Detecting Empty Seats in Public Spaces

Project Plan

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Background

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 organisations is estimated to show a compound annual growth of 39.2% towards the end of 2027, with organisations trying to increase efficiency and creating an improved customer experience [1]. Similarly, our project aims to make use of machine learning to detect empty seats in public spaces, mainly Chi Wah Learning Commons, Main Library and restaurants in The University of Hong Kong (HKU).

The University of Hong Kong is one of the most prestigious universities in the world, having 10 academic faculties with more than 29,000 students and over 7,000 academic staff [2]. This huge number of students and staff usually tends to overcrowd the learning spaces and eating outlets on the campus. The main library in HKU has a total of 115 seats, even though the chi wah learning commons is way bigger in comparison to the main library, the seating space is not enough to accommodate the huge number of students [3]. More often than not, students have to walk around the entire campus looking for empty seats to study or to relax in between lectures. Although, HKU boasts of a wide range of eating outlets on the campus, they are not equipped to cater to the large number of students and staff, especially during the lunch hours, resulting in long queues and a lot of students getting late for their lectures.

This issue is highlighted profusely during the exam season, when the majority of HKU students prefer studying in the main library or the chi wah learning commons. 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 in The University of Hong Kong. Solving this issue would not only lead to efficiency in terms of students’ time, but would also save them a lot in travelling expenses 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 [4]. Similarly, Amazon Go makes use of computer vision to create a seamless checkout-free shopping experience for their customers [5]. 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 HKU and expand this experience to other public spaces within Hong Kong.
Objectives

The aim of this project is to develop an affordable, fast, and easy to install system for detecting empty seats in public spaces. System would leverage computer vision techniques and realtime 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 (mobile application) for displaying the number of empty seats at selected locations in real-time.

Empty seat detection systems through computer vision along with mobile 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 utilise the system to their benefit. Additionally, at times when social distancing is necessary the general public can also utilize the mobile 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.

However, our main stakeholders for the current system design are students studying at The University of Hong Kong mainly because of two reasons:

- Enabling students to check empty seats at different public places on campus would be highly beneficial for them.

- Public spaces at The University of Hong Kong are easily accessible to our team for testing purposes.
Hence, the ultimate goal of the project with current design plan would be to be applicable in the following ways for our main stakeholders:

- **During normal semester:** Occupancy at public spaces on campus (like Chi Wah Learning commons and libraries) varies throughout the day. Hence, it happens very often that students spend time hopping from one place to another looking for empty seats. With the use of our application students can easily check whether empty seats are available at a particular place or not and then decide on visiting the place, hence, saving themselves time.

- **During lunch time:** Occupancy of seats on campus catering facilities during lunch time is at peak and a lot of time students have to wait for seats to get free before they can have their meal. With the use of our application students can check beforehand whether seats are available at a catering outlet or not and then proceed for a meal.

- **During exam time:** Occupancy rate of seats at libraries and learning commons is at peak during exam time and oftentimes students unnecessarily waste time by searching for an optimal place to sit and study. With the use of our application students can check, within an instant, for a place with empty seats and then can proceed to the place to study.

While at present we plan on developing our system in accordance with the concerns of our main stakeholders. This does not necessarily mean that the same system cannot be used at other places as mentioned above. We would aim to make the system modular enough so that it is flexible to be used at different places with minimal configuration, hence enabling other universities and places to use the system.
Methodology

As mentioned above our project aim is to develop an affordable, fast, and easy to install system for detecting empty seats in public spaces, along with a mobile application for realtime updates on empty seats at selected public spaces around campus. While evaluating different methods for developing the system, the following three criterias were kept in mind:

- **Affordable:** The system should be affordable and should try to use existing hardwares in place
- **Fast:** The system should have low latency for detection and realtime updates for being very useful for stakeholders.
- **Easy to install:** System should be easy to install and maintain in future.

After evaluating different techniques for developing our system we came to the conclusion that leveraging computer vision techniques along with a real time database would be the most optimal solution for the following reasons:

- Eliminates the use of additional hardware installation and leverages upon pre-installed existing camera surveillance systems. Hence, making the system affordable.
- The service can be installed on top of existing camera systems with the use of APIs making the system easy to install.
- Computer vision is widely used for low latency applications, proving it to be a reliable and low latency solution for our application as well.

Following are other methods that we thought to use, but eventually decided not to:
- **Using pressure sensors:** By installing a Piezoelectric Sensor 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 char and send the information to nearby wifi 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.

- **Use location data:** 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.

For delivering our objective we decided to employ machine learning (using computer vision techniques). Further, we would leverage Flask based back-end deployed on AWS/GCP and develop mobile application for iOS/Android for maximum user coverage. Below is a detailed description of our methodology.

### 3.1 Machine Learning Model

We propose two approaches in solving this problem. One approach utilizes the pre-trained model coupled with classic computer vision techniques, while approach two scrapes out computer vision and uses end-to-end training in identifying available seats.

