# Context-Aware Sensing for Aging-in-Place
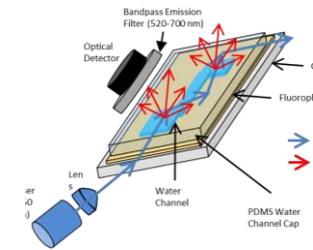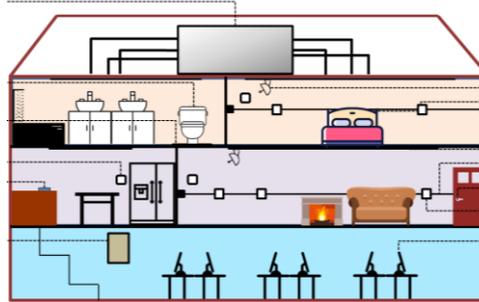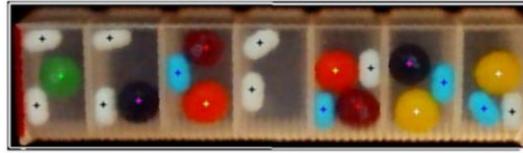

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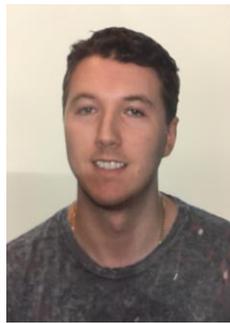
Hailey Wang   Oishee Ghosh   Michael Zon   Guha Ganesh
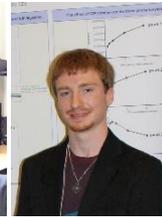
Ontario Health Expenditures

HEALTH CARE SPENDING BY ONTARIO'S GOVERNMENT IS UNSUSTAINABLE

HEALTH CARE SPENDING AS A SHARE OF PROGRAM SPENDING
- 1998: 35.9%
- 2015: 42.9%
- 2030: 49.5%

HEALTH CARE SPENDING AS A SHARE OF THE ECONOMY (GDP)
- 1998: 5.2%
- 2015: 6.9%
- 2030: 9.7%

Figure 2.1
Age pyramid of population estimates as of July 1, 1998 and 2018, Canada

Males / Females
- 2018
- 1998

per 1,000
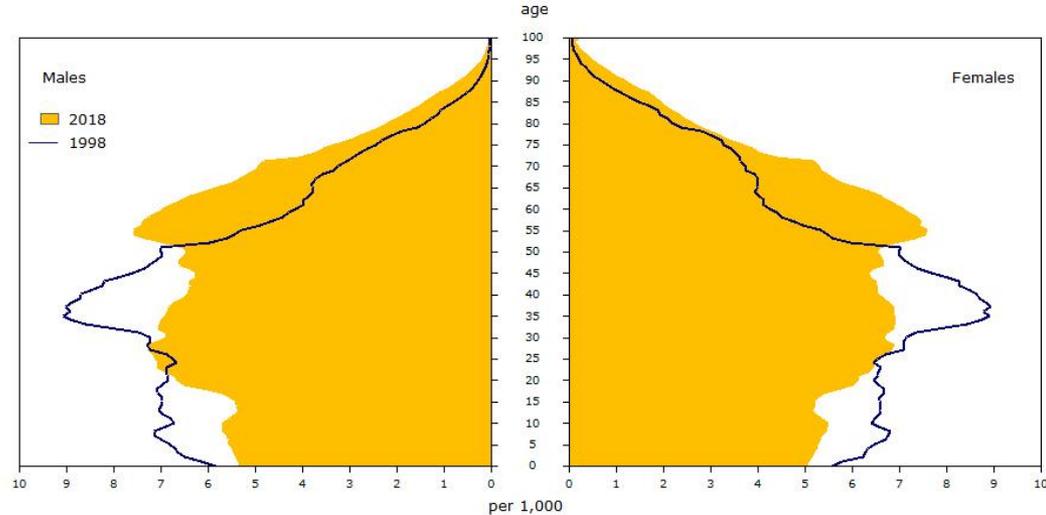
Source: Statistics Canada, Demography Division.

