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Smart Meeting Room Access Control and Management Via IOT

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Abstract
In Most Meeting Room Scheduling or Management System, The Availability of Meeting Rooms Are Mainly Based on Pre-Determined Schedules. However, Since the Meeting Duration Is Not Always Exact as It Is Scheduled, There Are Some Situations That A Meeting Room Is Underutilized. Therefore, In This Paper, We Present A Smart Meeting Room Scheduling and Management System Which Detect Occupancy Status of Meeting Rooms in Real Time and Integrate This Information into The Scheduling Application to Support Meetings and Increase Room Utilization. Occupancy Data Is Sent to A Central Application Server by UDP Over Ip Protocols. On This Server, A Web Application Is Developed and Hosted to Not Only Allow People Book Rooms for Their Meetings, But Also Check the Utilization of These Rooms Based on Predefined Policies. The System Also Supports Meetings by Providing Real-Time Availability of Meeting Rooms to Users.
Keywords: *Meeting Scheduling; Room Management; Real-Time Occupancy Detection; Utilization Control; Ad-Hoc Meetings*

1. Introduction
Meetings are essential in every organization, serving as a platform for sharing knowledge, exchanging information, and making key decisions. To support these activities, most research has focused either on enhancing scheduling software to help participants choose the best meeting times [1] [2], or on developing smart meeting rooms that automatically record audio-visual content for future reference [3] [4] [5]. However, there are very few systems that manage meeting rooms based on real-time availability and utilization. This study aims to address this gap by focusing on these specific areas and resolving the associated challenges. First, since a meeting room can only be booked for one appointment at a time, there are situations where these resources are underutilized [6]. For instance, a meeting might end earlier than scheduled or may not occur at all, but the room remains reserved in the scheduling software, preventing others from using it. Furthermore, traditional meeting scheduling systems do not support spontaneous or drop-in meetings because they lack real-time room availability information. For these types of meetings, finding an available room can take considerable time, especially when rooms are spread across multiple buildings. To address these challenges, this paper proposes a Smart Meeting Room Access Control and Management System Using IoT. The system integrates IoT-based occupancy detection to monitor real-time room availability and incorporates a web-based booking system that allows users to check and book rooms in real-time. The system also provides an automated reminder mechanism, which sends notifications to meeting participants who have not joined within 10 minutes of the scheduled meeting start time. This paper is organized as follows: Section II discusses related work in the field, Section III presents the system architecture and design, Section IV details the system implementation, Section V evaluates the system's performance, and Section VI concludes the paper with future directions.

2. Related Works
In recent years, significant research has been conducted on optimizing meeting scheduling software and enhancing smart meeting room capabilities. For example, studies have focused on improving software algorithms to help users find optimal meeting times based on availability [7].

Other research has concentrated on developing smart meeting rooms that automatically capture and record audio-visual content for later review [8-9]. Additionally, facial recognition has emerged as a powerful tool for secure access control in a variety of applications, including office entry systems. However, few studies have addressed the real-time management of meeting rooms, particularly in terms of occupancy and availability for ad-hoc meetings. Existing systems generally lack integration with real-time data, which leads to inefficiencies in room utilization. IoT-based solutions offer a promising approach to addressing these issues by enabling real-time monitoring of room occupancy and dynamic room management [10]. Our work builds on these approaches by integrating IoT technology with meeting room scheduling to create a more dynamic, responsive system that supports both pre-scheduled and ad-hoc meetings, and provides automated reminders to improve meeting participation.

2.1. Meeting Room Scheduling Systems

Several studies have focused on improving meeting scheduling through optimization algorithms. Wang et al. [1] introduced a system that improves meeting scheduling efficiency by minimizing time conflicts between participants. Similarly, Zhao et al. [2] worked on improving the time allocation algorithms to find optimal meeting times based on participants' availability. While these efforts enhance scheduling efficiency, they fail to address the issue of underutilization caused by meetings ending early or being canceled.

2.2. IoT in Smart Office Environments

The rise of IoT has enabled real-time monitoring of various office resources. Chen et al. [6] explored IoT solutions to control energy consumption in office spaces by detecting occupancy. Such systems aim to optimize energy use but do not directly improve the functionality of meeting room scheduling. Other studies, such as Li et al. [8], focus on improving office security through IoT-based systems. However, integrating IoT technology with room scheduling remain an underexplored area.

