Sensing Group Behavior

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Sensing Recap (So Far)

- Publication Recipe #1: *The “Surrogate Sensing” Recipe*
  
  - *Step 1:* Find/motivate an interesting new application (monitoring some aspect of a person’s activities or context)
  
  - *Step 2:* Show that it is hard to measure/detect it using current “traditional” approaches
  
  - *Step 3:* Collect a new combination of “surrogate” measurements of the activity or context using readily available sensors (typically those sensors are not intended to measure this type of activity or context – hence “surrogate”)
  
  - *Step 4:* Evaluate the quality/speed/accuracy of identifying the desired activity or context using those measurements
  
  - *Step 5:* Identify challenges, if any (e.g., resource demands, latency, environmental diversity, need for unsupervised learning, etc.) and show how to overcome them
GruMon
The Problem Statement

“Step 1: Find/motivate an interesting new application (monitoring some aspect of a person’s activities or context)”

- What human activity/context monitoring challenge is the subject of this paper?
- How is it motivated?
GruMon

Why is the Problem Difficult?

- “Step 2: Show that it is hard to measure or detect it using current traditional approaches”
  - Why is hard to detect groups?
  - What are “traditional approaches”?
GruMon

Why is the Problem Difficult?

“Step 2: Show that it is hard to measure or detect it using current traditional approaches”

- Why is hard to detect groups?
- What are “traditional approaches”? 
What’s wrong with

- Spatio-temporal clustering?
- Bluetooth-based group detection?
- Acoustic group detection?
- Social network based group detection?
GruMon
The Solution

*Step 3: Collect a new combination of surrogate measurements of the activity or context using readily available sensors (typically those sensors are not intended to measure this type of activity or context – hence “surrogate”)*
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- Step [1]: Each GruMon client detects diverse microactivity and location features using phone-embedded sensors. The features calculated on the clients are sent to GruMon server.
- Step [2]: The server first computes similarities between each pair of GruMon clients, using cross-correlation of the time-series of the computed features.
- Step [3]: The server then passes the pairwise similarities through a supervised binary SVM classifier, which classifies each pairwise edge as positive or group edge vs. negative or non-group edge, based on a pre-trained classification model.
- Step [4]: Finally, the server runs a clustering algorithm on the positive edges returned by the binary classifier, to output sets of individual clients as groups.
GruMon
The Solution

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GruMon
Features – The Secret “Sauce”

- Location Features
- Motion Features
- Turn Features
- Level-change Features

1. Feature computation at individual nodes
2. Edge computation with cross-correlation
3. Edge filtering with binary classifier
4. Edge clustering to detect groups
GruMon
Features – The Secret “Sauce”

- Location Features: *Insight – Collocation may be coincidental; correlated transitions are a much better indicator of group behavior.*
- Motion Features
- Turn Features
- Level-change Features
GruMon
Features – The Secret “Sauce”

- Location Features
- Motion Features: *Exploit correlations in motion patterns*
- Turn Features
- Level-change Features
GruMon

Features – The Secret “Sauce”

- Location Features
- Motion Features
- Turn Features: Detect correlated change in angle, while walking only
- Level-change Features
GruMon
Features – The Secret “Sauce”

- Location Features
- Motion Features
- Turn Features
- Level-change Features:
  *Detect correlated changes in barometer reading*
GruMon
The Rest of the Algorithm

- Features converted into binary time-series
  - Different features weighted differently
- Correlations are computed between time-series and classified into two types: positive and negative
- Clusters of positively correlated nodes are computed
Evaluation

“Step 4: Evaluate the quality/speed/accuracy of identifying the desired activity or context using those measurements”
QueueVadis
The Problem Statement

“Step 1: Find/motivate an interesting new application (monitoring some aspect of a person’s activities or context)”

- What human activity/context monitoring challenge is the subject of this paper?
- How is it motivated?
QueueVadis

Why is the Problem Difficult?

“Step 2: Show that it is hard to measure or detect it using current traditional approaches”

- Why is hard to detect queues?
- What are “traditional approaches”?
QueueVadis
Why is the Problem Difficult?

“Step 2: Show that it is hard to measure or detect it using current traditional approaches”

- Why is hard to detect queues?
- What are “traditional approaches”?

