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Seat Sight: Public Space Occupancy Detection System

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ABSTRACT: This paper presents a novel use of deep learning methodology to develop an affordable, fast, and easy to install system for detecting empty seats in public spaces. System would leverage computer vision techniques and real-time database capabilities for easing the task of empty seat detection system installation and maintenance. Along with an empty seat detection system our final product would also consist of a consumer facing application (WEB application) for displaying the number of empty seats at selected locations in real-time. Empty seat detection systems through computer vision along with web applications for real-time updates can easily be used at any public space with pre-installed cameras, making our system widely applicable. Places like public libraries, restaurants, coffee shops can easily utilize the system to their benefit. Additionally, at times when social distancing is necessary the general public can also utilize the web application to check seat occupancy before visiting a public space. Similarly, the system can also be used to regulate social distancing rules, though it should be noted that the current design of the system can only estimate seat occupancy rate. For this, a deep learning model is trained to correctly identify the Empty seat from the seat image database provided, using the cameras image uploaded to the database. The Convolutional Neural Network (CNN), a highly effective deep learning technique for image-based applications is adopted here for object detection. Human descriptors are extracted from the images using a pre-trained CNN model YOLO-v3 deep architecture. Compared with normal deep learning applications, our algorithm uses convolution network only as a high-level feature extractor and the seat recognition is done by the trained SVM classifier. Choosing the best performing CNN model for face recognition, YOLO-v3 and proper training of it results in a deep learning model invariant to noise, illumination, contrast, occlusion, image pose and it outperforms earlier methods in human recognition based vacant seat identification.

I. INTRODUCTION

Nowadays, technological advancement is augmenting all aspects of the human lifestyle, by creating a well-oiled environment of artificial intelligence with machine learning at its core. The market of the use of machine learning in organizations is estimated to show a compound annual growth of 39.2% towards the end of 2027, with organizations trying to increase efficiency and creating an improved customer experience. Similarly, our project aims to make use of machine learning to detect empty seats in public spaces. The NCET is one of the most prestigious colleges in Bengaluru, having lots of students and over 100 academic staff. This huge number of students and staff usually tends to overcrowd the learning spaces and eating outlets on the campus. The main library in NCET has limited seats, even though the learning spaces like several sitting spaces near our college ground is way bigger in comparison to the main library, the seating space in library is not enough to accommodate the huge number of students. More often than not, students have to walk around the entire campus looking for empty seats to study or to relax in between lectures. This issue is highlighted profusely during the exam season, when the majority of NCET students prefer studying in the main library or common learning places. Students tend to reserve seats for themselves and/or their friends by placing laptops, books or bags on the seats, leading to irritation and angst amongst the students and staff alike. The ideation of the project to detect empty seats in public spaces is inspired by the need to solve the seating issues in learning spaces as well as the eating outlets. Solving this issue would not only lead to efficiency in terms of students' time but would also save them a lot in tiredness and ultimately work towards improving their morale. Our project is also inspired by WeWork and Amazon Go. WeWork is a commercial real estate company based out of America. They use computer vision to detect empty spaces in their shared workspaces. Similarly, Amazon Go makes use of computer vision to create a seamless checkout-free shopping experience for their customers. Taking inspiration from two very advanced customer experiences of WeWork and Amazon Go, we aim to provide a similar experience to the students and staff of NCET and expand this experience to other public spaces within college.

II. RELATED WORK

Currently only manual counting based on data entered by user is available or using hardware's like pressure, infrared or temperature sensor.

By installing a Piezoelectric Sensor [6] on a chair, it is possible to detect whether someone is sitting on it or not. The system would need Piezoelectric Sensors configured to detect when someone is sitting on chair and send the information to nearby WI-FI router through Bluetooth for uploading to the cloud server. Installing sensors on every seat and handling network connections in public spaces is not easy, scalable, and affordable. Also, there would be a feeling of discomfort if a sensor is placed on the sitting area of the seat.

Developing mobile applications that will gather location data from its users and estimate the number of people present at a pre-defined space. Henceforth, estimating the number of seats empty at that space, assuming most people sit. Even though this solution is fast and affordable, the accuracy would not be good. Additionally, users are not comfortable sharing their location constantly, GPS location estimation is not fairly accurate in enclosed spaces, the application relies on users to download the app, and the application can have other negative consequences as well.

III. METHODOLOGY

For our project, the chosen programming language is Python. Python is widely recognized as an easy-to-learn and powerful programming language.

Libraries:

PyTorch: PyTorch is a popular open-source machine learning library widely used for developing and training neural networks. which allows us flexible and efficient execution of our neural network models.

Matplotlib : It offers a wide variety of plot types, including line plots, scatter plots, bar charts, histograms, heatmaps, and Seaborn to enhance the visual appeal of the plots generated with Matplotlib. These visualizations helps us analyze and present data related to the empty seat detection system, such as occupancy rates, seat utilization patterns, or real-time visual feedback on seat availability.

Open-CV : OpenCV's algorithms is used to perform person detection and chair detection in real-time camera feeds. This is particularly important for the empty seat detection, as it requires processing video streams in real-time to identify and track people and chairs.

