14TH ITU ACADEMIC CONFERENCE

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ACCRA 2022

Enhancing user experience in pedestrian navigation based on Augmented Reality and landmark recognition

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Session 2 – Augmented reality systems: design and implementation

Paper S2.2

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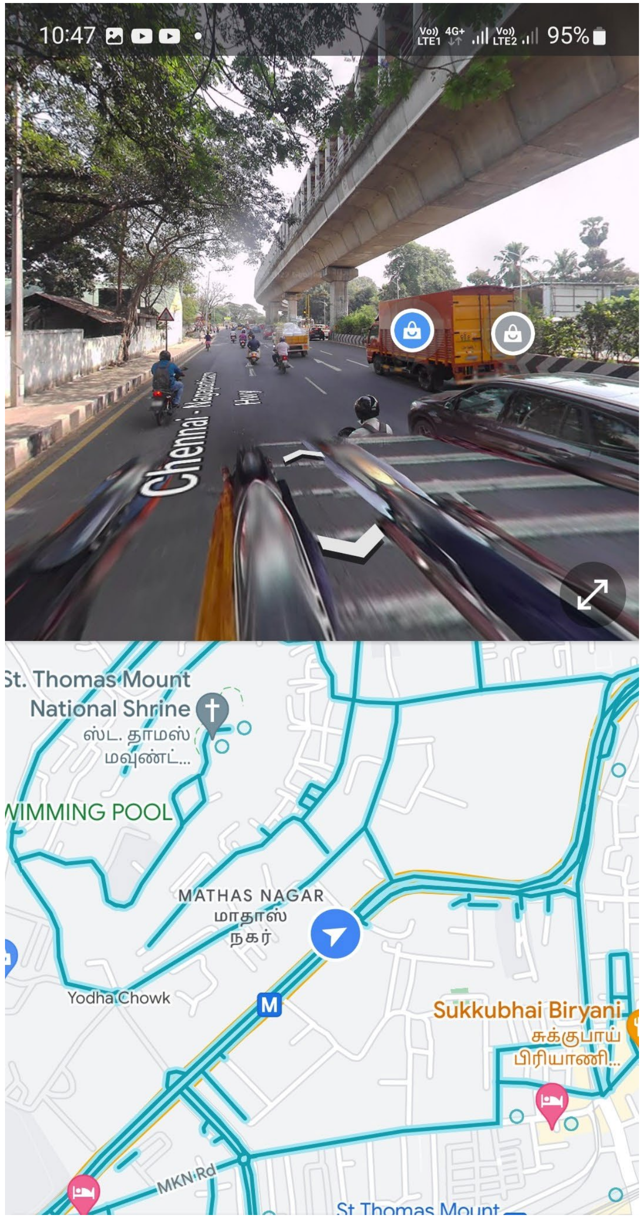
Outlines

- Motivation
- Background and related technology
- Architecture of the proposed system
- Algorithms
- Experimental evaluation
- Conclusion and standardization perspectives

Motivation

- Mobile Augmented Reality (MAR) is forecasted to grow 7.6 billion U.S. dollars in 2020 to over 30 billion U.S. dollars by 2025 (i.e., CAGR of 31.1%)
- In location-aware system, a continuous user interface across all the user locations needed
- Enhancement of user experience (detection of various points of interests) during pedestrian/road navigation
- Limitations of popular existing digital map services (such as *Google Street View*)
  - Outdated data, limited functions/accuracy
  - Reliance on GPS signal



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Background & Related Technologies

- **Digital map based on the Global Positioning System (GPS)**
  - Online map service for optimized route
- **Landmark recognition**
  - Real-time response on demand
- **Augmented Reality based solution**
  - Landmark recognition
  - AR navigation
  - Digital map
  - Digital map + AR navigation + Landmark recognition
- **In absence of GPS**
  - Technique based on footstep count
  - Calibration of measured data

