MobiCeil

Cost-Free **Indoor Localizer** for Office Buildings

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Indoor Positioning System (IPS)

IPS identifies and tracks the location of object/people inside a building.

Office buildings consume **40%** of the overall energy consumption.

Employee occupancy information can enable

- dynamic thermal load management
- optimizing seat allocation
- sending printouts to the nearest printer

Thus, **reducing cost and environmental sustainability**.

Can also help with indoor navigation, *e.g.*, nearest washroom or fire exit.

Previous Solutions

Infra-Red (IR)
- \+ Cheap
- – Only works in line-of-sight
- – Requires additional hardware

Radio Frequency (RF)
- \+ Increased Coverage Area: Travel through walls and humans
- \+ Inexpensive: as it reuse existing RF infrastructure (WLAN, BT)
- – Needs object being tracked to be equipped with RF technology

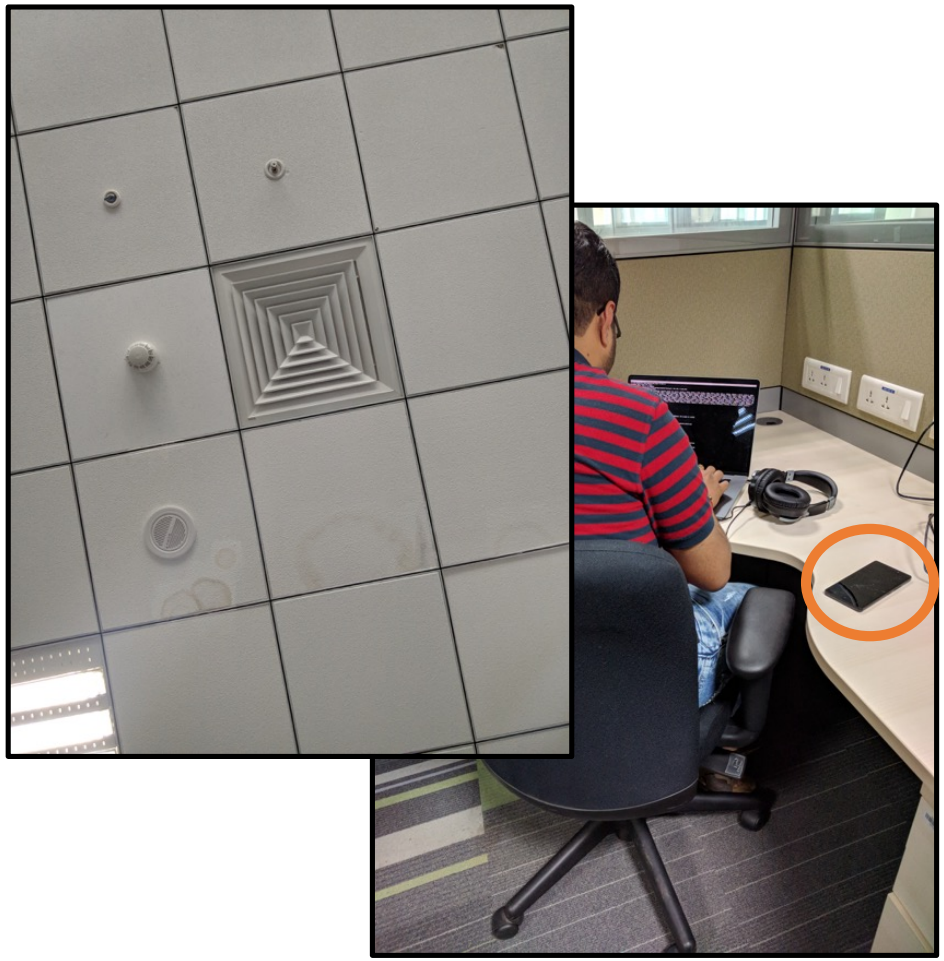
Vision-based Systems
- \+ No need for objects being tracked to be equipped with any sensor
- – Deploying cameras is expensive
- – Privacy Issues

Our Solution

MobiCeil

A novel phone-based **offline**, **low complexity**, **automated** indoor localization technique.

It uses image captured from phone's camera to identify the **unique ceiling structure** of any particular location in the office building.



Observations

1 Workplaces have a standard set of ceiling landmarks.

Such as HVAC vents, lights, motion sensors, microphones, WiFi routers, etc.

This reduces the complexity of landmark identification.

