Context-Aware Sensing for Aging-in-Place

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in 2014, the average per-person government spending on health care for Canadians

15yr – 64yr: $2,664
65 + yr: $11,625

https://www.fraserinstitute.org
Ontario spends $791 million on ER visits or $148/visit.

Does not account for building and staffing an ER
Yet not all ER visits are Urgent

<table>
<thead>
<tr>
<th>Level</th>
<th>Acuity</th>
<th>Patient Symptoms</th>
<th>% of Emergency Dept. Visits</th>
</tr>
</thead>
</table>
| 1     | resuscitation | • cardiac and/or pulmonary arrest  
                     • major trauma (severe injury and burns)  
                     • unconscious                           | 0.6                         |
| 2     | emergent    | • chest pain with cardiac features  
                     • stroke  
                     • serious infections                      | 12.9                        |
| 3     | urgent      | • moderate abdominal pain  
                     • moderate trauma (fractures, dislocations)  
                     • moderate asthma                          | 39.0                        |
| 4     | less urgent | • constipation with mild pain  
                     • ear ache  
                     • chronic back pain                           | 39.0                        |
| 5     | non-urgent  | • medication request or dressing change  
                     • sore throat  
                     • minor trauma (sprains, minor lacerations) | 8.5                         |

Nearly half of the ER visit can be avoided by improve care and monitoring at home.
Aging-in-Place?

• US CDC: “... the ability to live in one's own home and community safely, independently, and comfortably ...”
  – Independence, community and social/support networks, cost
  – Still need to integrate with transition to institutionalized care in later phases
  – ...

Keyword: Place
• Single family detached building
• Multi-unit low rise building
• Multi-unit high rise building
• Managed living communities:
  • Long term care facilities
  • Hospitals and managed intense care facilities

Intelligent Sensors for the Smarter Home

- Non-video based physical activity tracking
- In-door localization and context aware activity analysis
- Sensors for Physiological Parameter Tracking
- Multimodality Medication compliances

http://www2.hill-rom.com/canada/SmartBeds.htm
http://images.businessweek.com/ss/09/10/1005_smart_grid_101/16.htm
### Detecting False Alarms by Analyzing Alarm-Context Information: Algorithm Development and Validation

**JMIR Med Inform 2020;8(5):e15407, doi: 10.2196/15407**

<table>
<thead>
<tr>
<th>Alarm-related issue</th>
<th>Causes</th>
<th>Consequences to the staff</th>
<th>Consequences to patient care</th>
<th>Avoidance strategies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excessive false positive alarms</td>
<td>Can be attributed to patient manipulation (ie. motion artifact), Apathy and desensitization Mistrust</td>
<td>Reduction in responding, Lack of caregiver response, Real events being less likely to be acted on</td>
<td>Suspension of alarms for a short period prior to patient manipulation</td>
<td>Statistical methods should be suitable to decrease the number of false positive alarms</td>
</tr>
<tr>
<td>Frequent insignificant or irrelevant alarms</td>
<td>Use of the default alarm settings, Poor staff education on alarm management</td>
<td>Distraction, Reduction in trust</td>
<td>Disruption of patient care, Disabling of alarm systems by staff</td>
<td>Eliminating nonessential alarms, Adjusting alarm parameters on monitors to suit patients' conditions, Staff education on alarm management</td>
</tr>
</tbody>
</table>

**Fernandes C, Miles S, Lucena CJP**

**Detecting False Alarms by Analyzing Alarm-Context Information: Algorithm Development and Validation**

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**The Apple Watch heart monitor sends too many people to the doctor**

Only a handful of people the watch flagged actually had a heart problem


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**2023-6-28**

McMaster Biophotonics
Mobility Decline

• Long term daily activity monitoring
  – Mobility and its changes over time
  – Multimorbidity and Polypharmacy: Living with multiple chronic diseases
  – In home rehabilitation
  – Dietary and nutrition monitoring
  – Cognition and mental health
  – ...

