Landmarks as Beacons: Pedestrian Navigation Based on Landmark Detection and Mobile Augmented Reality

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Introduction

- Navigation as one basic application of the Location-Based Services (LBS) is of great importance to travel activity

- Traditional map-based methods may lead to ambiguity as people may have different spatial cognition and interpretations due to the isolation between map instructions and the environment

- The conversion from salient landmarks into navigational cues remains a challenge

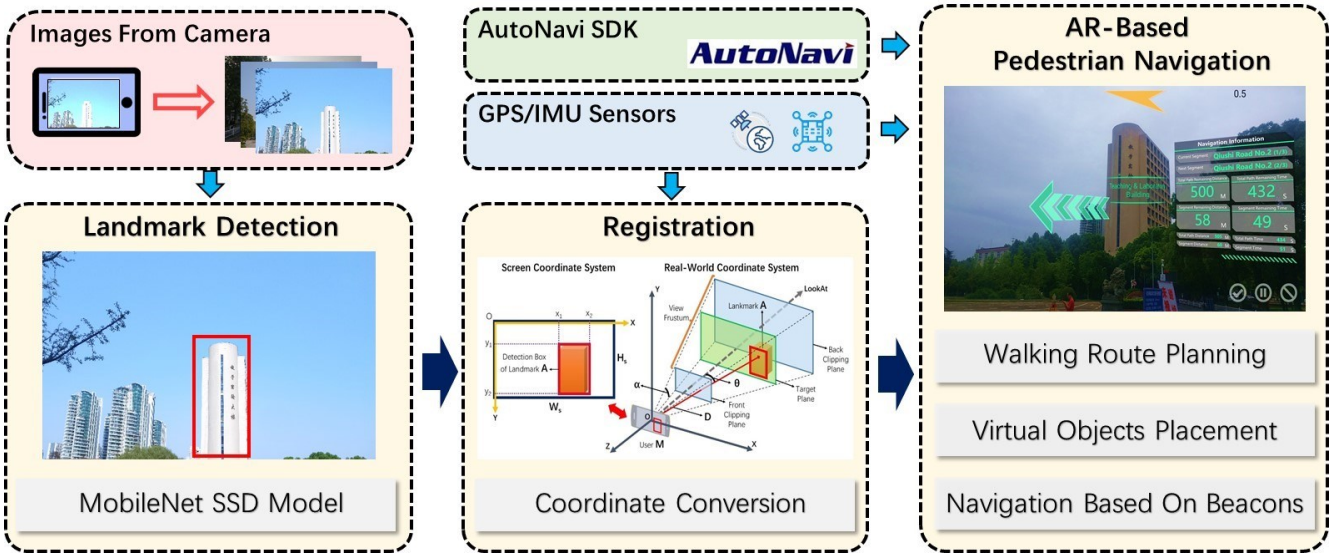
Introduction

- In this paper, we aim to present a new pedestrian navigation method that combines landmarks and mobile Augmented Reality (AR)

- We convert the visually salient building landmarks into beacons by placing virtual arrows and information panels around them on the screen to guide users to their destinations

Method - Overview

- The method proposed in this paper mainly consists of three parts: Landmark Detection, Registration, and AR-based pedestrian navigation