Numpy: It allows us to work with large amounts of data efficiently and perform various operations on arrays. It utilizes optimized C code under the hood, making it significantly faster than traditional Python lists for numerical computations. This speed advantage is crucial for processing large amounts of data in real-time, which is often required in computer vision tasks like seat detection.

Detection of chair and person using pretrained YOLOv3 model:

- i. Initialize the Model: In the system's implementation, we load the pretrained weights and the model architecture using a deep learning framework PyTorch. This process initializes the YOLOv3 model with the learned parameters.
- ii. Preprocess Input Images: Before passing the images to the YOLOv3 model for detection, we preprocess them by resizing them to the required input size and normalizing pixel values.
- iii. Perform Inference: Feed the preprocessed images through the YOLOv3 model to obtain predictions for chair and person detection. The model predicts bounding boxes, class labels, and confidence scores for objects in the image.

IoU algorithm to determine whether Chair is vacant or occupied:

- i. Intersection over Union (IoU) Calculation: The IoU calculation is performed to assess the overlap between the bounding boxes of chairs and persons. It determines how much two bounding boxes intersect with each other.



- ii. Union-over-Intersection Threshold: A threshold value is set to determine when a person is considered to be sitting on a chair. If the IoU between a chair bounding box and a person bounding box exceeds the threshold, it indicates that the person is sitting on the chair.
- iii. Occupancy Determination: Based on the results of the IoU calculation and the threshold comparison, the algorithm determines whether a person is occupying a chair or not. If the IoU is above the threshold, the person is classified as sitting on the chair. Otherwise, they are considered to be standing or not sitting on any chair. By implementing this algorithm and performing the IoU calculation, the system can determine whether a person is sitting on a chair based on the degree of overlap between their respective bounding boxes.

Working Model:

A. Input from camera feed:

The camera feed passed through pretrained YOLOv3 model to obtain bounding box predictions for chairs and persons in the input image or video frame. The YOLOv3 model processes the image and outputs a set of bounding boxes along with corresponding class probabilities and confidence scores.

B. Process the bounding boxes:

The Intersection over Union (IoU) algorithm used to determine whether a person is sitting on a chair by finding the overlapping region between the bounding boxes of the chair and the person. This is done by determining the coordinates of the intersecting rectangle (i.e., the region where the bounding boxes overlap).

C. Backend Development with Django:

Django backend acts as the core engine of our system, managing the data, implementing the seat detection, managing libraries, handling request, process the data, integrating machine learning models, and providing the necessary APIs for frontend interaction. It ensures the smooth functioning and coordination of all components to deliver the desired occupancy detection functionality.

