Did you see Bob?

Escort - Human Localization using Mobile Phones

Finding person in a public place

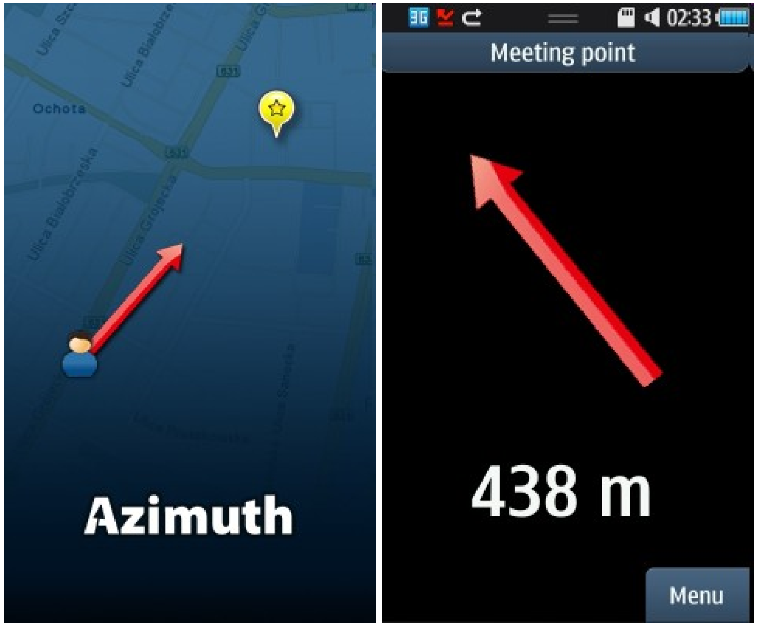
Localization methods

GPS

- fairly accurate
- battery-draining
- not available inside buildings
- catching a signal takes time

WiFi/GSM

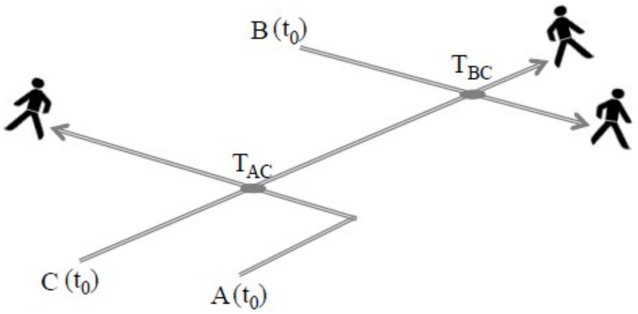
- longer battery life
- inaccurate results



Social approach to localization

The idea

- People building the graph of their movement traces
- Localization using phone sensors



Escort App

I'm entering the building.

Escort me to Bob!

Phone sensors used by Escort

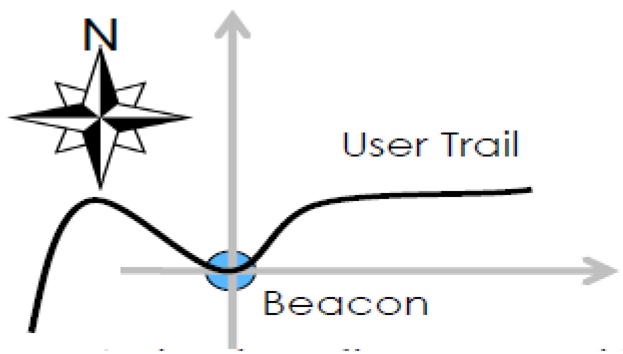
- Accelerometer (movements)
- Compass (direction changing)
- Audio sensor (encounters)

Challenges

- Accelerometers and compasses are noisy and inaccurate
- We don’t have any point of reference to correct errors
- Even if error can be correced sometimes, it is non-trivial to correct the entire trail of the user

