RESEARCH OPPORTUNITIES AND VISIONS FOR SMART AND PERVERSIVE HEALTH

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The **mission** of Computing Research Association's Computing Community Consortium (CCC) is to **catalyze** the computing research community and **enable** the pursuit of innovative, high-impact research.

**Promote Audacious Thinking:**
- Community Initiated Visioning Workshops
- Blue Sky Ideas tracks at conferences

**Inform Science Policy:**
- Outputs of visioning activities
- Task Forces – Health IT, Data Analytics

**Communicate to the Community:**
- CCC Blog - [http://cccblog.org/](http://cccblog.org/)
- Great Innovative Ideas
- White Papers

**Promote Leadership and Service:**
- Industry – Academic Collaborations
- Leadership in Science Policy Institute
- Postdoc Best Practices
THE RAPIDLY EXPANDING WORLD OF COMPUTING

CORE CSE

- Mobile
- HCI
- Machine Learning
- Cloud Computing
- Big Data
- Sensors
- Natural Language Process

- Medicine and Global Health
- Energy and Sustainability
- Security and Privacy
- Technology for Development
- Interacting with the Physical World
- Transportation
- Scientific Discovery
- Elder Care
- Neural Engineering
- Education
- Accessibility

Graphic: Lazowska

Computing Community Consortium
Catalyst
OUTREACH: HEALTH IT

October 2009 Workshop

National Institute of Standards and Technology
National Library of Medicine
Agency for Healthcare Research and Quality
Computing Community Consortium
Office of the National Coordinator for Health Information Technology
American Medical Informatics Association
National Institute of Standards and Technology

October 2012 Workshop

Directorate for Computer & Information Science & Engineering
SMART HEALTH AND WELLBEING (SHW)

CONTACTS
See program guidelines for contact information.

SYNOPSIS
Information and communications technologies are poised to transform our access to and participation in our own health and well-being. The complexity of this challenge is being shaped by concomitant transformations to the fundamental nature of what it means to be healthy. Having good health increasingly means managing our long-term care rather than sporadic treatment of acute conditions; it places greater emphasis on the management of wellness rather than healing illness; it acknowledges the role of home, family, and community as significant contributors to individual health and wellbeing as well as the changing demographics of an increasingly aging population; and it recognizes the technical feasibility of diagnosis, treatment, and care based on an individual's genetic makeup and lifestyle. The substrate of 21st century healthcare will be computing and networking concepts and technologies whose transformative potential is tempered by unresolved core challenges in designing and optimizing them for applicability in this domain.

The goal of the Smart Health and Wellbeing program is to seek improvements in safe, effective, efficient, equitable, and patient-centered health and wellness services through innovations in computer and information science and engineering. Doing so requires leveraging the scientific methods and knowledge bases of a broad range of computing and communication research perspectives.

Some illustrative examples are described here. Protecting patient privacy while providing legitimate anytime, anywhere access to health services will require new security and cryptographic solutions. Personalized medicine will require advances in information retrieval, data mining, and decision support software systems. Continuous monitoring and real-time, customized feedback on health and behavior will rely on remote and networked sensors and actuators, mobile platforms, novel interactive displays, and advances in computing and networking infrastructure.

Data collected by sensors, at clinics, and labs need to be anonymized and aggregated for community-wide health awareness and maintenance. Such data, especially collected over populations, can lead to inferences about best practices and cost savings in providing health services. Virtual worlds, robotics, image, and natural language understanding can facilitate better and more efficient delivery of health services. Software-controlled and interoperable medical devices are necessary for providing safe critical care. Healthcare systems and applications must be usable, to preclude or minimize failures due to human error; and they have to be useful, by matching the mental model of users, from provider to patient, so people make appropriate decisions and choices.

These examples are meant to convey the breadth of computing areas that...
OUTREACH: AGING IN PLACE

Joint NIH/CCC Meeting
September 2014

Produced Workshop Report
February 2015

NIH released new RFP
informed by AIP Workshop
October 2015

PCAST Report
March 2016
Visioning Activity

Cyber Social Learning Systems

Over the last decade, we have made great progress establishing scientific and engineering principles for cyber-physical systems (CPS). We are thus now on the threshold of a world of physical systems that are computational and connected at all scales, yielding radical improvements in function and performance.

The next major frontier in research and development is the integration of cyber-physical with complex human and social systems and phenomena at scale. Progress will catalyze the transformation of major existing systems into cyber-social learning systems (CSLS) that continually and rapidly improve in their function and performance in complex, evolving environments. Progress in the science and application of CSLS theory, technology, and practice has the potential to drive revolutionary advances across all sectors of our society, including health, healthcare, transportation, education, housing, justice, defense, and more.

The CCC will convene three workshops in order to develop and validate the propositions that there is a compelling
SMART AND PERVERSIVE HEALTH

WHERE ARE WE?

Engineering and Technology Drivers
• New capabilities

Systems and Scale
• Public to personalized health
• Resource allocation

Science
• Systems to Models
• Behavior Change

Impact and Barriers
• Evidence and Reliability
• Data Integration and Use

Disparities, Fairness
• All of Us

WE DO WE GO NOW?