The framework of the method

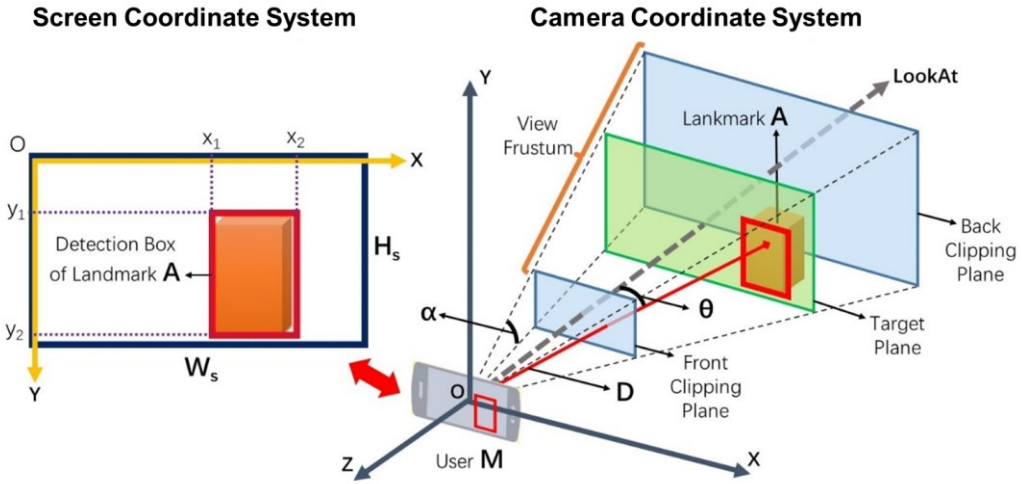
Method - Landmark Detection

- We collected and labelled the images of selected landmarks to create a landmark detection dataset
- We use MobileNet SSD, a deep-learning-based object detection model to achieve fast and precise landmark detection
- Using object detection, the landmark names and bounding boxes can be obtained, and these results can be utilized to register virtual objects (i.e., navigation arrows and panels)

Examples of landmark detection results

Method - Registration

- Registration means the correct alignment between the virtual object and the real world
- To achieve precise registration, the coordinate conversion between Screen Coordinate System (SCS) and Camera Coordinate System (CCS) need to be determined



The conversion between coordinate systems (modified from Rao et al., 2017)

Method - Registration

- the detection box of a landmark can be described by four pairs of coordinates in the SCS. For each pair of coordinates (X, Y) in the SCS, its corresponding coordinates (Xc, Yc) in the CCS can be determined by:

$$\begin{bmatrix} X_c \\ Y_c \\ 1 \end{bmatrix} = \begin{bmatrix} r & 0 & 0 \\ 0 & r & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 & -W_s/2 \\ 0 & -1 & H_s/2 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} X \\ Y \\ 1 \end{bmatrix}$$

- where Ws and Hs are the width and height of the screen; r is the scaling factor defined by:

$$r = \frac{2 \times \tan(\alpha/2 \times Z_c)}{H_s}$$

- where α is the vertical view angle of the camera. The Z value Zc can be determined by:

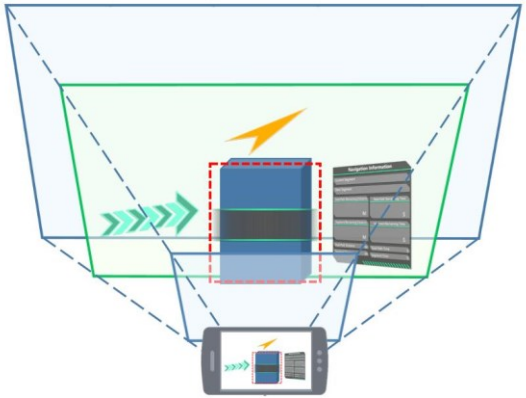
$$Z_c = D \times \cos(\theta)$$

- where D is the distance between the user and the landmark; θ is the included angle between the LookAt direction and the landmark direction.

- Thus, every screen coordinates (X, Y) of the landmark detection boxes can be converted to the corresponding camera coordinates (Xc, Yc, Zc), which can be used to register virtual objects

Method - AR-Based Pedestrian Navigation

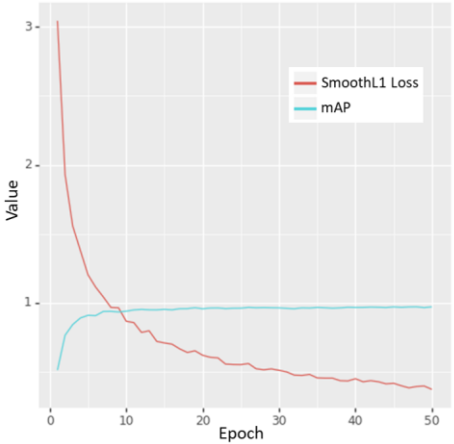
- When the user chooses a destination, a walking route (e.g., the shortest distance route) will be generated based on the user's current location and the destination
- The user then can use the camera to detect the nearby landmarks using landmark detection
- When a landmark is detected, it will be surrounded by virtual objects indicating where to go as well as other navigation information



