GROUP 14

Major Project Presentation

Subway Train Seat Occupancy Detection via Instance Segmentation and Point Regression for peri and post Covid-19

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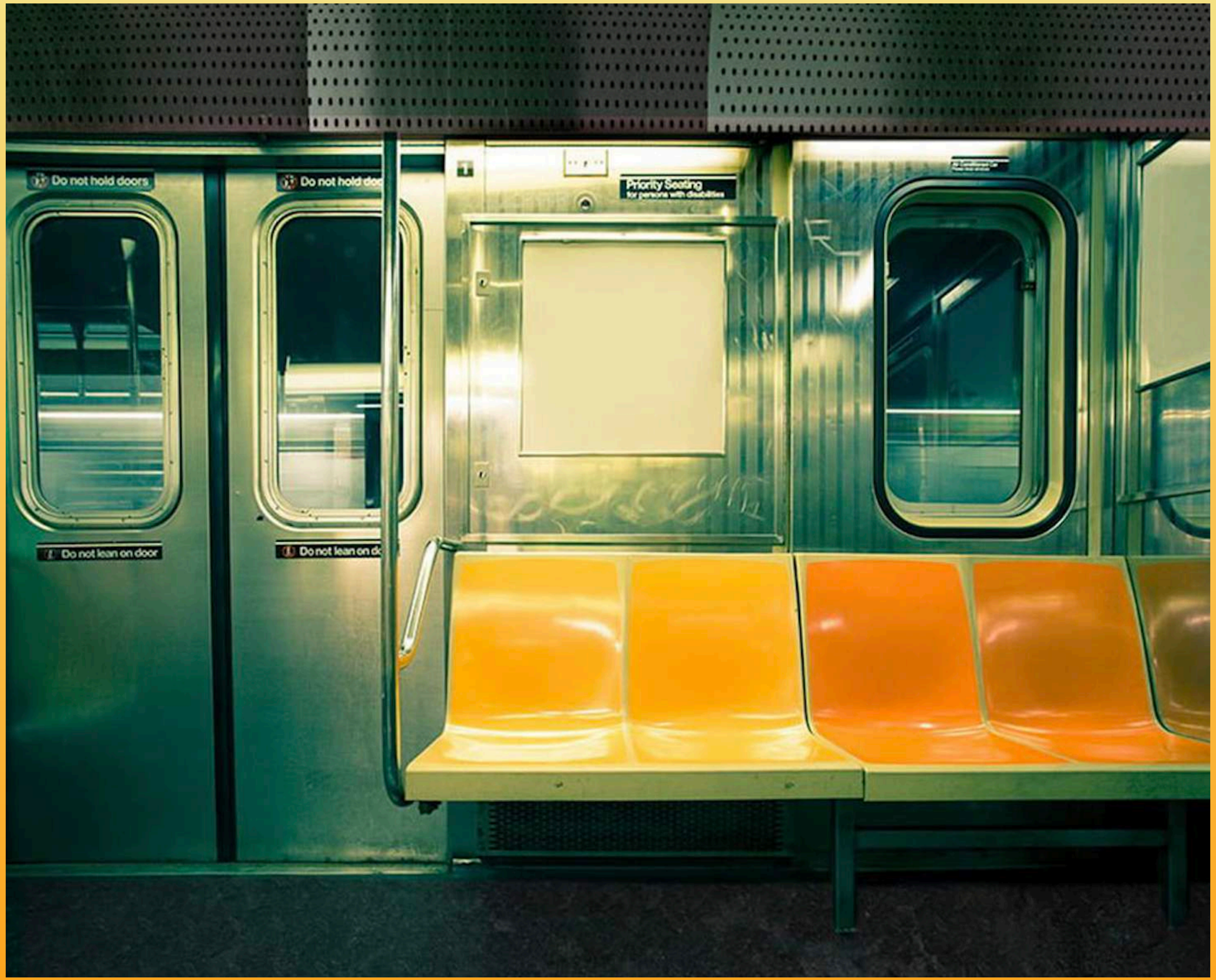
Key points to be covered in this presentation

- Problem Identification
- Solution
- Overview of the Project
- The benefits of the System
- Previous Works
- Methodology
- Results and Experimentation
- Why will our approach be better?
- Conclusions and Future Works



Problem Identification:
Seat Occupancy Monitoring for Subway Trains

- The problem of seat occupancy detection revolves around detecting the vacant seats in office spaces, libraries, trains, buses, cinema hall, etc.
- This is widely known and an on-going problem, which has attempted in the past several times as well, as it prevents hogging of seats in the libraries, checks up vacancies in cinema halls, buses, trains, and for marking/monitoring attendance/ work engagement in the offices.
- Mostly approaches involve the usage of sensors in the seats, capacitive and heating elements, the use of impedances, and some have implemented a textile engineering approach.
- All of the approaches so far are extremely expensive to implement on a large scale, are extremely fragile to implement, and demands continuous and costly maintenance checks as well.
- Our solution to the problem curbs all the mentioned problems with the existing approaches.

Our Solution:
Seat Occupancy Monitoring for Subway Trains

INPUT Image Frames from the footage of the CCTV cameras in Trains

Fig 1. Image from a CCTV installed in a subway train.

Our Solution:
Seat Occupancy Monitoring for Subway Trains

INTERMEDIATE OUTPUT

Detection of humans and segmentation

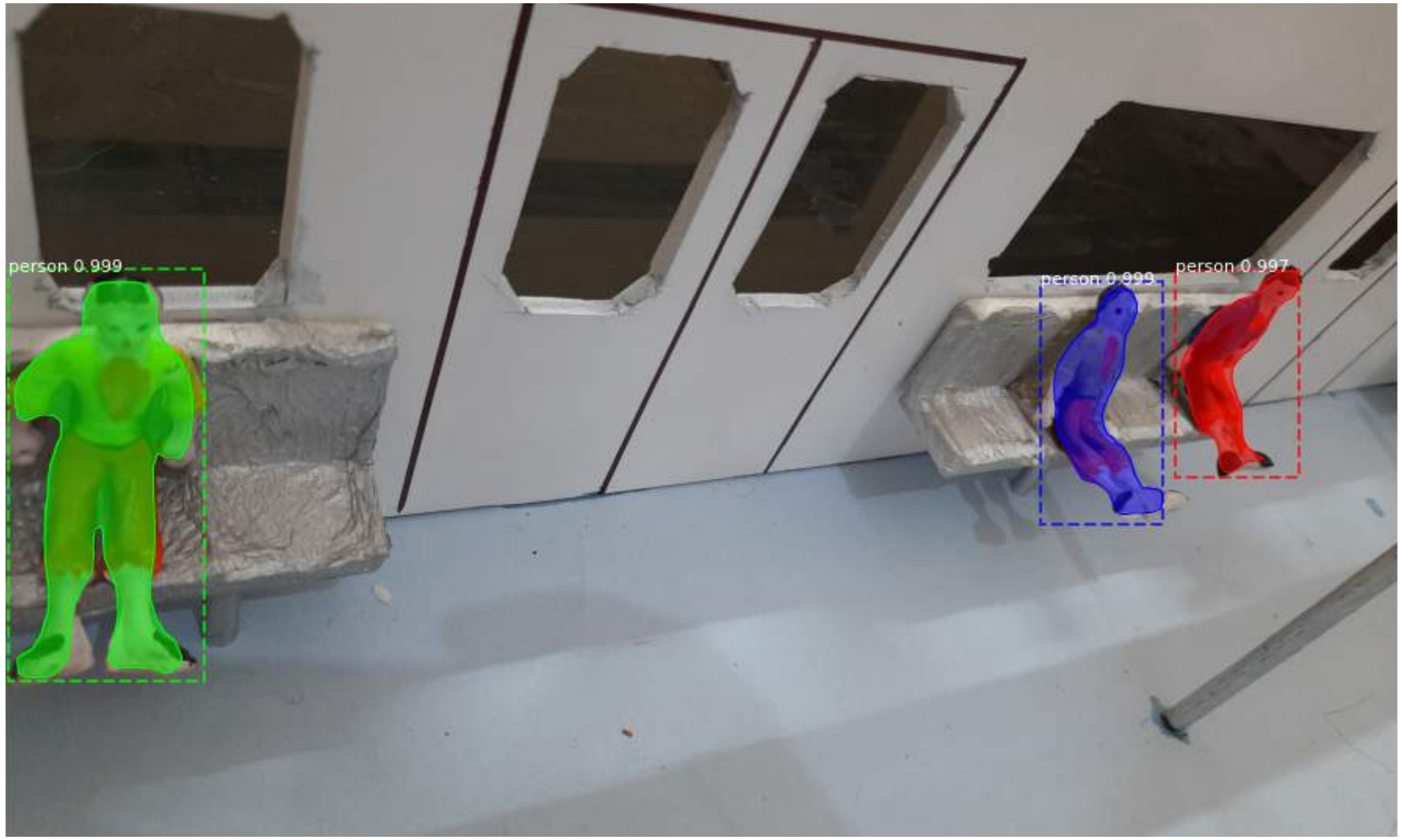


Fig 2. Detection and segmentation of humans sitting/ standing in a train.