[Graph showing service time for Monday, Wednesday, and Friday over 15 consecutive customers]

[Diagram showing layout of food stalls and seating, with arrows indicating the direction of queue]
Goals

- Detect queues of arbitrary shapes
- Adapt to various service times
- Disambiguate multiple nearby queues
- Work at low participation rates
- Minimize detection latency
- Offer resource efficiency
- Use no additional infrastructure
“Step 3: Collect a new combination of surrogate measurements of the activity or context using readily available sensors (typically those sensors are not intended to measure this type of activity or context – hence “surrogate”)

QueueVadis
The Solution
QueueVadis
The Solution

“Step 3: Collect a new combination of surrogate measurements of the activity or context using readily available sensors (typically those sensors are not intended to measure this type of activity or context – hence surrogate)” + “Step 4: Evaluate...”

- Use Accelerometers
- Micro-activity detection: Accelerometer features → activity label
  (MA2: static/motion; MA3: Static/Walk/Other; MA4: Static/Stepping/Walking/Other)
- High-level activity detection: Sequence of labels → queuing episodes
QueueVadis Challenges

- **Step 5:** Identify challenges, if any (e.g., resource demands, latency, environmental diversity, need for unsupervised learning, etc.) and show how to overcome them
  - No Optimal frame length
  - Termination detection
  - Early departure
QueueVadis Evaluation

Energy

Waiting time

<table>
<thead>
<tr>
<th>Ground Truth</th>
<th>100%</th>
<th>80%</th>
<th>60%</th>
<th>40%</th>
<th>20%</th>
<th>10%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean (sec)</td>
<td>25.01</td>
<td>21.81</td>
<td>21.54</td>
<td>22.02</td>
<td>22.17</td>
<td>21.24</td>
</tr>
<tr>
<td>Mean Stdev.</td>
<td>N/A</td>
<td>11.53</td>
<td>11.21</td>
<td>11.32</td>
<td>11.29</td>
<td>10.34</td>
</tr>
</tbody>
</table>

Same queue detection (MA time-series correlation)

Waiting time error statistics

Each bar represents 0th, 25th, 50th, 75th, and 100th percentiles in the distribution from the bottom to the top.
QueueVadis
Evaluation: Queue Disambiguation

<table>
<thead>
<tr>
<th>Class</th>
<th>Predicted Class</th>
<th>Accuracy (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Same Queue</td>
<td>Diff. Queue</td>
</tr>
<tr>
<td>Same Queue</td>
<td>47</td>
<td>14</td>
</tr>
<tr>
<td>Diff. Queue</td>
<td>3</td>
<td>50</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>No. of Intermed. People (K)</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Classification Accuracy</td>
<td>0.83</td>
<td>0.73</td>
<td>0.55</td>
<td>0.34</td>
<td>0.21</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Frac. of People with QueueVadis</th>
<th>100%</th>
<th>80%</th>
<th>60%</th>
<th>40%</th>
<th>20%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Classification Accuracy</td>
<td>0.78</td>
<td>0.74</td>
<td>0.71</td>
<td>0.63</td>
<td>0.60</td>
</tr>
</tbody>
</table>
Detecting Colocation (Group Activity)

- Main Idea: Silence patterns are a good “feature” for detecting co-location.
- Cosine similarity between two time-series decides if they are collocated
Detecting Colocation (Group Activity)
Implicit Group Creation Based on Matching Signatures

- Devices share their silence signature time-series.
- Central service matches the time-series to determine which devices are co-located.
- Co-located devices form groups that can be used for content sharing.
Evaluation

- The cosine similarity metric for collocated and non-collocated devices.
Evaluation

- Collocation detection latency

User 2 exits room

User 2 returns
Challenges

- Participation via telecons
- Purses, pockets, and pants
- Network delay and jitter
Homework

See class webpage.

Homework for 2/22 (in lieu of readings): The Ubicomp 2016 Exercise

- Pick a Ubicomp 2016 paper that is written according to the “Surrogate Sensing Recipe” (http://ubicomp.org/ubicomp2016/program/program.php)
- Prepare a 5-slide presentation (one presentation per group) with the following slides:
  - Slide 1: Describe the new application: What aspect of a person’s activities or context is being monitored? How is this application motivated?
  - Slide 2: Why is it hard to measure/detect it using current “traditional” approaches?
  - Slide 3: What’s the main idea? What new combination of surrogate measurements is used to monitor/detect the activity or context?
  - Slides 4-5: Identify challenges overcome in this paper, supported by evaluation results.
- Send me the title of the paper and slides by Tuesday night (PPT or PDF). Be prepared to present the paper in class on Wednesday.