

GOPA: Geometrical Optics Positioning Algorithm

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Project Overview

Objective

Developing Visible light communications (VLC) indoor positioning technology for indoor applications:

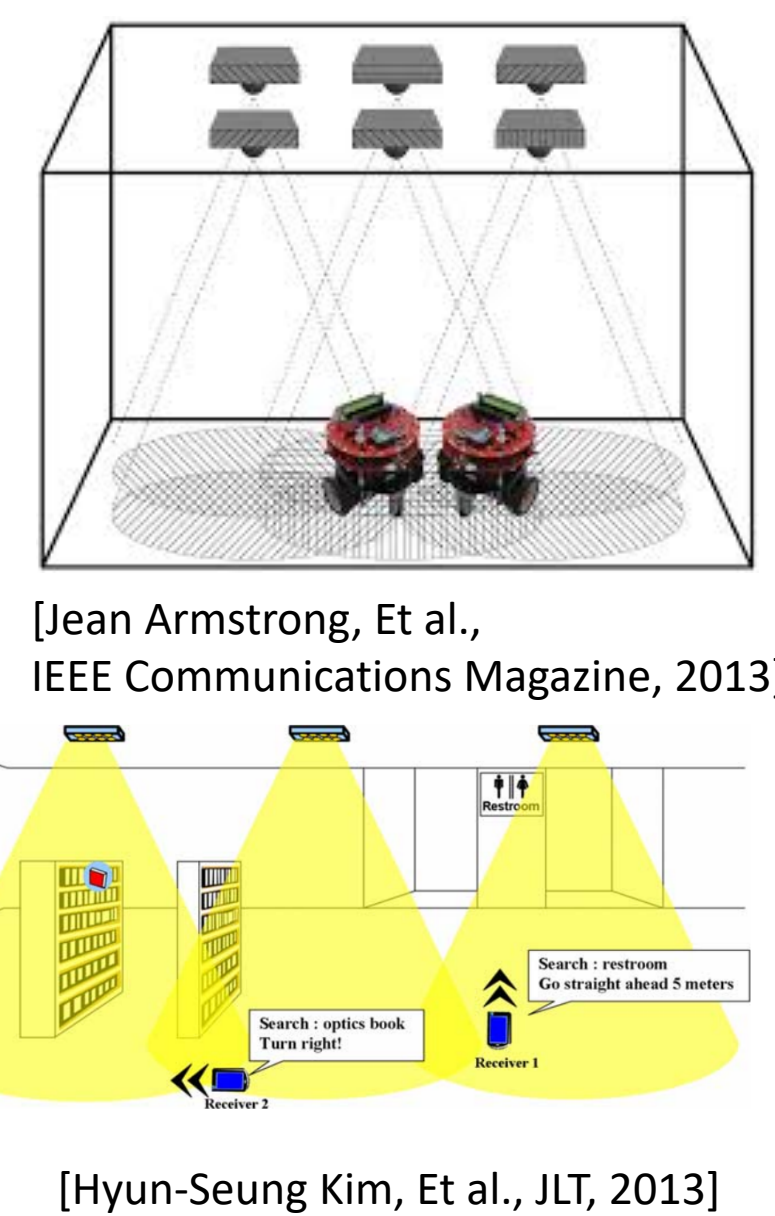
- Can be implemented as an smartphone app (No accessory hardware is required in user-side)
- Scalable spatial colored coded IDs

Motivation

- GPS has poor coverage and accuracy for indoor applications
- Wi-Fi based method:
 - Insufficient accuracy for indoor applications (in the range of meter)
 - Radio-frequency is forbidden in hospitals, near the airports, military fields
 - Do not provide orientation information

Applications

- Indoor navigation services
- Library services
- Retail marketing
- Indoor robotics