Our Solution:
Seat Occupancy Monitoring for Subway Trains

OUTPUT Detection of vacant seat

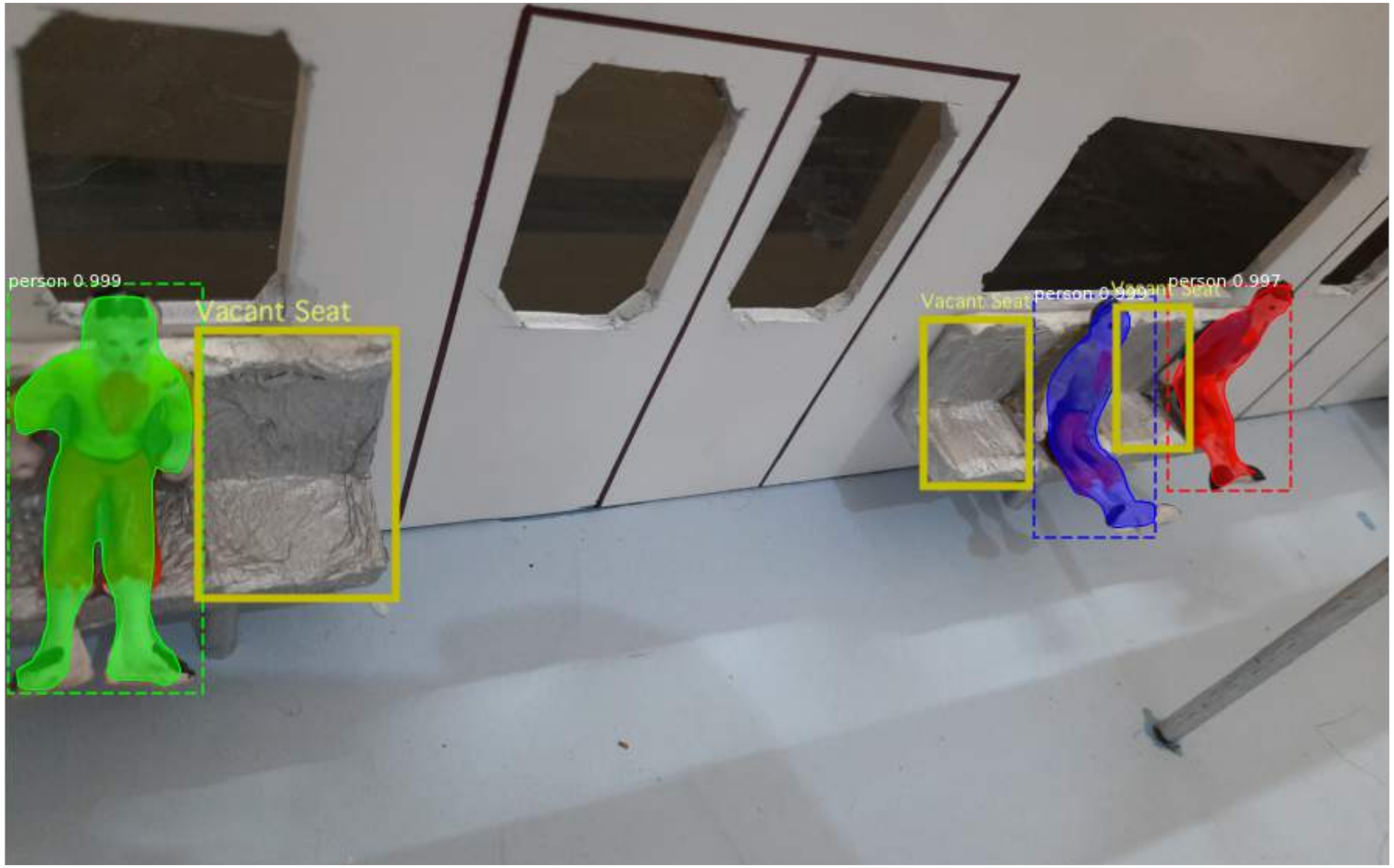


Fig 3. Detection of vacant seat.

Overview of the Project

- We have applied real-time occupancy monitoring for subway train's seats using Computer Vision.
- We have also detected if someone is breaking the social distancing norms in the train and sitting on the prohibited seats or not.
- Image-masking and human instance segmentation has been employed, so as to efficiently segregate the vacant seats from the crowd.
- As a generalized dataset cannot be used for this specific task, we created the dataset on our own by first constructing a miniature train model and then using it to create the dataset, by installing four cameras at different angles which cover the entire coach without any overlap.

Overview of the Project

- A single frame captures 6 seats at a time, and thus a total of 64 seating combinations. There are a total of 4 camera angles in this project, which have computationally led to a dataset of 256 total images, and is equal to 16777216 total combinations.
- An application/ user interface has also been created using Tkinter for the users, which will inform them about the location of the vacant seats in the train.
- The user interface cogently displays the exact number of seats, which have been color-coded to enhance the users' understanding of the application. Vacant seats are colored green, while the non-vacant seats are gray with a red cross on them.
- The model has been implemented to promote social distancing as well and keeps a check if the social distancing norms are being followed or not.

Dataset Created

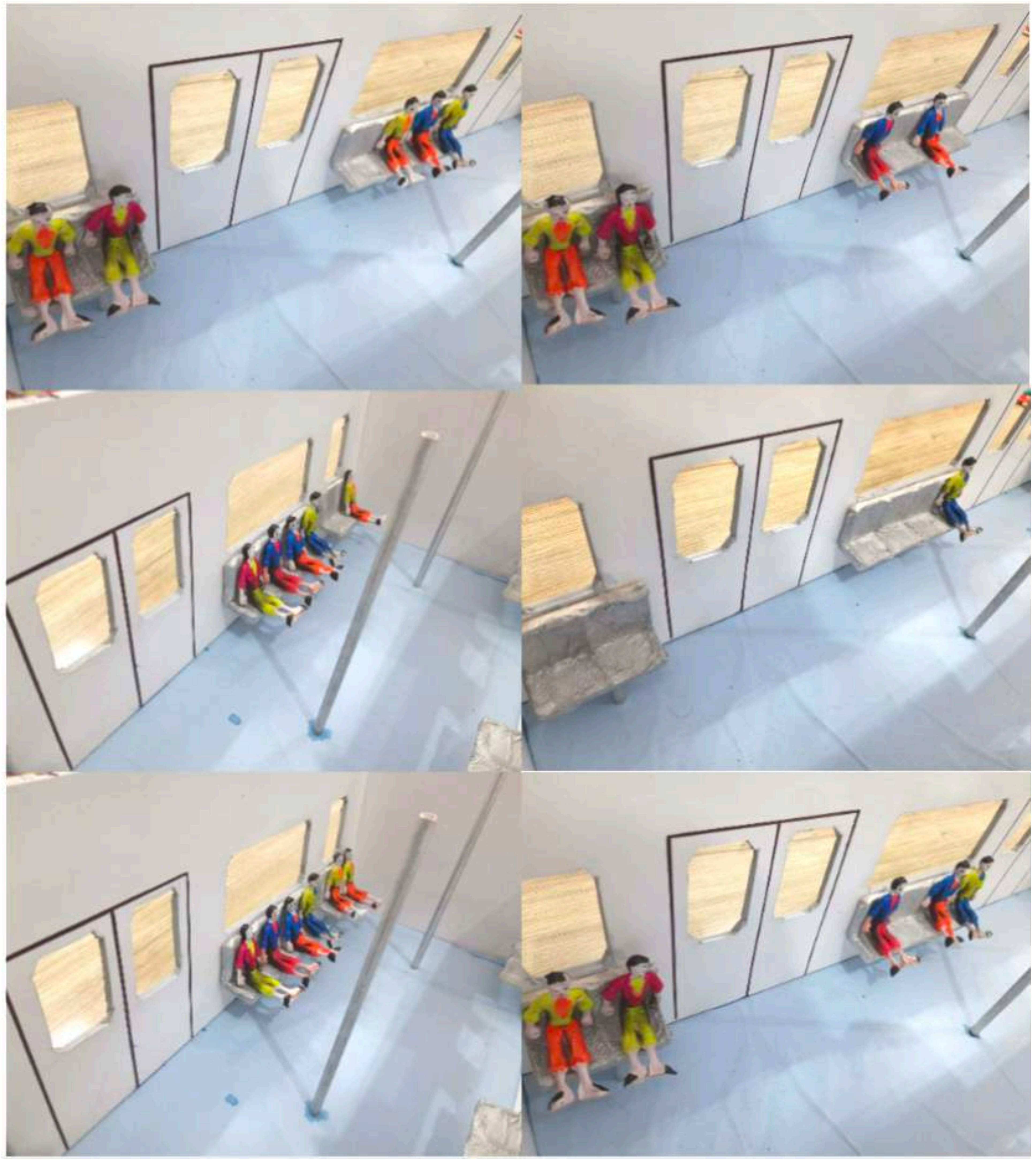


Fig 4. Images from the dataset created by us.