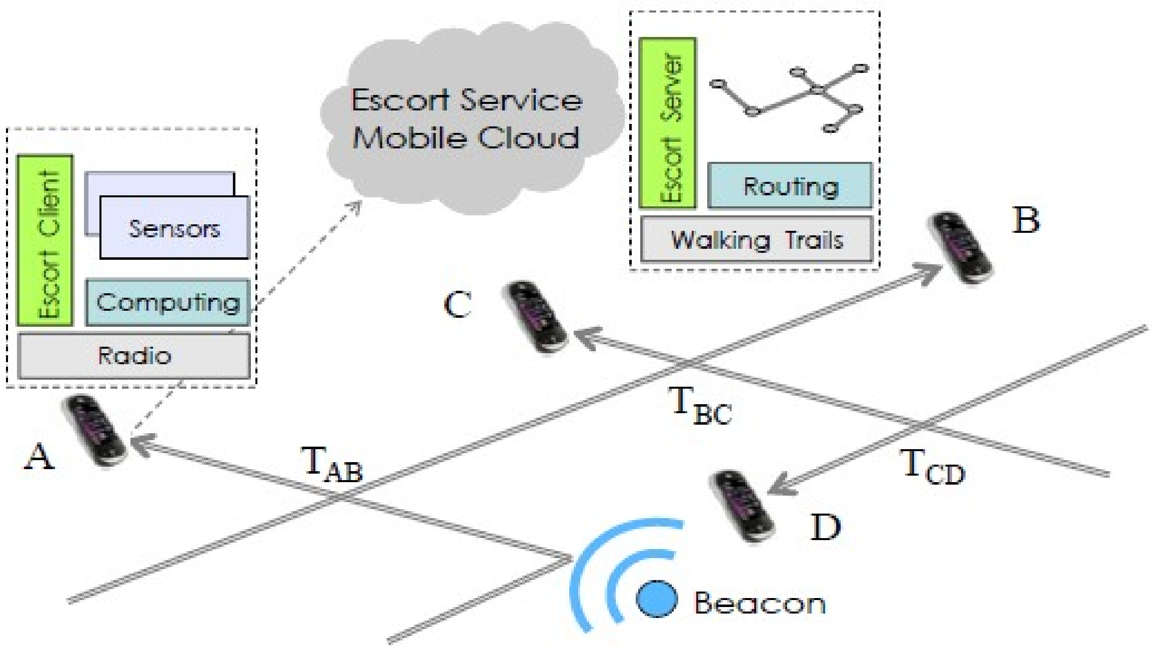
Improvements

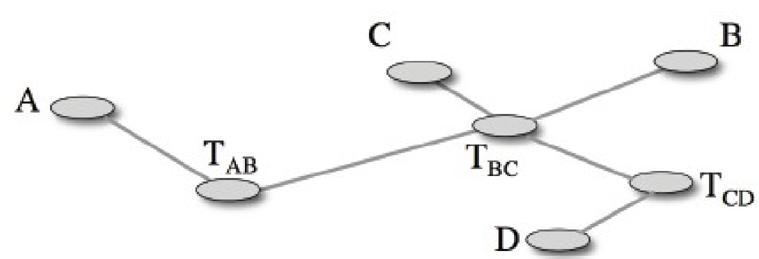
- Fixed beacon as an origin of virtual coordinate system



- Location diffusion algorithm
- Drift cancellation formula

Escort Architecture



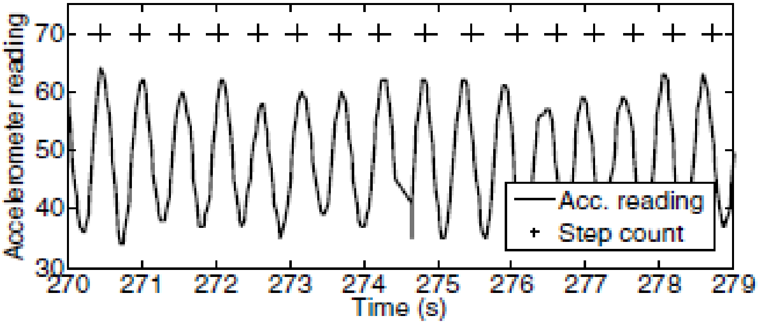


How do users join the system?