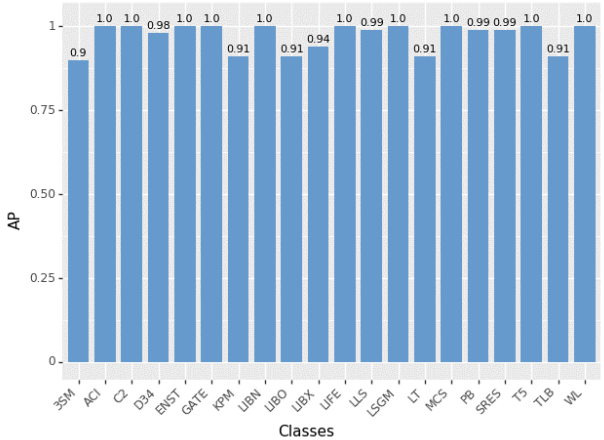
The design and placement of virtual objects

Experiment and Result

- We trained our landmark detection model on the collected landmark images.
- The training loss decreased significantly while the mean-average-precision (mAP) score on the validation set increased during the training process.
- The average precision scores on the test set indicate that the model is able to precisely detect these landmarks on campus.



Curves of the loss and the mean average precision

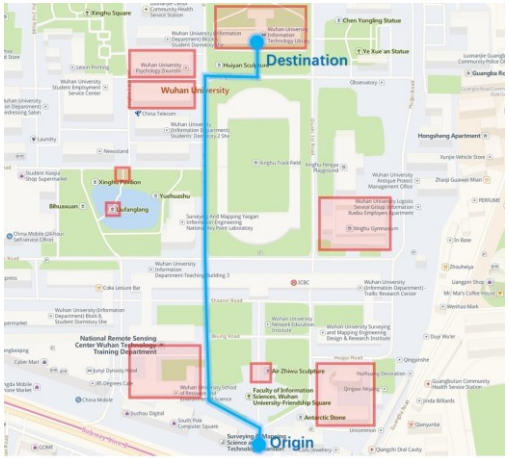


AP scores for all landmarks in our campus dataset

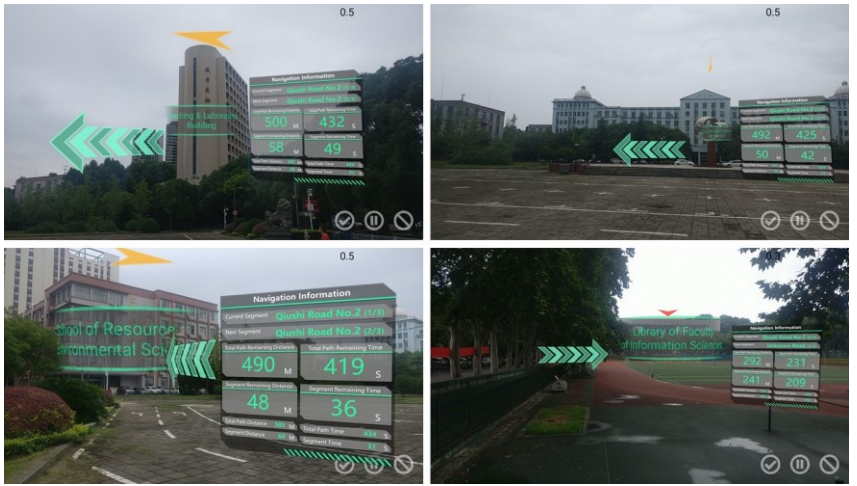
Experiment and Result

- We also developed a mobile AR prototype and conducted a pedestrian navigation experiment at the Wuhan University campus to validate the proposed method and to test its performance

- The user was guided step by step through the planned walking route and reached the destination in the end.



Experiment with the landmarks and the walking route between origin and destination



Several screenshots from the navigation experiment using our developed mobile AR prototype

Conclusion

- In this paper, we presented a novel AR pedestrian navigation method that uses landmarks as beacons to guide users' wayfinding

- Landmarks are detected using a vision-based model and then augmented by virtual arrows and panels with navigation information

- The result shows the potentials for combining AR-based visual clues and map-based route planning to facilitate pedestrian navigation

THANK YOU