2 Ceiling layout of different rooms or cubicles is unique.

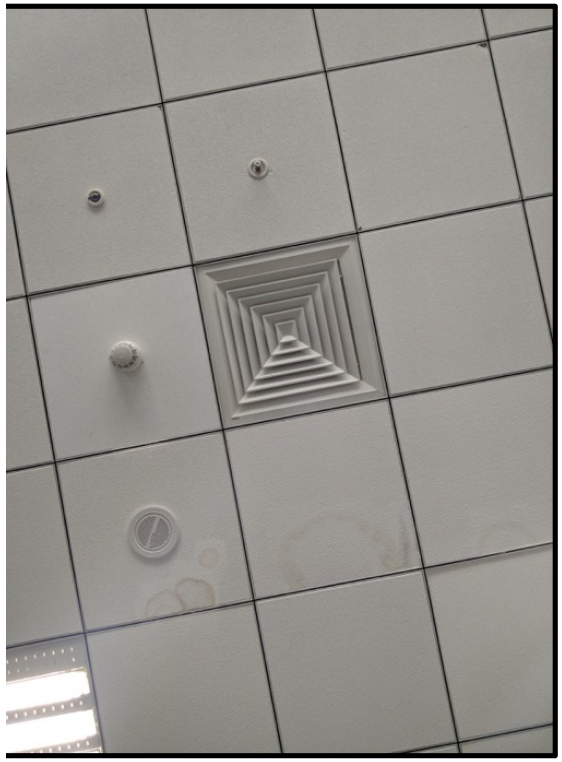
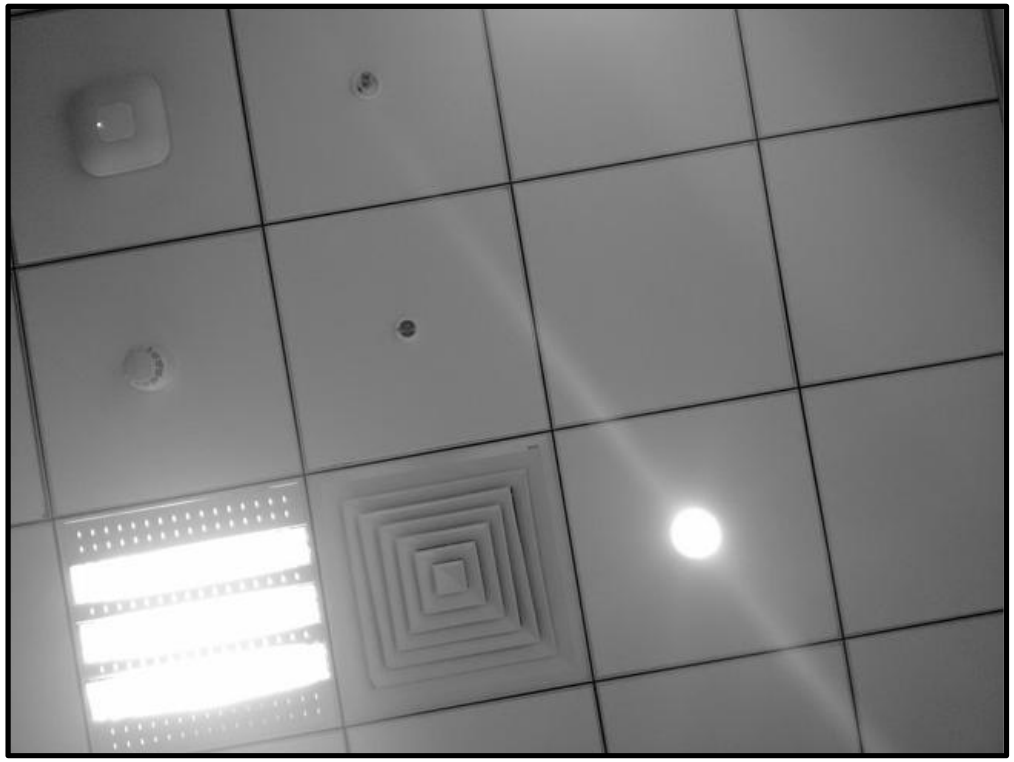
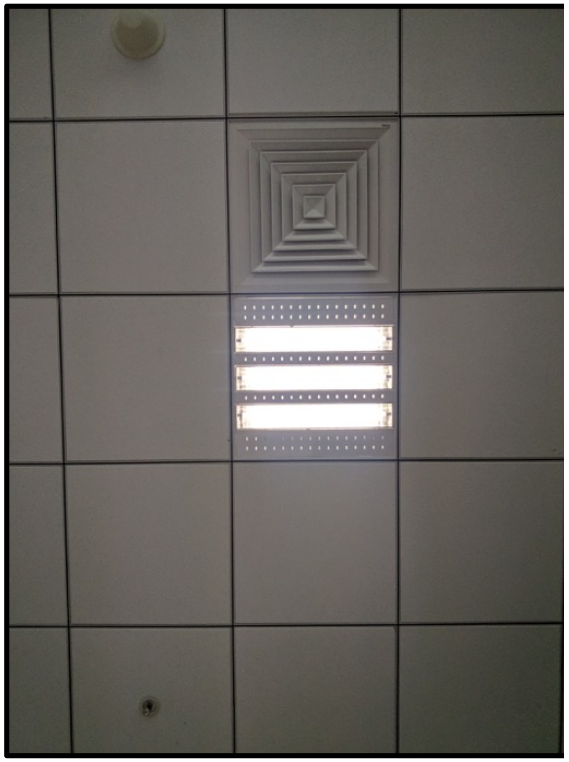
This ensures no ambiguity in identifying location corresponding to the input ceiling image.