https://www150.statcan.gc.ca/n1/pub/91-215-x/2018002/sec2-eng.htm
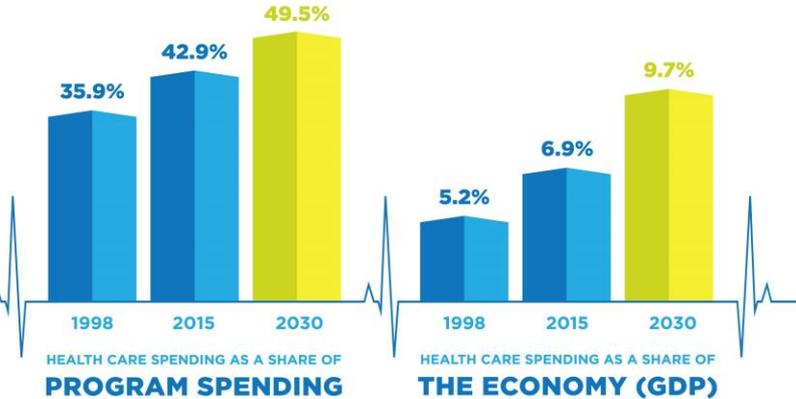
in 2014, the average per-person government spending on health care for Canadians

15yr – 64yr:	$2,664
65 + yr:	$11,625

https://www.fraserinstitute.org

http://www.businessinsider.com/chinese-population-demographics-2011-11?op=1

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Emergency Room visit is $$$$

Columns
CIHI Survey: ED Spending in Canada: A Focus on the Cost of Patients Waiting for Access to an In-Patient Bed in Ontario
Heather Dawson and Greg Zinck

Ontario spends $791 million on ER visits or $148/visit.

Does not account for building and staffing an ER

Figure 2. Total ED spending and percent spent on patients admitted via the ED, by LHIN

☐ Total ED's spending   ◆ Percentage spent on admitted patients
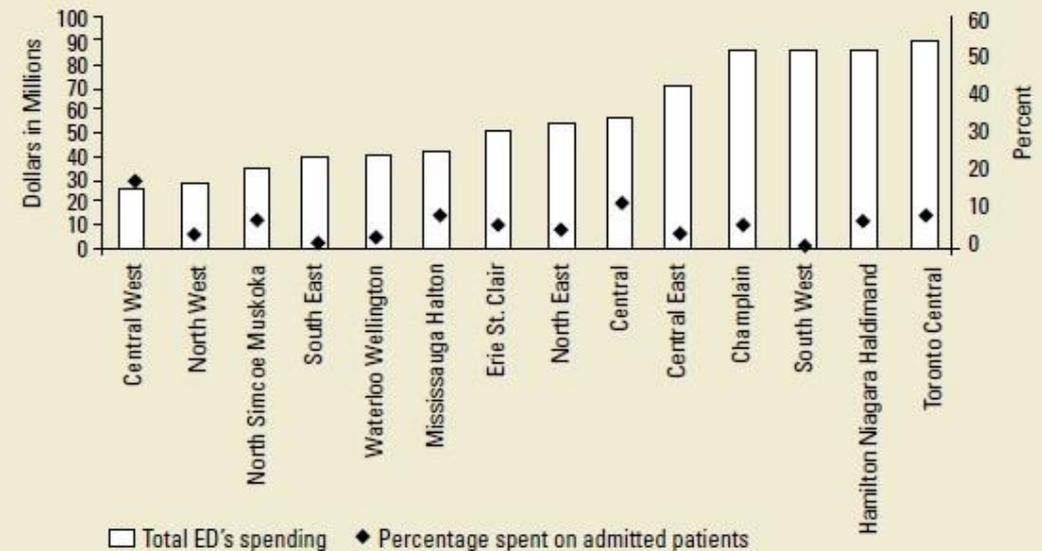
ED = emergency department; LHIN = Local Health Integration Network.
Sources: Canadian Institute for Health Information's Canadian Management Information Systems Database, 2005–2006, and National Ambulatory Care Reporting System, 2005–2006.

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Figure 2: Canadian Triage and Acuity Scale (CTAS) Levels and Emergency-department Visits, by Level, 2008/09

Source of data: CTAS Implementation Guidelines and Ministry of Health and Long-Term Care

Level	Acuity	Examples of Patient Symptoms	% of Emergency Dept. Visits
1	resuscitation	• cardiac and/or pulmonary arrest • major trauma (severe injury and burns) • unconscious	0.6
2	emergent	• chest pain with cardiac features • stroke • serious infections	12.9
3	urgent	• moderate abdominal pain • moderate trauma (fractures, dislocations) • moderate asthma	39.0
4	less urgent	• constipation with mild pain • ear ache • chronic back pain	39.0
5	non-urgent	• medication request or dressing change • sore throat • minor trauma (sprains, minor lacerations)	8.5

Chapter 3 Ministry of Health and Long-Term Care

Section 3.05

Hospital Emergency Departments

Nearly half of the ER visit can be avoided by improve care and monitoring at home

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Aging-in-Place?

