CIS 515 Final Project
ASU RoomSense : Real Time Room Activity/Occupancy Monitor

Presented By Team 107:

Deeksha Lingaraju
Reeve George
Shriya
Manish Reddy
Yashwanth Guruswamy

Introduction and Current Problem

- ASU offers an automatic scheduling system for reserving study rooms, collaboration spaces, and advising offices, but bookings do not guarantee actual usage.
- No-shows and overcrowding lead to inefficient space usage, lost opportunities, and student frustration.
- Current systems track reservations but lack real-time insights into room occupancy or zone activity.
- ASU RoomSense uses Computer Vision to monitor study spaces across campus and verify real-time usage, enhancing scheduling effectiveness.

Room Reservations

Booked rooms do not guarantee actual occupancy or usage.

No-Shows and Overcrowding

Frequent no-shows and overcrowding events are not detected in real-time.

Lack of Real-Time Insights

Existing systems only manage reservations, not live room activity or space utilization.

- Despite having automated scheduling systems, ASU lacks the ability to verify real-time room usage after a reservation. Traditional systems cannot detect no-shows, unexpected overcrowding, or active zone utilization inside reserved spaces.

- RoomSense addresses this gap by automating occupancy and activity monitoring using Computer Vision.

Key Stakeholders

Facilities Managers

Optimize space utilization by verifying actual room usage and detecting underutilized or overcrowded areas.

Student Services

Ensure equitable access to study rooms and collaboration spaces, improving the student experience.

Campus Scheduling Teams

Support data-driven scheduling decisions by validating real usage patterns alongside reservation data.

- RoomSense benefits multiple stakeholders by bridging the gap between room reservations and real-time usage.
- By providing occupancy verification, live alerts, and zone-specific analytics, the system enhances campus operational efficiency, improves space allocation decisions, and supports a better learning environment for students.

End-to-End Solution Lifecycle

1. **Problem Definition:**
   - **Problem**: Many ASU departments struggle with tracking real-time occupancy in various spaces such as student centers, meeting rooms, lobbies, and advising offices. The absence of real-time data results in inefficient space usage, poor resource allocation, and insufficient space management. Current methods like manual sign-ins or swipe-ins are unreliable.
   - **Scope:** Develop a real-time occupancy monitoring system using computer vision to track room occupancy and zone utilization at ASU. The system will help manage space utilization by detecting people in specific zones within a room.
   - **Value of the Solution:** Addresses the challenge of inefficient space usage and the lack of real-time occupancy tracking across campus.
2. **Data Acquisition and Preparation:**
   - **Data Collection**: Webcam captures real-time footage of rooms for occupancy detection.
   - **YOLOv5**: We leverage a pre-trained YOLOv5 model (using PyTorch) for object detection, which has been trained on a large set of images, including detecting people in various environments.
   - **Zone Definitions**: Specific zones in each room are manually defined within the video frame (e.g., entry point, collaborative area, help desk). These zones are crucial for tracking activity and ensuring accurate zone-based occupancy monitoring.
   - **Frame Consistency**: Ensure that every frame is properly timestamped and that the person count and zone activity data are consistent across frames.

End-to-End Solution Lifecycle

3. Feature Engineering:

- **Person Count per Zone**: Track how many people are present in each defined zone over time.
- **Time Stamps**: Each frame's detection and zone data is associated with a timestamp for temporal analysis.
- **Alert Triggers**: Prepare data based on predefined occupancy thresholds to trigger alerts when the room reaches maximum capacity or specific zones exceed activity limits.

4. Model Building and Evaluation:

- Used YOLOv5 (pre-trained model) for people detection in real-time video feeds.
- YOLOv5 is fine-tuned to detect people, focusing on accuracy and speed for real-time applications.
- Fine-tuned the YOLOv5 model on a dataset containing meeting room images to improve detection accuracy in specific environments.
- **Accuracy**: The system's ability to correctly detect people and track occupancy in real-time.
- **Alert Accuracy**: Timeliness and accuracy of the alert system when occupancy exceeds the predefined threshold.

