Activity Recognition using Cell Phone Accelerometers

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Introduction

- Today’s mobile devices are filled with a number of sensors
  - i.e. GPS, audio sensors, light sensors, accelerometers
- These sensors open up new opportunities
  - Especially in data mining research and applications
Accelerometers

- All modern smartphones contain accelerometers
  - Specifically tri-axial accelerometers (x,y,z)
- Accelerometers are capable of detecting device orientation
- Accelerometers included in devices initially to support:
  - Advanced game play
  - Automatic screen rotation
- But there are a number of other applications for this sensor
Goal

- Create a system which uses this data to perform activity recognition
  - Using the commercially available accelerometer in smartphones
Related Work

- Accelerometer-based activity recognition is not new
- Earliest works (i.e. Bao & Intille) use multiple accelerometers
  - Used 5 bi-axial accelerometers worn by each user
  - Found that sensor on thigh was the most powerful
- Another work (Krishna et. al.) claim that multiple accelerometers necessary for activity recognition
Related Work

- Combination of accelerometers and other sensors
  - Use heart monitor data (Tapia et. al.)
  - Parkka et. al. created system using 20 different sensors
  - Combination of accelerometer, angular velocity sensor, and digital compass (Lee and Mase)
  - “eWatch” devices

- These systems are not very practical
Related Work

- **Focus of this work is on using a single accelerometer**
  - Some work has been done on that

- **Work has been done to use the smartphones**
  - Some work just used the phone as a data collector from external sensors (i.e. “MotionBands”)
  - Others have used multiple phone sensors
    - Various degrees of accuracy
    - Model is trained for a specific user, not universal
Methodology (Data Collection)

- Data collected from 29 subjects
- Phone was carried in the front pant leg pocket
  - For all activities
- Accelerometer data collected every 50ms
  - 20 samples/second
Methodology

- Raw time-series data cannot be used with classification algorithms
- Data divided into 10-second segments
  - Chose duration because it captured repetitions of motion
- Generated features based on the 200 readings in each segment
Methodology (Feature Generation)

- **Average[3]**: Average acceleration (for each axis)
- **Standard Deviation[3]**: Standard deviation (for each axis)
- **Average Absolute Difference[3]**: Average absolute difference between the value of each of the 200 readings within the ED and the mean value over those 200 values (for each axis)
- **Average Resultant Acceleration[1]**: Average of the square roots of the sum of the values of each axis squared $\sqrt{(x_i^2 + y_i^2 + z_i^2)}$ over the ED
- **Time Between Peaks[3]**: Time in milliseconds between peaks in the sinusoidal waves associated with most activities (for each axis)
- **Binned Distribution[30]**: We determine the range of values for each axis (maximum – minimum), divide this range into 10 equal sized bins, and then record what fraction of the 200 values fell within each of the bins.
Methodology (Activities)

- Six activities considered
  - Walking, jogging, ascending stairs, descending stairs, sitting, and standing
- Repetitive motions should make activities easier to identify

Figure 1: Axes of Motion Relative to User
Methodology (Activities)

(a) Walking

(b) Jogging
Methodology (Activities)

(c) Ascending Stairs

(d) Descending Stairs
Methodology (Activities)

(e) Sitting

(f) Standing
Results

- 3 classification techniques using WEKA
- Able to achieve high accuracies (>90%) for most activities
- Stair climbing activity difficult to identify

<table>
<thead>
<tr>
<th></th>
<th>J48</th>
<th>Logistic Regression</th>
<th>Multilayer Perceptron</th>
<th>Straw Man</th>
</tr>
</thead>
<tbody>
<tr>
<td>Walking</td>
<td>89.9</td>
<td>93.6</td>
<td>91.7</td>
<td>37.2</td>
</tr>
<tr>
<td>Jogging</td>
<td>96.5</td>
<td>98.0</td>
<td>98.3</td>
<td>29.2</td>
</tr>
<tr>
<td>Upstairs</td>
<td>59.3</td>
<td>27.5</td>
<td>61.5</td>
<td>12.2</td>
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<tr>
<td>Downstairs</td>
<td>55.5</td>
<td>12.3</td>
<td>44.3</td>
<td>10.0</td>
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<tr>
<td>Sitting</td>
<td>95.7</td>
<td>92.2</td>
<td>95.0</td>
<td>6.4</td>
</tr>
<tr>
<td>Standing</td>
<td>93.3</td>
<td>87.0</td>
<td>91.9</td>
<td>5.0</td>
</tr>
<tr>
<td>Overall</td>
<td>85.1</td>
<td>78.1</td>
<td><strong>91.7</strong></td>
<td>37.2</td>
</tr>
</tbody>
</table>
### Closer Look at Results