Background

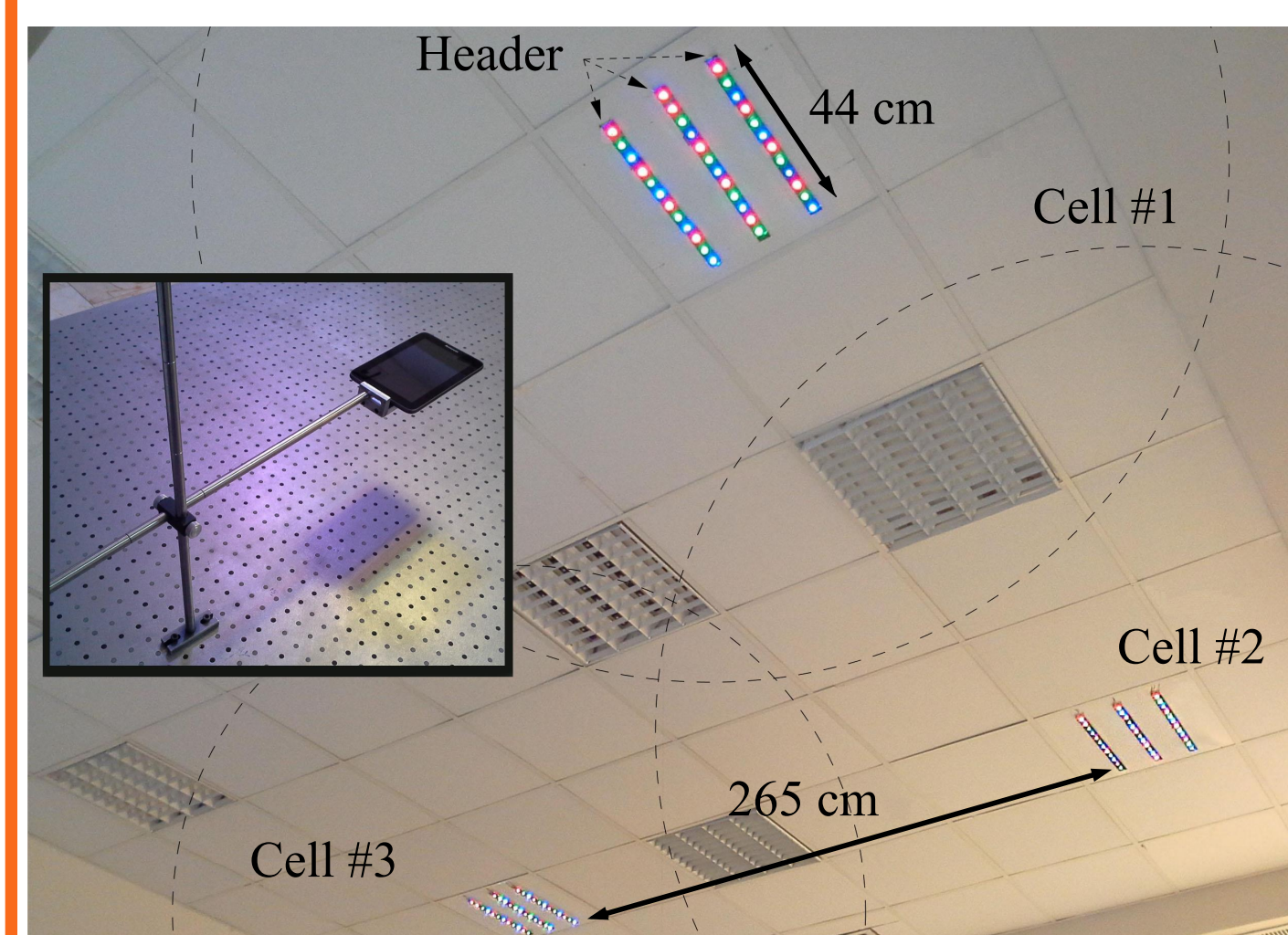
Method	Cell ID	# of Anchor points	positioning method	Rx	Pros	Cons
TOA	T, F, W	3	Trilateration	PD	Simple algorithm	-Dedicated Hardware -TX/RX time synchronization
TDOA	T, F, W	3	Trilateration	PD	Simple algorithm	-Dedicated Hardware required -TX time synchronization
RSS	T, F, W	3	Trilateration	PD	Simple algorithm	-Dedicated Hardware required -Sensitive to noise and RX tilt
Finger-printing	T, F, W	1	Fingerprinting	PD	Complicated algorithm and hardware	-Minimum number of Anchor points
AoA	T, F, W	3	Triangulation	Multiple PDs / Cam	Smartphone-based	
Proposed Method (GOPA)	S, W	1	Triangulation	Cam	+Smartphone-based +Scalable ID	

TOA: Time Of Arrival, TDOA: Time Difference Of Arrival, RSS: Received Signal Strength, AoA: Angle of Arrival, T: time, F: frequency, W: wavelength, S: space