End-to-End Solution Lifecycle

5. Deployment Monitoring and Maintenance:

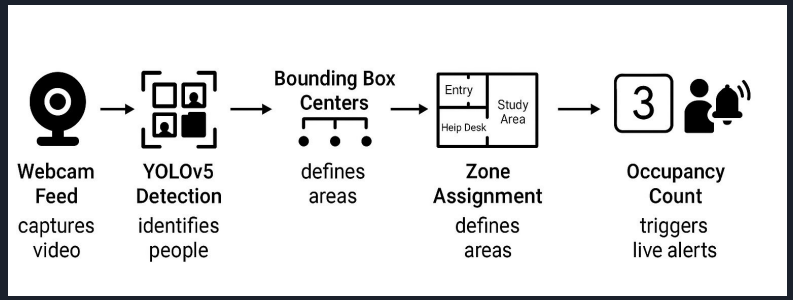
- **Real-Time Monitoring**: Continuous monitoring of system performance (e.g., processing speed, alert accuracy).
- Monitor for any hardware failures or video processing delays.
- Periodically update the software and model (e.g., incorporating better algorithms for detection, optimizing for different environments).
- **Error Logs**: Ensure the system logs errors and issues for further troubleshooting and updates.
- **Consequences**: Possible over-reliance on automated alerts could lead to situations where human judgment is still required. Additionally, some users may feel discomfort from being tracked, even without identifiable data.

6. Bias and Fairness Challenges:

- Limited or unrepresentative training data may lead to biased model performance in varied environments.
- Model may perform well in test environments (e.g., meeting rooms) but struggle with diverse room layouts or lighting conditions.
- Inaccurate detection of people in certain zones (e.g., near the camera vs. far from it) may skew activity tracking and resource allocation.
- Capturing real-time video could raise privacy issues, even without facial recognition, affecting trust and fairness.

How Our Solution Uses Computer Vision (CV)

- RoomSense uses CV to detect people in real-time using a webcam feed.
- A pre-trained YOLOv5 model identifies and localizes "person" objects in each frame.
- Detection outputs (bounding boxes) are mapped to predefined room zones.
- Enables real-time occupancy tracking, zone activity monitoring, and crowding alerts.



Why Computer Vision is Essential to RoomSense

- Manual monitoring is inefficient, error-prone, and non-scalable.
- Badge swipes and entry systems only capture entry/exit — not real usage or zone activity.
- Passive sensors (PIR) detect presence but cannot differentiate zones or group sizes.
- CV provides fine-grained, real-time, zone-specific spatial awareness.
- Without CV, verifying room occupancy and detecting overcrowding would not be possible.

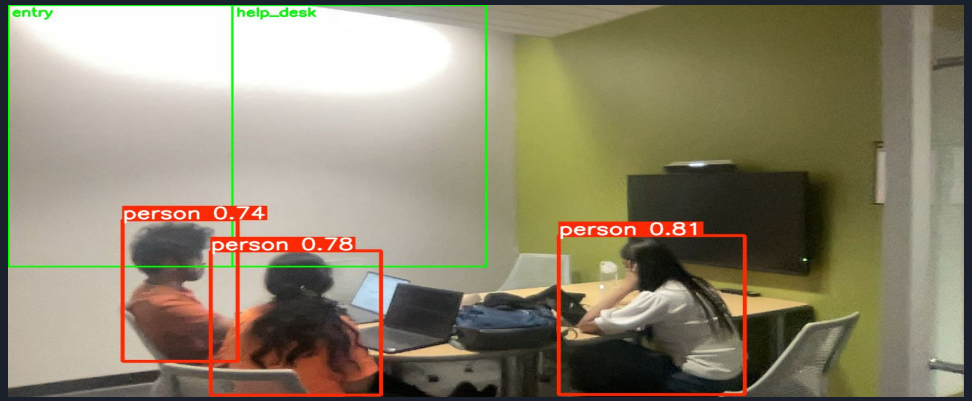
OpenCV Responsibilities

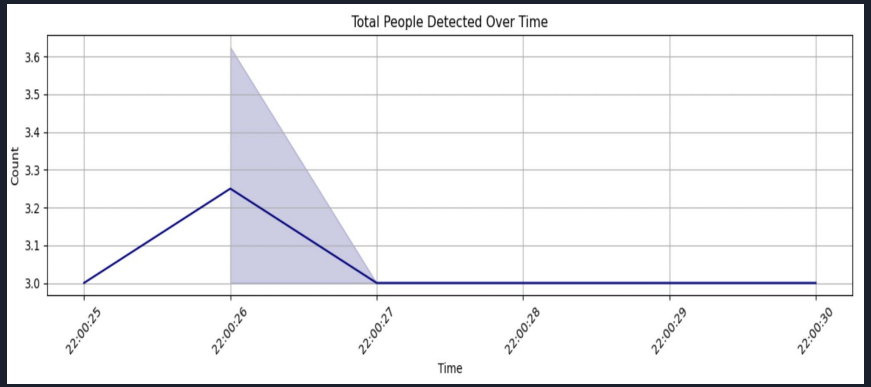
- Captures live video frames from webcam
- Preprocesses frames (resizing, color conversion)
- Displays frames with real-time bounding boxes
- Saves snapshots and frame logs