AGING IN PLACE
TIPS ON MAKING HOME SAFE AND ACCESSIBLE

- US CDC: "… the ability to live in one's own home and community safely, independently, and comfortably …"

  – Independence, community and social/support networks, cost

  – Still need to integrate with transition to institutionalized care in later phases

  – …

Keyword: Place
- Single family detached building
- Multi-unit low rise building
- Multi-unit high rise building
- Managed living communities:
- Long term care facilities
- Hospitals and managed intense care facilities

Clinical Decisions

Analytics

Networking

Sensors

https://www.nia.nih.gov/health/infographics/aging-place-tips-making-home-safe-and-accessible

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Intelligent Sensors for the Smarter Home

- Non-video based physical activity tracking

- In-door localization and context aware activity analysis

- Sensors for Physiological Parameter Tracking

- Multimodality Medication compliances
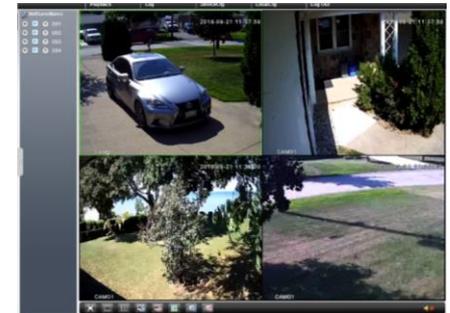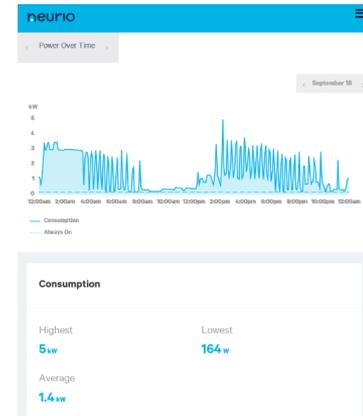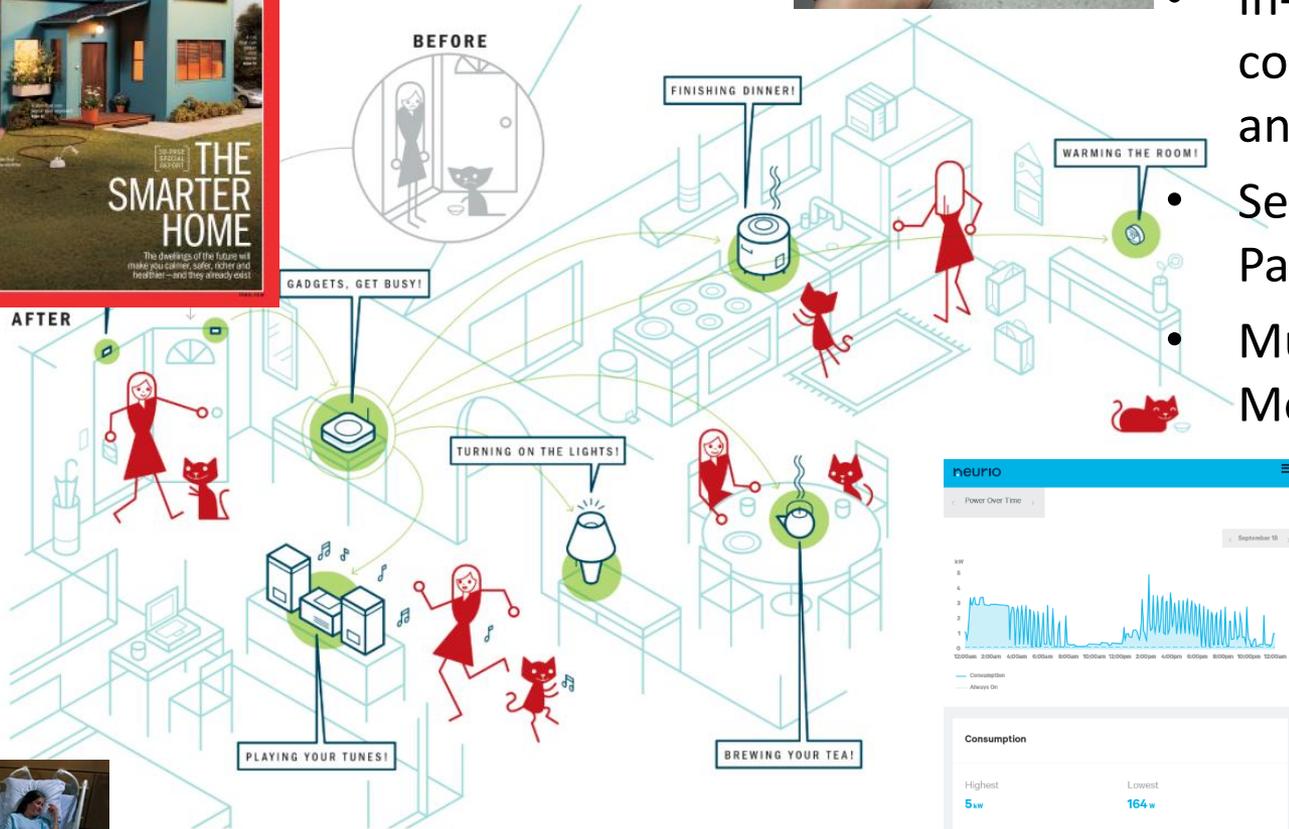
"Smart" Home & Alarm Fatigue

