Cyber Physical System Challenges for Human-in-the-Loop Control

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Motivation

- Human-in-the-Loop (HiTL) System

Wheelchair-Mounted Robotic Arm

Smart Thermostat (SenSys'10)

Challenges

1. Understanding complete spectrum of HiTL controls.
2. Deriving models of human behavior.
3. Determining how to incorporate these models into the formal methodology of FC.

Challenge#1

- Understanding complete spectrum of HiTL controls.
  - Determine the principles and subtleties
  - Future applications can exploit commonalities

- A taxonomy of HiTL applications
  - 3 categories

Challenge#1

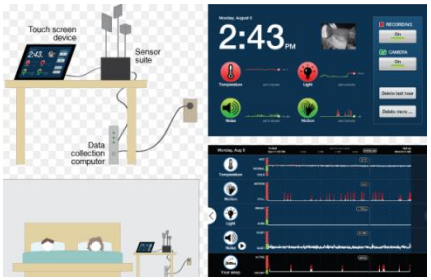
- Taxonomy

(i) Humans directly control the system

Wheelchair-Mounted Robotic Arm

-Supervisory Control
-Interfacing humans to control

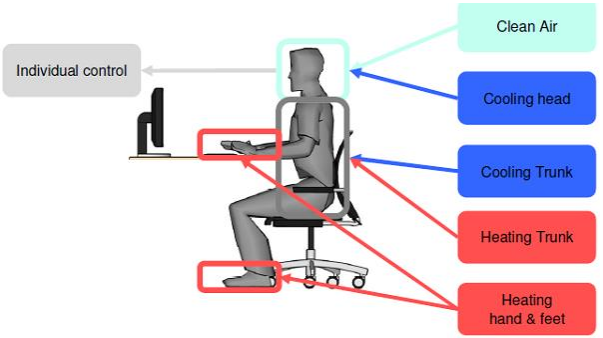
(ii) System passively monitors humans and take actions



Lullaby (UbiComp'12)

Advanced driver assistance System

(iii) Hybrid of (i) and (ii)



Smart Energy Management for comfort

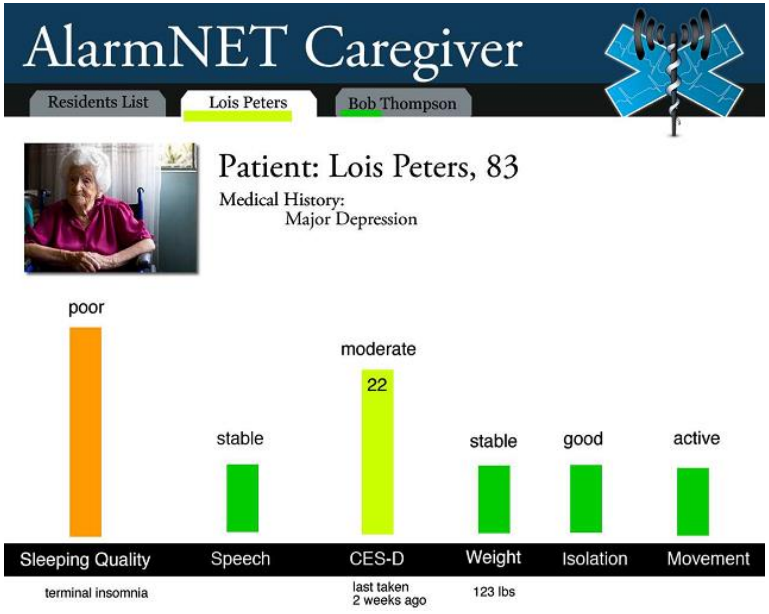
-Human feedback for set point temp

Challenge#1

- How many different types of HiTL?
  - Which ones can easily employ current FC tech
  - Which ones require fundamentally new FC tech
  - Which ones can only use the paradigm of FC, but not the mathematics.

Challenge#2

- How to model these behaviors using appropriate modeling techniques
  - System identification
    - Order, types of equations
    - Adequate testing inputs
    - Output variables
    - States, state transition

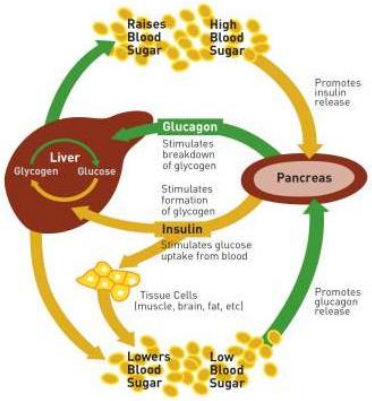


Empath (Wireless Health'11)

Challenge#2

- Current modeling techniques
  - Very general
    - HMM to model occupancy
  - Very specific
    - Mathematical model for injection of insulin for diabetes.
- Model holistic human behavior

Smart Thermostat (SenSys'10)



Modeling injection of insulin

Challenge#2

- System ID
  - High level black box approach
  - Useful?
    - Many HiTL models
      - Very detailed (model of artificial pancreas)
  - Combined with more detailed models?
- Other modeling techniques?
  - At what level, as input for Challenge#3

Challenge#3

- How to incorporate human behavior models into formal methodology of FC

-Smart Themostat
-Humans in the loop, but no active feedback

-Sometimes active feedback
-Hierarchical control

-Considers physiological states
-Human state detected by sensors guides the control

- Areas where a human model can be placed:
  - Outside of the loop
  - Inside the controller
  - Inside the system model

-Inside a transducer
-At various levels in hierarchical control

Challenge#3

- How to incorporate human behavior ***as part of the system itself***.
  - Stability, accuracy, settling time, overshoot
- Advantages:
  - Analyze the property of the whole system
  - Run optimization techniques across people in a home/building/city
  - Choose optimal parameters to maximize multidimensional utilities, e.g., health and energy

Operator behavior at electrical power system

Summary

- 3 Challenges
  - Understanding the complete spectrum of HiTL control
  - Modeling human behavior using appropriate modeling techniques
  - Incorporating these models into formal FC methodology

Thank you!

- Questions in the loop?