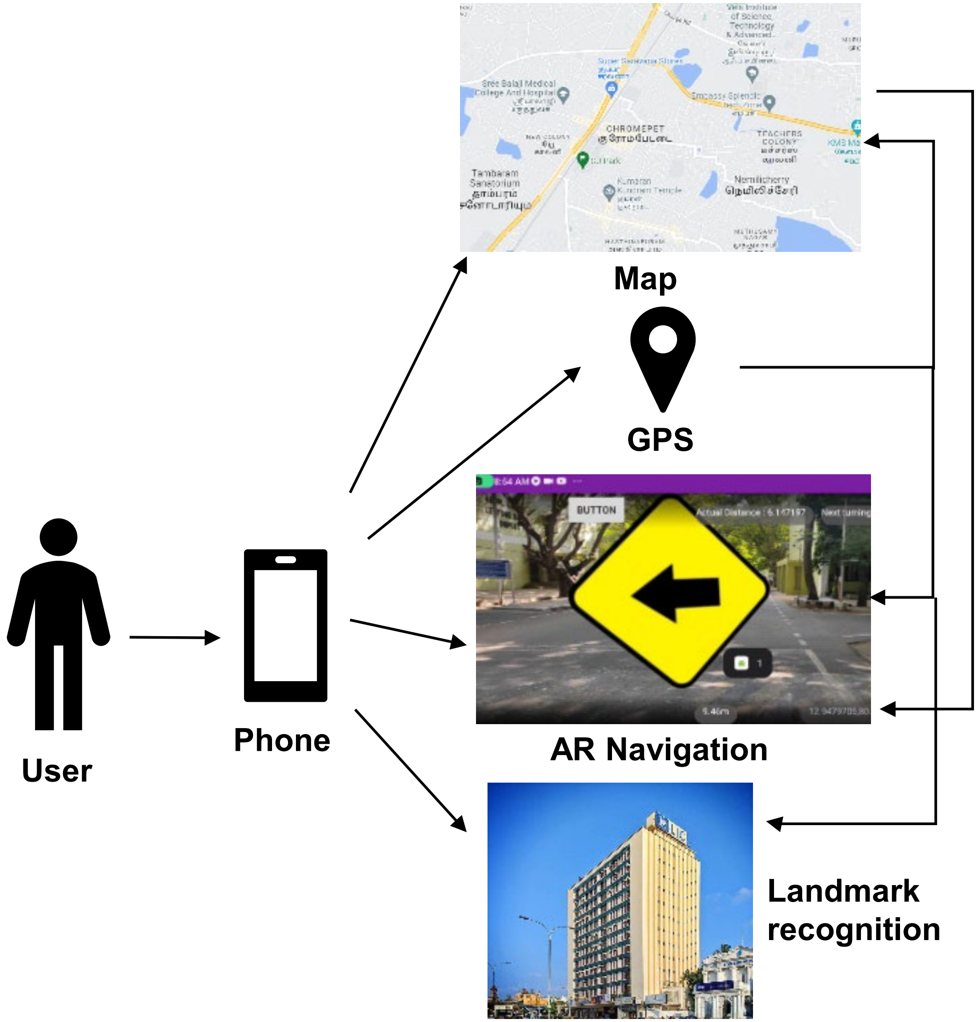
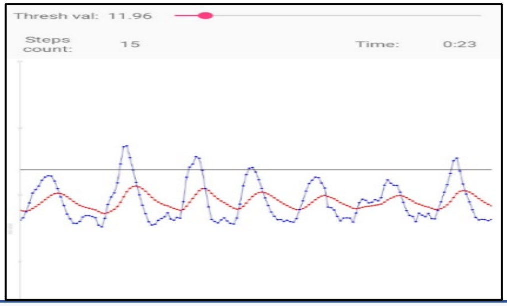
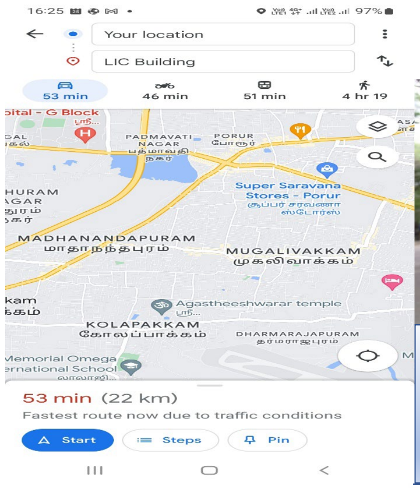