- New Escort client computes his own isolated coordinate system, relative to the initial, unknown location
- Two graphs are merged when user A meets user B
- The graph „knows” his location, when one of users encounters the beacon

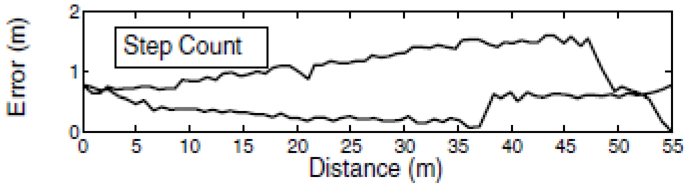
Determining user's trail: moving

Idea: identifying human walking patterns.



Displacement is computed by multiplying step count with the user's step size (function of the user's weight and height)

Step count accuracy: ~96%



Determining user’s trail: turning

- Compass sensors are noisy, because of user sway, movement irregularities, magnetic fields and internal bias.
- It is hard to determine user’s exact direction

Observations:

- Compass readings stabilize during constant walk
- After each turn new bias is imposed

Drift cancellation

$$L'(t) = L(t) + \vec{V}\frac{t - t_{r1}}{t_{r2} - t_{r1}}$$

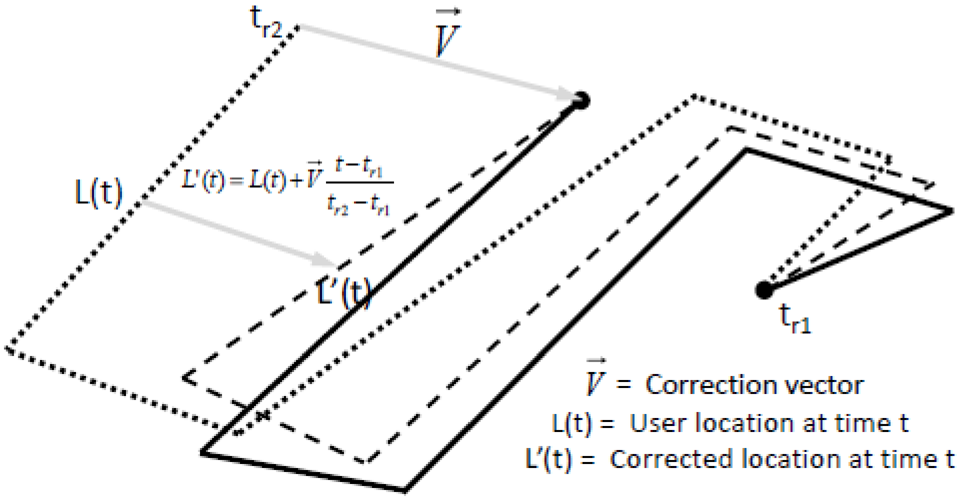
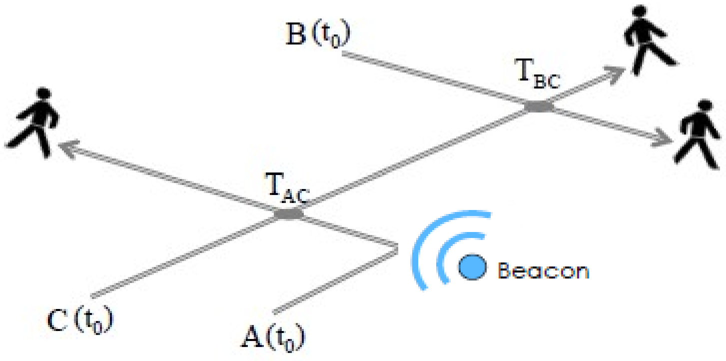


Figure 8: Drift Cancellation: the solid line is the actual user path, the dotted line represents the user computed trail, and the dashed line denotes the user trail corrected via Drift Cancellation.