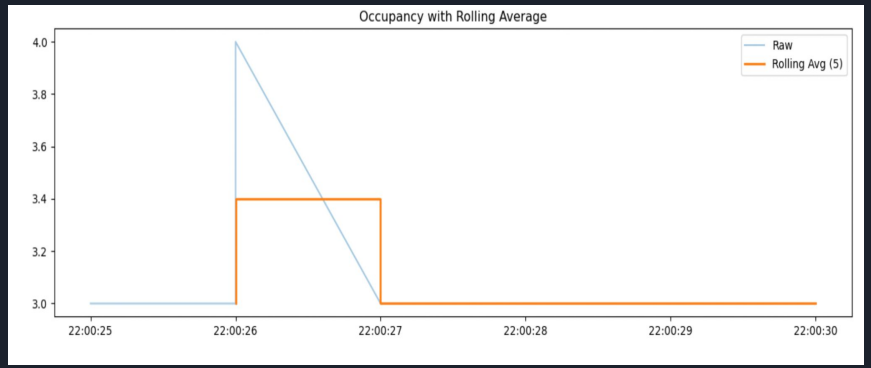
YOLOv5s Responsibilities

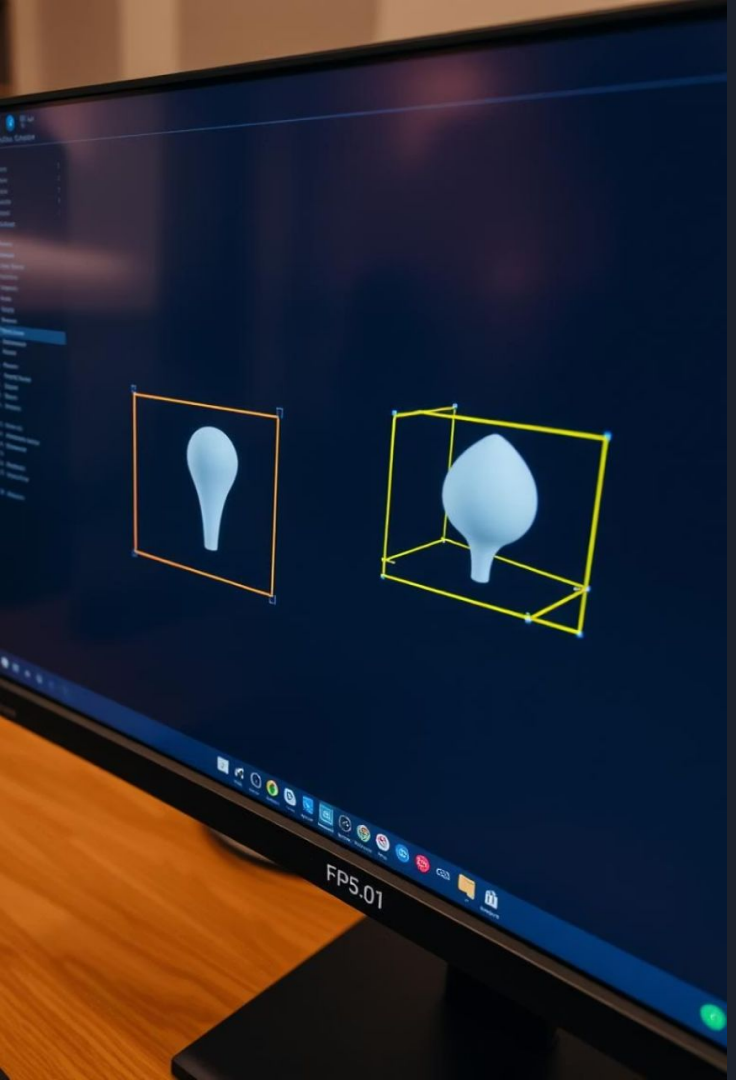
- Real-time detection of "person" objects
- Maps detections to predefined room zones
- Triggers real-time occupancy alerts

Proof-Of-Concept Demo









Performance Metrics

Accuracy

Detection Accuracy for person class exceeds 85%, with internal validation showing ~92% accuracy.

Speed

Achieves 140 FPS on GPU and approximately 15 FPS on standard CPU (MacBook M1).

Zone Mapping

Achieves 140 FPS on GPU and approximately 15 FPS on standard CPU (MacBook M1).

