Experiences with eNav: A Low-power Vehicular Navigation System

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Keeping Charger in Car?
Keeping Charger in Car?

- Always: 16%
- Most of the time: 20%
- Sometimes: 30%
- Very Rarely: 34%
Plug-in Phone during Navigation?

- Always: 16%
- Most of the time: 20%
- Sometimes: 36%
- Very Rarely: 28%
Energy-Efficient Navigator: Useful?
Energy-Efficient Navigator: Useful?

- 61% would use it when their battery is low.
- 30% would make it their default navigator.
- 9% would not find it useful.
- I'd make it my default navigator.
- I'd use it when my battery is low.
- I would not find it useful.
Intuition
Navigator Design Sketch
Navigator Design Sketch

- GPS - **accurate localization** only when approaching way-points
Navigator Design Sketch

- **GPS** - accurate localization only when approaching way-points

- **ACC** - roughly estimation driving progress
Navigator Design Sketch

- GPS - **accurate localization** only when approaching way-points

- ACC - **roughly estimation** driving progress

- Under-estimation results in way-point misses
Navigator Design Sketch

- **GPS** - *accurate localization* only when approaching way-points
- **ACC** - *roughly estimation* driving progress
- Under-estimation results in way-point misses
- We want *over-estimation*
missed :(
Also, In Practice...

- PCA-based driving direction extraction
- Car-turning detection
- Car-idling detection
Analyze current data frame (O1)

Car idling? (eD1)
  Yes
  Car turning? (eD2a)
    Yes
    Can localize using map? (eD2b)
      Yes
      Notify user of upcoming waypoint (O5)
      No
      Update motion and location estimations (O2)
    No
    Notify user of navigation completion (O6)
  No
  Update motion and location estimations (O2)

Actually close to next waypoint? (D4)
  Yes
  Notify user of navigation completion (O6)
  No

Deviating from route? (D3)
  Yes
  Can localize using map? (eD2b)
    Yes
    Notify user of navigation completion (O6)
    No
    Update motion and location estimations (O2)
  No
  Deviating from route? (D3)
    Yes
    Notify user of navigation completion (O6)
    No
  Final destination? (D2)
    Yes
    Notify user of navigation completion (O6)
    No

Sample GPS (O3)

Possibly close to next waypoint? (D1)
  Yes
  Notify user of upcoming waypoint (O5)
  No
  Notify user of navigation completion (O6)

START
User Study

- 33 external volunteer participants
- Various road/traffic/weather/time-of-day conditions
  - urban, rural
  - rush hour, quiet hour
  - daytime, nighttime
  - sunny, rainy, snowy
Phase I - Trace Analysis

- Participants asked to drive as they wished
- GPS+ACC traces logged by vehicle-resident phones
- 2 months total, 3 weeks per participant
- 6,000 km driving data
0 way-point misses

~78.4%
What if: simply down-sample GPS?

- Sampling period: 1s -> 83s
- Missing 83.2% waypoints!
Energy Savings Break-down
An Example Trace
Phase II - eNav Navigation

- Participants asked to drive w/ eNav for navigation
- 3 routes (with strange destinations) per participant
- 2,000 km
Energy Savings E-CDF
“It’s hard to tell the difference between your service and real GPS!”
Thanks
backups
Accelerometer?
Acc Estimation Error
ACC estimation error (m/s²)
Deviations

- User makes a turn too early
- User makes a turn too late
- User fails to make a turn and keeps driving
2 Driving Motion Detections

- Turn and Idle detections
- DecisionTree based classifiers
- ~99% accuracies for both
Orientation?
PME
GPS Energy Profiling

![Graph showing energy consumption over sampling period.](image)
Which do you think is more important for GPS navigation?

- Voice: 46%
- Screen: 25%
- Either: 29%

If battery is running low, would you be willing to rely just on voice guidance?

- Yes: 82%
- No: 18%
Phase II Screen-On e-CDF

Percentage of Trips (%) vs. Total Screen-On Time Proportion (%)