Hardware

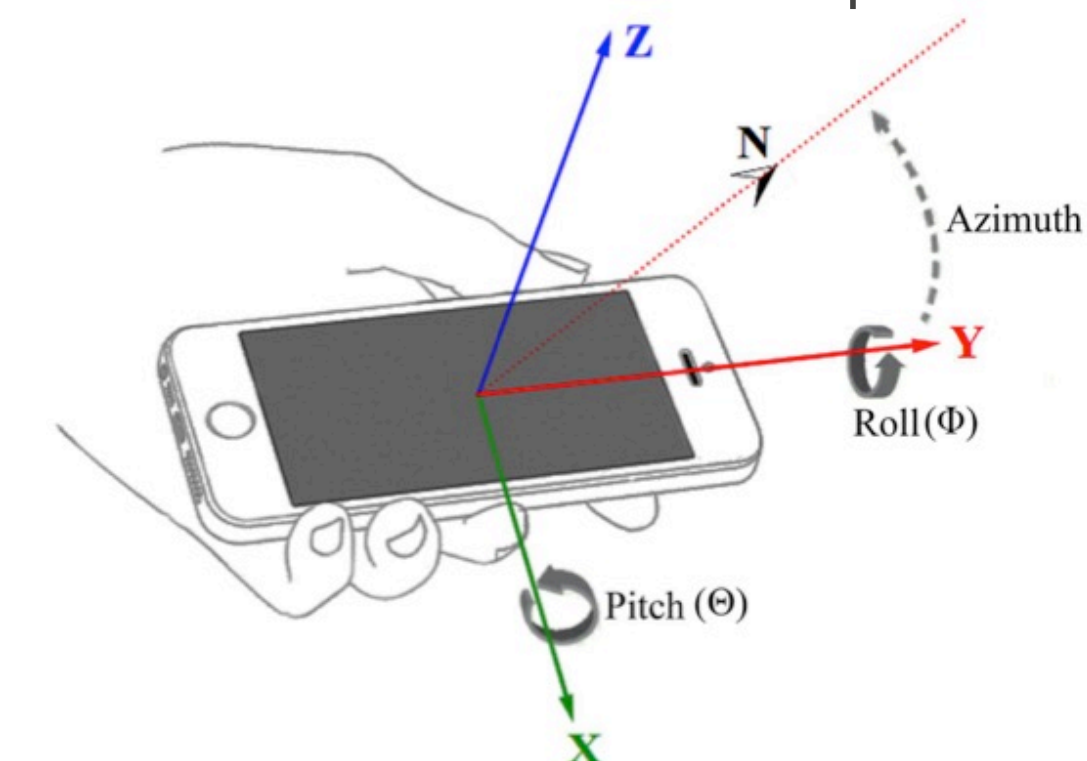
VLC Network Infrastructure

- Dividing an indoor area into cells with unique spatial color code landmarks



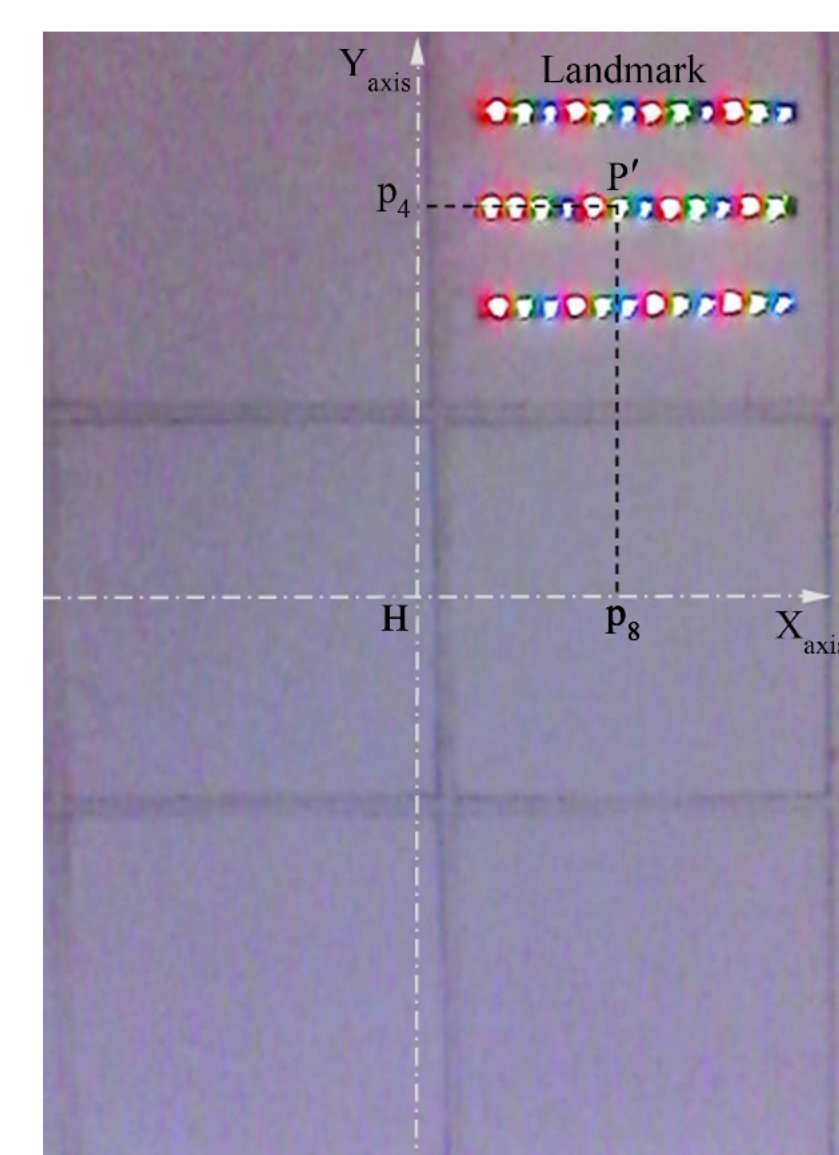
User-side Hardware

- Using front facing camera and accelerometer data as input data



Global (Inter-Cell) Positioning

- Detecting of color coded landmarks on image plane
- Finding the global location of the cell inside the building