#### Table 3: Confusion Matrix for J48

<table>
<thead>
<tr>
<th>Actual Class</th>
<th>Predicted Class</th>
<th>Walk</th>
<th>Jog</th>
<th>Up</th>
<th>Down</th>
<th>Sit</th>
<th>Stand</th>
</tr>
</thead>
<tbody>
<tr>
<td>Walk</td>
<td>Walk</td>
<td>1513</td>
<td>14</td>
<td>72</td>
<td>82</td>
<td>2</td>
<td>0</td>
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<tr>
<td>Jog</td>
<td>16</td>
<td>1275</td>
<td>16</td>
<td>12</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Up</td>
<td>88</td>
<td>23</td>
<td>323</td>
<td>107</td>
<td>2</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Down</td>
<td>99</td>
<td>13</td>
<td>92</td>
<td>258</td>
<td>1</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Sit</td>
<td>4</td>
<td>0</td>
<td>2</td>
<td>3</td>
<td>270</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Stand</td>
<td>4</td>
<td>1</td>
<td>2</td>
<td>7</td>
<td>1</td>
<td>208</td>
<td></td>
</tr>
</tbody>
</table>

#### Table 4: Confusion Matrix for Logistic Regression

<table>
<thead>
<tr>
<th>Actual Class</th>
<th>Predicted Class</th>
<th>Walk</th>
<th>Jog</th>
<th>Up</th>
<th>Down</th>
<th>Sit</th>
<th>Stand</th>
</tr>
</thead>
<tbody>
<tr>
<td>Walk</td>
<td>Walk</td>
<td>1575</td>
<td>14</td>
<td>53</td>
<td>36</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Jog</td>
<td>15</td>
<td>1294</td>
<td>6</td>
<td>6</td>
<td>0</td>
<td>0</td>
<td></td>
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<tr>
<td>Up</td>
<td>277</td>
<td>36</td>
<td>150</td>
<td>77</td>
<td>1</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Down</td>
<td>259</td>
<td>6</td>
<td>136</td>
<td>57</td>
<td>3</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Sit</td>
<td>1</td>
<td>0</td>
<td>4</td>
<td>11</td>
<td>260</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>Stand</td>
<td>3</td>
<td>1</td>
<td>7</td>
<td>3</td>
<td>15</td>
<td>194</td>
<td></td>
</tr>
</tbody>
</table>

#### Table 5: Confusion Matrix for Multilayer Perceptron

<table>
<thead>
<tr>
<th>Actual Class</th>
<th>Predicted Class</th>
<th>Walk</th>
<th>Jog</th>
<th>Up</th>
<th>Down</th>
<th>Sit</th>
<th>Stand</th>
</tr>
</thead>
<tbody>
<tr>
<td>Walk</td>
<td>Walk</td>
<td>1543</td>
<td>5</td>
<td>73</td>
<td>60</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Jog</td>
<td>3</td>
<td>1299</td>
<td>16</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Up</td>
<td>84</td>
<td>24</td>
<td>335</td>
<td>98</td>
<td>2</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Down</td>
<td>108</td>
<td>10</td>
<td>136</td>
<td>206</td>
<td>2</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Sit</td>
<td>0</td>
<td>2</td>
<td>4</td>
<td>1</td>
<td>268</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>Stand</td>
<td>1</td>
<td>0</td>
<td>5</td>
<td>4</td>
<td>8</td>
<td>205</td>
<td></td>
</tr>
</tbody>
</table>
Results

- To limit confusion between ascending and descending
  - Combine both activities together
- Results are much better
  - But stair climbing is still difficult to identify

Table 6: Confusion Matrix for J48 Model (Stairs Combined)

<table>
<thead>
<tr>
<th>Actual Class</th>
<th>Predicted Class</th>
<th>Accur. (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Walk</td>
<td>1524</td>
<td>90.6</td>
</tr>
<tr>
<td>Jog</td>
<td>10 1280</td>
<td>96.9</td>
</tr>
<tr>
<td>Stairs</td>
<td>185 33 784</td>
<td>77.6</td>
</tr>
<tr>
<td>Sit</td>
<td>4 0 2 272</td>
<td>96.5</td>
</tr>
<tr>
<td>Stand</td>
<td>3 1 10 0 209</td>
<td>93.7</td>
</tr>
</tbody>
</table>
Conclusion

- Demonstrated that activity detection can be highly accurate using smartphone accelerometers
  - Most activities recognized over 90% of the time
Future Work

- Platform and data to be available to public
- Activity recognition improvements
  - Recognize bicycling and car-riding
  - Obtain more training data
  - Additional and more sophisticated features
  - Look at impact of carrying phone not in pant pocket
- Look at possibility of displaying results in real-time
References


- **J48 Classification**
  [http://monkpublic.library.illinois.edu/monkmiddleware/public/analytics/decisiontree.html](http://monkpublic.library.illinois.edu/monkmiddleware/public/analytics/decisiontree.html)

- **Logistic Regression, Wikipedia**

- **Multilayer Perceptron, Wikipedia**
QUESTIONS?