The Apple Watch heart monitor sends too many people to the doctor

Apple Watch Photo by Amelia Holowaty Krales / The Verge

/ Only a handful of people the watch flagged actually had a heart problem

https://www.theverge.com/2020/10/1/21496813/apple-watch-heart-monitor-ekg-false-positive

By Nicole Wetsman
Oct 1, 2020, 2:00 PM EDT | 0 Comments / 0 New

https://static.carthrottle.com/workspace/uploads/posts/2015/08/image-55c680b22c160.jpg

| Alarm-related issue	Causes	Consequences to the staff	Consequences to patient care	Avoidance strategies
Excessive false positive alarms	Can be attributed to patient manipulation (ie, motion artifact)	Apathy and desensitization Mistrust	Reduction in responding Lack of caregiver response Real events being less likely to be acted on	Suspension of alarms for a short period prior to patient manipulation Statistical methods should be suitable to decrease the number of false positive alarms
Frequent insignificant or irrelevant alarms	Use of the default alarm settings Poor staff education on alarm management	Distraction Reduction in trust	Disruption of patient care Disabling of alarm systems by staff	Eliminating nonessential alarms Adjusting alarm parameters on monitors to suit patients' conditions Staff education on alarm management

Fernandes C, Miles S, Lucena CJP Detecting False Alarms by Analyzing Alarm-Context Information: Algorithm Development and Validation JMIR Med Inform 2020;8(5):e15407, doi: 10.2196/15407

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Mobility Decline

- Long term daily activity monitoring
  - Mobility and its changes over time
  - Multimorbidity and Polypharmacy: Living with multiple chronic diseases
  - In home rehabilitation
  - Dietary and nutrition monitoring
 - Cognition and mental health
  - …
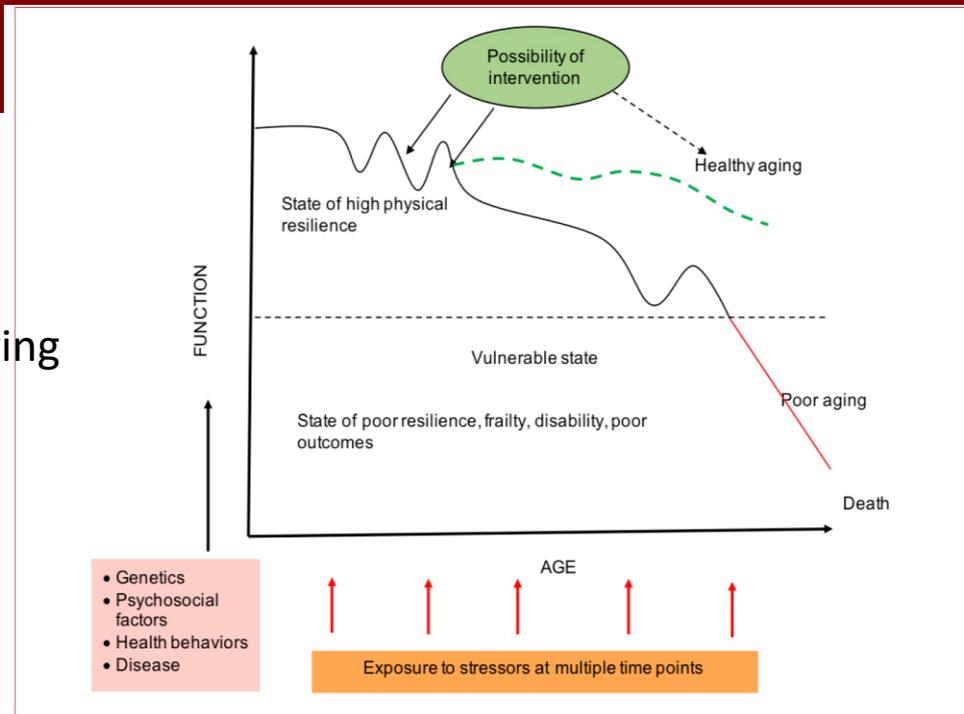
Physical Resilience: A novel approach for healthy aging, Chan et al., 2021, Journal of Frailty Sarcopenia and Falls 07(01) http://dx.doi.org/10.22540/JFSF-07-029