Figure 1 – Schematics of pedestrian navigation

Overview of the Proposed System

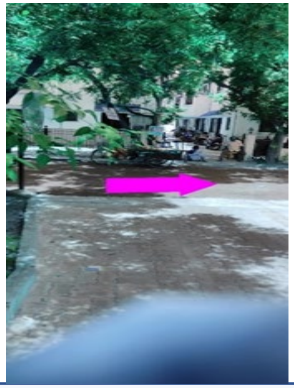


Step count-based Distance Estimation (SDE) Module



Input received from User

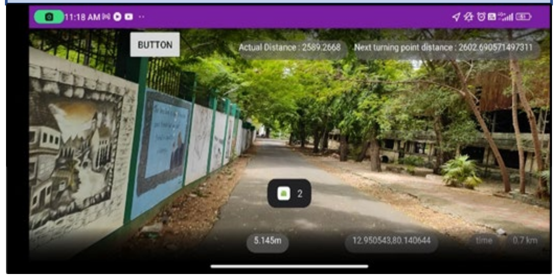
Augmented Reality Navigation (ARN) Module



Landmark Recognition (LR) Module

Localizing and anchoring AR Objects

Rendering of AR Objects



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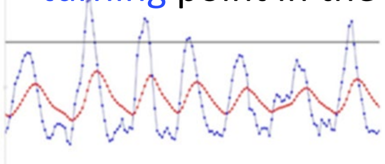
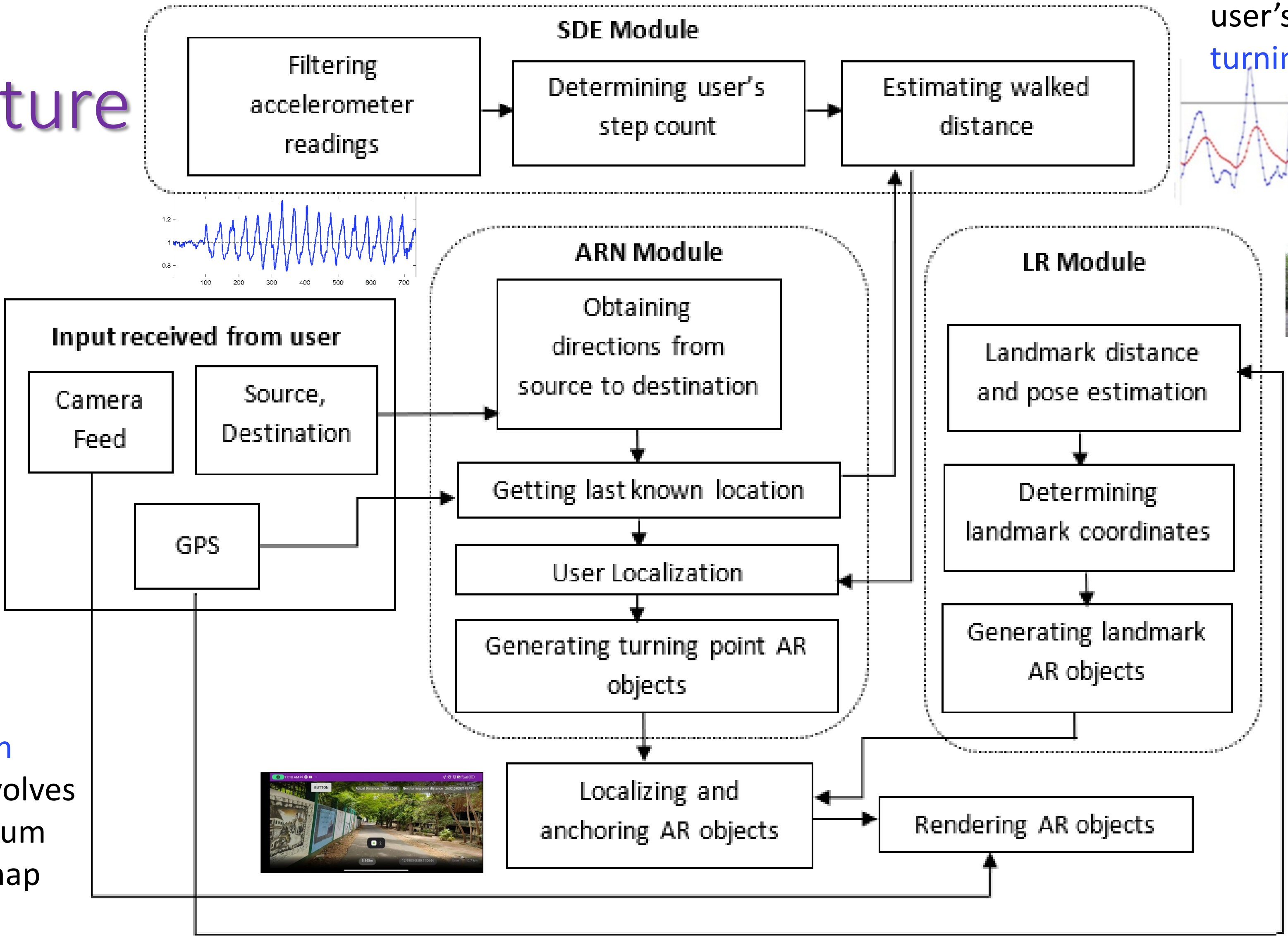
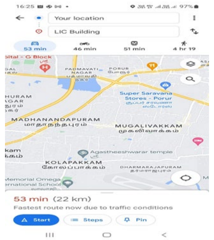
System Architecture