3 Employees tend to keep their phones on the table.

While working in their cubicle, or brainstorming in the meeting room.

Observation Test# 1

1 Workplaces have a standard set of ceiling landmarks.

Observation Test# 2

2 Ceiling layout of different rooms or cubicles is unique.

Data: 18 rooms and 6 cubicles | IT office building | Tile size: 1.9ft x 1.9ft

Created a matrix of integers for each room and cubicle, with each integer representing a tile landmark: ***Ceiling Pattern Matrix***

17 unique landmarks | ~36.75 tiles/room (std=14.5, min=20, max=70) | 16 tiles/cubicle

Most common landmarks: Empty tiles (30.8%), HVAC vents (12.3%), and lights (16.5%).

We found that no 3x3 sub-matrix of the matrix representation of the complete ceiling layout, matches with that of the other!

Observation Test# 3

3 Employees tend to keep their phones on the table.

Randomly noted the phone position of 47 employees at 11 am in office

25 were working in their cubicle + 22 employees in 6 different meeting rooms

76.5% employees (19/25 employees in their cubicle, and 17/22 employees in meeting rooms) had their phones lying on the table!

MobiCeil System

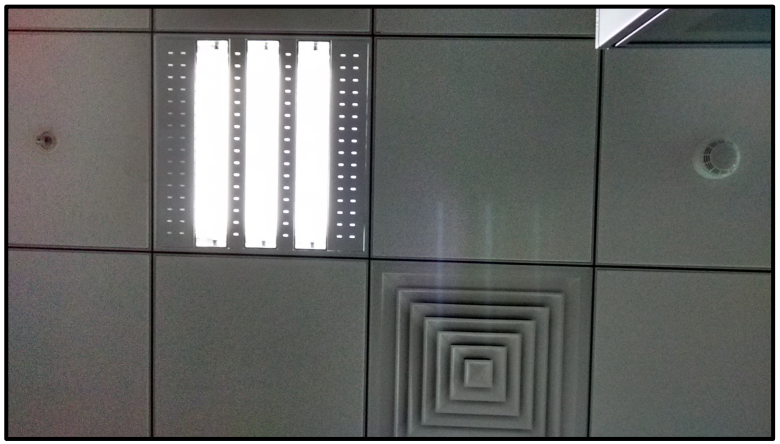
Static Input

Multiple images of each *landmark*

5	0	0	6	0	0	1	8	3
0	1	7	0	1	9	0	1	0
4	0	0	5	1	1	2	0	4
0	1	1	2	3	0	0	3	0
1	2	0	0	2	4	0	9	0
3	6	1	7	0	2	8	0	6

Ceiling pattern matrix of each room and cubicle

Input



Output Room/Cubicle number

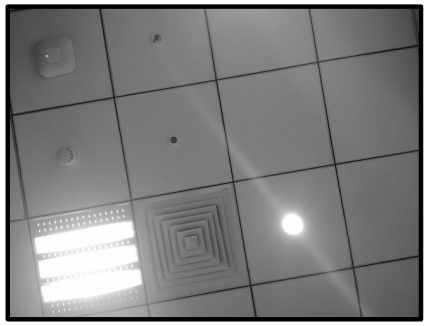
Static Input Data

1. **Ceiling pattern matrix** of the 18 meeting rooms and 6 cubicles
2. 72 images of each of the 17 unique landmarks, totaling **1224** images

9 tile positions	Place the phone directly below the landmark tile and below each of the 8 tiles adjacent to the landmark tile
2 cameras	Front and back
2 light modes	On and Off
2 times	

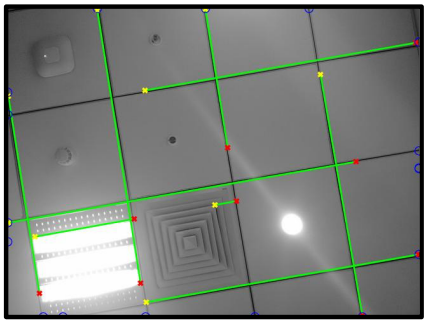
Image was cropped to extract the landmark tile, and resized to 255 x 255 pixels