Clinical Decisions

Analytics

Networking

Sensors

Keyword: Place
- Single family detached building
- Multi-unit low rise building
- Multi-unit high rise building
- Managed living communities:
- Long term care facilities
- Hospitals and managed intense care facilities

Smart Home for Aging-in-PlacE (SHAPE)

High-velocity HVAC

Urinalysis toilet

Force plate / electronic scale
Smart thermostat
Pill-box monitoring

Energy monitoring
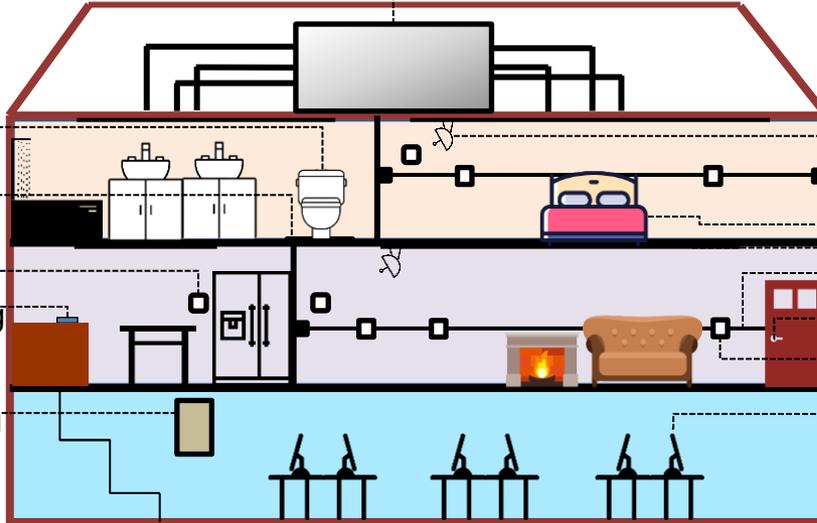
Indoor positioning
Pressure sensors

Ceiling track
Electrical raceway
Smart Lock
Smart Outlet

Office

"Half-way" between the lab and the home

- Open platform open to internal and external researchers as well as the community
- "Half-way" between the lab and the home
- Simulated experiments to optimize sensors and clinical protocols
- Industry partnership projects
- Clinical studies
- Student projects
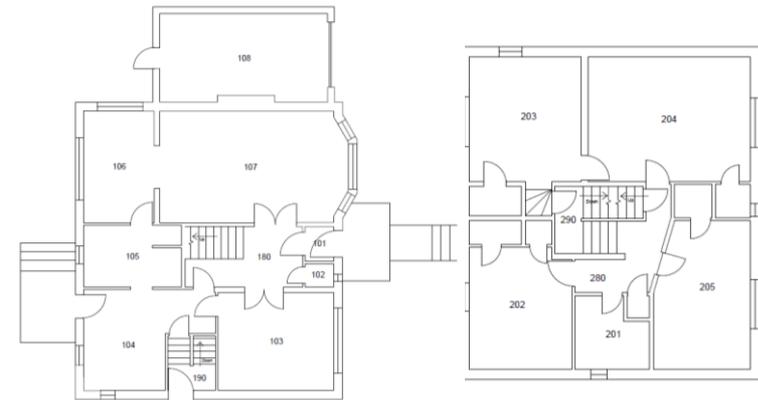
Situation awareness/contextual sensing