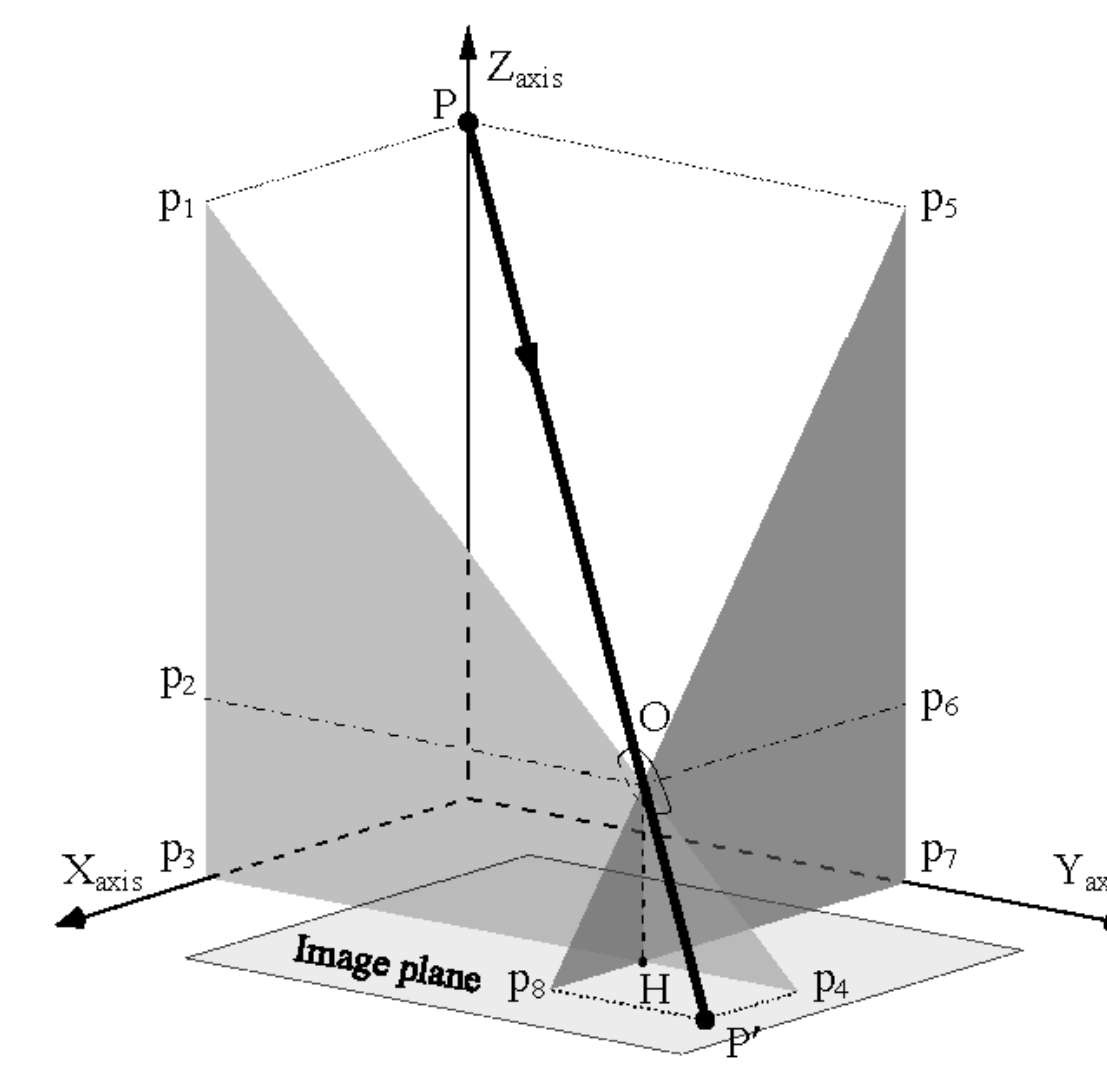


Methodology

Local (Intra-cell) Positioning

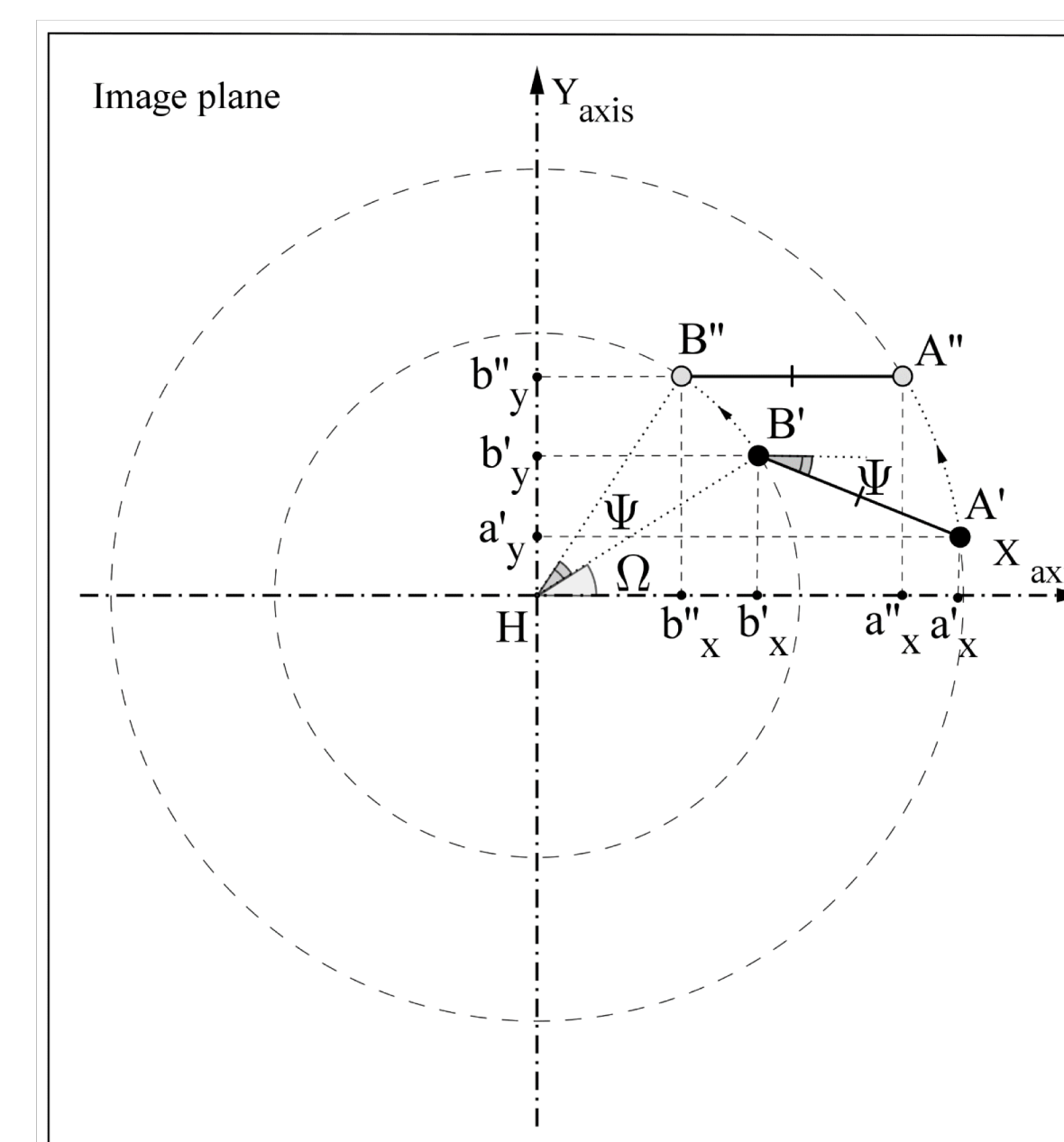
