Opportunistic CrowdSensing

Nic Lane
Mobile and Sensing Systems Group (MASS)
Microsoft Research Asia (MSRA)
On-going Large-scale Opportunistic CrowdSensing Investigations in MASS

Lowering Energy Consumed by Participation

Incentivizing Users to Participate with Thomas Moscibroda

Characterizing Places (POIs)

Understanding Users and Communities

Ubicomp ‘12 Best Paper
On-going Large-scale Opportunistic CrowdSensing Investigations in MASS

Lowering Energy Consumed by Participation

Understanding Users and Communities

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collaboration

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Novel Uses of Large-scale Crowdsourced Sensor Data

Characterizing Places (POIs)

Ubicomp ‘12

Best Paper
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Lowering Energy Consumed by Participation

Eliminating Bottlenecks to Collecting Large Amounts of Data

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Ubicomp ‘12 Best Paper
Low-Energy Opportunistic CrowdSensing

Nicholas D. Lane, Yohan Chon, Lin Zhao
Yongzhe Zhang, Guandong Ding, Fan Li, Feng Zhao

Under Submission
Participation in existing Crowdsourcing Mobile Sensor System drains Smartphone Batteries
Collect GPS Traces from Traffic

Even an hour or two of participation can reduce battery life by 10+ stand-by hours or more
Opportunistic CrowdSensing (OCS)

Approach: Sense When Users Perform a Phone Task
Being Opportunistic Saves Energy

Sensing energy savings as much as 33%, 50%, 100%

![Bar chart showing energy consumption savings for Camera, Microphone, and GPS. The savings are indicated by arrows pointing downwards.](chart.png)
Opportunistic CrowdSensing Framework
External Crowdsourcing App

[ sensor type, computation, sample rate, ...]
External Crowdsourcing App

Computation and Sensor Sampling Planner

Application Utility / Cost Estimation
Application Prediction Model

Camera IMU Mic. GPS
External Crowdsourcing App

Computation and Sensor Sampling Planner

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Camera IMU Mic. GPS
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Application Utility/Cost Estimation

<table>
<thead>
<tr>
<th>Application</th>
<th>Sensor Quality</th>
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<tbody>
<tr>
<td>Camera</td>
<td>Accuracy</td>
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<td>IMU</td>
<td>Quantity etc.</td>
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<td>Mic.</td>
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External Crowdsourcing App

Application Utility/Cost Estimation

Utility \sim \text{Sensor Quality}

\[ f\left( \text{Category, App} \right) = \text{Sensor Quality} \]

Cost \sim \text{Energy Used}

\[ f\left( \text{Category, App} \right) = \text{Energy} \]
Application Utility/Cost Estimation

Utility \sim Sensor Quality

\[ f\left( App_{Category}, Crowd_{App} \right) = Sensor\ Quality \]

Cost \sim Energy Used

\[ f\left( App_{Category}, Crowd_{App} \right) = Energy \]
Application Prediction Model

$f(\text{Location }, \text{Context }, \text{Phone State}) = \text{Application App Duration}$

- Online version of Naïve Bayes Model
- Incrementally learn per-user patterns
- Operating with low-cost features
External Crowdsourcing App

Computation and Sensor Sampling Planner

Camera | IMU | Mic. | GPS

Application Utility / Cost Estimation

Application Prediction Model

Cost

Utility

Current

Time
External Crowdsourcing App

Computation and Sensor Sampling Planner

Camera  IMU  Mic.  GPS

Computation and Sensor Sampling Planner
Application Utility / Cost Estimation
Application Prediction Model

Cost
Utility

App1  App2  AppN

Time

Current Predictions

Microsoft Research
External Crowdsourcing App

Computation and Sensor Sampling Planner

\[ \max \sum r_i \mu_i \lambda_i x_i - d \cdot E[ > b | x_i] \]
\[ s.t. x_i \in \{0, 1\} \]

Camera IMU Mic. GPS

Computation and Sensor Sampling Planner

Application Utility / Cost Estimation

Application Prediction Model

Cost Utility

App1 App2 AppN

Time

Current Predictions
External Crowdsourcing App

Computation and Sensor Sampling Planner

- Camera
- IMU
- Mic.
- GPS

Application Utility / Cost Estimation

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Current Predictions
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App2

AppN

AppN+1

Microsoft Research
Evaluation
Questions Answered

1. How well can we predict application usage?
2. How much additional data can OCS collect?
   - Comparison to alternative approaches
3. If we embed OCS into an existing Crowdsourcing App - Indoor WiFi mapping - what is performance w.r.t:
   - Energy Saving
   - Impact on Accuracy

Experiment Data

Simulation (questions 1 & 2)
- App Trace of Smartphone Usage - 1320 Users Worldwide [AppJoy Project]
- Fine-grain measurements of App and Sensor energy costs

Case Study (question 3)
- 20 users - 3 weeks - MSRA building.
Low-cost Online Per-User Prediction of Application Usage
Application Prediction Accuracy Improves over Time

![Graph showing improvement in prediction accuracy over time for Top-1, Top-3, and Top-5 categories.](image-url)
OCS collects more data across various crowdsourcing scenarios

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<th>Energy Budget ( % of phone battery)</th>
<th>Periodic</th>
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**Experiment Parameters**
- Assumed Fixed Energy Budget (approx. 1 - 2 \% of daily battery life)
- Ignores Uploading Cost (assumed to occur overnight during recharge)
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**Experiment Parameters**
- Assumed Fixed Energy Budget (approx. 1 – 2 % of daily battery life)
- Ignores Unloading Cost (assumed to occur overnight during recharge)

On average OCS collects 48% more data across all tested scenarios assuming the same energy budget
OCS results in personalized Sensing Schedules

OCS maximizes the unique app-usage based opportunities to sense w.r.t to crowdsourcing needs
Case Study
Low Energy WiFi Maps for Indoor Localization

Methodology

• 13th floor of MSRA building
• Intern data collection, replicate typical mobility patterns
• Measure sensor quality and cost w.r.t the location accuracy and the default data collection application
• Prediction model trained from large-scale AppJoy dataset
• Simplified version of indoor navigation code
  • For example: No personalization
• Ground-truth: Basic corner-detection + IMU step detection during map construction
Significant energy savings with acceptable accuracy reductions
Significant energy savings with acceptable accuracy reductions
Significant energy savings with acceptable accuracy reductions
Conclusion

Low-Energy Opportunistic CrowdSensing

- **Insight**: Low-energy sensing opportunities presented by app usage
- OCS framework provides a sensing decision engine that makes the most of limited app opportunities.
- Systematic evaluation and case study (WiFi localization)

On-going Agenda examining Opportunistic Crowdsensing

- Characterizing Places (POIs)
- Understanding Users and Communities
- Lowering Energy Consumed by Participation
- Incentivizing Users to Participate