- Combining positioning/path with activities/vital signs

Ultrasonic Sensor

RGB LED

Photoresistor

IPS Enclosure

Temperature Sensor

ESP32 Slave

Motion Sensor

ESP32 Master

Raspberry Pi
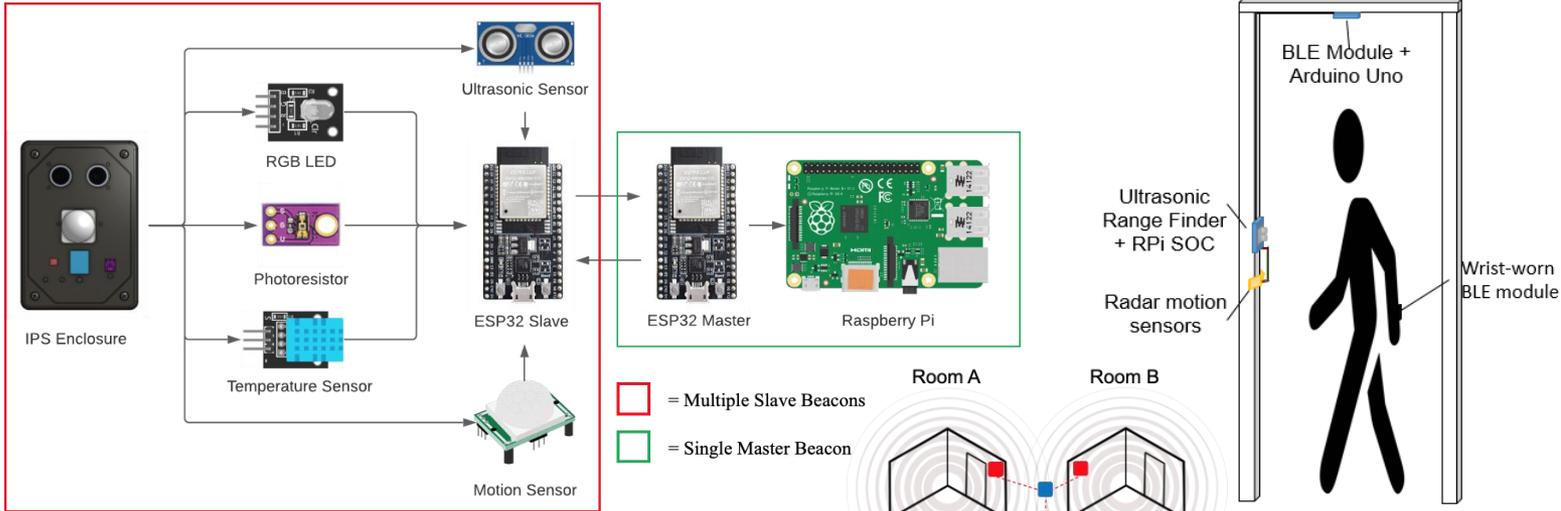
Indoor Positioning System

READ Last mySQL Value

= Multiple Slave Beacons

= Single Master Beacon

Room A

Room B

BLE Module + Arduino Uno

Ultrasonic Range Finder + RPi SOC

Radar motion sensors

Wrist-worn BLE module
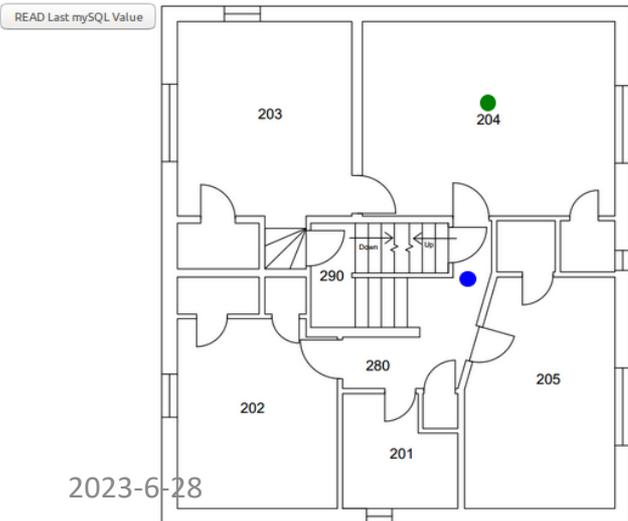
| Motion and Ultrasonic Detection Analysis	Subject 1	Subject 2	Total
Motion Detection Testing			
Number of Tests	150	150	300
Correct Motion Detection (Presence Detected)	141	138	279
Incorrect Motion Detections (Presence Not Detected)	9	12	21
% Accuracy	**94.00**	**92.00**	**93.00**
Ultrasonic Detection Testing (2m Threshold)			
Number of Tests	150	150	300
Correct Ultrasonic Detection (Within Threshold)	126	110	236
Correct Ultrasonic Detection (Not Within Threshold)	24	40	64
% Accuracy	**84.00**	**73.33**	**78.67**

IPS Study 2021-2023

- Study by the #:
  - 20 homes, 23 participants,
  - 65-80yr, healthy

- Parameters measured
  - Hub/Beacon: BLE Name & RSSI; Humidity, temperature, Light level, proximity (NIR), ultrasonic distance,
 - acceleration, gyroscope, step count, heartrate, state analysis

Functional Area Time in Household Between Two Participants
2022-12-02 vs 2022-12-05