Zero Tilt and Orientation

- Employing Geometrical Optics technique to estimate position of smartphone



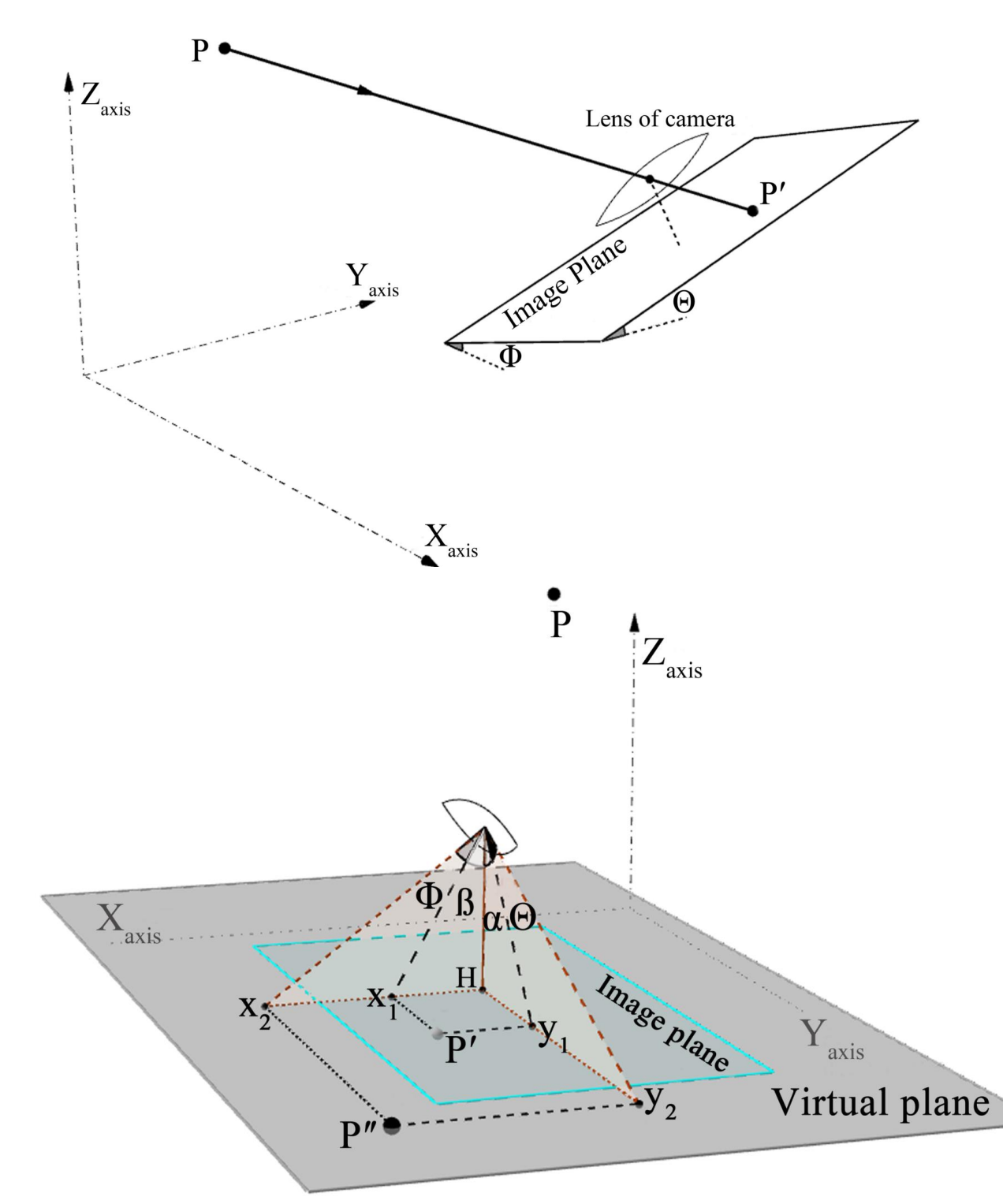
Orientation Compensation

- Employing image processing technique on "image plane" to estimate direction of smart-phone