Blueprint of the Model

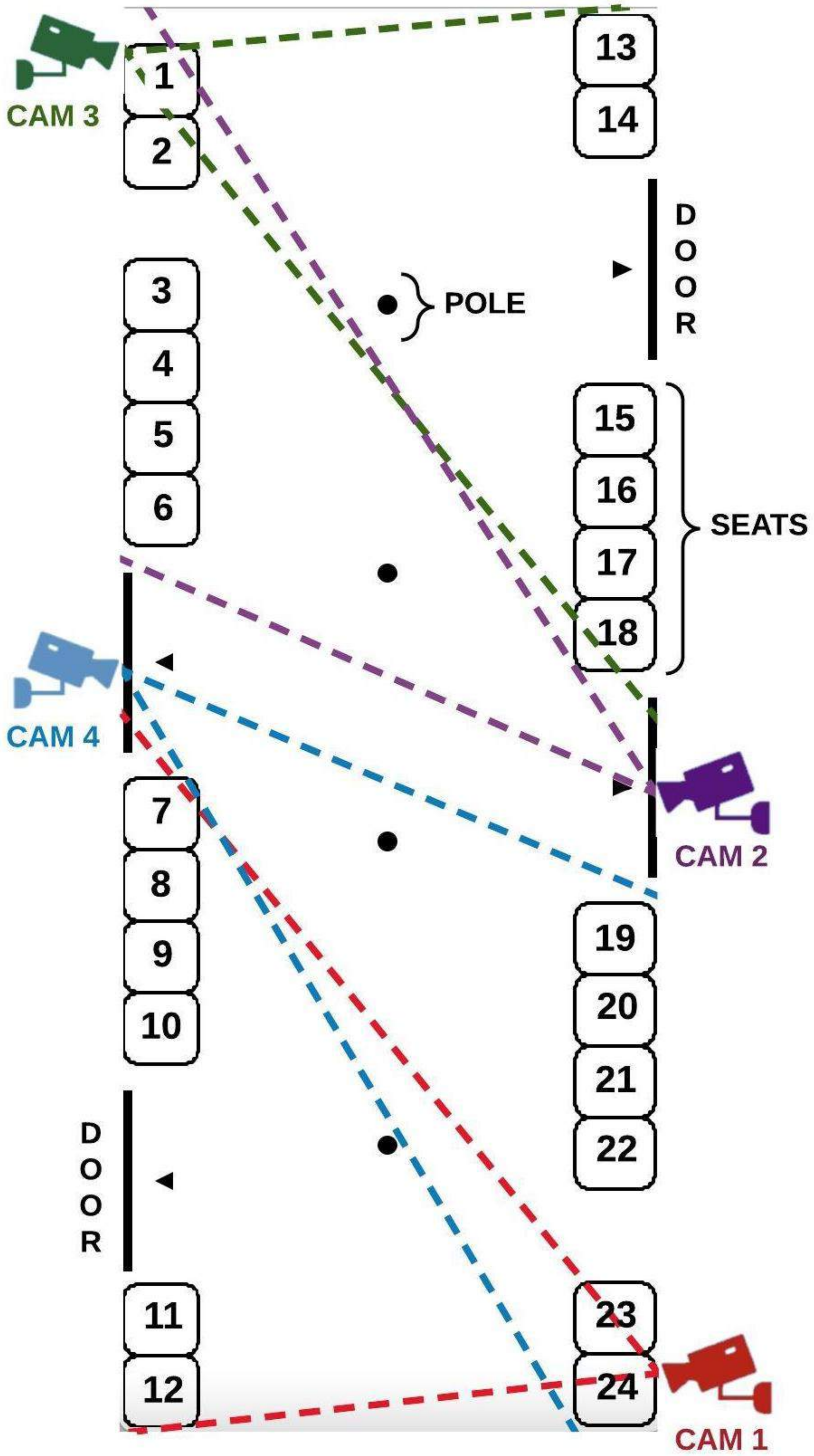


Fig 5. Blueprint of the train model created by rescaling the original official blueprints of the Delhi Metro.

Interface

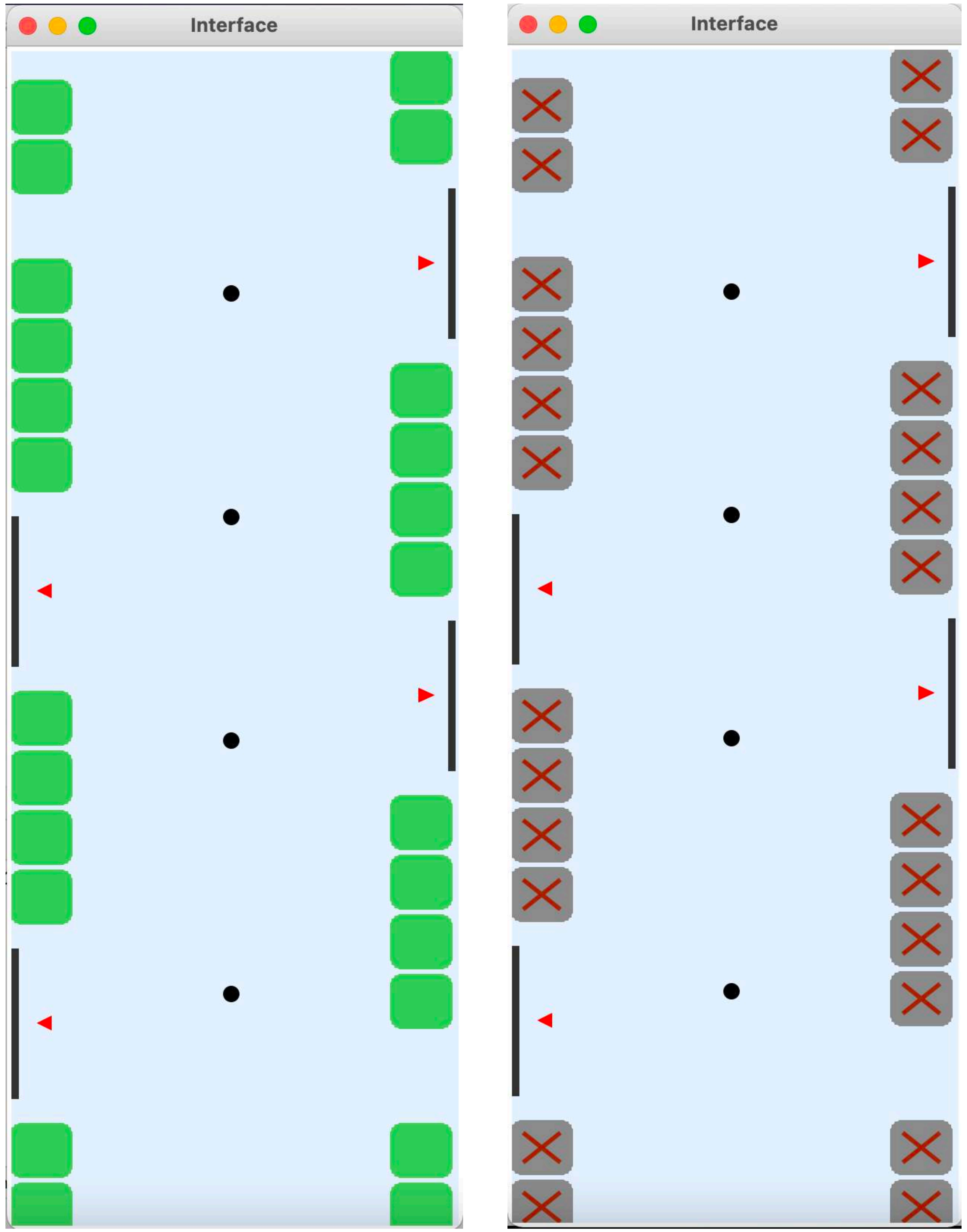
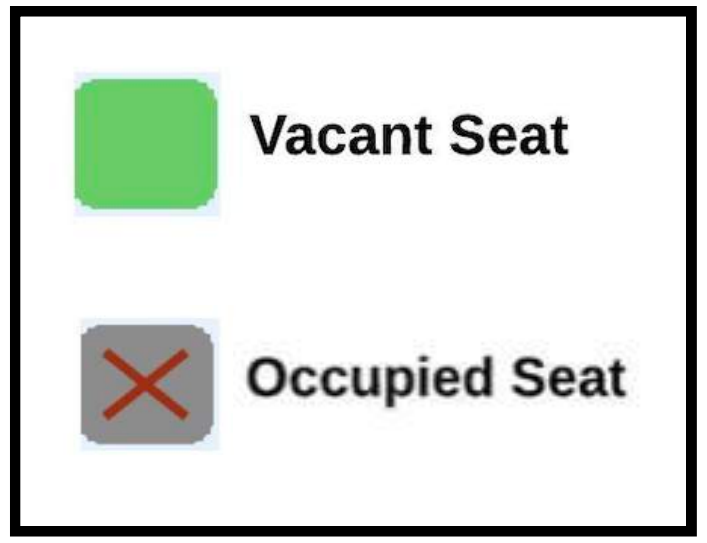
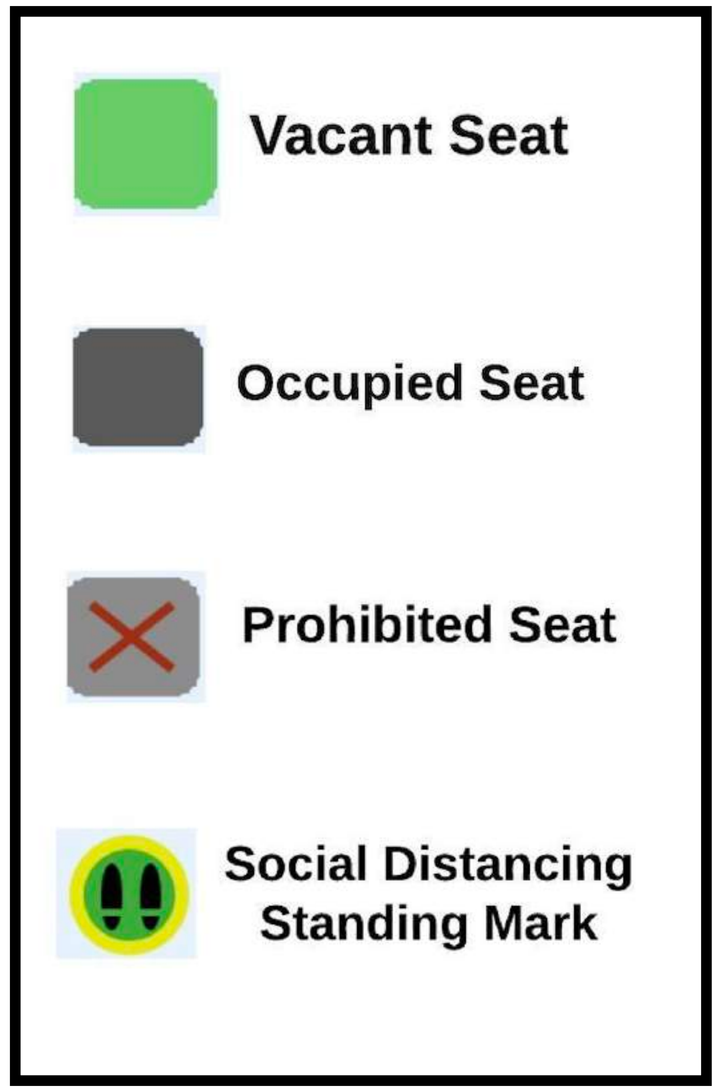


Fig 6. Interface for post-covid times; All seats vacant (left) & All seats occupied (right).