The SDE module helps in localizing the user's position with respect to the turning point in the absence of GPS.





The LR module estimates the location of the landmark which the user's camera is pointed to and displays relevant information



The AR Navigation (ARN) module involves getting the optimum route on digital map

The AR objects (generated by the ARN and LR modules) are anchored to their geo-positions, localized with respect to the user's camera view and rendered on the user's screen.

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Algorithms

1. With GPS (Normal Workflow)

- AR Navigation (ARN) algorithm with
- Landmark Recognition (LR) method

2. Absence of GPS

- Step count-based Distance Estimation (SDE) algorithm with
- Gait Calibration (GC) mechanism

AR Navigation (ARN) Algorithm

Purpose: Get direction mark in AR environment on smartphone

Input: Digital online map direction service

Output: AR direction mark

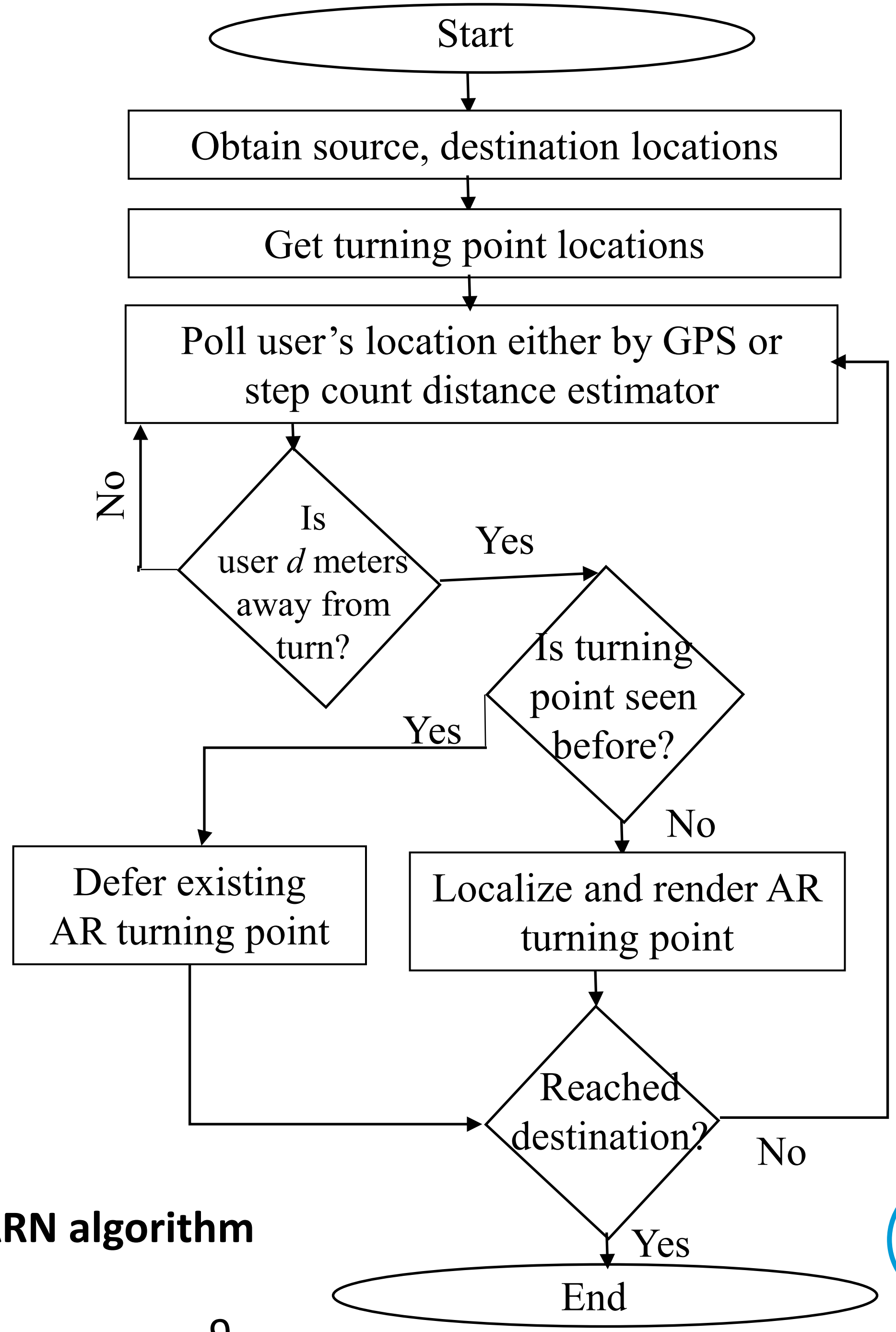

Figure : **ARN algorithm**

The online directional map service finds an optimal route from source to destination.
Since the turning points obtained from the route appear one after the other, a first-in first-out pattern is used to process them.

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Step count-based Distance Estimation (SDE) Algorithm

Purpose: Estimate the walked distance to display direction mark in AR environment on smartphone

