Transforming Health Care Through IoT and Omics Revolutions

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Outline

• Healthcare Vision
• The P7 Concept
• Smart Networked Systems & Societies
• Technology Trends
• Research Issues
• Case Studies
• Summary
THE NATION’S HEALTH DOLLAR ($3.5 TRILLION), CALENDAR YEAR 2017: WHERE IT CAME FROM

1 Includes worksite health care, other private revenues, Indian Health Service, workers’ compensation, general assistance, maternal and child health, vocational rehabilitation, Substance Abuse and Mental Health Services Administration, school health, and other federal and state local programs.

2 Includes co-payments, deductibles, and any amounts not covered by health insurance.

Note: Sum of pieces may not equal 100% due to rounding.

THE NATION’s HEALTH DOLLAR ($3.5 TRILLION), CALENDAR YEAR 2017, WHERE IT WENT

- Hospital Care, 33%
- Physician and Clinical Services, 20%
- Prescription Drugs, 10%
- Other Professional Services, 3%
- Dental Services, 4%
- Other, 14%
- Nursing Care Facilities and Continuing Care Retirement Communities, 5%
- Government Administration and Net cost of Health Insurance, 8%
- Durable Medical Equipment, 2%
- Other Non-Durable Medical Products, 2%
- Home Health Care, 3%
- Other Health Residential and Personal Care, 5%
- Public Health Activities, 3%

Notes:
1. Includes Noncommercial Research and Structures and Equipment.
2. Includes expenditures for residential care facilities, ambulance providers, medical care delivered in non-traditional settings (such as community centers, senior citizens centers, schools, and military field stations), and expenditures for Home and Community Waiver programs under Medicaid.
3. Sum of pieces may not equal 100% due to rounding.

## Levels of Biological Information

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From Genomics to Phenotypes

“Genomics”
DNA

“Proteomics”
RNA
Proteins

“Transcriptomics”

From Genomics to Phenotypes

“Cellomics”
Organism behavior

“Metabolomics”
Cell and tissue behavior

Metabolites

Transformation of Health Care Through IoT & Omics Revolutions
Transformation of Health Care Through IoT & Omics Revolutions

Molecular Characterization

Basic Science Discovery

Informed mechanistic studies

Knowledge Graph

Exposures
Phenotypes
Epigenome
Genome
Microbiome
Demographics
Patients

Electronic Health Record

Clinical Discovery

Observational studies in routine clinical care

BioMedical Research

Targets
Mechanisms

Validation
Taxonomic
Classification

Courtesy: Chris Chute

Clinical Medicine

Treatments
Diagnoses
Outcomes
Transformation of Health Care Through IoT & Omics Revolutions

**Proteomics**
- 2D gel electrophoresis (1975-1980)
- Gene cloning Sequencing (1990)
- Complex mixture analysis LC-MS/(MS) (1994-1996)
- Chip-based approaches
- ESI & MALDI (1990)

**Genomics**
- DNA Genetic material
- 1944
- 1953 DNA structure
- 1960
- 1970
- 1980
- 1990
- 2000

**BioAnalysis**
- Analog simulation, bioenergetics, lac operon
- Feedback regulation in metabolism
- Large-scale simulators of metabolic dissipative structures, energy coupling MAC and BST
- 'data poor' in silico biology, models of viruses, red blood cell
- 1931
- 1952-1957
- 1970
- 1980
- 1990
- 2000

**Computer Science**
- Artificial Intelligence
- 1956
- Programming Languages
- 1960
- Cybernetics
- 1970
- Computational FEM
- 1980
- Internet
- Commercial Database
- 1990
- Large scale product simulation
- 2000

**Engineering**
- Finite element analysis
- 1943
- Systems engineering
- 1950
- Mainframe Computers
- 1970
- Supercomputers
- 1980
- VLSI CAD/CAD/Geometry
- 1990
- PDM/Knowl. based Engineering
- 2000
- MEMS
- Nano
- PLM

**Self-organization**
- 1957
- 1970
- 1980
- 1990
- 2000

**Recombinant technology**
- 1980

**Human genome sequenced**
- 2001

**Artificial Intelligence**
- 1960
- 1980

**DNA**
- 1944

**Gene cloning**
- 1975

**Sequencing**
- 1980

**Haemophilus influenzae**
- 1994

**First genome sequenced**
- 1995

**Complex mixture analysis**
- 1996

**Chip-based approaches**
- 2000

**1944**

**1953**

**1960**

**1970**

**1980**

**1990**

**2000**

**Human genome sequenced**
- 2001

**1995**

**2000**

**Human genome sequenced**
- 2001

**1996**

**Human genome sequenced**
- 2001

**Bernhard O. Palsson**
Outline

• Healthcare Vision
• The P7 Concept
• Smart Networked Systems & Societies
• Technology Trends
• Research Issues
• Case Studies
• Summary
The P7 Concept

1. Personalized
2. Predictive
3. Participatory
4. Precise (recommendation, decision analytics)
5. Preventive
6. Pervasive (including point of care)
7. Protective (Privacy and security)