Internal Validation Process

Manual Headcount Comparison

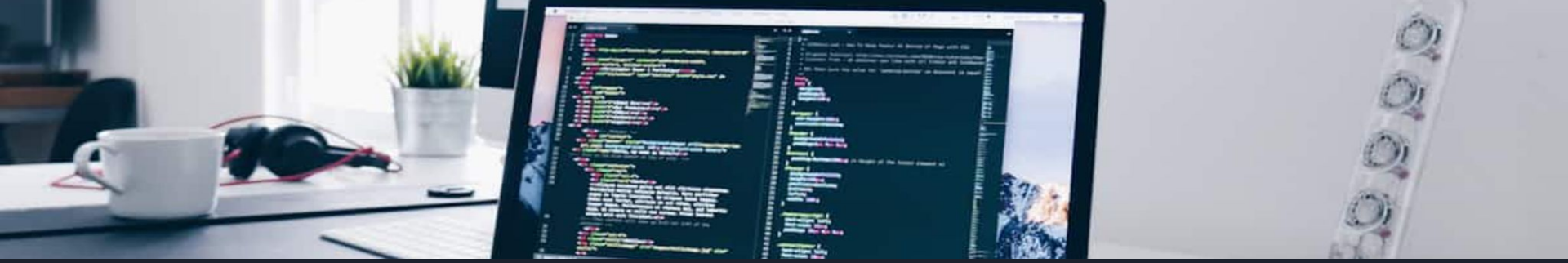
Live webcam feeds were cross-checked with manual counts to verify detection accuracy.

Occupancy and Zone Validation

Detected occupancy was compared with ground truth, and zone mapping accuracy was measured.

Performance Measurement

Frames per second and false positive rates were monitored to ensure real-time operation.



External Validation Plan

1. **Pre-Deployment Testing**
   Simulated occupancy tests with varying crowd sizes and confusion matrix generation.
2. **Post-Deployment Audits**
   Random manual audits during operational hours and cross-verification with RoomSense logs.
3. **User Feedback**
   Collecting input from facility managers and security teams for continuous improvement.
4. **Fine-Tuning**
   Ongoing adjustments based on discrepancies observed during audits and feedback.

System Benefits and Scalability

Efficient Monitoring

Lightweight and fast pipeline enables real-time people tracking with minimal hardware requirements.

Scalable Solution

Designed for easy expansion to other smart campus applications and environments.

High Accuracy

Reliable detection and zone mapping ensure precise occupancy monitoring for classrooms.

Monitoring & Model Update Strategy

Monitoring Post-Deployment:

- Logs occupancy counts and zone data into CSV during runtime.
- Snapshots during alerts act as a manual validation tool for overcapacity events.
- **Post-monitoring analysis** includes:
  - **Line chart** of occupancy over time (via Matplotlib).
  - **Basic statistical summaries** printed to the console.

Update Plan:

- Continue with manual snapshot reviews to validate detection accuracy.
- Optionally enhance with automated report generation or integrate dashboards in future versions (e.g., move towards Streamlit).

Outcome-Action Pairings

- **Detailed Outcome-Action Table:**

Model Outcome	Action Taken	Cost Consideration
True Positive	Accurate detection → counts & alerts logged	Expected system behavior, no extra cost
False Positive	Unnecessary alert or incorrect tagging	Minor → temporary user inconvenience
False Negative	Missed detection → under-reported occupancy	Critical → Safety risk if overcrowded
True Negative	No detection, no action	No action, no cost

Cost-Benefit Summary:
The system's lightweight hardware requirement (webcam + CPU) offers a low-cost solution with significant operational benefits in safety and space optimization

Action Adjustments:

- **Overcapacity detection:** Triggers in-frame alert text + snapshot saving.
- The cost analysis and impact of FP/FN remain the same.

Conclusion

Solution Summary:

- ASU RoomSense leverages Computer Vision to monitor real-time room occupancy and zone activity, complementing scheduling systems by verifying actual space usage.

Key Findings:

- CV-based detection provides fine-grained spatial awareness, real-time occupancy tracking, and actionable insights for campus space optimization.

Limitations:

- System accuracy may vary with lighting conditions, crowded scenes, and camera positioning; real-time performance depends on hardware capabilities.

Possible Extensions:

- Integration with ASU's scheduling systems for live utilization dashboards.
- Model fine-tuning for campus-specific environments
- Enhanced privacy safeguards and on-device (edge) processing.

Future Work

Planned Enhancements:

- **Fine-tune YOLOv5 on ASU-specific data:**
  - Collect images from **ASU campus environments** to retrain the model for **better context adaptation** (e.g., unique lighting, room setups).
- **Expand to multi-camera systems:**
  - Deploy **multiple camera feeds** to cover **larger or complex spaces** (e.g., lecture halls, open areas).
- **Integrate predictive analytics:**
  - Use historical occupancy data to **forecast peak usage times** for **proactive space management**.
- **Dynamic zone configurations:**
  - Enable **adaptive or AI-suggested zones** based on **real-time movement patterns** and **space utilization heatmaps**.
- **Automate reporting and alerts:**
  - Extend the current **snapshot & CSV logging** to generate **automated reports** and **email alerts** for facility managers.

Thank you!