In-door-position in Functional Areas and Step Count

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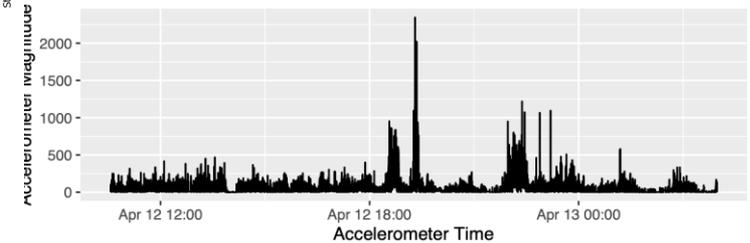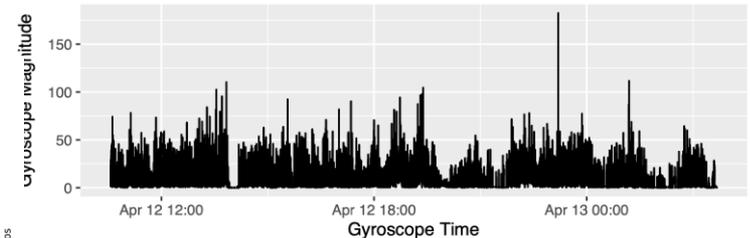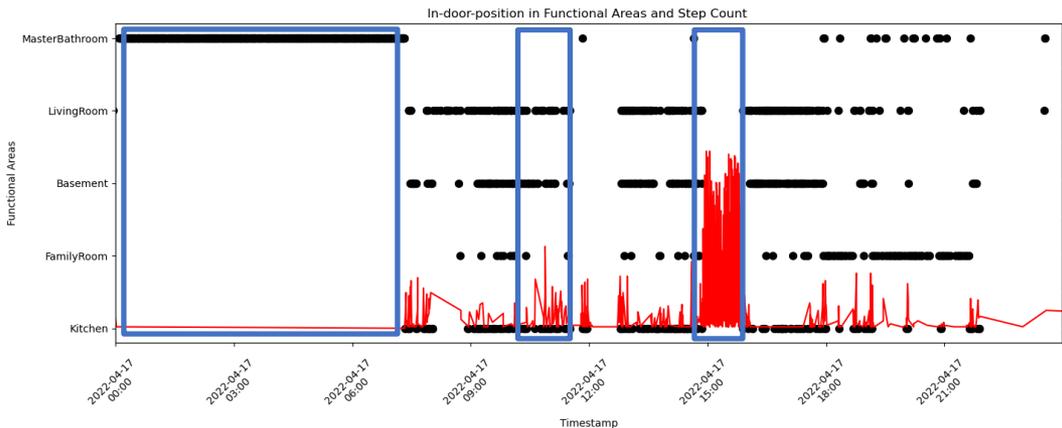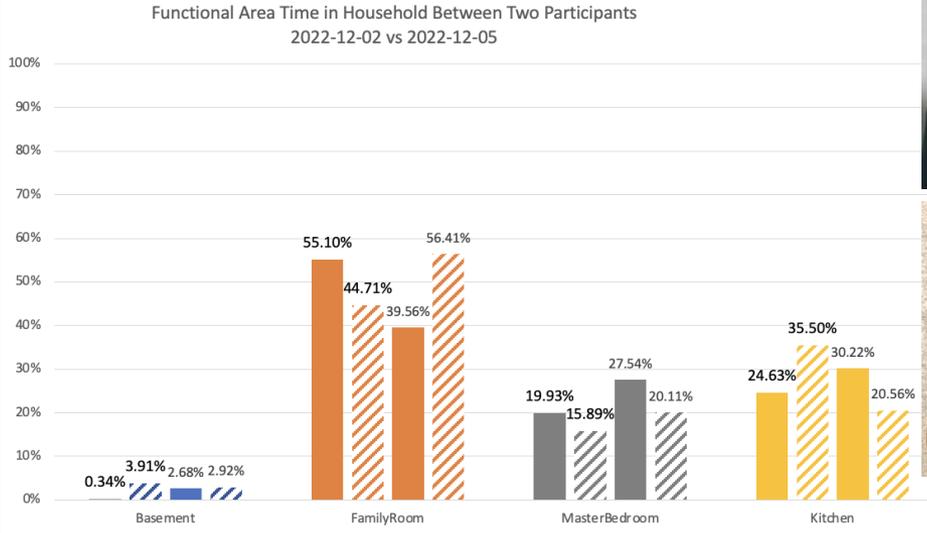
A simple dietary tracking application for users with digestive diseases and eating disorders.

Mobile Application

- Bluetooth to smartphone pairing
- Position capturing

Software

- App development
- Machine learning
- Design and Testing

Help physicians monitor patient nutrition intake

- Sensors
- Monitoring Devices
- Statistics

Eng Phys

Justin Prez
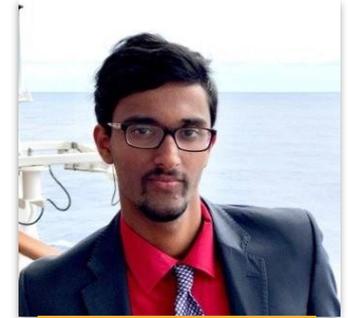
Harshil Modi

Jaclyn Winitsky

Arjun Jagota

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At Home Rehabilitation Training

Neuromuscular Exercise (NEMEX)