Input: Accelerometer data on smart phone

Output: Distance traveled

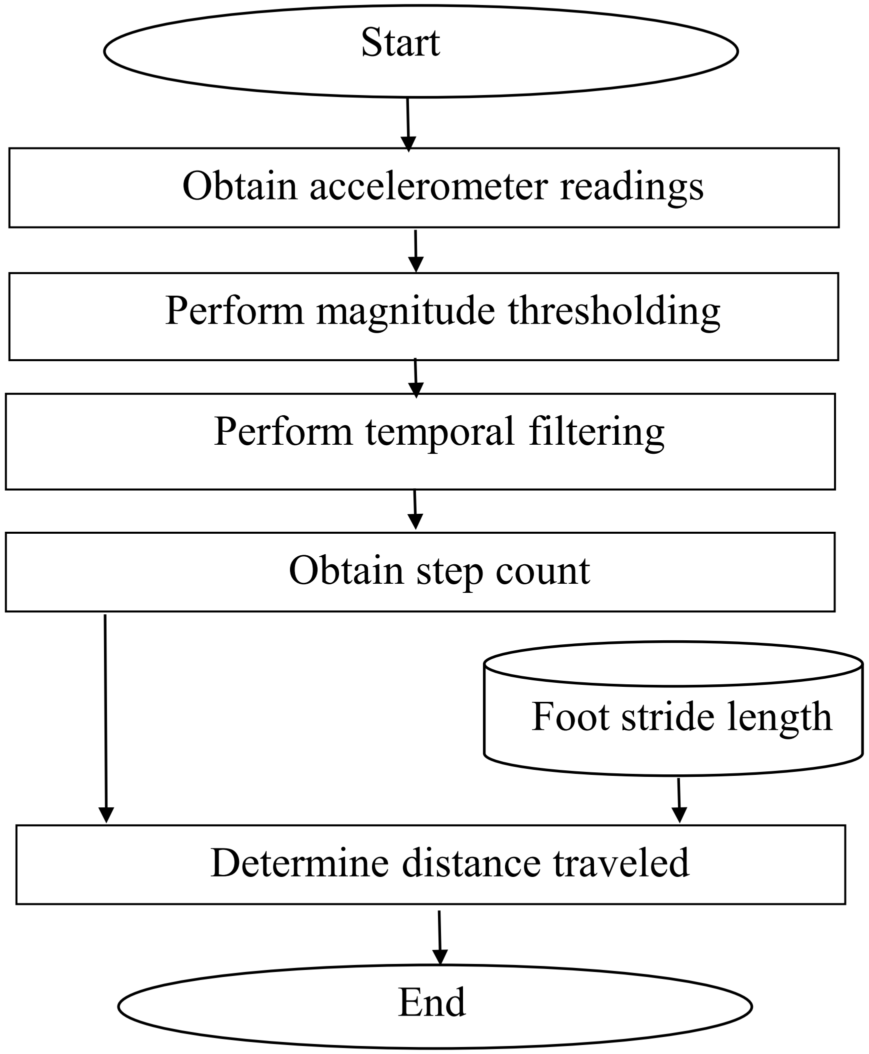

Figure : **SDE algorithm**

In **absence** of the **GPS**, the step count-based distance estimation algorithm works by filtering their phone's accelerometer data and estimating the distance traveled by the user as a product of the calculated footsteps and the length of the foot stride.

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Gait Calibration Algorithm

Purpose: To calculate the foot stride of the user which is used to approximate the distance travelled by the user combined with the number of footsteps walked.

Algorithm:

Input – User's current location, Phone's GPS

Output – User's foot-stride length

1. Initialize start location as user's current location
