ISSUES IN IMPLANTABLE VS INSERTABLE BIOSENSORS

Robin A. Felder, PhD
The University of Virginia
Department of Pathology
Motivation for Biosensors as a Tool in the Pursuit of Wellness

- State of complete physical, mental and social well-being
- Health results from primarily positive perspectives and choices by which to live
- Diagnostics can provide information that facilitates positive choices

© Felder, 2011

Wellness Balance

Physical

Social

Cognitive

6.2

9.1

8.0
Wellness Support

- Growing need for new sources of data, and data interpretation
- Integration of multiple diagnostic sources (lifestyle, self testing, doctor’s office testing)
- Integrated wellness and health record
- Ongoing information support for maintaining healthy lifestyles
Diagnostic Wellness Technologies

- Biomarkers
- Nutrition
- Exercise
- Biometrics
- Pain
- Stress
- Sleep
- Mood
Wellness Support

- Food coaching
- Rewards
  - Exercise
  - Nutrition
  - Therapeutic compliance
- Consequence reporting
- Consequence forecasting

Overcome vicarious goal fulfillment or, “exhaustion of self-control”
Home Health IT

- New revenue sources: Medical Cloud coaching and Interpretations

Technologies will be needed to measure the spectrum of health

Wellness → Disease
Wellness Tools

- Accelerometer based
- Various models for data delivery
- Basic physiologic measurements

Information Week
Implantable Continuous Glucose Monitoring

Dexcom
Challenges With Implantable Sensors

- Negative tissue response
- Poor sensor temporal responses
- Sensor fouling
- Implantation trauma
- Implantation infections
- Aesthetics
Portable Diagnostics

- iPhone based portable ultrasound
- EKG
- Otoscope
- Dermatoscope
- Microscope
Cell Scope™

- Dermatoscope – iPhone clip-on
  - Transmits high quality magnified pictures of skin blemishes
- “Smart Otoscope” – iPhone ear drum microscope
  - Transmits pictures of videos of the ear canal and ear drum
  - Looks at progression or regression of disease
Otoscope Images

Normal Ear Drum  Ear Infection  Ruptured ear drum
Cloud Based Diagnosis of Parkinson's

- Non-invasive phone based
- Accurate (98%)
- Remote, non-expert
- Low Cost
- Rapid diagnosis
- Scalable to large populations

Max Little - Parkinson’s Voice Initiative
TED Conference 2012
Wearable Cancer Detection

- First Warning Systems™ heat distribution sensing sports bra
iPhone Body Fluid Diagnostics

- Biosense Technologies
  - uCheck

- ToucHb
KNOWS
You and what is around you

LEARNS
What you like

DISCOVERS
Things relevant to you

FILTERS
Out the irrelevant

SENSING
Local content & services discovery

SEEING
Augmented reality UI: Map, 3D, in building navigation

INTERACTING
Connection manager (WAN, Wi-Fi)

Source: Jarrin (Qualcomm)
<table>
<thead>
<tr>
<th>KNOWS</th>
<th>LEARNS</th>
<th>DISCOVERS</th>
<th>FILTERS</th>
</tr>
</thead>
<tbody>
<tr>
<td>You and what is around you</td>
<td>What you like</td>
<td>Things relevant to you</td>
<td>Out the irrelevant</td>
</tr>
</tbody>
</table>

**SENSING**  
Wellness, Local content & services discovery

**SEEING**  
Augmented reality UI: Map, 3D, in building navigation

**INTERACTING**  
Connection manager (WAN, Wi-Fi)

Source: Jarrin (Qualcomm)
The Passive In-Home Health Monitoring Project

- Create a model where the impact of chronic disease is delayed or avoided
- Provide opportunity for medical intervention before a crisis occurs
- Minimize impact of chronic disease on the healthcare system
- Develop a platform on which passive biosensor technologies may be deployed
Passive Remote Sensing

- Wireless Sensor Array (WSA) – gathers data on daily activities and physiology
- Data Manager (DM) – transmits data to data analysis servers
- Capture Analysis & Reporting Engine (CARE) – captures potential problems and alerts caregiver
Passive Proximity and Gait Sensors

Proximity and vibration sensors placed in the house detect occupant gait and location.
Passive Proximity and Gait Sensors

Pulse and breathing sensors embedded in chairs and beds
Passive Vital Sign Bed Monitor

Mattress pad to measure:
- Sleep quality
- Pulse (and HRV)
- Breathing
- Movement/restlessness
- Bed exit
- Subject position/turning
- Body temperature
- Blood Pressure
Sleep Quality Graphs