Location diffusion algorithm

- The error grows in time



User with „fresher" location information bequeaths it to other users during encounters.

The beacon corrects users location, and then, they correct other encountered users' location.

Encounter detection

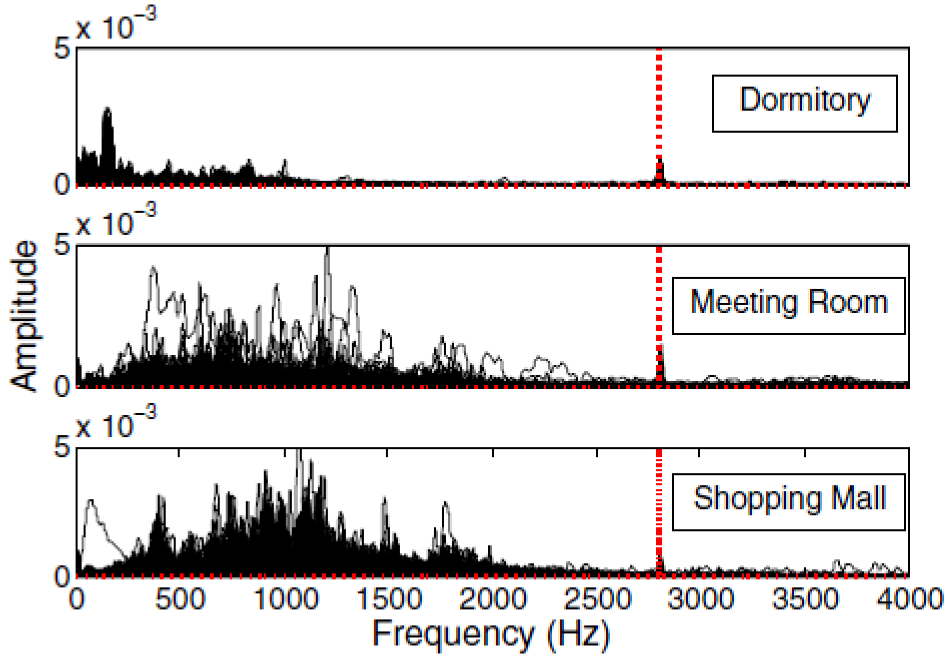


Figure 6: Tone detection in three test scenarios: (a) student dormitory, (b) meeting room, and (c) shopping mall. The red dotted line marks the tone frequency.