Keyword: Place

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Smart Home for Aging-in-PlacE (SHAPE)

“Half-way” between the lab and the home
- Open platform open to internal and external researchers as well as the community
- “Half-way” between the lab and the home
- Simulated experiments to optimize sensors and clinical protocols
- Industry partnership projects
- Clinical studies
- Student projects
Indoor positioning and context awareness sensing

**Situation awareness/contextual sensing**

- Combining positioning/path with activities/vital signs

**Indoor Positioning System**

<table>
<thead>
<tr>
<th>Motion and Ultrasonic Detection Analysis</th>
<th>Subject 1</th>
<th>Subject 2</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Motion Detection Testing</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of Tests</td>
<td>150</td>
<td>150</td>
<td>300</td>
</tr>
<tr>
<td>Correct Motion Detection (Presence Detected)</td>
<td>141</td>
<td>138</td>
<td>279</td>
</tr>
<tr>
<td>Incorrect Motion Detection (Presence Not Detected)</td>
<td>9</td>
<td>12</td>
<td>21</td>
</tr>
<tr>
<td>% Accuracy</td>
<td>94.00</td>
<td>92.00</td>
<td>93.00</td>
</tr>
<tr>
<td>Ultrasonic Detection Testing (2m Threshold)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of Tests</td>
<td>150</td>
<td>150</td>
<td>300</td>
</tr>
<tr>
<td>Correct Ultrasonic Detection (Within Threshold)</td>
<td>126</td>
<td>110</td>
<td>236</td>
</tr>
<tr>
<td>Correct Ultrasonic Detection (Not Within Threshold)</td>
<td>24</td>
<td>40</td>
<td>64</td>
</tr>
<tr>
<td>% Accuracy</td>
<td>84.00</td>
<td>73.33</td>
<td>78.67</td>
</tr>
</tbody>
</table>
IPS Study 2021-2023

- Study by the #:
  - 20 homes, 23 participants,
  - 65-80yr, healthy

- Parameters measured
  - Hub/Beacon: BLE Name & RSSI; Humidity, temperature, Light level, proximity (NIR), ultrasonic distance,
  - acceleration, gyroscope, step count, heartrate, state analysis

McMaster Biophotonics
A simple dietary tracking application for users with digestive diseases and eating disorders.

Mobile Application
- Bluetooth to smartphone pairing
- Position capturing

Software
- App development
- Machine learning
- Design and Testing

Help physicians monitor patient nutrition intake

Eng Phys
- Sensors
- Monitoring Devices
- Statistics
At Home Rehabilitation Training

Neuromuscular Exercise (NEMEX)

Core Stability
Alignment of Joints
Leg Strength
Functional Exercise

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Smart Medication Compliance

Camera

Concave Mirror

Pillbox

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Smart Toilet

Smart Toilets: Doctors in Your Bathroom

BY AARON SAENZ ON MAY 12, 2009 | LONGEVITY

Diode Laser (450 nm)

Objective Lens

Optical Detector

Emission Filter

PDMS Water Channel Cap

Emission Light (650 nm)

θ

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d

d

Diode Laser

Objective Lens

Optical Detector

Emission Filter

PDMS Water Channel Cap

Emission Light (650 nm)

θ

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d

Holographic opto-fluidic microscopy

Waleh Biharsy,1 Hongyi Zhu,1 and Aydogan Ozcan1,2

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McMaster Biophotonics
Lessons Learned

• Sensing modalities and clinical relevance:
  – Motions are easy to measure
  – Activities are hard to determine
  – Glucose, sweat, saliva, pressure/weight
  – Feeling, pain

• Analytics
  – Edge computing, battery issues
  – Longitudinal data
  – Personalized Machine Learning

• Data security and privacy
  – Patient owned data
  – How about processed data?

• Cost?
  – Equipment purchase, Installation, Operation

• Equity, Diversity, and Inclusive

• Regulatory Issues: Health Canada, FDA, EMA

Physical Resilience: A novel approach for healthy aging, Chan et al., 2021, Journal of Frailty Sarcopenia and Falls 07(01)
http://dx.doi.org/10.22540/JFSF-07-029
Additional thoughts

• What is “Smart” or “intelligent”?
  – Smart means capability of decision making beyond a static decision tree;
  – Ideally, in new situations
  – We are only at the sensing level
  – Will AI/ML take us there?
  – Regulatory approval is far

• Design for 60+yr old
  – Not limited to rehab scenarios
  – Workplaces
Acknowledgement

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  - Prof. Jamal Deen
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  - Dr. Henry Siu