Personalized e-Health: Status and Challenges


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June 15, 2011
Outline

- Healthcare – A Global Challenge
- Global Healthcare Trend
- eHealth Development Stages
- Personalized eHealth Solution Framework  
  - Medical Sensing & Measurements  
  - Data Aggregation & Computation  
  - Medical Situation Awareness & Analysis
- Health Cloud Services
- NIH Priority eHealth R&D Topics
- Summary - Challenges & Opportunities
- References
Healthcare – A Global Socio-Economic Challenge

- Healthcare is a socio-economic challenge around the world
  - US alone spent about US$2.5 Trillion in 2010 (17% of GDP) with an average increasing rate of 6-8%
  - Population aging (65+) is becoming a global demographic phenomena
    - US (19.6% in 2030), Europe (~40% in 2050), Japan (36% in 2050), China (10% in 2006 to >28% by 2040)
    - Healthcare cost per capita (aged >65 years) = 3~5 x Healthcare cost per capita (aged <65 years) (USA and other developed countries)

- Healthcare system inefficiency* is identified as one major factor of healthcare cost excess:
  - Behavioral where individual behaviors are shown to lead to health problems, and have potential opportunities for earlier, non-medical interventions
  - Clinical where medical care itself is considered inappropriate, entailing overuse, misuse or under-use of particular interventions, missed opportunities for earlier interventions, and overt errors leading to quality problems for the patient, plus cost and rework
  - Operational where administrative or other business processes appear to add costs without creating value

Global Healthcare Trend

Global Healthcare Trend -> Personalized Healthcare

As-Is
- Treatment focus
- Patient’s coaching focus on obey of medical care practice and medicine use

To-Be
- Through prevention-oriented life style changes to facilitate recovery or avoid medical condition worsen
- Patient’s coaching focus on assisting patient’s life style changes and self-care

Tailored Personalized Healthcare

Treatment → Prevention

Sub-Acute Care

At-Risk

An estimated 70% of Chronic Disease is the result of “life style choices”*


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Personalized e-Health

- Personalized eHealth is being supported by major world governments as a way to reduce costs and improve medical quality
  - Personalized healthcare moves traditional treatment-centric disease management toward prevention through lifestyle changes
    - A partnership-oriented model emphasizing the systematic use of information about an individual patient to select or optimize that patient's preventative and therapeutic care (Wiki)
    - Consumer-empowerment and information-rich “Smart Healthcare” (US DHHS)
  - eHealth provides ubiquitous and reliable support and access of healthcare management
eHealth Development Stages

Health Information Exchange

Communication & Information Access

Lifestyle infrastructure

Life Assistance

Personalization of Healthcare

Behavior Assistance & Disease Management

- Domain Knowledge
- Personalized Profile
- Risk Classification, Root Cause Analysis and Triggering
- Behavior Monitoring & Coaching

Health Information Exchange

Health Carers-assisted eHealth (Tele-Care)

- Remote Monitoring

Knowledge-based Personalized eHealth (Smart Healthcare)

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Personalized eHealth End-to-End Solution Framework
(Context-Aware Monitoring, Coaching & Clinical Decision Support)

(Personalized Medical Context)

(BioTech Context)
Context-aware Medical Sensing, Measurement

ICT Context)
Context-aware Data Aggregation & Information Management

Knowledge-based Personalized Medical Situation-Awareness & Decision Support

Healthcare Team Performing Diagnosis, Consultation, & Treatments

Telehealthcare (Monitoring)
Knowledge-based Personalized eHealth (Context-Aware Monitoring, Coaching & Clinical Decision Support)

<OUTCOMES>

** Operations: Cloud or Non-Cloud
5R - “Right Data sent to Right Person at Right Time in Right Form at Right Cost”

**Get and Exchange**

- **Provider asks if there are records for his/her patient**
- **Responds with location of any records of interest**