POST-COVID KEY



PERI-COVID KEY



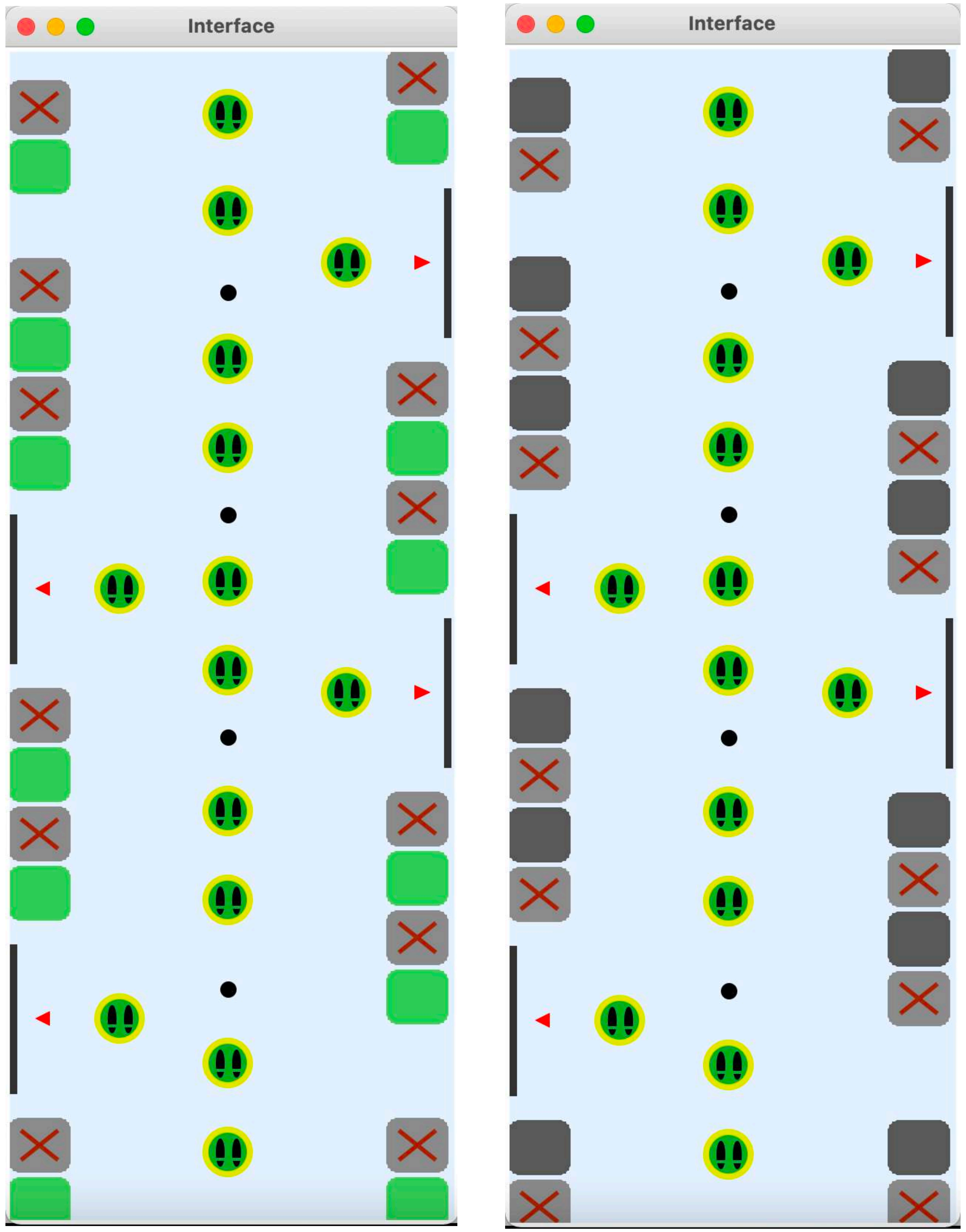


Fig 7. Interface for peri-covid times; All seats vacant (left) & All seats occupied (right).

SVIRO Dataset

Fig 8. Few Images from the SVIRO dataset.

- SVIRO[30] is a Synthetic dataset for Vehicle Interior Rear seat Occupancy detection and classification.
- The dataset consists of 25,000 sceneries across ten different vehicles and provides several simulated sensor inputs and ground truth data.
- We used SVIRO to evaluate the generalization capacities of our model and reliability as it is trained on a limited number of variations.

Benefits of this System

- Much shorter passenger dwelling time on the station. A similar real-world system Alstom, has shown a 10% decrease in passenger dwell time and 30% of waiting passengers influenced [24].
- Can help in redistribution of crowd on the platform, and thus in the train.
- Will enhance travel experience of the passengers.
- Will give an insight to the passenger whether to board this particular compartment of the train, which compartment to board, or not to board at all.

Benefits of this System

- This system is essentially useful during the covid times, as it detects if someone is breaking the social distancing norms in the train and sitting on the prohibited seats, or if someone is standing close to someone else and not standing on the "Social Distancing Standing Marks", such that it breaks the social distancing norms.
- This information will be visible to the controller, in the form of bounding boxes on the people breaking these norms.
- This following of social distancing norms can contain the spread of novel coronavirus.
- This system will ensure safe travel during the covid period.

Previous Works

- The task of seat occupancy monitoring and detection has been mostly done by the use of electronic sensors, by installing a sensor in the seat [1] which then gives the acquired data to the data sink where it is processed.
- Various methods of sensing seat occupancy have been proposed and researched, including capacitive sensing [2], [3] and facial recognition cameras [4].
- FreeSeat [5] is also one such project which aimed to utilize sensors to give information about seating availability in public transport.
- The occupancy detection system has been utilized not only for public transports, but for movie theatres [6], offices, work spaces and libraries as well [7].

Previous Works

- Major works follow a similar approach of using sensors, but have applied the concept in different domains and applications, like passenger counting [8], seat availability details [9] and water level detection [10],etc.
- [11] addresses the problem of library seat management. It presents the design and implementation of a solution combining hardware and web application that allows students and librarians to verify the identity of library seat occupants and occupancy status of the library seats from a remote location over the Internet.
- [12], [13] presents a microcontroller-based measurement system to detect and confirm the presence of a subject in a chair. The system relies on a single Force Sensing Resistor (FSR), which may be arranged in the seat or backrest of the chair, that undergoes a sudden resistance change when a subject/object is seated/placed over the chair.

Previous Works

- In-vehicle occupancy detection [14], [15], [16], [17], [18], [19], [20] also works similar, using 360° NIR cameras and convolutional neural networks on thermal images. This work was conducted in a car and could be extended to public transit smoothly.
- Seat occupancy has also been detected using a textile-based optical fiber sensor [21] designed and the effect of automotive seat covering including face material and foam backing on a sensor's performance was analyzed.

Methodology

- The proposed vacancy two tier system runs in two phases:
    A. Phase I is the initialization phase in which the system calculates certain parameters for smooth detection later.
    B. Phase II is the detection phase in which the system detects the seat vacancy in real time using the parameters calculated in Phase I.
- Phase I for the proposed system is only needed to be run once at the time of installation and after only when the environment, in which the CCTVs are installed, changes.
- This phase outputs a masked image to separate out the ROI from an image and the constants for the equation of ellipse.