2.3. Facial Recognition for Secure Access

Facial recognition technology has been widely used in securing access to physical spaces. Huang et al. [9] demonstrated the effectiveness of using deep learning for facial recognition in workplace security systems. While these systems improve security, they have yet to be integrated into meeting room management systems, where both security and convenience are critical. In this paper, we bridge these gaps by developing a system that combines IoT-based occupancy detection and facial recognition for secure, real-time room management [11].

3. System Architecture and Design

3.1. System Overview

The proposed Smart Meeting Room Access Control and Management System comprises four main components:

- Occupancy Sensors: IoT sensors installed in meeting rooms to detect the real-time status of the room's occupancy.
- Facial Recognition Access Control: A camera system integrated with facial recognition software to authenticate registered users before allowing them access to the meeting room.
- Central Server: A web-based server that processes occupancy data, facial recognition authentication, and sends reminders to users.
- User Interface: A web-based application where users can book meeting rooms, check real-time availability, and manage their schedules.

3.2. Real-Time Occupancy Monitoring

Real-time room occupancy is monitored using IoT sensors, such as camera-based motion sensors. These devices detect the presence of individuals in the meeting room and relay the data to the central server. If a room is booked but found to be unoccupied, the system releases the reservation, allowing the room to be used for other meetings. Additionally, the system supports meetings by allowing users to view current room availability [12].

3.3. Facial Recognition-Based Access Control

To ensure that only authorized participants can access the meeting room, a facial recognition system is deployed. Upon arrival at the meeting room, the participants' faces are scanned using a high-definition camera at the entrance. The captured images are compared against a database of pre-registered attendees using a facial recognition algorithm based on deep convolutional neural networks (CNNs). Only authorized individuals are granted access [13].

3.3.1. Authentication Process

- Image Capture: When a person approaches the meeting room, the system captures their face via the installed camera.
- Facial Recognition: The captured image is processed by a CNN-based facial recognition algorithm, which matches it against the database of registered participants.
- Access Control Decision: If the person is a registered attendee, access is granted; otherwise, the door remains locked. This process not only secures access but also logs the entry of each participant, contributing to attendance tracking and compliance.

3.4. Automated Reminder System

To minimize disruptions caused by absenteeism or late arrivals, the system sends automated reminders to participants who have not entered the meeting room within 10 minutes of the scheduled start time. This reminder is sent via email or push notification and helps ensure timely attendance. The notification system is integrated with the booking platform, automatically sending notifications based on meeting schedules and attendance data.

3.5. Communication and Data Flow

Data is transmitted between IoT sensors, the facial recognition camera, and the central server via UDP over IP for occupancy updates and secure HTTPS for facial recognition and booking information. The system is designed for scalability, allowing it to manage multiple rooms and large numbers of users efficiently.

4. Implementation Details

4.1. Hardware Components

- Occupancy Sensors: We use PIR motion sensors to detect the presence of individuals in the room. These sensors provide a cost-effective and reliable solution for occupancy detection.
- Cameras for Facial Recognition: High-definition cameras are installed at the entrances of the meeting rooms. These cameras are optimized for facial recognition in various lighting conditions.
- Microcontrollers: Devices such as Raspberry Pi are used to collect sensor data and communicate with the central server.

4.2. Communication Protocols

The communication between the IoT sensors, facial recognition system, and the centralized server is crucial for maintaining real-time synchronization. The UDP (User Datagram Protocol) was chosen for its low-latency nature, allowing for quick updates on room occupancy without introducing significant network overhead. Since room occupancy data is not sensitive to packet loss (missing a few occupancy packets doesn't greatly affect overall system performance), the UDP protocol is ideal for this application. For secure user authentication and facial recognition data transmission, the system employs HTTPS (Hypertext Transfer Protocol Secure). This ensures that sensitive data, such as user credentials and facial scans, are transmitted securely between the client devices (e.g., mobile phones, web browsers) and the server.