Server – computing directions

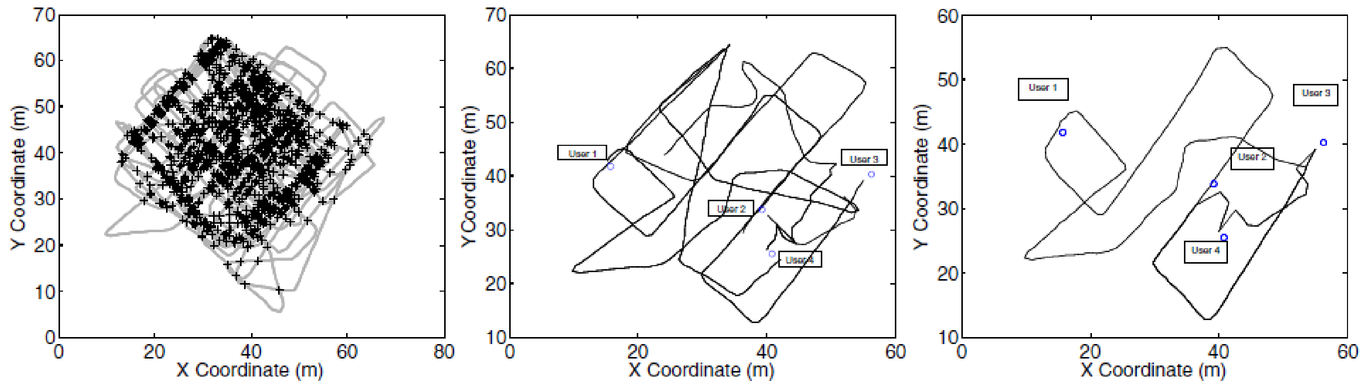
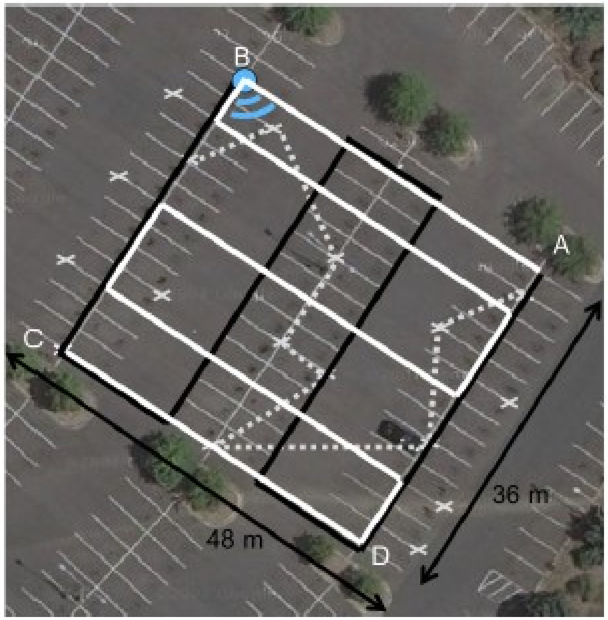


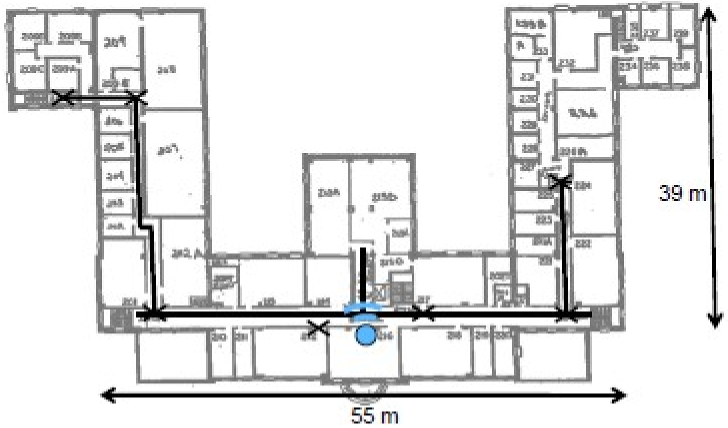
Figure 9: (a) The trail graph after tracking 4 users for 10 minutes. (b) The resulted graph after applying the pruning heuristic. (c) Running Floyd-Warshall and the graph of user paths.

1. Because of graph density server applies pruning heuristic
2. The Floyd-Warshall algorithm is applied on the output graph
3. As users move, Escort keeps adding new edges and vertices
4. Pruning algorithm is applied periodically