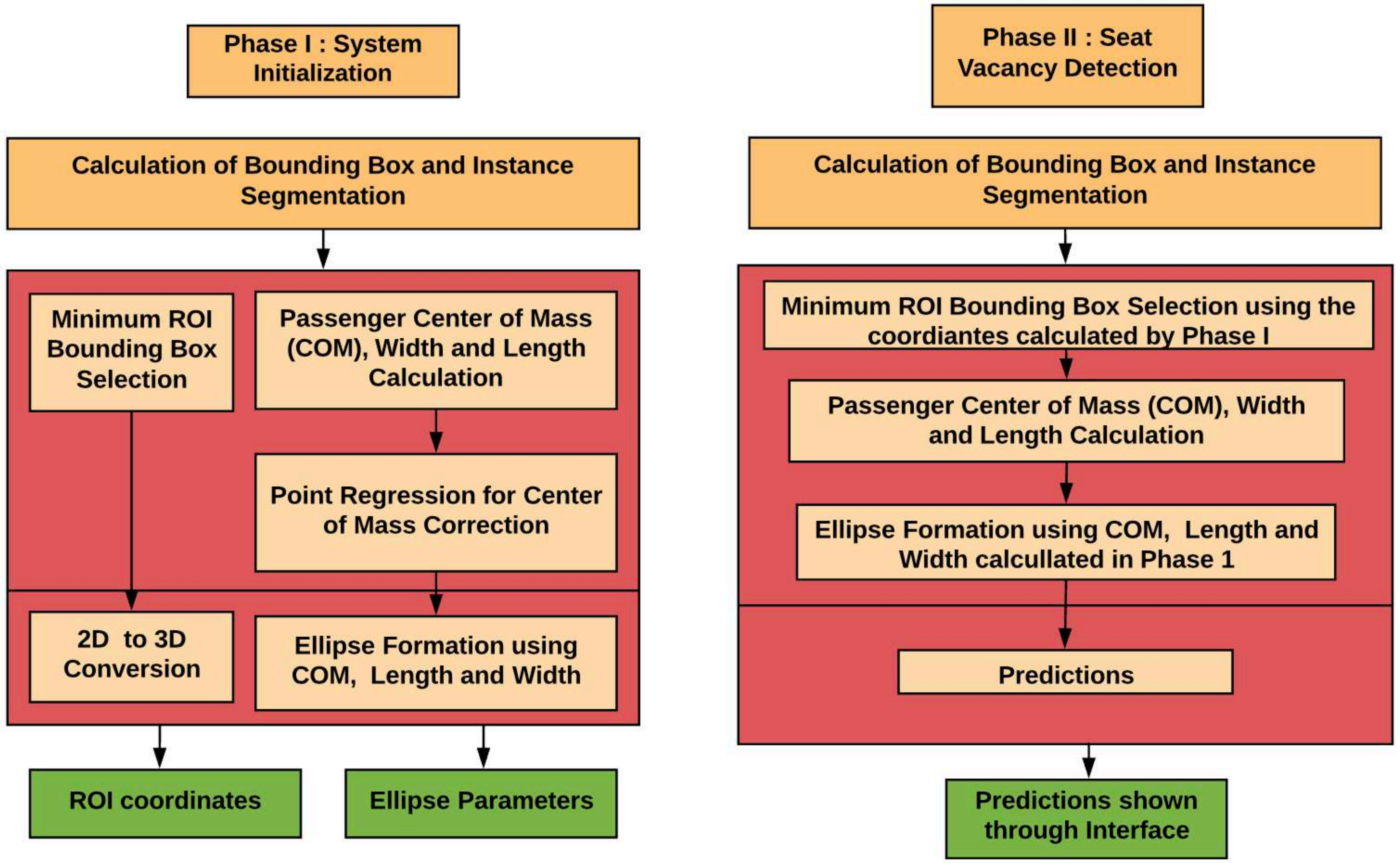


Fig 9. Phase I and Phase II Flow Diagrams.

Methodology

Phase I

- Calculation of Bounding Box and Instance Segmentation
- Minimum ROI Bounding Box Selection
- 2D to 3D Conversion
- Passenger Center of Mass (COM), Width and Length Calculation
- Point Regression for COM correction
- Ellipse Formation using COM, Length and Width

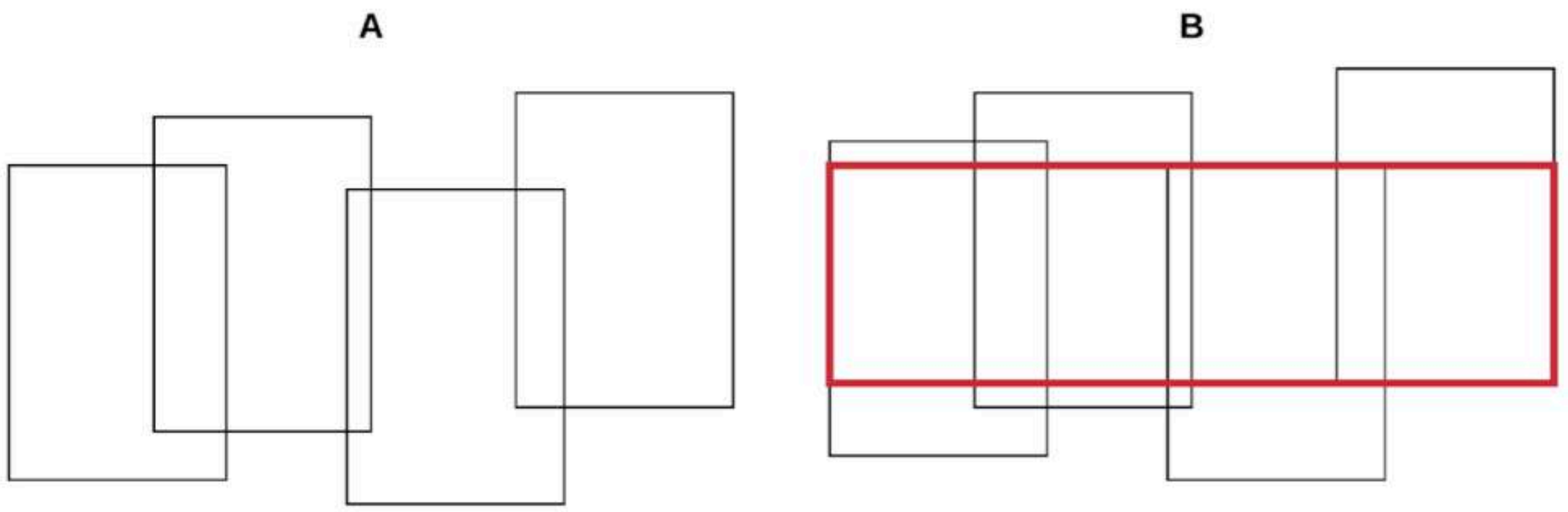


Fig 10. Minimum ROI bounding box selection.

Methodology

Phase I

- Calculation of Bounding Box and Instance Segmentation
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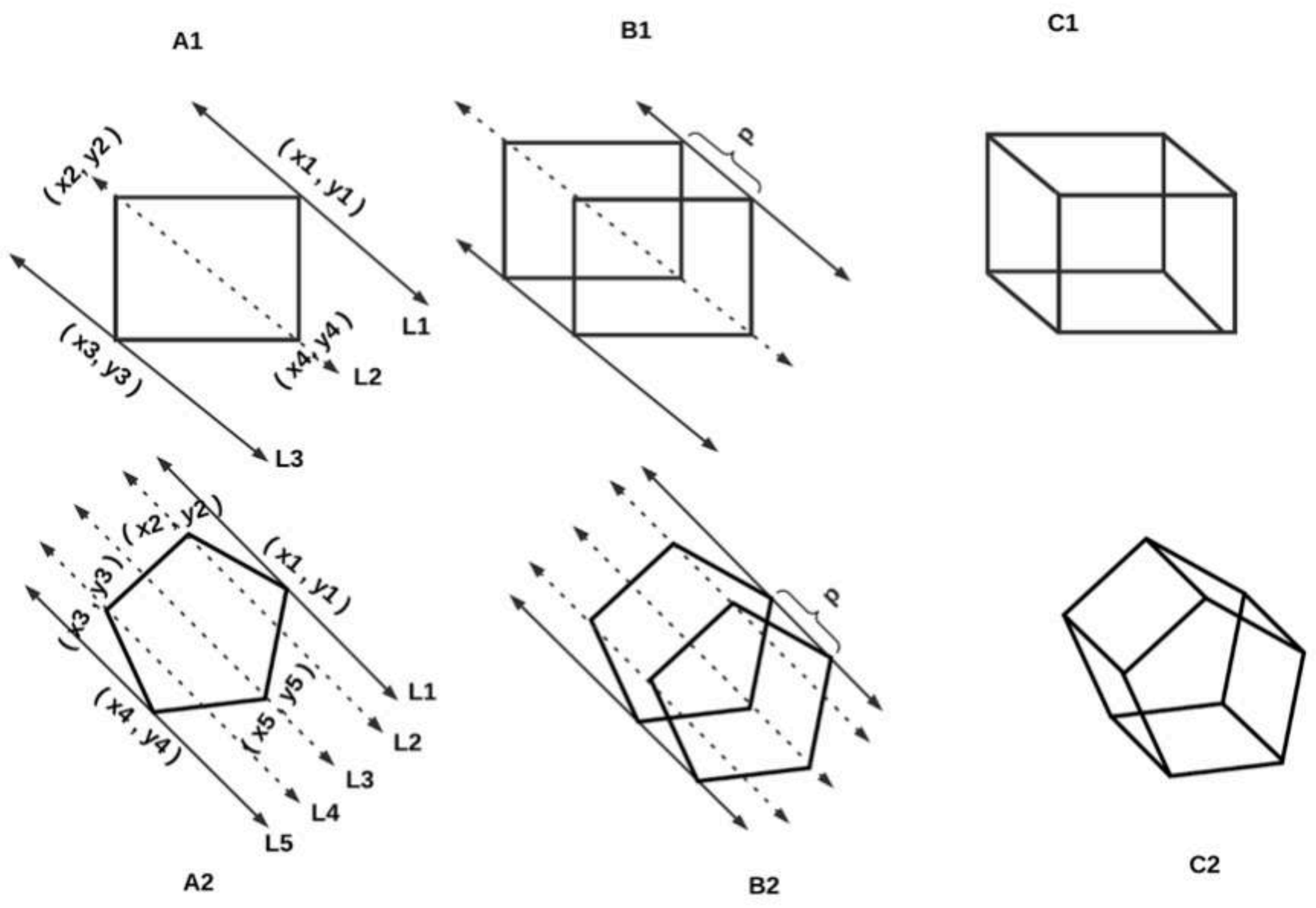


Fig 11. 2D to 3D Conversion of figures.