4.3. Database Design

The system employs a database due to its flexibility and scalability, especially when managing large amounts of unstructured data such as IoT sensor logs, facial recognition images, and room schedules. The database schema is designed as follows:

- Users Collection: Stores user information, including names, email addresses, and facial recognition data (image vectors).
- Meetings Collection: Contains meeting information, such as the organizer, participants, room ID, start and end times, and current status (scheduled, in-progress, or completed).
- Rooms Collection: Holds data about each room, including occupancy status, room capacity, and equipment available in the room (e.g., projectors, screens).
- Notifications Collection: Logs all reminders sent to participants, including timestamps, recipient details, and whether they were opened.

The database design also supports horizontal scaling, making it adaptable to larger organizations with multiple meeting rooms across different locations.

4.4. Facial Recognition Software

The facial recognition system uses a pre-trained deep learning model based on convolutional neural

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networks (CNNs) for image processing. The model is capable of recognizing and verifying individual faces with high accuracy. During the training phase, facial features are extracted from the input images, creating a unique identifier for each registered participant.

- Pre-Processing: When an individual approach a meeting room, the system captures an image using the room's camera. The image undergoes pre-processing to remove noise, adjust brightness, and enhance contrast to improve facial detection accuracy.
- Feature Extraction: A Convolutional Neural Network (CNN) extracts key facial features from the image and transforms them into a feature vector.
- Matching: The feature vector is compared with existing vectors in the database using Euclidean distance. If the distance between the vectors is below a predefined threshold, the system identifies the individual and grants access.
- Post-Processing: After authentication, the system records the access event, updating the user's attendance and sending it to the database.

Facial recognition system accuracy is enhanced by periodic re-training using newly captured facial images, ensuring that minor changes in appearance (e.g.. hairstyle glasses) do not affect recognition accuracy [14].

4.5. V. Notification System Implementation

The notification system uses a scheduler module that tracks meeting times and checks for user check-ins after 10 minutes. If a participant hasn't checked in, the system automatically sends a reminder through email or SMS based on the user's preferences. This reminder includes meeting details, such as room number and the meeting link for virtual participants. The notification module integrates with third-party services such as Twilio (for SMS) and SendGrid (for email). The system is also capable of escalating notifications. If the participant still doesn't check in after an additional 10 minutes, the system can notify a supervisor or automatically mark the participant as absent, depending on the configuration settings.

4.6. VI. Server-Side Logic

The central application server is responsible for:

- Processing occupancy data: The server continually receives occupancy updates from the IoT sensors, adjusting room availability status in real time.
- Managing bookings: Users can book rooms through a web interface, which is linked to the server to synchronize meeting schedules.
- Handling facial recognition: The server compares captured images from the room's cameras with the registered participants' data, ensuring only authorized attendees can access the room.
- Sending reminders: If a participant fails to enter the meeting room within 10 minutes of the meeting's start time, the system automatically sends them a reminder.

The server is implemented using E-Mail.js to manage bookings, facial recognition profiles, and attendance logs [15].

4.7. User Interface

The web-based interface provides an intuitive platform for users to:

- Book rooms: Users can view real-time availability and reserve rooms for future meetings.
- View meeting details: Participants can see details of upcoming meetings and access related resources.
- Receive notifications: Automated reminders and booking confirmations are sent via the web interface or mobile notifications.

5. Results and Evaluation

5.1. Occupancy Detection Performance

The IoT sensors successfully monitored real-time occupancy across multiple test rooms. The occupancy data allowed for the dynamic updating of room availability, reducing instances of blocked rooms due to canceled or prematurely-ended meetings. Testing showed a 25% improvement in room utilization due to the system's ability to release unused rooms for meetings.

- Scenario1: Normal Meeting: A meeting scheduled for 1 hour, with participants entering on time and staying until the end. The system accurately detected occupancy for 100% of the meeting duration.

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- Scenario2: Early Departure: Participants left the room 15 minutes before the scheduled end time. The IoT sensor correctly identified that the room became available, allowing other users to re-book the room.
- Scenario3: No Show: A meeting was scheduled, but no participants arrived. The system detected no motion and released the room after 10 minutes of inactivity, increasing room utilization efficiency.

Over a month of testing in different environments, the PIR motion sensors demonstrated an overall detection accuracy of 97%, with minor errors arising from brief periods of inactivity within the room.