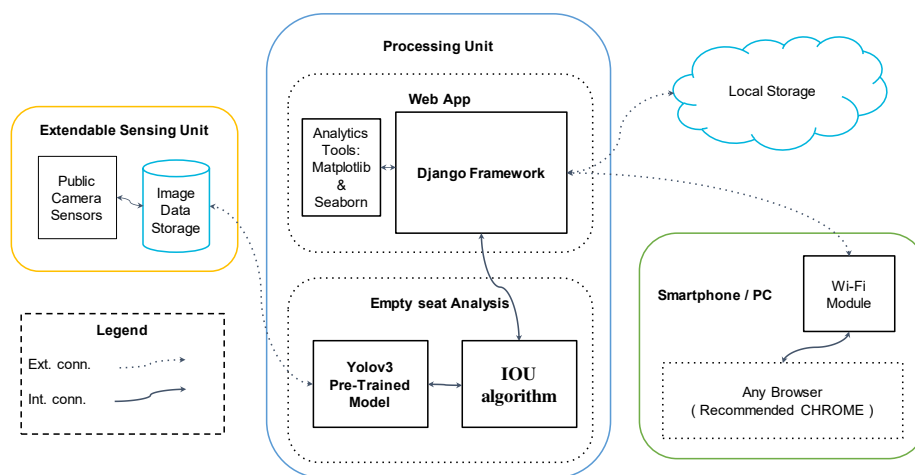
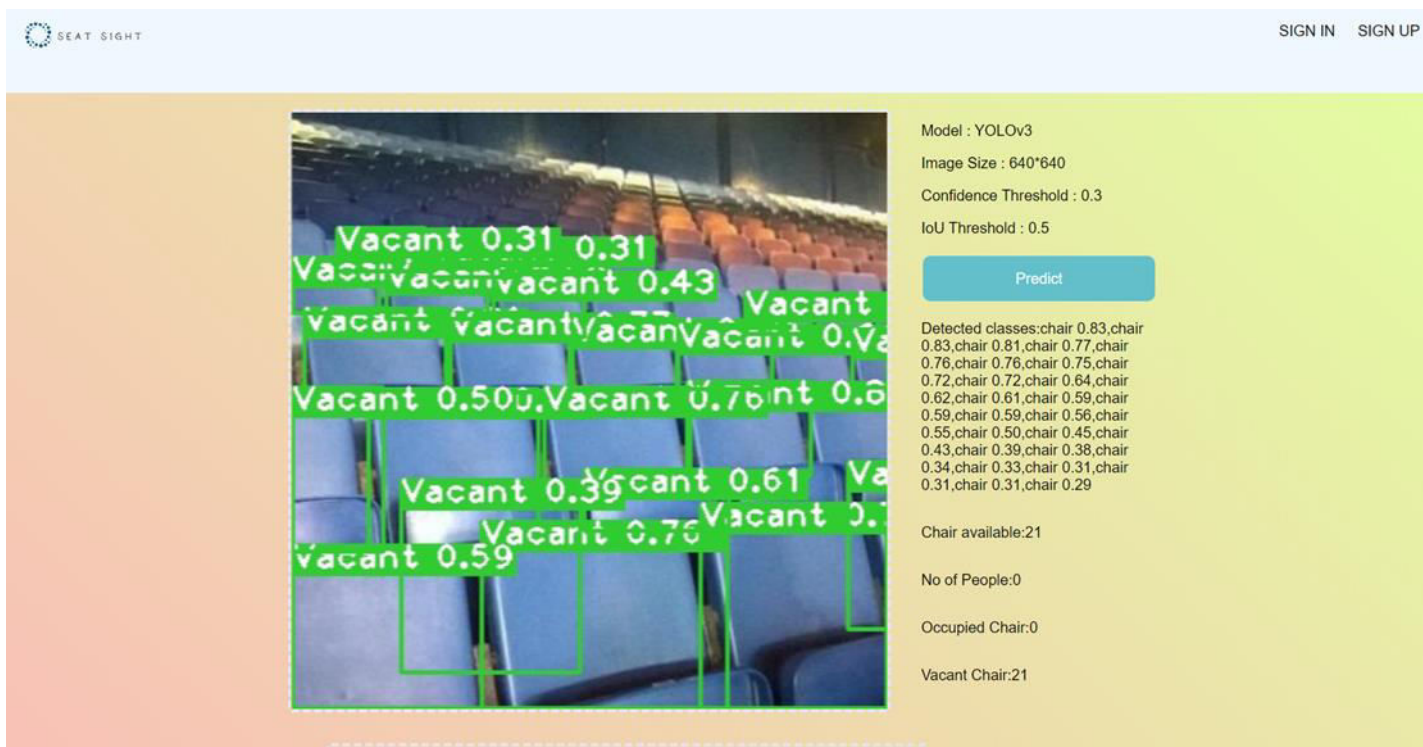
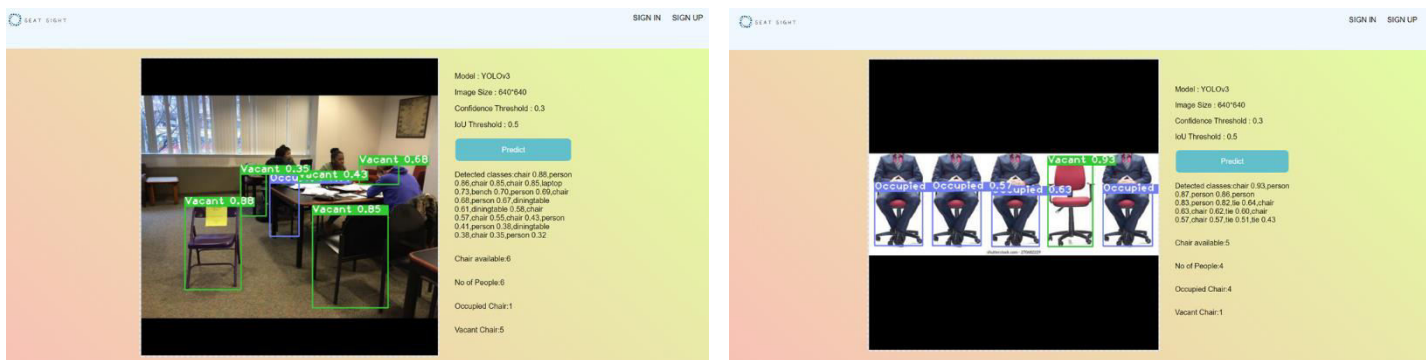


Fig. 1. Flow chart



IV. EXPERIMENTAL RESULTS

Figures shows the results of seat detection



V. CONCLUSION

In this work, we have used image and video for seat occupancy detection. From in depth analysis and experiment, we show our project which can clearly distinguish people occupancy with detection accuracy for unoccupied and occupied state along with probability. These simple and low cost project have reached our initial goal to build such application that are easy to deploy and have good accuracy for practical use in library, canteen and other public places. The vacant seat detection aimed to develop a system that could accurately identify and detect vacant seats in an environment using image processing techniques. However, it is important to note that the system does have limitations. The accuracy of seat detection can be affected by factors such as occlusions, partial seat visibility, and variations in lighting conditions. The performance of the system heavily relies on the quality and diversity of the training dataset. The vacant seat detection using image project successfully developed a system capable of accurately detecting vacant seats. While there are limitations to consider, the project lays a foundation for further advancements in seat detection technology, with



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potential applications in various domains such as smart offices, public spaces, and transportation.

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