Methodology

Phase I

- Calculation of Bounding Box and Instance Segmentation
- Minimum ROI Bounding Box Selection
- 2D to 3D Conversion
- Passenger Center of Mass (COM), Width and Length Calculation
- Point Regression for COM correction
- Ellipse Formation using COM, Length and Width

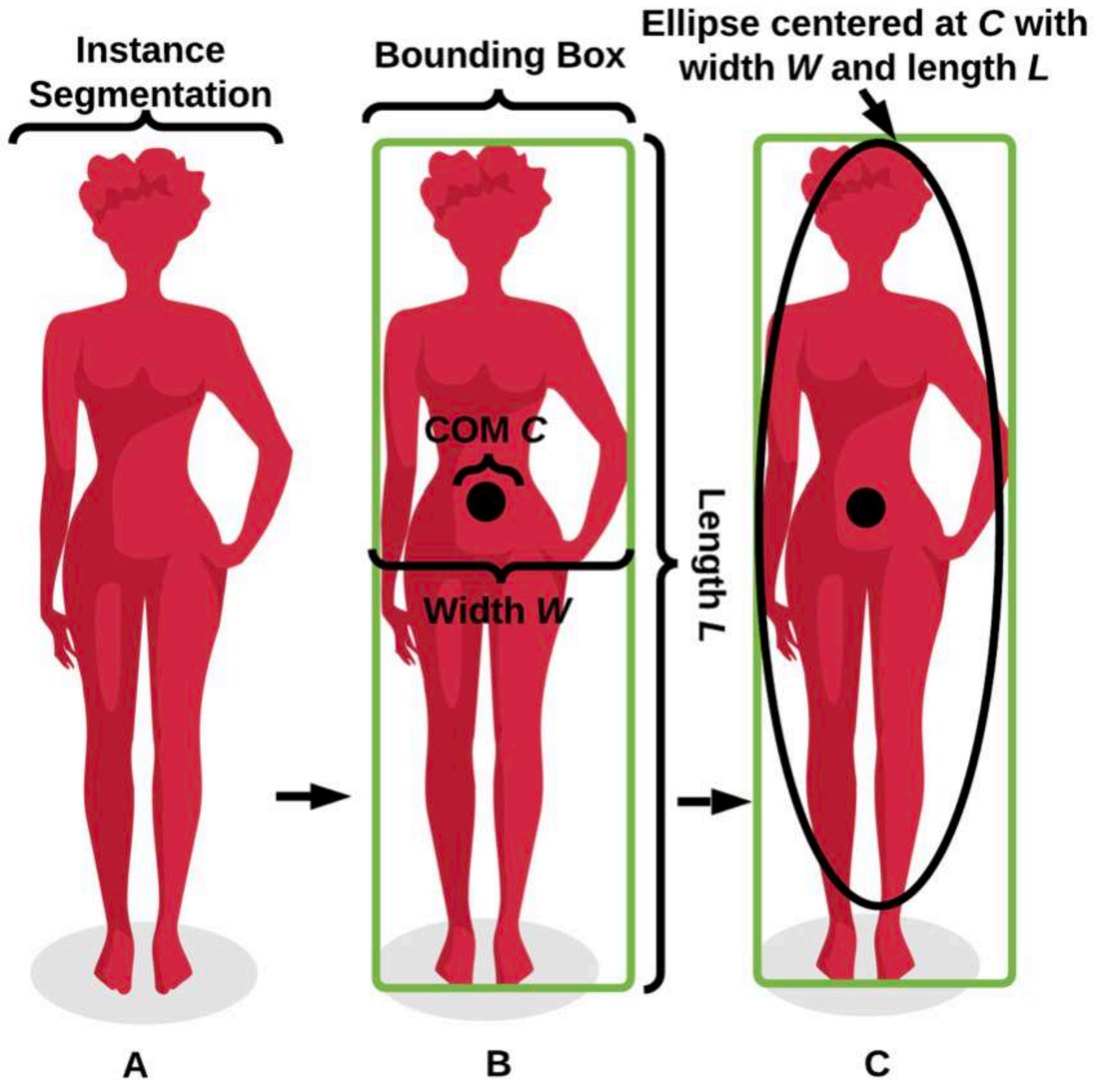


Fig 12. Ellipse formation.

Methodology

<u>Phase I</u>

- Calculation of Bounding Box and Instance Segmentation
- Minimum ROI Bounding Box Selection
- 2D to 3D Conversion
- Passenger Center of Mass (COM), Width and Length Calculation
- Point Regression for COM correction
- Ellipse Formation using COM, Length and Width

Training Algorithm 1: The algorithm for this regression model G(x), having parameters θ

for number of training iterations **do**
  for λ steps **do**
    Calculate cost or average loss $J(\theta)$ over batch B:

$$J(\theta) = \sqrt{\left(H_{ix} - T^{i}_{\lambda x}\right)^2 + \left(H_{iy} - T^{i}_{\lambda y}\right)^2}$$

    Update *G(x)*'s parameters θ by ascending their stochastic gradient or using *Adam* Optimizer:

$$\theta \leftarrow update\ using\ Adam : \tfrac{d}{d\theta} J(\theta)$$

  end for
end for

Algorithm 1. Regression Algorithm.

Methodology

Fig 13. Workflow of Phase I.

Methodology

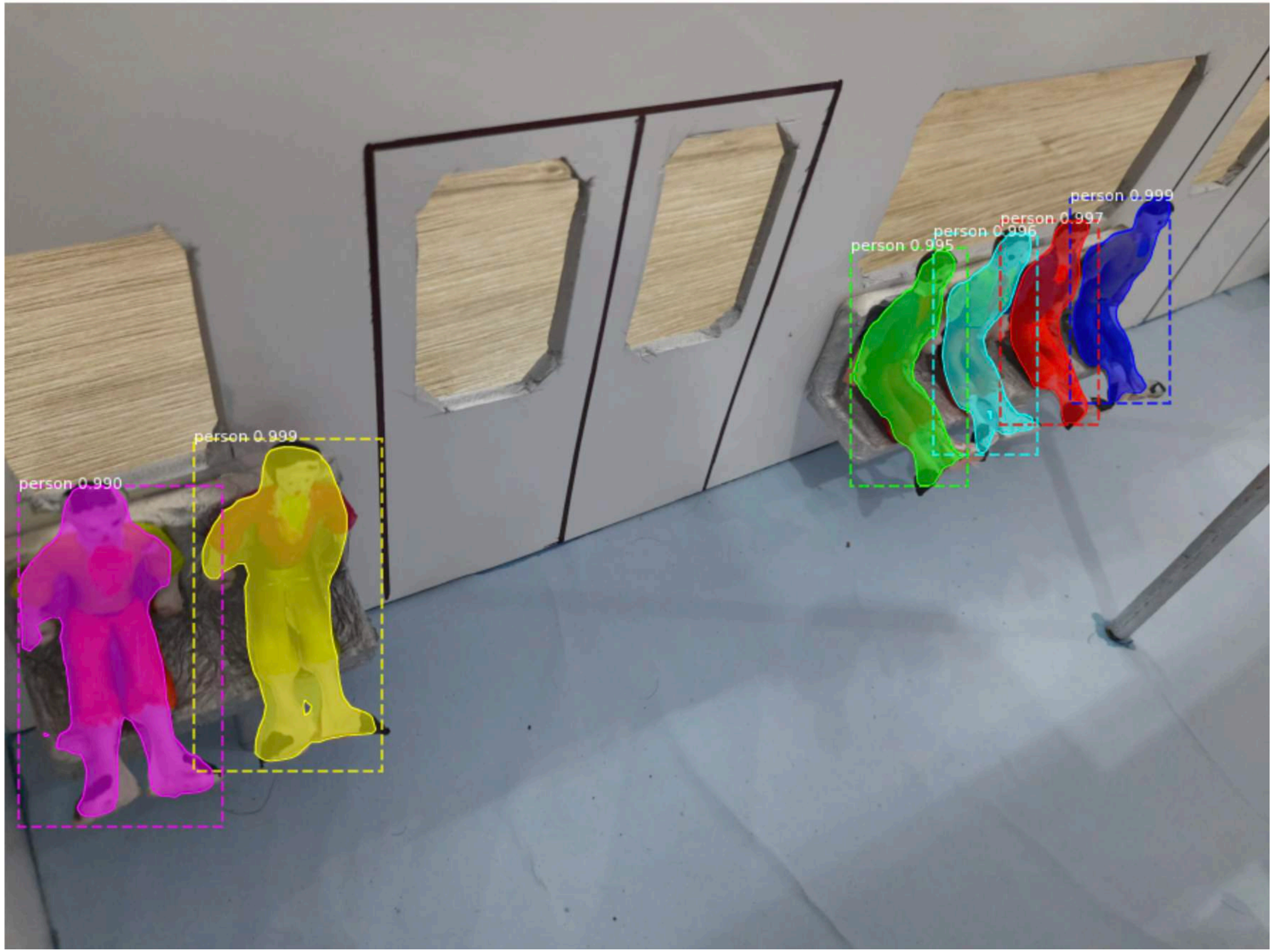


Fig 13. Workflow of Phase I.