**FIND**

- **Publishing Application registers indexes of patient records**

**Record Locator Service**

**SEND**

- **Application asks for and receives records**
- **Requested Records are sent**
- **Publishing Application may push report-specific data**

**Information Transfer**

**End-Point Systems**

- **Provider Applications**
- **Health Data Aggregator**

**End-Point System Publishing Applications & Repository**

**End-Point Systems**

- **Provider Applications**
- **Health Data Aggregator**

**National Health Information Network (NHIN)**

**End-Point System Reporting Router**

**Public Health**

- **De-Identified Data**

**Public Health Authorities**

- **Research**

**De-Identified Data**

- **Alerts**
- **Reports**

**Source:** The Markle Foundation 2004.
Ten Core Services – National Health Information Network (NHIN) (USA)

Current Tele-Care System Configuration for Remote Home-based Monitoring

Front-End System

At-Risk/illPatient

Internet/3G

Backend System

Case Manager

Physician

Hospital Tele-Care System

Hospital HIS

HIS: Health Information System
A Typical Personal Health Ecosystem (Continua)

Personalized Tele-Care System Configuration

Personalization:
- Personalized Clinical Decision Support System (P-CDSS)
- Personalized Context-Aware Coaching System
Sensing and Measuring System Evolution

- Intelligent physiological sensors
- Low power IC
- Advanced wireless communications

Medical Body Area Network (MBAN) - A number of intelligent physiological sensors being integrated into a wearable wireless body area network, which can be used for computer assisted rehabilitation or early detection of medical conditions through measuring changes of co-related vital signs (e.g., pulse, cardiac and stress sensors)
  - Passive continuous monitoring
  - Active selected monitoring

Standards: IEEE 802.15.4 (extend IEEE802.15.6 (BAN) to MBAN)
Context-Aware/Driven Monitoring

- Combine on-board event correlation on the mobile device along with context from cloud to determine “activity state” of patient and use as a trigger for monitoring.

- Use a combination of
  - **Cloud** context (sentiment analysis, semantic location tracking)
  - **Cell phone** context (e.g., GPS, noise level of phone)
  - **Body-wearable** sensors (e.g., ECG, GSR, accelerometer)

- Provide **low-overhead context capture** through transmission of model-based storage of processing graphs and operator state.
  - Enable the storage of metadata that describes why and how the process of monitoring was affected by user’s activity, environmental conditions etc.

*Source: A. Misra, 1st AMA-IEEE Medical Technology Conference, March 2010*
Medical Guideline Database

Symptom Information

Personalized Risk Assessment & Management Report

Personalized Healthcare & Self-care Plan

Sub-Acute Patient Alert Reminder

Case Manager

Sub-Acute Patient

Smart u-Pad

CDSS

- Risk Classification
- Root Cause Analysis
- Risk Continuum Trigger Prediction
- Alerts & Actionable Recommendations

EMR: Electronic Medical Record
PHR: Personal Health Record

Fact Memory

Rule/Inference Engine

Pattern Matcher

Alert Reminder

Physician

Vital-Sign Measurement

Sensor & personal Profile Data Retrieval

EMR Database

Medical Guideline Database

Life Style Choices for Each Disease

Personalized Risk Assessment & Management Report

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# Heart Failure Symptom-Cause-Effect-Type Diagram