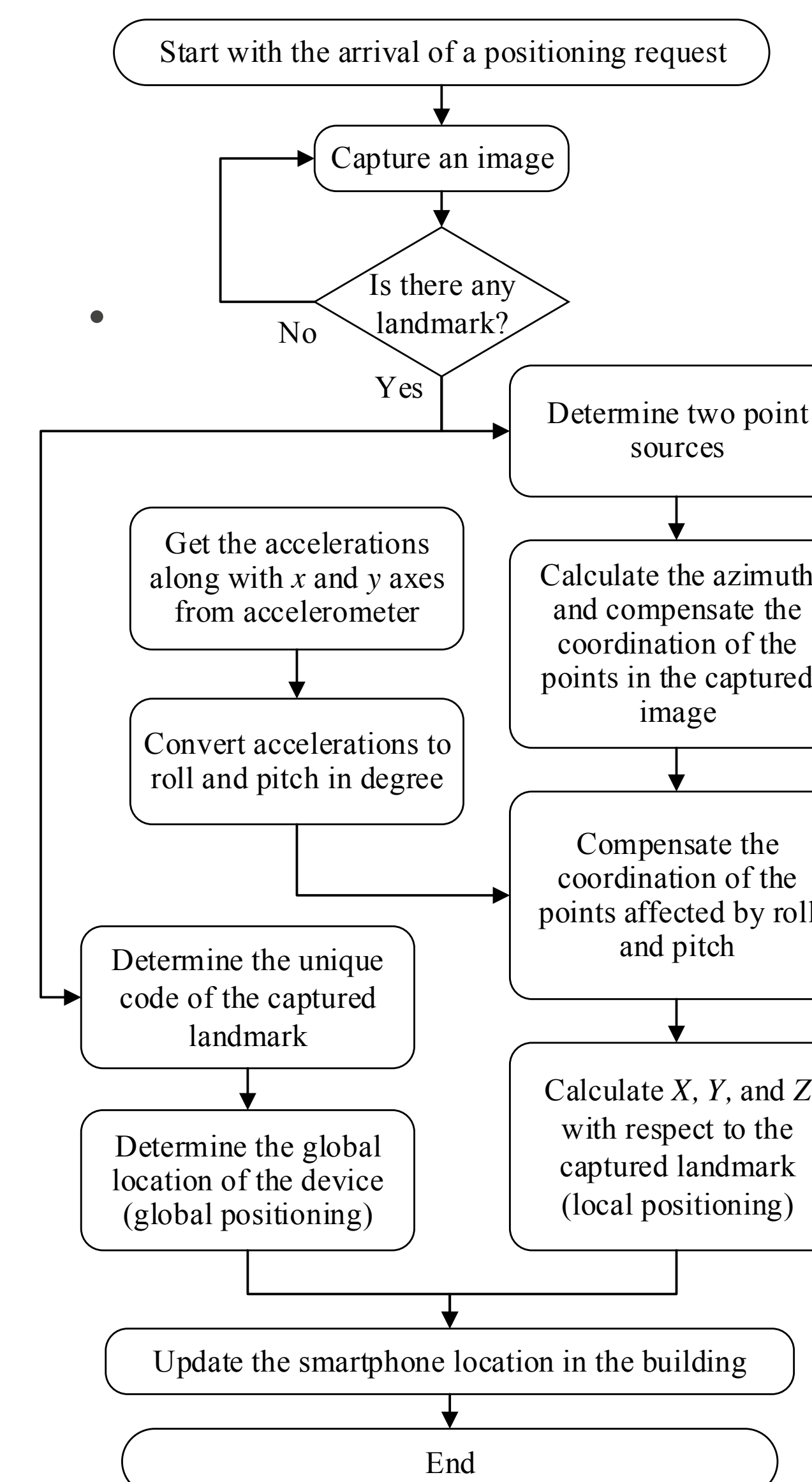


Roll and Pitch Compensation (Virtual Plane Idea)

- Introducing "virtual plane" to:
 - Increase the field of view
 - hand-arm motion consideration