MobiCeil System

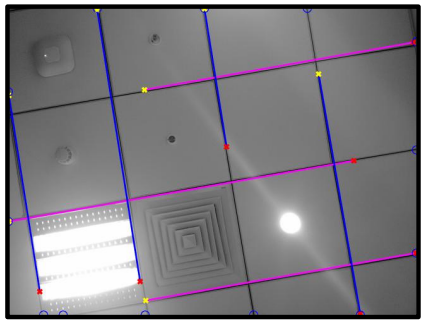


Input image

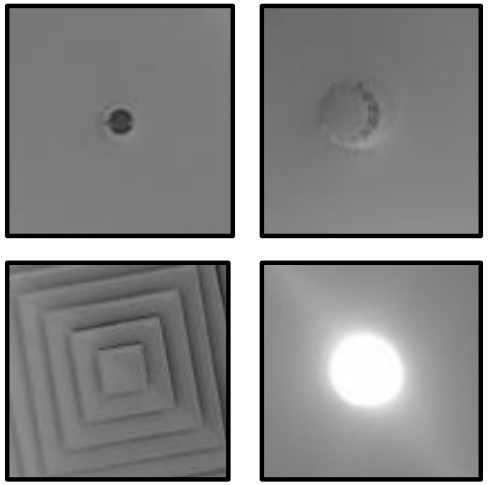
Hough Transform



Filter Gridlines



Obtaining intersection pointes and smaller tiles



Map landmarks to form query matrix

SURF

11	7	0	-1
10	9	0	0
3	1	4	0
-1	0	0	-1

Searching all ceiling pattern matrices

Location: Room 803

Data Collection: Test Dataset

960 ceiling images

Place the phone on the table in front of each chair, in three different rotation angles of 0, 30 and 60 degrees.

10 medium rooms x 5 chairs x 3 phone rotations x 2 cameras x 2 light modes

8 small rooms x 3 chairs x 3 phone rotations x 2 cameras x 2 light modes

6 cubicles x 1 chair x 3 phone rotations x 2 cameras x 2 light modes

Results: Accuracy

88.2% accurate

84.7%: Front camera

91.6%: Back camera (as higher resolution)

91.3%: Lights Off

85.2%: Lights On (as lights resulted in glare)

No difference with different rotations, as SURF is rotation invariant.

No difference between meeting rooms and cubicles.

Results: Computational Complexity

2.8s (std=0.5) per image

0.8s (std=0.2): Tile extractor module

1.3s (std=0.3): Landmark detector to generate query matrix

0.7s (std=0.1): Location matching using ceiling pattern matrix

Limitations

1. Works only for buildings with **tiled ceiling layout**, with unique ceiling layout in different zones of a floor.

2. Requires the phone to be **lying flat on the table**.

3. Camera images can trigger **privacy concerns**.
   - Images are captured only when the user is inside the office (GPS data) and only when the phone is static on a flat horizontal surface (IMU data).
   - Images are stored only on the phone, its all **on-device computation**.

Thank You!

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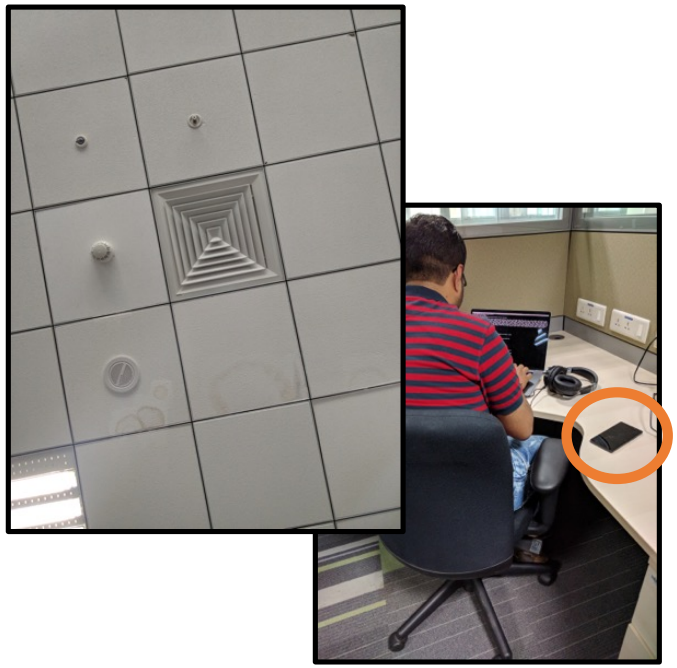

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