## (An Example of CDSS Design Complexity)

<table>
<thead>
<tr>
<th>Heart Failure Symptoms (Bio-signals)</th>
<th>Effects</th>
<th>Causes</th>
<th>Heart Failure Types</th>
<th>Lifestyle Choices</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fatigue</strong></td>
<td></td>
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<tr>
<td><strong>Shortness of breath</strong></td>
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<tr>
<td><strong>Heartbeat Speed up</strong></td>
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<tr>
<td><strong>Chest congestion</strong></td>
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<tr>
<td><strong>Edema or ankle swelling</strong></td>
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<tr>
<td><strong>Dizziness &amp; Unconscious</strong></td>
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<tr>
<td><strong>Cold Hands and Feet</strong></td>
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<tr>
<td><strong>Weight gain</strong> (Increase in the number of KGs within a few days)</td>
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<tr>
<td><strong>Anorexia, nausea</strong></td>
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<tr>
<td><strong>Confusion, Decreased ability to think</strong></td>
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<tr>
<td><strong>Varix of the neck</strong></td>
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<tr>
<td><strong>3rd heart sound is palpable</strong></td>
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<td></td>
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<tr>
<td><strong>Coughing or wheezing</strong></td>
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<tr>
<td><strong>Hepatomegaly</strong></td>
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<tr>
<td><strong>Decreased urination</strong></td>
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<tr>
<td><strong>Weakness or fainting</strong></td>
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<td></td>
<td></td>
</tr>
<tr>
<td><strong>Unexplained upper abdominal pain or indigestion</strong></td>
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</tbody>
</table>

### Physical effects

1. Enlarged heart, ejection fraction output less than the baseline
2. Sympathetic nervous system activation
3. Renin-angiotensin-aldosterone (RAAS)
4. Other complications

### Mental effects

1. Anxiety
2. Insomnia

### Causes

- **Caused by cardiac ischemia, such as:**
  - Myocardial infarction
- **Caused by congenital diseases, acute inflammation, or Toxin invasion, such as:**
  - Enlarged heart, Myocardial inflammation, heart toxin (Alcohol, chemotherapy drugs, urea).
- **Caused by pressure overload, such as:**
  - Hypertension or aortic stenosis
- **Caused by Excessive volume loading, such as:**
  - Congenital heart disease, Valve regurgitation
- **Caused by Metabolic abnormalities, such as:**
  - Hyperthyroidism, siderosis
- **Caused by Serious arrhythmia, such as:**
  - Bradycardia or tachycardia

### Heart Failure Types

- **Class I (Mild)**
  - No limitation of physical activity. Ordinary physical activity does not cause undue fatigue, palpitation, or dyspnea (shortness of breath).
- **Class II (Moderate)**
  - Slight limitation of physical activity. Comfortable at rest, but ordinary physical activity results in fatigue, palpitation, or dyspnea.
- **Class III (Critical)**
  - Marked limitation of physical activity. Comfortable at rest, but less than ordinary activity causes fatigue, palpitation, or dyspnea.
- **Class IV (Severe)**
  - Unable to carry out any physical activity without discomfort. Symptoms of cardiac insufficiency at rest. If any physical activity is undertaken, discomfort is increased.

### Lifestyle Choices

- **Smoking**
- **Obesity**
- **Excessive caffeine consumption**
- **Long-term high-fat and salty food consumption**
- **Lack of exercise**
- **Stressful life**
- **Excessive drinking**
- **Don’t control the weight**
- **Lifestyle is bad & stay up late**
- **Bad air environment**

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Source: New York Heart Association & http://www.heartdisease.idv.tw/

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Critical Issues to be Addressed (CDSS)

- Medical terminologies used to diagnosis and knowledge share among healthcarers depend on education, training and experiences
  - How to design a knowledge-based terminology service that translates clinical knowledge into a form easier for decision making and clinical practice recommendations among healthcarers
- Data for mining, analysis and trending are usually dynamic and incomplete
  - Design and modeling for data fusion and mining to extract a set of relevant attributes from context information to build association meaningful for medical event analysis
  - Modeling and algorithms for correlating complex and dynamic system parameters for risk/disease root cause analysis; and trending risk continuum pattern for next-level risk trigger identification used as benchmark of systematically coaching behavior change toward prevention
- Measurements of the solution’s effectiveness in a clinical setting
- In addition, “Lessons to Learn” from CDSS National Roadmap study on “CDSS market penetration” (USA, 2007)
  - Integration of the input data store/retrieve/update of CDSS with the clinical workflow management system.
  - User-friendly human-computer interface (User Insight)
CDSS Context Configuration

Data Processing Suite (Sensor Messaging Middleware & Data Mining)

