Detecting Health and Behavior Change by Analyzing Smart Home Sensor Data

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Health and Behavior Monitoring

Age, injury, or health-related impairments can impact health

Benefits of health and behavior monitoring

• Health insights
• Longitudinal tracking
• Aging in place

Preferably monitor 24/7

Objective data collection

CLINICAL STUDIES SUPPORT A RELATIONSHIP BETWEEN DAILY BEHAVIOR AND COGNITIVE AND PHYSICAL HEALTH
Technologies for Behavior Monitoring

Ambient sensors (installed in the environment)

Wearable sensors (inertial, vital sign, etc.)

Smartphone/tablet apps

SELF-PERCEPTION OF BEHAVIOR OFTEN DOES NOT ALIGN WITH DIRECT MEASUREMENT
Smart Home Environments

Ambient sensors installed in the home

- Motion, door, temperature, etc.
- Fire event when state changes

WE COLLECTED DATA FROM SMART HOMES WITH OLDER ADULT RESIDENTS

= infrared motion / light sensor

= door / temperature sensor
Activity Recognition (AR)

CASAS-AR algorithm assigns activity labels

- Machine learning
- Cook, eat/drink, relax, sleep, enter/leave home, etc.

<table>
<thead>
<tr>
<th>Timestamp/Identifier/Message</th>
<th>Sensor Location</th>
<th>Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>2014-06-15 03:38:28.094897 M009 ON</td>
<td>BedroomMotion</td>
<td>Sleep</td>
</tr>
<tr>
<td>2014-06-15 03:38:29.213955 M009 OFF</td>
<td>BedroomMotion</td>
<td>Sleep</td>
</tr>
<tr>
<td>2014-06-15 03:38:17.814393 M015 ON</td>
<td>BathroomMotion</td>
<td>Bed-Toilet</td>
</tr>
<tr>
<td>2014-06-15 03:38:58.584179 M015 OFF</td>
<td>BathroomMotion</td>
<td>Bed-Toilet</td>
</tr>
<tr>
<td>2014-06-15 03:39:17.814393 M009 ON</td>
<td>BedroomMotion</td>
<td>Sleep</td>
</tr>
</tbody>
</table>
Tracking Behavior Changes

Analyze AR-labeled data to track resident behavior

Behavior Change Detection (BCD) framework

• Input: AR-labeled data
• Output: Quantification of change
• Output: Explanation of change

Focus on indicators of health events

BCD IS A FRAMEWORK FOR INVESTIGATING BEHAVIOR CHANGE
Behavior Change Detection (BCD) Framework
BCD Framework

1. Window the data
2. Compute change score
3. Test significance of change
4. Analyze source of change
Change Detection Algorithm

A change detection algorithm
• Accepts two windows of data
• Quantifies the change
• double changeScore = computeChange($Window_i$, $Window_j$)

Different algorithms detect different change
• Virtual Classifier [Hido et al., 2008]
• RuLSIF [Liu et al, 2013]
• sw-PCAR [Sprint et al., 2016]

Focus on Virtual Classifier
Results
Case Studies

Smart home residents with health events

- **SH1**: 86 year old female
  - Diagnosed with lung cancer
  - Started radiation treatment during week 10

- **SH2**: 91 year old female
  - Diagnosed with insomnia during week 11
SH1 Health Event Results
(started radiation treatment during week 10)

BCD DETECTS SH1’s HEALTH EVENT WHEN IT OCCURS
SH1 Explanation of Change
(started radiation treatment during week 10)
SH2 Health Event Results
(diagnosed with insomnia during week 11)

BCD DETECTS
SH2’s HEALTH
EVENT BEFORE
DIAGNOSIS
SH2 Explanation of Change
(diagnosed with insomnia during week 11)

Enter Home Sensor Count $\leq 119$

- True
  - Health Event
- False
  - Baseline

Top-level decision tree rule
What’s Next?

Impact

- Relationship between health and behavior
  - Over time
- Aging in place
- Motivation toward health goals

Future Work

- Different health events
- Vital sign data
- Interface caregivers
Thank You!

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Acknowledgments
- Co-authors: Diane Cook, Shelly Fritz, Maureen Schmitter-Edgecombe
- WSU CASAS-AR algorithm: [NC Krishnan and Diane Cook, 2014]

Related Publications
Thank you

FEEDBACK? RATE AND REVIEW THE SESSION ON OUR MOBILE APP
Download the GHC 17 app at http://bit.ly/ghc17app or search GHC 2017 in the app store
Virtual Classifier

Train a binary decision tree classifier

- Extract features
- Label feature vectors in $Window_i$ as positive class
- Label features vectors in $Window_j$ as negative class
- Average K-fold cross validation accuracy

Investigate source of change

- Accuracy significant?
- Investigate decision tree

WE TRAIN DECISION TREES TO LEARN THE DIFFERENCES BETWEEN TWO WINDOWS