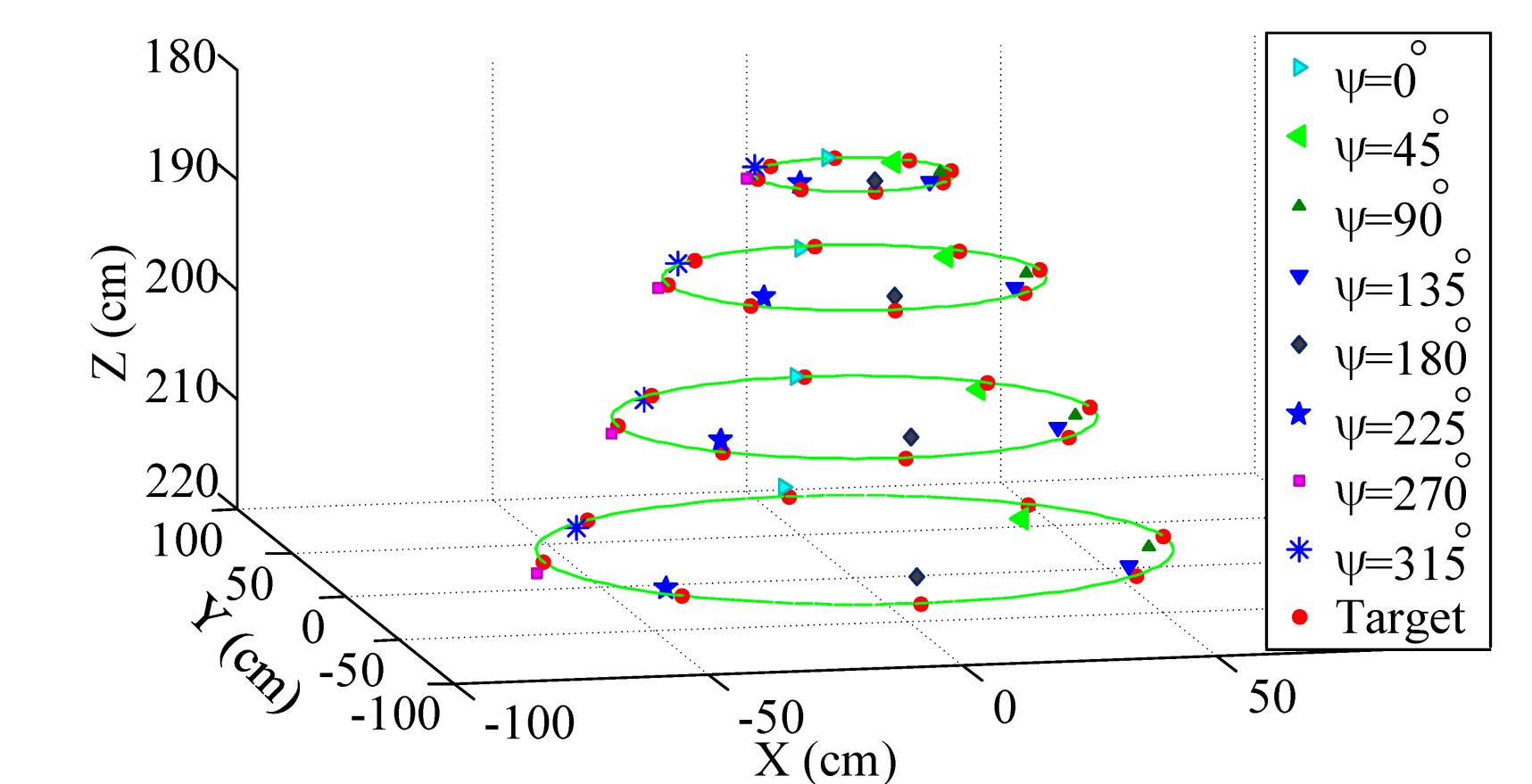
Algorithm Flowchart



Results

Dimension	Azimuth (deg.)	Tilt (deg.)	Average Error (cm)	Potential Applications
2-D	90 (fixed)	0	0.54	Hospital wheelchairs and robots
	0	0	1.24	
3-D	275	0	1.85	Realistic positioning applications on smartphones
	275	35	6.02	

- Estimating 3 dimensional location of smart-phone within a positioning cell



Concluding marks

- 3D localization and illumination system
- Closed equations and accurate algorithm
- Low computational load on smartphone

Reference

- Salehi, J.A., Hosseinianfar, H. and Chizari, A., 2018. *Methods and systems for geometrical optics positioning using spatial color coded LEDs*. U.S. Patent 9,939,275.

Acknowledgement

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