- Event Extraction Engine
- Event Awareness Engine
- Action Engine

Reasoning Mechanism

- Disease domain knowledge
- Personal profile & history, environment
- IF-THEN rules
- Heuristics or probabilities

Analysis & Justification

- Medical Problem Description

Medical Use Cases

Medical Literatures

Data Processing Suite

- Sensor messaging middleware, data fusion and mining

Event Extraction Engine

- Related combined bio-signal data
to a model of a physical patient world for analysis

Event Awareness Engine

- Event pattern matching and anomalous event detection

Action Engine

- Alerts and human tasking for further analysis

Feedback

Used to adapt models

Disease Pattern Library

Social Networks

Medical Problem Description

Disease domain knowledge

Reasoning Mechanism

Knowledge-Based

- Disease domain knowledge
- Personal profile & history, environment
- IF-THEN rules
- Heuristics or probabilities

Data Processing Suite - Sensor messaging middleware, data fusion and mining

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Health Cloud Services

- Cloud computing model would help healthcare solutions in scalability and on-demand and affordable pricing realization, assuming privacy-preserved security concern is addressed.
- Current cloud computing for healthcare solutions focuses on health/medical information exchange services (Baseline)
  - Ubiquitous health/medical record storage, access and management
  - Health/medical data sharing for healthcare community collaboration
  - E-Prescription
  - Business process management
  - Regulatory compliance
- Emerging health cloud services
  - Leverage baseline health cloud health/medical record services to build value-added clinical decision support services that would help healthcare providers make diagnosis, treatment, consultation more accurate, and faster/timely with lesser cost.

Cloud Computing Stack

- **Monitoring as a Service (MaaS)**
  - Data storage and retrieval
- **Platform as a Service (PaaS)**
  - Analytics platform
- **Software as a Service (SaaS)**
  - Software tools
NIH-ARRA Highest eHealth Priority Challenges Topics

- 15 priority challenges topics are selected under American Recovery & Reinvestment Act (ARRA) of 2009 (>200M for FY2009-2010)
  - eHealth is listed as Topic 10 (Representing priority health ICT technology portfolio in NIH-ARRA national program)
  - Cyber-Infrastructure for Health: Building Technologies to Support Data Coordination and Computational Thinking
  - Engineering improved quality of health care at a reduced cost
  - Develop data sharing and analytic approaches to obtain from large-scale observational data, especially those derived from electronic health records, reliable estimates of comparative treatment effects and outcomes of cardiovascular, lung, and blood diseases
  - Informatics for post-marketing surveillance
  - Advanced decision support for complex clinical decisions
  - Adapt existing genetic and clinical databases to make them interoperable for pharmacogenomics studies
  - Information Technology Demonstration Projects Facilitating Secondary Use of Healthcare Data for Research
  - Innovative information and communication technologies to enhance capabilities of U.S. institutions in global health research and research training

Summary - Challenges & Opportunities

- Personalized eHealth poses significant challenges in both solution implementation due to
  - Life & liability nature involving many stakeholders, including patients, physician, healthcare professionals, hospitals, insurers, etc
  - Complex biological processes, involving constantly changing dynamic factors such as physiologic bio-symptoms, emotional behaviors, family medical history, social relationships and diverse environmental contributors
  - Complex data integration with the “incomplete” picture for analysis and diagnosis
  - Human behavior dynamics and human-computer interfaces with social context will need to be incorporated

- Cloud computing model might be used to ensure scalability, adaptability, and usability as long as privacy preserved security can be assured

- Metrics and Methods for measuring accuracy, reliability, effectiveness, and safety of a personalized eHealth solution are critical, and remain to be studied

- However, these challenges present opportunities for novel research & development, and potential innovative but practical ubiquitous personalized eHealth solutions
Reference Information

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  - http://healthit.hhs.gov/
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- Panel Report on “International Research And Development In Biosensing,” (Schultz, J. (Chair), et al., World Technology Evaluation Center (WTEC), August 2004.