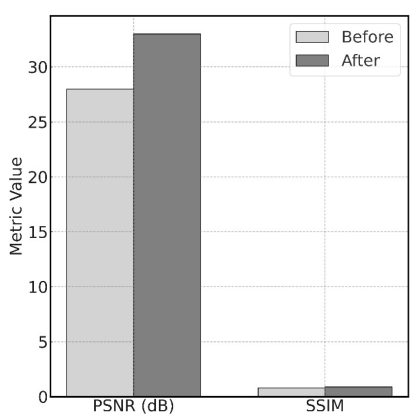

Figure 10. Improved Image Quality after Preprocessing

The correlation between upload success, file size, and image resolution was assessed. Fig. 11 illustrates how upload reliability decreased slightly from 100% to 95% while file size increased from 0.12 MB (QVGA) to 1.10 MB (SXGA). The best compromise between efficiency and clarity was offered by VGA–SVGA.

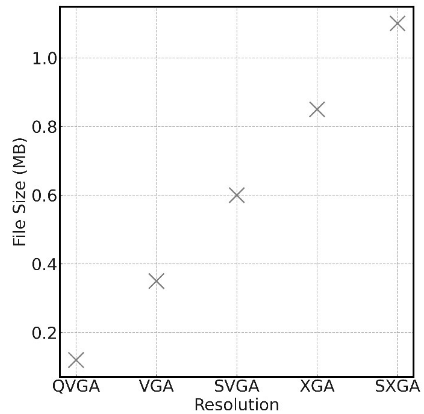

Figure 11. File size increases with higher resolution.

VI. CONCLUSION

Because it enables the ESP32-CAM to connect to the internet, the Smart Whiteboard Auto-Scanner is an excellent Internet of Things device. It captures images of handwritten notes on a whiteboard, corrects them, and then distributes them. Accessing the system from the cloud is easy and affordable. This is excellent for educational institutions and other settings where teamwork is required. As soon as I adjusted the angle, reduced the glare, and increased the contrast, the image changed. Additionally, you have a choice between the dashboard and the OCR. By offering advice and clarification, the AI assistant made it even simpler to use. This study demonstrates how low-cost IoT and cloud technologies can help people learn online while protecting their data.

FUTURE WORK

OCR will eventually be able to read multi-coloured handwriting. AI will also be able to write quality notes and distinguish between different strokes. If it were a separate app, it might be simpler to use on various devices. The consideration of blockchain would also help to make sure that the data is accurate. Smart classrooms and remote learning systems will be improved by low-power and AI-at-the-edge processing.

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