Methodology

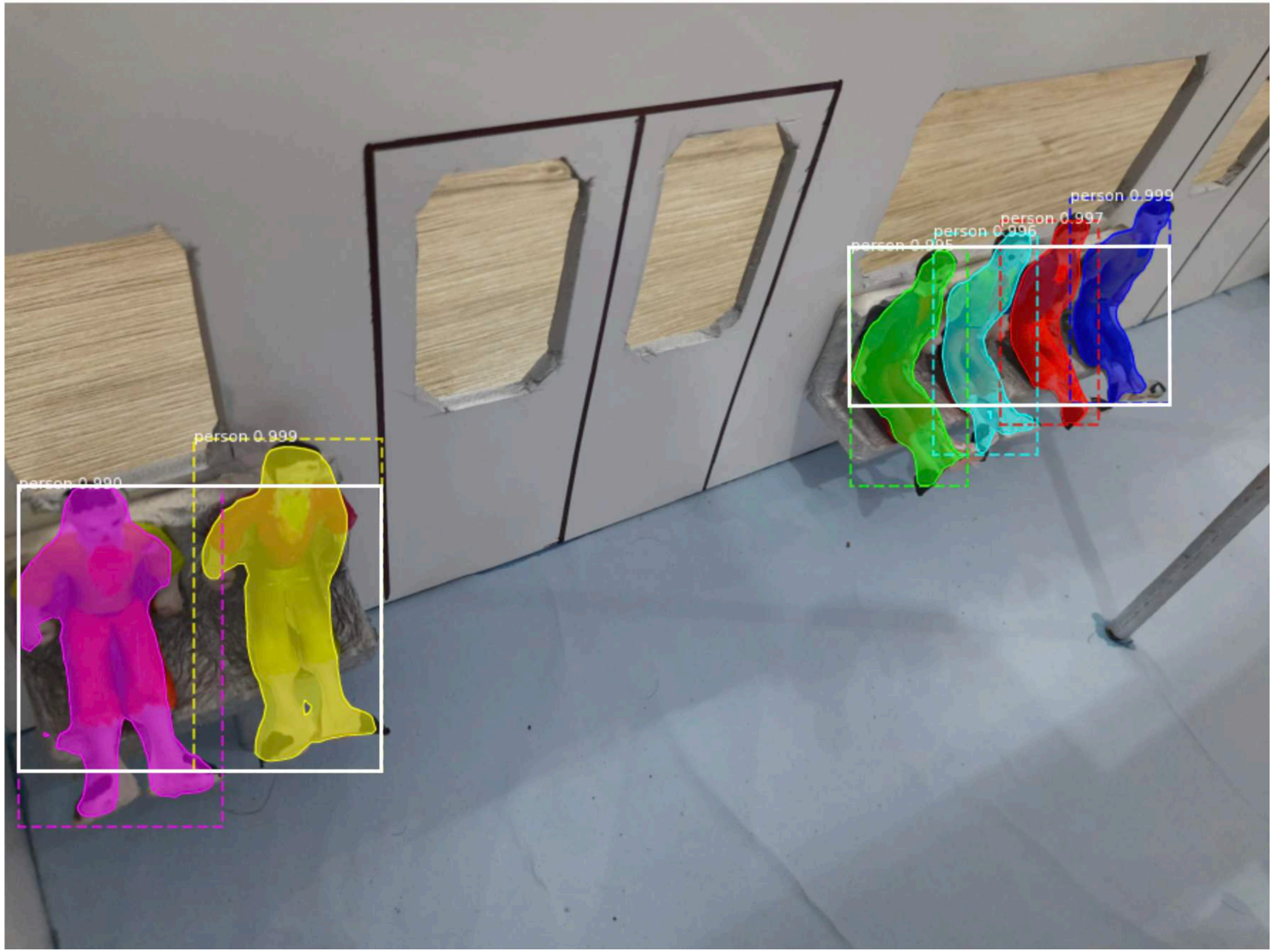


Fig 13. Workflow of Phase I.

Methodology

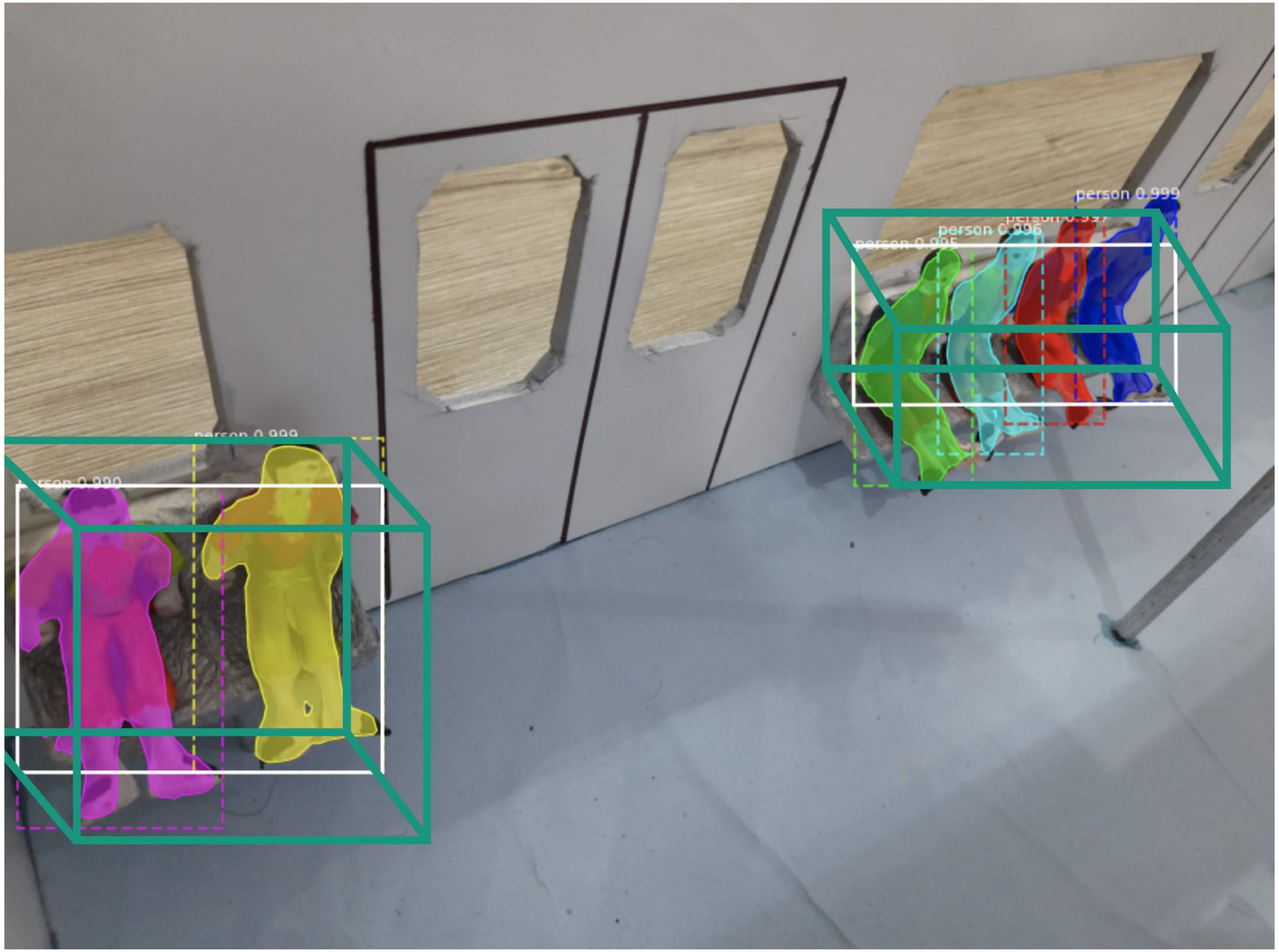


Fig 13. Workflow of Phase I.

Methodology

Fig 13. Workflow of Phase I.

Methodology

Fig 13. Workflow of Phase I.

Methodology

Fig 13. Workflow of Phase I.

Methodology

Phase II

- In this phase the detection of vacant seats takes place. It uses the COM, L and W calculated during Phase 1 to detect whether the seat is vacant or not.
- Phase II is a 2 Tier architecture consisting of 4 parts namely : Calculation of Bounding Box and Instance Segmentation, Passenger Center of Mass (COM), Width and Length Calculation and Prediction. Most of the parts work the same as Phase I except Prediction.

Prediction: In this layer the vacancy is detected. If the coordinates of COM: (a1,b1) calculated in Phase II lies inside the ellipse formed, with center *(h,k)* for that particular seat in Phase I thus satisfying the condition:

