Smart Home Monitoring of the Physiology and Physical Activity of Seniors with Heart Failure

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Problem Statement

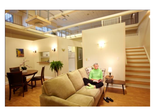
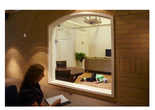
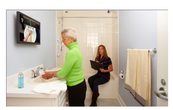
- Effective self-care is a cornerstone of Heart Failure (HF) management
- Many seniors are unfamiliar with the methods, frequency or actions required to self-monitor their HF
- Many seniors are unable to operate their devices
- Growing demand for technology that could aid in the care of seniors within their own homes and communities
- Current products focus on *physiology* and *activity* as separate entities which lead to uni-dimensional data requiring user or caregiver to interpret significance

Research Objective

- A smart home system that will autonomously monitor the physiology and physical activity of seniors without any conscious effort from users
  - Provide timely context-aware feedback to users and healthcare providers
  - Impact key clinical outcomes such as a reduction in re-admission rates

Research Questions

1) What are the needs of seniors with HF and their healthcare providers with regard to physiology and activity monitoring toward improving key clinical outcomes and disease management?
2) Can zero-effort technology accurately measure vital signs and activity?
3) Can a novel smart home system successfully reflect the changes in vital signs as a senior with HF performs regular activities of daily living?

Methodology

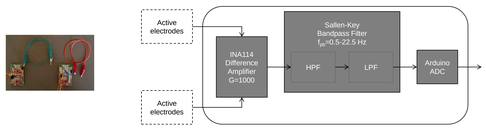
1) Needs assessment
   - Online survey to collect information regarding the usefulness and recommended measurement frequency of various HF parameters
   - Advisory committee of clinicians and cardiac specialists to maintain continuous contact through all phases of the design and evaluation process.
2) Embedded System Design
   - Following the Human Activity Assistive Technology (HAAT) framework.
3) Testing in the Home Lab at TRI
   - 20 seniors with HF from the Peter Munk Cardiac Care Centre will test the new designs compared to gold standard methods such as chest straps and blood pressure cuffs

Design Example: Capacitive ECG sensor

- Electrocardiogram signal (ECG) represents the electrical activity during heart muscle contractions

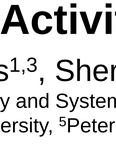
- Copper tape sensing surface

- Active electrode and analog processing circuit

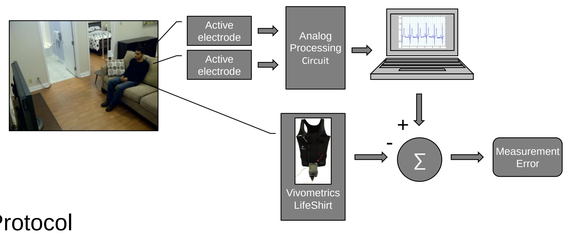


- Software
  - *Arduino IDE:* ADC and transmission
  - *Processing:* display of ECG signal in real-time
  - *Matlab:* peak detection and interval measurements

- Sensor locations
  - Back of couch cushion and office chair
  - Back and seat of dining chair
  - Handles of walker

- Data collection
  - 2 healthy subjects
    - 34 year-old female, cotton top and skirt
    - 20 year-old male, cotton top and jeans



  - Protocol
    - Sit or stand in common positions for 4 minutes
    - Measurements recorded through clothing (exception: walker)
    - Ground truth: LifeShirt System by Vivometrics, 3-lead ECG gel electrodes
- Results
  - ECG signals

Design Example: *(cont'd)*

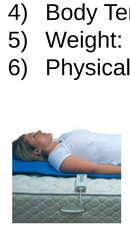
- Measurement accuracy

File #	Subject #	Embedded Location	Sensor HR (BPM)	Ground Truth (BPM)	Measurement Error (%)
1	1	Office Chair Back	80	81	1.2
2	1	Couch Back	82.5	81	1.9
4	1	Dining Chair Back	84	86	2.3
5	1	Dining Chair Seat (through skirt)	83	84	1.2
6	2	Office Chair Back	57	56	1.8
7	2	Couch Back (through 2 shirts)	56	55	1.8
8	2	Walker Handles (direct contact)	60	59	1.7

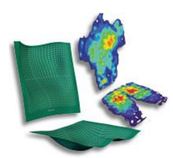
  - Highly accurate (<2.3% error) when no considerable subject movement
    - Reading, watching TV, computer use, sleeping
    - R-peak can be difficult to distinguish when electrical noise is high
  - Measurement reliability
    - Largest source of unreliability caused by motion artifacts
    - 15.3% of total recording time across subjects
- Conclusions and future work
  - Embedded sensor successful in heart rate measurement through 1 and 2 layers of clothing
  - Motion artifacts and electrical noise identified as largest sources of error and unreliability
  - Integration into a printed circuit board and addition of occupancy sensor

Sensing Modalities under Investigation

1) Heart Rate: reflective $Sp0_2$
2) Respiratory Rate: pressure sensors
3) Blood Pressure: custom floor tile
4) Body Temperature: thermistors, IR camera
5) Weight: load cells, pressure sensors
6) Physical Activity: computer vision






Expected Implications

- Reduce the burden of chronic disease management on seniors with HF and their caregivers without interfering with daily activities
- Enable the early detection of functional decline by providing clinicians with accurate and reliable real-time information

This work was supported by the Natural Sciences and Engineering Research Council and industrial and clinical partners through the *Healthcare Support through Information Technology Enhancements (hSITE)* Strategic Research Network, and by the Canadian Institutes of Health Research (CIHR)