Testing



Parking lot



Indoor test

Test results – parking lot

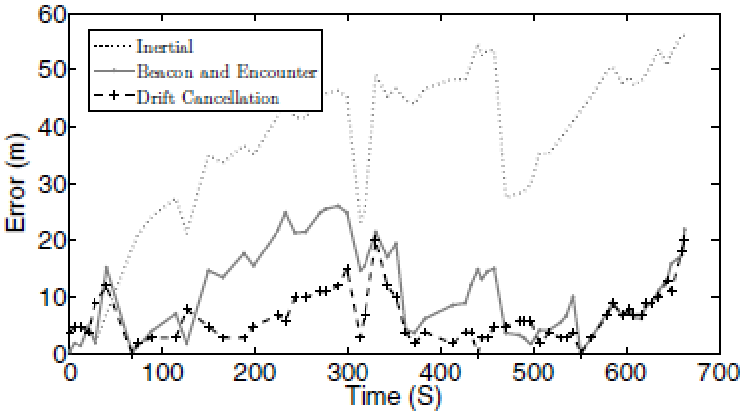


Figure 15: User 2 instantaneous error with time

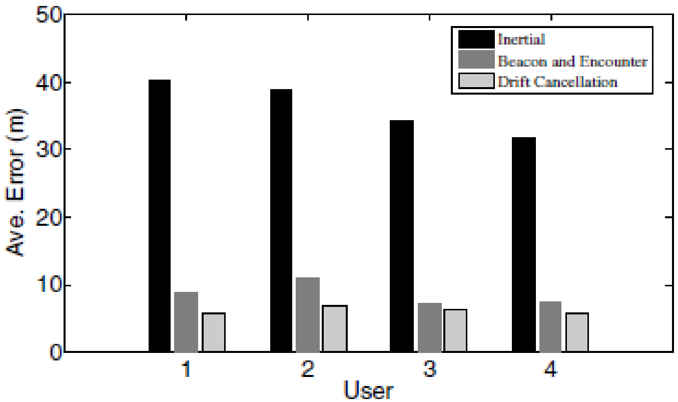


Figure 16: Average instantaneous error per user.

84% tests exhibit less than 10m error of the final distance between two users.

The average result value was 8.2m

Test results - indoor

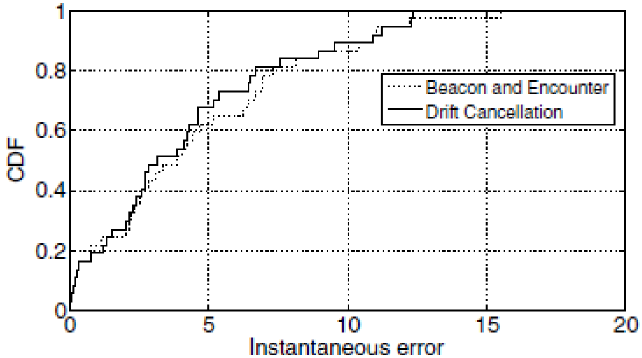


Figure 20: CDF of the instantaneous error in the indoor environment.

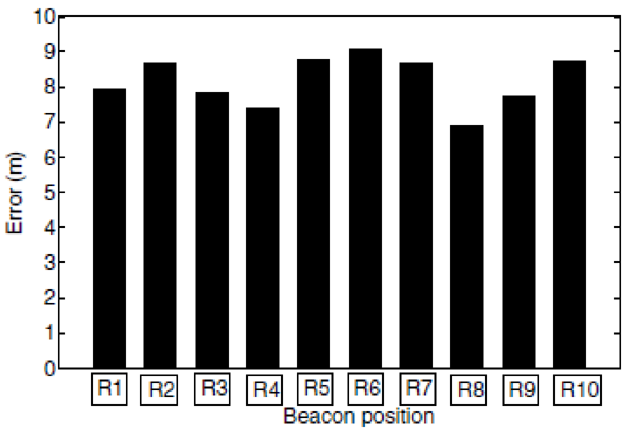


Figure 21: Average instantaneous error across all users with random placements of the beacon.

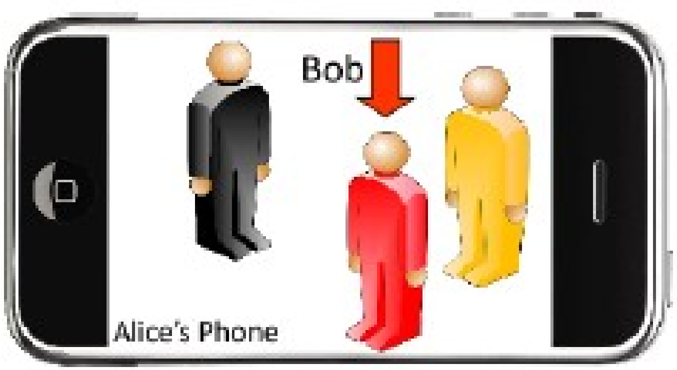
Test	1	2	3	4	5	6	7	8	9	10
Err	5.2	3.2	12	0.8	3.7	X	5.2	1.5	3.7	1

Table 1: Final-distance error in meters after routing indoors. X denotes user could not be routed.