2. Increment step count of the user using the footstep counting method
3. Update the user's current location using GPS
4. If the user doesn't stop, go to Step 2
5. Find the distance between the starting location and the current location using the Haversine formula [14]
6. $Foot\_stride\_length = distance \,/\, step\_count$
7. Return the foot-stride length

Haversine formula:

$a = \sin^2(\Delta\phi/2) + \cos\phi 1 \cdot \cos\phi 2 \cdot \sin^2(\Delta\lambda/2)$

$c = 2 \cdot \mathrm{atan2}(\sqrt{a}, \sqrt{(1-a)})$

$d = R \cdot c$

Where φ is latitude, λ is longitude, R is earth's radius

(mean radius = 6,371km);

Source: https://www.movable-type.co.uk/scripts/latlong.html

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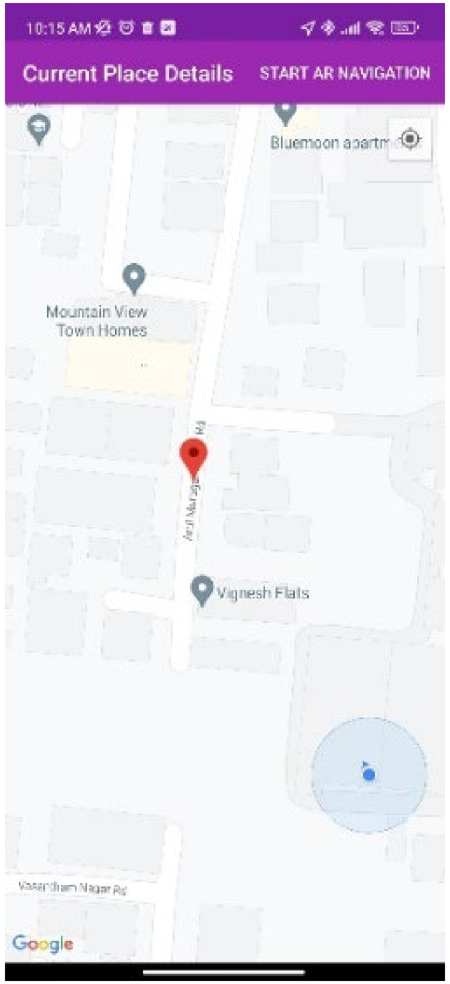
Implementation Overview

