Personalizing Healthcare through Wearable IoT

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Who am I?

• Nik Dutt
  – Grew up in India & Japan; in USA since 1981
  – PhD in CS from Illinois in 1989
  – UCI faculty since 1989
  – Currently Distinguished Professor of CS, Cognitive Sciences & EECS

• Research Interests
  – Embedded Computer Systems: software and hardware
  – Healthcare IoT
  – Brain-inspired Computing

• Teaching
  – Ugrad: mainly digital design, embedded systems, architecture
  – Grad: advanced research topics in these areas
Dutt Research Group: Who are we?

https://duttgroup.ics.uci.edu/

Team

− Grad & Undergrad Students
  • Bryan Donyanavard, Roger Hsieh, Kasra Moazzemi, Hamid Nejatollahi, Biswadip Maity, Sina Labbaf, Emad Kasaeyan, Delaram Amiri, Saehanseul Yi, Caio Batista, Michael Lee, Hee-Jeong Han, Ajan Subramanian

− Visiting Faculty
  • Prof. Amir Rahmani (TU Vienna, Austria & Turku, Finland)
  • Prof. Sung-Soo Lim (Kookmin University, Korea)

− Visiting Researchers
  • Luis Freire (Monterrey Tec, Mexico)
  • Arman Anzanpour (Univ Turku, Finland)
What is IoT?

• A network of physical “things” empowered by:
  - **Sensors**: to collect information
  - **Identifiers**: to identify the source of data (e.g., sensors and devices)
  - **Software**: to analyze data
  - **Internet connectivity**: to communicate and notify

Interested? take CS 147: IoT Software and Systems
THE IOT “THING” CONNECTED TO THE INTERNET

Forecasts by Cisco Systems
PEOPLE CONNECTING TO THINGS
THINGS CONNECTING TO THINGS

- Complex and heterogeneous resources and networks
MANY EMERGING MARKETS

Wearable Tech

Healthcare

Smart Appliances

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Internet of Things in Healthcare

- **IoT and wearable technologies:**
  - Continuously track patients
  - Personalization
  - Predict health status
  - Self-management
  - Prevention & Smart intervention

- The IoT paradigm holds significant promises in healthcare domain.
  - access to care
  - personalized to individual’s profile
  - reduce healthcare costs
IoT in Healthcare Market

Global IoT in healthcare market size $98.4B in 2016!

Quality of Experience Management

- IoT-based health monitoring applications need to provide a high level of quality attributes.
Emerging Concepts

- We leverage two concepts to achieve high quality attributes during health monitoring:
  - Fog/Edge computing
  - Computational self-awareness
IoT-based Early Warning Score
Everyday Settings

IoCT-CARE: Internet of Cognitive Things for Personalized Healthcare, jointly funded by Academy of Finland, TEKES, and National Science Foundation (NSF) 04/2017-03/2019
Early Warning Score (EWS)

- **Early Warning Score** is a method to detect the deterioration of a patient’s condition
  - 24 hours prior to serious impacts
- Currently done **manually in clinical settings**

### Early Warning Score Parameters

<table>
<thead>
<tr>
<th>Physiological parameters</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Respiration rate</td>
<td>≤8</td>
<td>9-10</td>
<td>12-20</td>
<td>21-24</td>
<td>≥25</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oxygen saturation</td>
<td>≤91</td>
<td>92-93</td>
<td>94-95</td>
<td>≥96</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Any supplemental oxygen</td>
<td>Yes</td>
<td>No</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Temperature</td>
<td>≤35.0</td>
<td>35.1-36.0</td>
<td>36.1-38.0</td>
<td>38.1-39.0</td>
<td>≥39.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Systolic BP</td>
<td>≤90</td>
<td>91-100</td>
<td>101-110</td>
<td>111-219</td>
<td>≥220</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heart rate</td>
<td>≤40</td>
<td>41-50</td>
<td>51-90</td>
<td>91-110</td>
<td>111-130</td>
<td>≥131</td>
<td></td>
</tr>
<tr>
<td>Level of consciousness</td>
<td>≤40</td>
<td>41-50</td>
<td>51-90</td>
<td>91-110</td>
<td>111-130</td>
<td>V.P or U</td>
<td></td>
</tr>
</tbody>
</table>
IoT-based In-Home EWS System

Cloud Server: EWS Control Panel

Smart Pain Assessment Tool Based on IoT

**PASI**: Personalized Pain Assessment System based on IoT, A. Rahmani, ICT 2023 programme jointly funded by *Academy of Finland* and TEKES, UTU Dept. of Future Technologies and Dept. of Nursing Science *Consortium 01/2018-12/2019*

**SPA**: Smart Pain Assessment Tool Based on Internet-of-Things, A. Rahmani, ICT 2023 programme jointly funded by Academy of Finland and TEKES, UTU Dept. of Future Technologies and Dept. of Nursing Science *Consortium 01/2015-12/2016*
Pain Assessment

• Assessment of pain is difficult when the **ability** of the patient to **communicate** is limited.
  – during critical illness
  – under sedation
  – under anesthesia
  – for infant

• Pain is a highly **subjective** experience
Pain Reflectors

- The activity of **facial muscles** is under control of the **facial nerve**.
- The amplitude of frontal muscle activity during **sedation** and **anesthesia** reflects
  - increases during painful stimuli
- Some **physiological** signs can also reflect **autonomic nervous system** activity
Smart pain assessment tool based on IoT

- **To provide an automatic multi-modal tool to detect and assess pain:**
  - **Behavioral**
    - Facial muscle activity (sEMG)
  - **Physiological**
    - Heart rate
    - Heart rate variability
    - Electrodermal activity
    - Breathing rate
Wearable Mask

Transparent polydimethylsiloxane (PDMS) material


First Pain-related Bio-signal Acquisition device

Dashboard and Cloud Connectivity
Ongoing Trials

- Parallel trials in **Finland** (TYKS) and the **US** (UCIMC)

- Elective **surgical patients**
  - requiring **recovery room care** treatment after surgery
  - requiring **general anesthesia**
Family Centered Monitoring in Maternity Care
Preterm Birth Prevention in Everyday Settings

• We aim to create a ubiquitous monitoring, early detection, and prevention system for mothers at the risk of preterm birth to be used in their everyday settings.
UNITE: Smart, Connected, and Coordinated Maternal Care for Underserved Communities

NSF Smart and Connected Communities project
$2.1M for 4 years

Objective is to develop IoT-based Personalized Monitoring and Recommendation System
To support and enhance self-management of mothers in the MOMS OC community
To expand community outreach
Key Takeaway 1: Internet of Things in Healthcare

- **IoT and wearable technologies:**
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  - Predict health status
  - Self-management
  - Prevention & Smart intervention

- The IoT paradigm **holds significant promises** in **healthcare** domain.
  - access to care
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  - reduce healthcare costs
Key Take-away 2: Quality of Experience Management

- IoT-based health monitoring applications need to provide a high level of quality attributes.

- Need a cognitive architecture to support intelligent IoT
Questions?

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