In 80% cases error was lower than 7m.

Visual Identification of User

- Identification of the user using phone camera
- Generating user „fingerprint” using his actual photos after joining the Escort



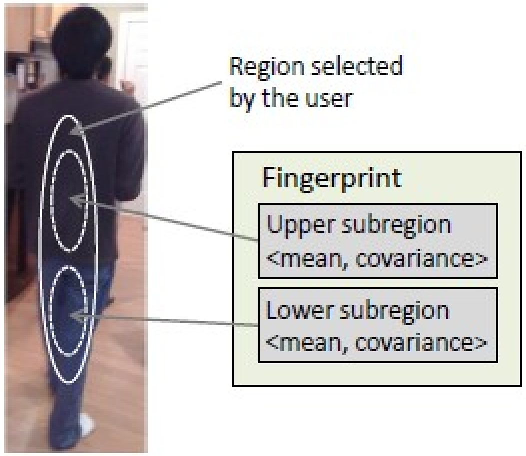


Figure 12: Generating the user fingerprint.

Visual identification test results

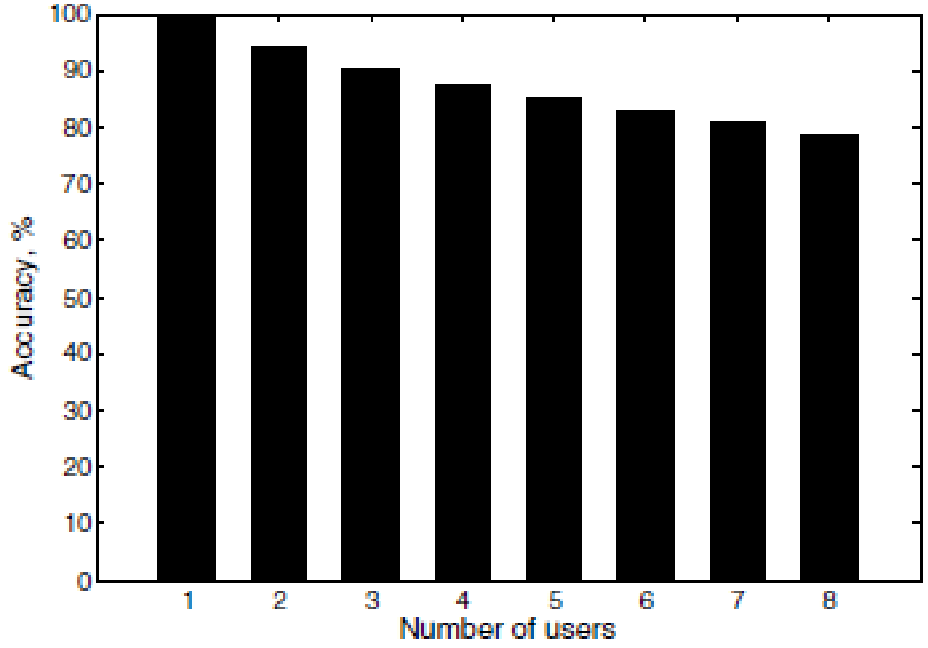


Figure 22: Accuracy of visual identification using the phone camera.

Limitations and future ideas

- Energy uptake optimalization
- Routing through physical obstacles
- Better routing paths
- Routing instructions with use of low quality data
- Phone placement
- Behavior under heavy user load

- Questions