Footfall – GPS Polling Scheduler for Power Saving on Wearable Devices

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Talk Outline

• Background
• Current GPS Usage Model
• Footfall Design and Implementation
• Experiment and Evaluation
• Conclusions
Smart Wearables

- Computing device that is worn on the body
  - Smartwatch, fitness tracker, eyewear, etc.
- Growing segment of electronics market
  - 350 million devices installed by 2020

Wearable Use

• Most common use of smartwatches is fitness/activity tracking
• Fitness/activity trackers projected to make up more than 50% wearable sales in 2019
Tracking Fitness

- Accomplished with embedded sensors
  - Accelerometer, gyroscope, heartrate sensors, etc.
- Logged and later transferred to another processing/visualizing unit

Role of GPS in Wearable

• Wearables begin to include GPS in order to directly sample location information.
• Goal: Track distance traveled in real time, reconstruct traveled route for later viewing.
• Useful for both calorie tracking and training.

Weaknesses of GPS

• Accurate distance measurement is difficult
• High power consumption when enabled
Existing Applications

• Existing fitness apps request high sample rate when recording route
• Forces GPS unit into high power mode
• 30 minutes of GPS = 20% of battery capacity
Research Question

• Can we provide target features at lower power by...
  • Using existing sensors instead of GPS to accurately estimate distance traveled?
  • Reconstructing the traveled route in a more intelligent manner?
Feature #1: Distance Traveled

- Smartwatch already records step count
  - Very mature technology
- Combine with stride length to get distance
Feature #2: Route Traveled

- Can utilize map-matching algorithms (MMA’s)
- Modern MMA’s can function with very sparse data
How It Works

• Road network is edges and nodes
• Location sample compared to candidate points on underlying network
• True location is considered candidate point that most closely matches observed
Footfall Design

Temporal Component
- Await Step
- Increment Steps Count
- Evaluate Cadence
- Estimate Stride Length
- Update Distance Traveled

Spatial Component
- Movement Database

GPS Scheduler
- Evaluate Velocity
- Determine Sampling Period
- Identify Scheduling Method
- Wait Sample Period
- Sample GPS Location

Apply MMA
## Android GPS Management

- GPS power mode is managed by system
- Hardware supports 3 power modes: 
  - **navigate**, **hibernate**, and **off**

<table>
<thead>
<tr>
<th>Power Mode</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Navigate</td>
<td>Powered on, actively sampling</td>
</tr>
<tr>
<td>Hibernate</td>
<td>Powered on, not actively sampling</td>
</tr>
<tr>
<td>Off</td>
<td>Completely powered off</td>
</tr>
</tbody>
</table>
Periodic Samples, <10 Seconds

Request Location → Location Returned → Request Location → Location Returned

Enable Sampling

Data Stream Acquired

Navigate
Hibernate
Periodic Samples, ≥10 Seconds

Request Location → Location Returned → Request Location

Enable Sampling → Hibernate → Wake → Hibernate

Data Stream Acquired

Navigate

Hibernate
GPS Scheduler

- Existing scheduler is optimized for higher sampling rate
- Can update the scheduler to more efficiently utilize the time between samples

<table>
<thead>
<tr>
<th>Sample Period</th>
<th>Power Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>$T &lt; 2$</td>
<td>$G_{NAV} \times t$</td>
</tr>
<tr>
<td>$2 \leq T \leq 13$</td>
<td>$\frac{t}{T} \times {[G_{NAV} \times TTAA] + [G_{HIB} \times (T - TTAA)]}$</td>
</tr>
<tr>
<td>$T &gt; 13$</td>
<td>$\frac{t}{T} \times [G_{NAV} \times (TTFF + TTAA)]$</td>
</tr>
</tbody>
</table>
Periodic Samples, <2 Seconds

Request Location

Location Returned

Enable Sampling

Data Stream Acquired

Navigate

Hibernate
Periodic Samples, $2 \leq T \leq 13$ Seconds
Periodic Samples, >13 Seconds

- Request Location
- Enable Sampling
- Data Stream Acquired
- Navigate
- Hibernate
- Location Returned
- Request Location
- Disable
- Enable
- Data Stream Acquired

[Diagram showing the flow of operations related to location requests, sampling enablement, and data stream acquisition.]
What Does This Allow?

- Intelligently scheduling GPS power allows significant reduction in power per sample

**Graph:**

- **Original**
  - $\{G_{NAV}\}$
  - $\{G_{NAV}, G_{HIB}\}$
  - $\{G_{NAV}, G_{OFF}\}$

- **Footfall**
Footfall Design

Temporal Component
- Await Step
- Increment Steps Count
- Evaluate Cadence
- Estimate Stride Length
- Update Distance Traveled

Spatial Component
- Movement Database
- Sample GPS Location

GPS Scheduler
- Evaluate Velocity
- Determine Sampling Period
- Identify Scheduling Method
- Wait Sample Period
- Apply MMA
Experimental Evaluation

• Captured information from routes traveled on local roads by 5 users
• Varied in length, elevation, and underlying road network complexity
Accuracy vs Existing

- Distance traveled estimation remained high
- Route reconstruction proved robust to low sample rates
Power Picture
Reductions in Power

• Updated scheduler reduces power consumption by up to ~75%
• Obvious relationship demonstrated between power utilization and route accuracy
Conclusions

• Existing wearable fitness application inefficiently utilize GPS capabilities
• GPS power overhead can be greatly reduced while still providing target features
• A updated GPS scheduler can provide significant power savings at low sample rate
Thank You!