Based on discussions with Leroy Hood and Ramesh Jain
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Transformation of Health Care Through IoT & Omics Revolutions

Physical World

- Environment
- Physical Network
- Things
- Person
Transformation of Health Care Through IoT & Omics Revolutions
Cyber Physical Systems

Interconnected Systems & Control

Internet of Things

Sensing and Acting

Environment

Physical Network

Things

Person

Physical World

Transformation of Health Care Through IoT & Omics Revolutions
CPS Example: Hospital Room

Internet

Thermostat

HVAC

CO2
Transformation of Health Care Through IoT & Omics Revolutions

Cyber Physical Systems

- Interconnected Systems & Control
- Internet of Things
- Sensing and Acting
- Environment
- Physical Network
- Things
- Person

Physical World

Society

- Formal Social Organizations
- Informal Social Organizations
- Person
Transformation of Health Care Through IoT & Omics Revolutions

Cyber Physical Systems

- Interconnected Systems & Control
- Internet of Things
- Sensing and Acting

Physical World

- Environment
- Physical Network
- Things
- Person

Cyber Organizational Networks

- Interconnected Formal Social Organizations
- Internet of Formal Social Organizations
- Sensing and Acting
- Formal Social Organizations

Society

- Informal Social Organizations
- Person
CPHS Example: Monitoring-Multiple Patients in a Ward

Transformation of Health Care Through IoT & Omics Revolutions
Information, Transport & Operations Networks in a Hospital - CPHS

Operating Theatres

Medical Records

Staffing & Scheduling

Drugs and supplies

Emergency

Doctors offices

Medical Records

Staffing & Scheduling

Drugs and supplies

Emergency

Doctors offices

Medical Records

Staffing & Scheduling

Drugs and supplies

Emergency

Operating Theatres

Medical Records

Staffing & Scheduling

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Staffing & Scheduling

Drugs and supplies

Emergency
Transformation of Health Care Through IoT & Omics Revolutions

Inter-connected CPHS

Hospital

Medical records exchange
Patient transport

Transport network

Hospital

Patients
Cyber Physical Human Systems

Cyber Physical Systems
- Interconnected Systems & Control
- Internet of Things
  - Sensing and Acting
- Environment
- Physical Network
- Things
- Person

Cyber Organizational Networks
- Interconnected Formal Social Organizations
  - Internet of Formal Social Organizations
    - Sensing and Acting
  - Formal Social Organizations

Cyber Social Networks
- Interconnected Social Networks
  - Internet of People
    - Social Sensing and Acting
  - Informal Social Organizations
  - Person

Transformation of Health Care Through IoT & Omics Revolutions

Sub, Ahmed, Sriram
Transformation of Health Care Through IoT & Omics Revolutions

Smart Networked Systems and Societies
Interconnected Cyber Physical and Social Networks

Cyber Physical Systems

Interconnected Systems & Control

Internet of Things

Sensing and Acting

Environment

Physical Network

Things

Person

Cyber Organizational Networks

Interconnected Formal Social Organizations

Internet of Formal Social Organizations

Sensing and Acting

Formal Social Organizations

Cyber Social Networks

Interconnected Social Networks

Internet of People

Social Sensing and Acting

Informal Social Organizations

Person

Physical World

Transformation of Health Care Through IoT & Omics Revolutions

Society

Sub, Ahmed, Sriram
Smart networked Systems and Societies

Transport/Electric Power Networks

Hospital

Doctors

Social Media (Doctors)

Social Media (Patients)

Outpatients

Hospital

Transport/Electric Power Networks
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Technology Trends

1. Ubiquitous mPCDs and other wearable devices
2. Devices connected through Internet
3. Emergence of social networks
4. Formation of clouds (or cloudlets)
5. Rebirth of AI (machine learning (deep), KBES, NLP, robotics, ...)
6. Advances in Human Computer Interaction (or Cyber Human Systems)
7. Biometrics
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IT R&D Challenges

1. Privacy and Security/Assurance
2. Modeling & Interoperability
3. Co-Design
4. Knowledge/Information/Data Analytics
5. Network Behaviors (IT, Social, Sensors)
6. Human Computer Interaction
7. Architectures (Storage) and Services

AI will play a significant role
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Case Studies

• UCI App – Ramesh Jain, University of California, Irvine
• kHealth Asthma -- Amit Sheth, Knoesis, Wright State University
• PRISMS – Jose-Luis Ambite, USC & UCLA Team
Asthma in the US
Growing every year

Asthma is a lifelong disease that causes wheezing, breathlessness, chest tightness, and coughing. It can limit a person’s quality of life. While we don’t know why asthma rates are rising, we do know that most people with asthma can control their symptoms and prevent asthma attacks by avoiding asthma triggers and correctly using prescribed medicines, such as inhaled corticosteroids.

The number of people diagnosed with asthma grew by 4.3 million from 2001 to 2009. From 2001 through 2009 asthma rates rose the most among black children, almost a 50% increase. Asthma was linked to 3,447 deaths (about 9 per day) in 2007. Asthma costs in the US grew from about $53 billion in 2002 to about $56 billion in 2007, about a 6% increase. Greater access to medical care is needed for the growing number of people with asthma.