5.2. Facial Recognition Accuracy

The facial recognition system demonstrated a high accuracy rate of 98%, successfully identifying authorized users while rejecting unauthorized access attempts. Tests were conducted under varying lighting conditions, and the system maintained reliable performance, with minimal false positives or negatives. The Table 1 facial recognition system was evaluated using a dataset of 100 employees, tested under different conditions, including various lighting scenarios and participant angles:

Table 1 Facial Recognition Accuracy

Condition	Accuracy (%)
Well-lit environment	99%
Low-light environment	95%
Different facial angles	92%

These results indicate that while the system performs exceptionally well under most conditions, some challenges remain in low-light scenarios or extreme facial angles. Future work will focus on improving these areas through data augmentation techniques and incorporating infrared cameras for better performance in poor lighting.

5.3. System Latency

One of the key evaluation criteria for the system was latency—the time it takes for users to interact with the system and receive a response. The system was tested for:

- Room Status Updates: The average time to detect a room's occupancy change and reflect this on the web interface was 500ms, which is near real-time.
- Facial Recognition Response Time: The time between a user standing in front of the camera and being granted access to the room averaged 1.5 seconds. This is within acceptable limits for a real-time system.
- Reminder Notification: Reminder notifications were sent out within 10 seconds of the 10-minute mark, ensuring timely reminders without excessive delay.

These low-latency results make the system suitable for dynamic environments where real-time decision-making is essential.

5.4. User Feedback and Usability

To assess user experience, 50 participants from a medium-sized organization used the system over the course of one month. A survey was conducted to gauge user satisfaction:

Table 2 User Feedback and Usability

Metric	Satisfaction (%)
Ease of Booking Rooms	90%
Facial Recognition Usability	85%
Timeliness of Notifications	88%
Overall Satisfaction	87%

Most users reported that the system significantly reduced the time spent looking for available rooms, and the facial recognition access control was generally well-received. However, some users experienced difficulties with the facial recognition in dimly lit environments, which will be addressed in future updates, shown in Table 2.

5.5. Reminder System Effectiveness

The automated reminder system effectively improved participant punctuality. In trials, 85% of participants who received a reminder entered the room within five minutes of receiving the notification, significantly reducing meeting delays and disruptions.

5.6. Scalability and User Feedback

The system was tested with multiple rooms and participants across different organizational departments. The web interface was well-received, with users praising the real-time availability feature and the secure access control.

6. Future Work and Challenges

While the current system has shown promising results, there are several areas for improvement and future work. These include:

- Integration with Calendar Systems: Integrating the meeting room management system with widely-used calendar systems such as Google Calendar and Microsoft Outlook is an essential next step. This will allow for seamless booking experiences across platforms, enabling users to manage their schedules more efficiently. The challenge lies in ensuring data consistency between the systems and handling synchronization issues, particularly when rooms are overbooked or underbooked.
- Energy Efficiency Enhancements: Incorporating energy-saving features, such as automatic lighting and HVAC control, can make the system more sustainable. When a meeting room is detected as unoccupied, the system can turn off lights and adjust HVAC settings to save energy. The system will need to integrate with smart building management systems to achieve this.
- Advanced Analytics for Room Utilization: Collecting and analyzing data on room usage patterns will allow organizations to make more informed decisions about resource allocation. For example, heatmaps showing room usage frequency can help identify underused spaces, leading to more efficient space planning. An AI-driven analytics dashboard could be developed to provide insights into meeting behaviors, such as average meeting durations, room preference trends, and optimal room allocation based on historical data.
- Security Enhancements: While facial recognition improves access control, additional security features could be added to protect against spoofing attacks. Techniques such as liveness detection (which ensures that a live person is attempting access, rather than a photo or video) could be integrated to further enhance the robustness of the security system.

Conclusion

This paper presented a Smart Meeting Room Access Control and Management System Using IoT. The system optimizes room utilization by providing real-time occupancy updates, enhances security through facial recognition access control, and improves meeting efficiency by sending reminders to participants who are late. The integration of IoT and facial recognition creates a robust, scalable, and secure solution for managing meeting rooms in modern organizations. Future work will explore integrating energy management features and improving facial recognition algorithms to handle more complex scenarios.

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