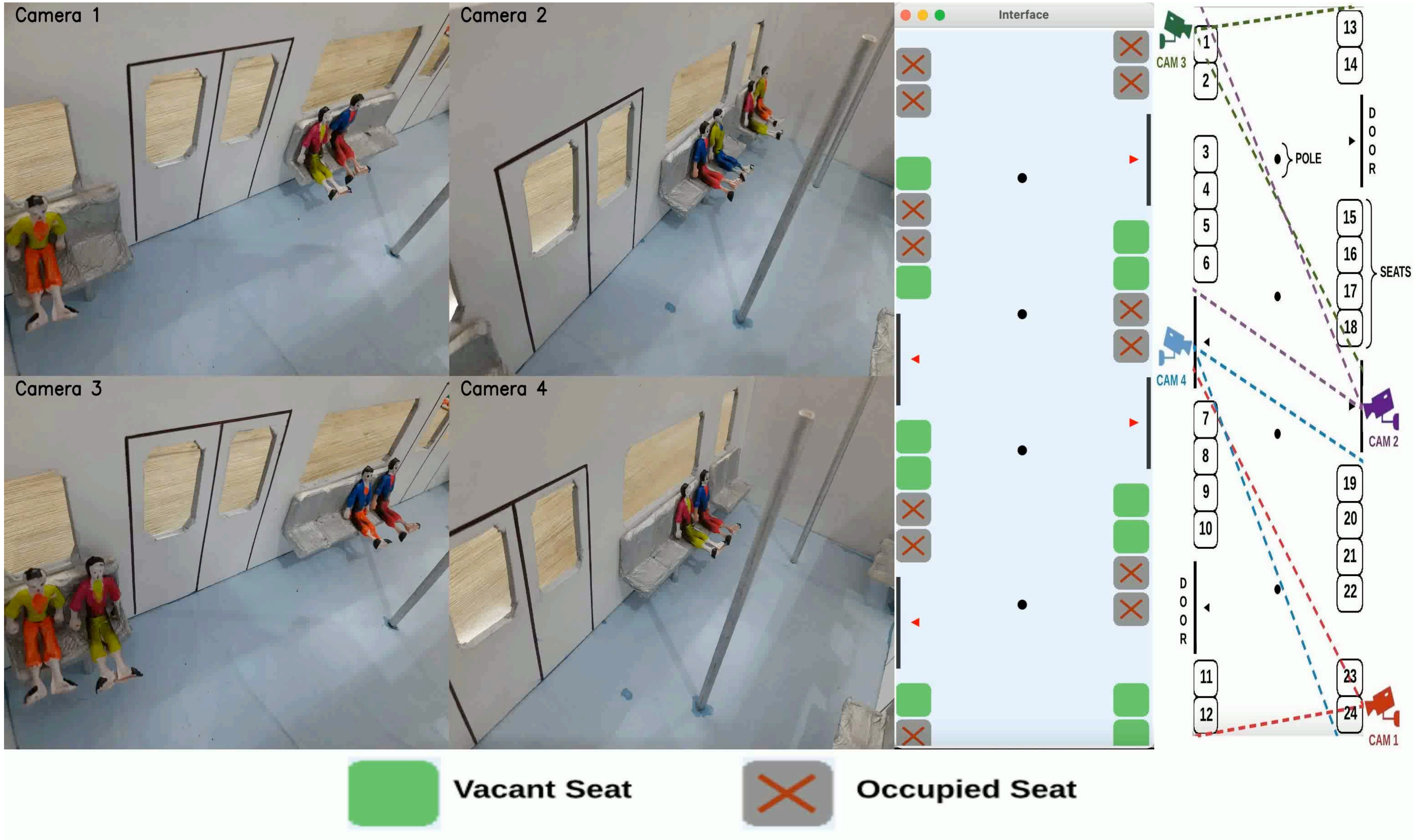
$$(a1 - h)^2/a^2 + (b1 - k)^2/b^2 \leq 1 \quad (1)$$

then it means that the seat is not vacant.

Results & Experimentation

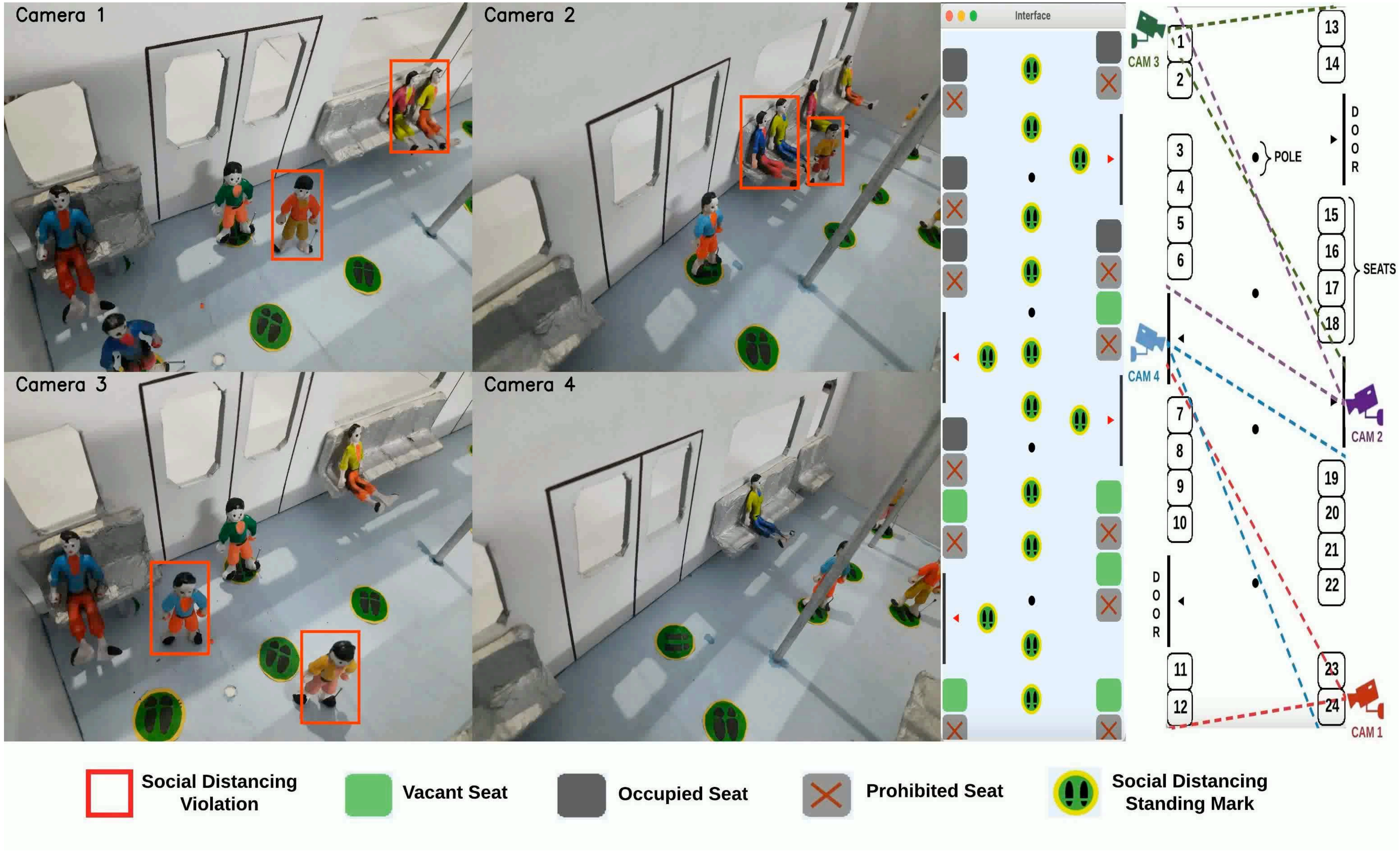
- The entire system has been written in Python 3.7. Tkinter's Canvas widget has been used to create the interface.
- Google Colab was used to run the Initialization and Detection Modules, while PyCharm was used to run the Interface Module on a 2.3 GHz Dual-Core Intel Core i5 MacBook Pro.
- Nikon CoolPix camera was used for clicking the pictures for the dataset from all the four angles.
- The output of the Detection module is the input of the Interface Module, which is in the form of an array of size (1, 24), and consists of 0 or 1, for occupied and vacant respectively, for post-covid; and 0, 1 and 2 for occupied, vacant and prohibited seats respectively, for peri-covid system.

Results & Experimentation



Video 1. Implementation video of the system post-covid times.

Results & Experimentation



Video 2. Implementation video of the system peri-covid times.

Results & Experimentation

Table 1. Comparison of algorithms on our proposed dataset and SVIRO using different performance metrics.

ALGORITHM	YEAR	SUMMARY	DATASET	ACC	PRECISION	RECALL	F1 SCORE
R-CNN [25]	2014	The RCNN is a region proposal based object detection algorithm. Its stands for region based convolutional neural network.	PROPOSED	0.989	1.0	0.978	0.989
			SVIRO	0.95	1.0	0.900	0.947
Fast R-CNN [26]	2015	It is an improvised version of the rcnn. It has advantages like Higher detection quality (mAP) than R-CNN, less Time of Computation etc,.	PROPOSED	0.991	1.0	0.982	0.991
			SVIRO	0.947	1.0	0.894	0.944
Faster R-CNN [27]	2015	It is a much efficient solution to Object Detection.	PROPOSED	0.982	1.0	0.964	0.982
			SVIRO	0.952	1.0	0.904	0.950
DenseNet [28]	2016	A type of convolutional neural network that utilises dense connections between layers, through Dense Blocks, where we connect all layers (with matching feature-map sizes) directly with each other.	PROPOSED	0.982	1.0	0.96	0.982
			SVIRO	**0.98**	1.0	0.960	0.980
Mask R-CNN [29]	2019	Mask RCNN extends Faster Rcnn by adding a parallel mask output branch. It is a very important method used in instance segmentation.	PROPOSED	**0.998**	1.0	0.996	0.998
			SVIRO	0.978	1.0	0.956	0.978

Why will our Approach be better?

- This proposed project will be extremely cost efficient for using in public transport, as many public transits around the globe already have CCTV cameras, who's footage can be used without needing any extra hardware.
- It does not require sensors be to be installed in individual seats, thus, maintenance will also be less frequent and cost effective.
- It can open doors to newer applications utilizing the existing hardware

Conclusion and Future Works

- We are proposing a system which can detect the vacant seats in a subway train by utilizing the footage from the existing CCTV cameras.
- Our proposed system will not require any sensors to be installed in any seat whatsoever, which gives it an edge over other existing and previously proposed approaches in the form of cost efficiency and lower maintenance costs altogether.
- We have created a user interface for the users to locate the vacant seats before the arrival of the subway train, which will give user the information about whether to board this train or not, or which compartment to board.
- This application will also help in a somewhat even distribution of crowd within the train, which can enhance the safety in the train.

Conclusion and Future Works

- This application can be transitioned into practical life-size subway trains with proper training and little to none tweaks.
- It can very easily be used to keep a check on the social distancing norms being followed by the general public in public transportation.
- The controller will be able to see the people who are breaking the social distancing norms with the help of a bounding box.
- It can further be used to detect people not wearing face masks.
- The system can also be trained to perform extra existing features like crime activity detection, suspicious activity detection, all of which can enhance the safety of passengers within the train.
- Comparison with other segmentation algorithms reveal favorable results.

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Thank you!