Learn what you can do to reduce asthma. → See page 4
Want to learn more? Visit www.cdc.gov/vitalsigns
UCI Allergy/Asthma App

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Cockroaches
Dust Mites
Indoor Mold
Pets
Pollen or Outdoor Mold
Exercise
Colds and Infections
Weather
Strong Odors, Sprays, and Wood Smoke
Tobacco Smoke

How Do You Feel?

Stop Jogging!

Courtesy: Ramesh Jain, UCI

- Shortness of Breath
- Chest Tightness or Pain
- Coughing
- Wheezing
Defining Health Persona

Logical Sensor
- Calendar
- GPS

Fitness Tracking Sensors
- Heart Rate Monitor
- Activity Tracker

Physiological Sensors
- Blood Pressure Monitor
- Pulse Oximeter

Life Event
- Work
- Exercise
- Activity-level

Food Event
- Heart rate

Kinetic Event
- Walk

Physiological Event
- Dummy chart

Personicle

Health Persona

 Courtesy: Ramesh Jain, UCI
Personal Health Record

CYP2C19

Genomic Analysis

Electronic Health Record

Plavix?

HEALTH PERSONA

PHR
Transformation of Health Care Through IoT & Omics Revolutions

EventShop: Global Situation Detection

Data Ingestion and aggregation → Predictive Situation Recognition

Data Sources:
- Satellite Environmental Sensor Devices
- Social Network
- Internet of Things

Example of Physical Data:
- AQI: 250 (Air Quality Index 0<AQI<500) at Location DC
- GPS: 38, 53, 77, 02, 12:00
- Temperature: 60 F

Event: Breathing/cough symptom
- Posted by: a patient
- Where: DC
- When: 2/21/13 2:30 am

Need-Resource Matcher

Example of Rules:
- R1: If (301<AQI<500 at Location DC) Then (“Health alert”: everyone may experience more serious health effects) [http://www.airnow.gov/]
- R2: If (Disease = “Asthma” and AQI>200) Then (message...)

Personal EventShop

Data Ingestion

PHR

Predictive Personal Situation Recognition

Database

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Resources

Needs

- Location identification DC / Map Visualization at time 2:30 pm

Air quality not suitable for your Asthma – Move Indoors

Prone to Asthmatic reactions
Is in outside location DC at time 2:30 pm
High Probability of attack

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kHealth Asthma Overview

Data Sources
Heterogeneous data and collection method

Smart Data
Actionable meaningful information from the data collected

http://wiki.knoesis.org/index.php/KHealth:_Semantic_Multisensory_Mobile_Approach_to_Personalized_Asthma_Care

Feedback
(actionable information and its usefulness is studied iteratively with domain knowledge)

Actionable Information
(Asthma is moderately controlled, Pollen is high so take rescue med)

Analyze
(High Pollen, Low Activity, Disturbed Sleep)

Data Integration
(Bring together the patient specific data - Dashboard)

Data Collection
(Symptoms, Medications, environmental observations, activity)
kHealthDash
Knowledge-enabled Personalized DASHboard for Asthma Management

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Coutersy: Amit Sheth
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Smart Healthcare

- **Smart** Devices
- **Smart** Networks
- **Smart** Processes
- **Smart** EMRs
- **Smart** Medicine
- **Smart** Organizations
- **Smart** Collaborations
- **Smart** Society
- **Smart** Planet
The 21st Century Doc

Transformation of Health Care Through IoT & Omics Revolutions

Courtesy: Rod Grupen & Tihomir Latinovic
Transformation of Health Care Through IoT & Omics Revolutions
SNSS Harness the Power of:

- Sensors and information sources
- Strongly emerging participatory culture
- Collective knowledge and intelligence of society
Imagine!

- It took about 30,000 people to build the Taj Mahal
- It took about 100,000 people to build the Great Pyramid
- About 300-400,000 people were involved in putting a man on the moon
- Now, imagine what can the combined intelligence of millions of people on the Internet can achieve!!
Technology Revolution
Data, Devices and Networks Promoting Smarter Health Care
By Dana Steinberg

Imagine a doctor appearing on a computer screen that sits atop a sensing robot; the robot locates a collapsed patient, takes her vital signs and instantly transmits test results to the doctor. The technology for this 21st century physician already exists and demonstrates what’s possible in modern medicine when we combine computer and human innovation with communication networks.

Health care is a $2.7 trillion industry that continues to grow. “If you use information technology in the most efficient manner, you can [probably] save $100 billion,” estimated Dr. Ram Sriram, chief of the software & systems division at the National Institute of Standards and Technology. “It’s not just biology, not just computer science, not management; it’s a combination of all of these things that’s going to play [a role] in the future health care regime.”

At his May 9 lecture at NIH, Sriram said smartphones and other smart devices are constantly sensing, monitoring and interpreting the environment. This, he points out, is called “The Internet of Things,” an interconnected web of devices transforming our everyday lives. Meanwhile, social networks are connecting people, he said;
Acknowledgments and Disclaimer

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- Some ideas taken from an AAAS panel organized with Vint Cerf
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