Restless Resident

Restful Resident

Graphs showing the number of motion sensor firings over time for Restless and Restful Residents.
Automated Triage

- Real time assessment of participant health status/well being
- Ability to drill down to specifics
- Built in automated optimized dispatching
- Manual override of dispatch event or downstream processes
## Resident Management Overview

**Total Residents:** 52

### 6/18/2009

<table>
<thead>
<tr>
<th>Name</th>
<th>Care Level</th>
<th>Location</th>
<th>Site ID</th>
</tr>
</thead>
<tbody>
<tr>
<td>Laverne Elwood</td>
<td>AL</td>
<td>Deweese, NE</td>
<td>DW2598</td>
</tr>
<tr>
<td>Humphry Curtis</td>
<td>AL</td>
<td>Rochester, MN</td>
<td>WCST1111</td>
</tr>
<tr>
<td>Karen Cierra</td>
<td>NC</td>
<td>Oakbark, MN</td>
<td>THAO1217</td>
</tr>
<tr>
<td>Xavier Gord</td>
<td>NC</td>
<td>Rochester, MN</td>
<td>THAO2854</td>
</tr>
<tr>
<td>Ada Thomson</td>
<td>NC</td>
<td>Rochester, MN</td>
<td>WCST1235</td>
</tr>
<tr>
<td>Phoebe Myrtle</td>
<td>AL</td>
<td>Deweese, NE</td>
<td>DW7632</td>
</tr>
<tr>
<td>Elizabeth Burwell</td>
<td>AL</td>
<td>Deweese, NE</td>
<td>DW3493</td>
</tr>
<tr>
<td>Ina Starkie</td>
<td>NC</td>
<td>Oakbark, MN</td>
<td>THAO2456</td>
</tr>
<tr>
<td>Beatrice Parker</td>
<td>NC</td>
<td>Oakbark, MN</td>
<td>THAM317</td>
</tr>
<tr>
<td>Melba Bryce</td>
<td>HH</td>
<td>Charlottesville, VA</td>
<td>WATS1342</td>
</tr>
<tr>
<td>Sue Nadab</td>
<td>AL</td>
<td>Deweese, NE</td>
<td>DW5478</td>
</tr>
</tbody>
</table>

### Care Level Legend
- **Impacts**
- **Stove**
- **Sleep**
- **Bathroom**
- **Shower**
- **Medicine**
- **Movement**
- **Socialization**

**Search**

**Narrow Results**

**View All**
One Click Trending

- Health
- Socialization
- System utilization
Telehome Monitoring Decreases Costs by 74%

Overall Cost of Care Comparison

Unmonitored: $67,757.88
Monitored: $17,407.02

N=21 in each group, P<0.05;
Passive Wellness Monitoring

- Body temperature
- Pulse
- Blood Pressure
- Body fat percentage

Vital Sensor

Urine protein
Urine glucose

Urine analyzer

Healthcare providers

Data management PC

Network
Passive Automated Pharmaceuticals

- iPill (Philips) Networked pills (Proteus Biomedical)
  - Instrumented Pills
  - Cost < $0.01
  - Measure and send physiologic signals through body electrically
  - Receiver is a patch worn on the body that also logs respiration, heart rate and body movement, sleep patterns
The Eye as the Window to Health

UCSD

Preventive Science Inc.

Univ. of MD, Baltimore
MeyeChem, LLC: Lachrylmal Canaliculus Tear Based Chemistry Lab

- Measures tear chemistry continuously
- Reports values to cell phone
Manufacturing Process
Amperometric detection of 20-200 μM glucose using a 1232A CH Instruments Electrochemical Analyzer, then filtering the data to smooth out the noise using an 8th ordered Low Pass Filter with the MATLAB software.
Long Term Stability of Glucose Measurements

![Graph showing the current ratio output (i/i₀) over day number. The graph indicates a decreasing trend in the ratio output as the day number increases.]
MeyeChem, LLC

- Real time glucose monitoring
- Alerts for low or high glucose concentrations
- Trend analysis and prediction
- Food coaching via tele-nutritional-mentoring
Summary

- Ubiquitous computing will enable portable health
- Sensors will be inserted, implanted, worn, and passive
- Interpretation will be automated
- Motivation for wellness will be self directed or coached by a wide variety of providers
Medical Automation.org

A non-profit educational organization improving healthcare quality and efficiency through teaching automation principles and their application in health systems

http://medicalautomation.org
TagLine - BioMedical reality

http://medicalautomation.org