The proposed system (MAR-PNS) was developed using:

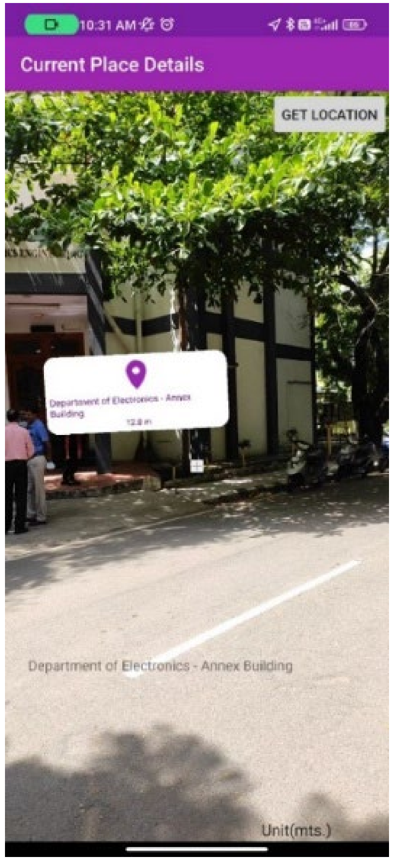
- Android Studio (Arctic Fox 2020.3.1)
- Google Cloud Platform
- Beyond AR Framework
- For getting directions and details of locations:
  - Google Directions API
  - Google Places API are used



Experimental Results (1/3)

Table 1 – Locational accuracy and latency (ARN and LR Modules)

Actual location	Estimated location	Distance deviation (m)	Latency (ms)
12.949037, 80.140572	12.949024, 80.140599	3.3	72
12.948213, 80.139994	12.948214, 80.140013	2.1	77
12.948849, 80.140914	12.948865, 80.140930	2.5	82
12.949498, 80.139833	12.949510, 80.139847	2	71
12.950599, 80.140618	12.9506038, 80.1406339	1.8	68
	Average	2.34	74



The testing for the landmark recognition module involved validation of the location received from Google Maps and the location calculated by the landmark recognition algorithm.