- **Pre-Trained Models coupled with traditional Computer Vision techniques** - Initial analysis and breakdown of the problem lead us to the conclusion that the classic computer vision techniques were powerful enough to solve this problem. The seat detection is easily achievable using CV and Machine Learning but CV techniques are
not reliable enough for the task of human detection. CV techniques like Histogram of Oriented Gradients are not powerful enough to give accurate results in case of human detection, especially from different angles and in various poses [7]. However, Convolution Neural Networks are powerful enough to handle the aforementioned issues. COCO dataset is one of the most widely used datasets by machine learning models for multi-class object detection [7]. ImageNet is another popular choice to go with but COCO dataset has object categories which are much more relevant to our task than ImageNet. Therefore we will be using models trained on the COCO dataset. Tensorflow has an Object Detection API which comes loaded with several pretrained models on the COCO dataset. Faster R-CNN, Mask R-CNN, Mobilenet v2 are some of the promising ones available in the Tensorflow API [7].

OpenCV will be used to define seat bounding boxes. The image will be fed through the machine learning model to filter the boxes down to the human and chair classes. If a significant overlap is found then the seat will be marked occupied [7].

- **End to End Training** -

This approach would leverage Tensorflow APIs to build our own model. In addition to using a pre-trained model, we will train a deep learning model for explicitly labeling seat status [7].

A deep convolutional neural net will be implemented. It takes in a lot more data than we have so we plan to make our own dataset to train this model. To get the most out of this resource heavy model, we plan on training it on the HKU GPU farm. Initially, we plan on using 36000 images collected from different angles, to train the model. However, the final number of images can vary depending on the computational power available.

As the project moves forward, further research will be conducted to identify the loop holes in various pre-trained models. Final selection would be made either from one of the aforementioned models, or from a different new model. Different techniques, like calculating seat status on basis of average result of every 100 frames, will be used to handle anomalies like
when some walks past a seat or accidentally hits the seat.

3.2 Flask Backend and a Realtime Database

For the trained model to predict data, the video streams in form of frames will be fed from the required CCTV cameras. For the model to work at a real-time speed, it will be deployed on a GPU powered instance along with a Flask backend. The model will be deployed on several nodes in a cluster for more computational power. It will help the model leverage more computational power and ensure scalability. Several AWS based services like Amazon Elastic Kubernetes Service, Amazon Elastic Container Service and others will be used to satisfy our cloud requirements.

The project will also require a realtime database for our Flask server to update the seat status which then can be simultaneously updated in the mobile application. For the initial stages of the project we will be using Firebase as the realtime database. It is easy to setup and is a light weight database. It also provides out of the box functionality for user registration and user login. In later stages scalability might become an issue for Firebase, then database can be migrated to PostgreSQL. Hasura and GraphQL can be leveraged to use PostgreSQL as a realtime database.

3.3 Mobile Application

A cross platform mobile application compatible with both iOS and Android will be delivered by the end of this project. The users can select the available locations from a dropdown and can find the empty seats available at that location. It will be made using React Native and key development areas would be connecting to the realtime database and a cloud server. User login and other user oriented features like frequently visited places can be added in the later stages.
Though, it is the only user facing deliverable of our project, the mobile application cannot be developed without the machine learning model and the backend in place. Therefore, it will be the last feature developed.
Schedule And Milestones

4.1 September 2020

i. Research on technology behind OpenCV and Deep Convolution Networks.

ii. Study Tensorflow APIs that can be used for the project.

iii. Creation of detailed project plan to outline project background, objectives, methodology, schedule and milestones.

iv. Website development to display key information about the project

4.2 October 2020 to December 2020

i. Phase 1 Deliverables due 04th October, 2020.

ii. Try out Approach One and analyse the results.

iii. Collect the data for approach two.

iv. Try out Approach Two and analyse the results.

v. Finalization of the approach.

vi. Final training of the model.

vii. Deploy the model, initialize the Flask Server and Database.
4.3 January 2020 to February 2020

i. Testing and finalization of the Flask server.

ii. Start building the mobile application with a basic UI.

iii. Creation of a detailed Interim Report, explaining current progress, implementation, and scope of development.

iv. Initial Presentation Deck, for presentation of current progress and other analysis

v. First Presentation between 11th to 15th January 2021.

vi. Phase 2 Deliverables due 24th January 2021.

4.4 March 2020 to April 2020

i. Complete the mobile application with a polished UI and link it with the cloud servers.

ii. Creation of Final Report to comprehensively explain the work done, problems solved, limitations, and future scope.

iii. Final Pitch Deck to demonstrate the use of the platform and present any significant findings.

iv. Phase 3 Deliverables due 18th April 2021.

v. Final Presentation between 19th to 23rd April 2021.

4.5 May 2020 to June 2020

i. Project Competition on 4th May, 2021.

ii. Project Exhibition for selected projects on 2nd June, 2021.
References


Available: https://github.com/RexxarCHL/library-seat-detection/