• What are the gaps?
• What would be a discontinuous advance?
• What are our “orphan” diseases?
• Data analytics for n=1?
• Closed Loop. Automation
• Sensing. Modeling. Treatment
• Robustness and scale
• What are the barriers in our path
  – Testbeds
END OF DAY 1 – WITH VOTES

Group 1
Mixed-Inactive System for Collaboration/Interpersonal Reasoning
Argument not autonomous
Integrate sensors and analytics

Group 1
Multi-Tiered Sensing, Modeling, & Control
With all these problems
Opportunities abound at Higher Level
Multiple layers

Group 1
Design for Barriers to Actual Comprehension
Responsibility is on the design, not on a person to be "intuitive"
Communicating risks/tradeoffs

Group 2
JITAI for communities
Smart data to empower leadership in important decisions

Team 3 - Breakout 1
1. Value of data: incentivize? personalize?
2. Data phenotypes: precision health/all of us
3. Correlations and context: behavioral data

Team 3 - Breakout 2
2.1. problem @a time
OR
1. Acknowledge Health Issues

Group 4
I. Building & coordinating large-scale systems to support scalability, agile research, agile learning
II. Identifying optimal value-terms
III. Developing methods for actionable, adaptive, far-term models for (human) decision-making
IV. How to adapt CLHS when people do not follow the suggested actions?
V. Taxonomies of models to do CL control for healthcare

GROUP 2
1. Personal care at home: Track
2. Capturing context for decision making
3. DHT stakeholder incl industry
4. Harnessing resources to prevent, distributed, proactive care
5. Interwoven-mesh modeling
COMPUTING ADVANCES:
HOLISTIC SENSING, ADVANCED ANALYTICS AND
COMPREHENSIVE DECISION SUPPORT

• How can we measure key environmental variables and infer a comprehensive characterization of individual behavior?
• How can we model the effect of environmental and social factors on behavior regulation?
• How do we capture and effectively model the context of and around an the “hows” of health care delivery
• How can we support decision-making where prioritization of key factors is critical to effective clinical care?
• How can we improve robustness and reliability of these systems operating “in the wild” outside of the traditional confines of healthcare environments?
COMPUTING ADVANCES:
HOLISTIC SENSING, ADVANCED ANALYTICS AND COMPREHENSIVE DECISION SUPPORT

- Combining large-scale population “big data” with sparse individual data, controlling for biases in each;
- Visualizing context-aware mix-modality data analytics and high-level abstraction and summarization of large-scale, multi-modality data with uncertainties;
- Designing time-series pattern mining methods to extract events of interest from multi-modality data stream with varying temporal granularity, spatial irregularity, varying reliability and validity, and data incompleteness; and
- Developing provenance systems that capture both metadata and annotations of the entire data processing stage to facilitate both interpretability and comparative analysis;
COMPUTING ADVANCES: HUMAN-CENTRIC SYSTEMS

Mixed Initiative Systems and Closed Loop Systems
- Dynamic roles and responsibilities (participant, providers, caregiver)
- Automation to informing human action for “closing the loop”
- Creating mixed-initiative and closed-loops systems typically involves choosing an objective to optimize

Multi-Tiered Sensing, Modeling and Control Systems
- Adaptively selecting different models at different time scales and abstraction to flexibly integrate multiple sources of data, from real time sensing to public health data.
- Enabling transitions for interventions that operate on population-based data to those that gradually incorporate more individual data and shift to personalized models.
- Balancing tradeoffs in sensing, model prediction, data sharing, and privacy needs.
- Engineering systems to optimize resources across multiple data gathering, modeling, and decision-making processes.
- Dynamically and iteratively gathering information as needed, such as incrementally gathering contextual information as a person’s activity changes throughout the day.
COMPUTING ADVANCES: HUMAN-CENTRIC SYSTEMS

• Modeling complex dynamical systems with uncertainties from multiple sources to allow inference making in the presence of temporal and spatial imprecision;

• Understanding how are inferences and predictions created, how is uncertainty represented, and how can humans understand the rationale and limits of these systems?

• Deriving predictive models that efficiently process multi-modality data, incorporate multi-dimensional data analytics, and perform multi-variable statistical inferences from “digital biomarkers” to facilitate decision making;

• Integrating analytical techniques (machine learning, deep learning, data mining, Bayesian reasoning), and dynamical system and control system theories with cyber physical systems for real-time control.
INTEGRATING ADVANCED COMPUTING CAPABILITIES INTO HEALTHCARE DELIVERY

Distributed Coordinated Care Delivery
- Modeling caregiver capabilities and human limitations
- Modeling empirical workflows
- Dynamic scheduling and assignment
- Effective assistance

Just-In-Time Adaptive Interventions (JITAI)
- Effective dynamic interventions
- Balancing tradeoffs of action and inaction
- Incremental context gathering
- Training JITAI systems
- Interfaces to care networks
COMPUTING ADVANCES:
SECURITY CHALLENGES AND PERVERSIVE COMPUTING

- Safety: implantable medical devices
- Many points of entry: what is the weakest (device) link
- Many users (patients, care givers, healthcare providers)
  - Role based models are too brittle; auditing capabilities
- Devices cross institutional boundaries (home, hospital, public spaces)
- Privacy challenges abound
SUPPORTING NEW HEALTHCARE PARADIGMS

• Value-Based Treatment Plans
• Accountable and Patient-Centered Care
• Informing Public Health
• Decreasing Healthcare Disparities
CROSS CUTTING ISSUES AND BARRIERS TO SUCCESS

- Infrastructure Challenges: Platforms
- Collaboration Challenges: Data, Expertise, Personnel, and Interventions
- Healthcare Disparities
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