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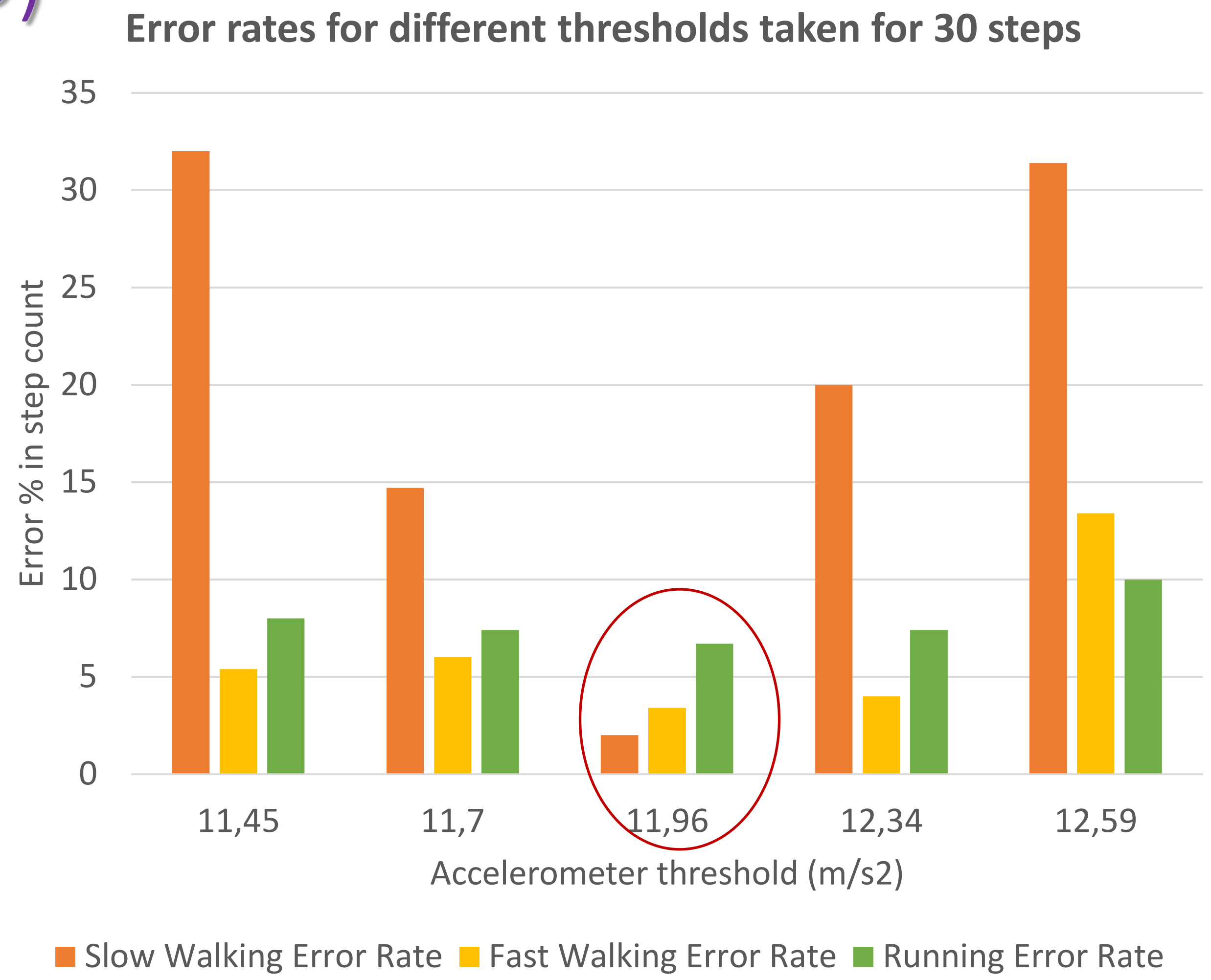
Experimental Results (2/3)

Table 2 – Determination of threshold (SDE Module)

Threshold	Slow Walking (30)	Fast Walking (30)	Running (30)
11.45	20.4	28.4	27.6
11.7	25.6	28.2	27.8
11.96	29.4	29	28
12.34	24	28.8	27.8
12.59	20.6	26	27

A threshold for acceleration was chosen (11 to 13) based on a trial-and-error method for each experiment and the user had to slow-walk, fast-walk and run for 30 steps five times for each threshold.



After experiment, the threshold value was set to 11.96 in the SDE algorithm.

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Experimental Results (3/3)

The error rate comparison of our experimental findings with two smart watches (Realme Dizo Watch 2, and MI Band 3)

Table 3 – Step count validation

Model	Navigational Mode	Average Estimated steps (out of 30)	Error %
Realme Dizo Watch 2	Walking	29.1	3%
	Running	28.5	5%
MI Band 3	Walking	29	3.34%
	Running	28.8	4%
MAR-PNS System	Walking	29.2	2.67%
	Running	28	6.67%

Table 4 – Distance estimation experiments

Actual Distance (m)	Calculated Distance (m)	Squared error (m)
25	23.4	2.56
30	27.6	5.76
52	53.2	1.44
70	69.3	0.49
100	99.4	0.36
	RMSE	1.45

The MAR-PNS model is well suited when the user is walking as the error rate is 0.5% less than of the smart watches. However, it is observed that it shows 2% more error when the user is running.

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Conclusion & Standardization Perspectives

Conclusion:

- Enhancement of user's experience and reliability of navigation system
- The latency and accuracy of the proposed system meets the requirement of pedestrian navigation
- Improvement of over existing digital map based navigation

Standardization Perspective:

- ➢ The proposed system complies with Recommendation ITU-T Q.4066 "Testing procedures of augmented reality applications"
- ➢ It is highly relevant to the Recommendation ITU-T Y.4562 "Functions and metadata of spatiotemporal information service for smart cities"
- ➢ We would like to present the research contribution to ITU-T SG-16 & SG-20

Thank you!