GLA:D CANADA

Core Stability
Alignment of Joints
Leg Strength
Functional Exercise

Pain Mapping

Voice Feedback

Sit To Stand Accelerometer #1 (Thigh)

Seated Knee Extensions Accelerometer #2 (Shank)

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Smart Medication Compliance
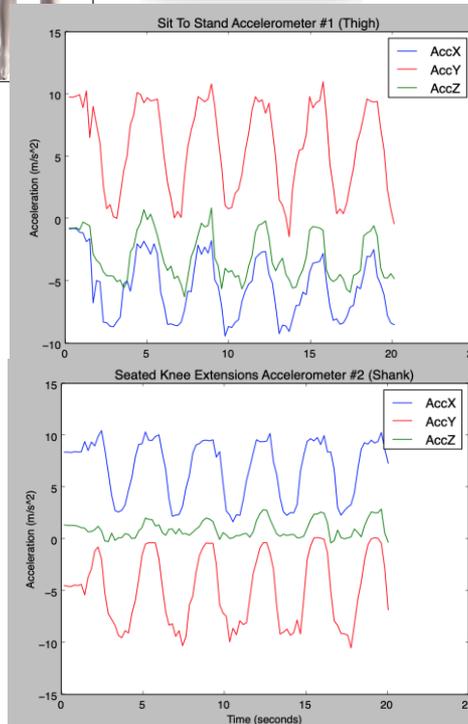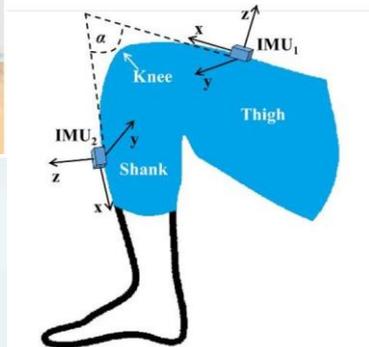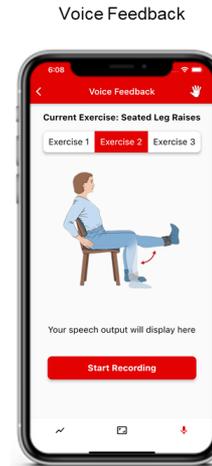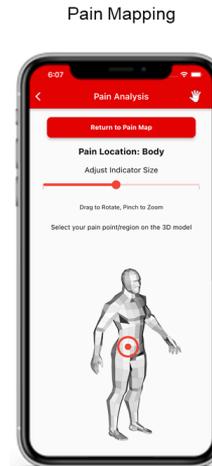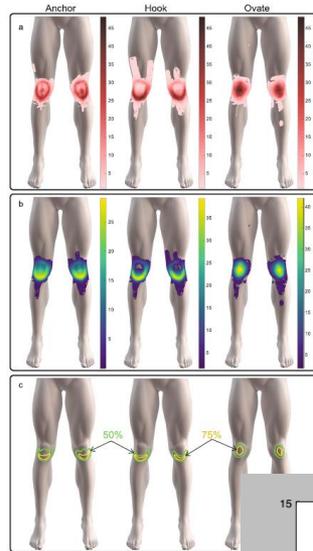
McMaster Biophotonics

Smart Toilet

http://www.weirdasianews.com/wp-content/uploads/2010/08/Intelligent-Toilet.jpeg
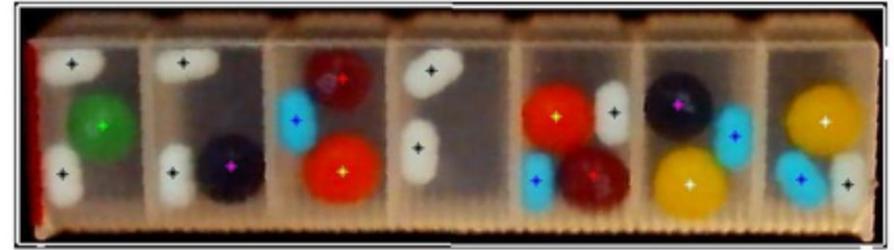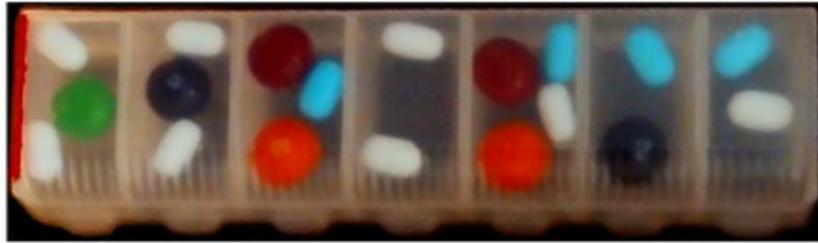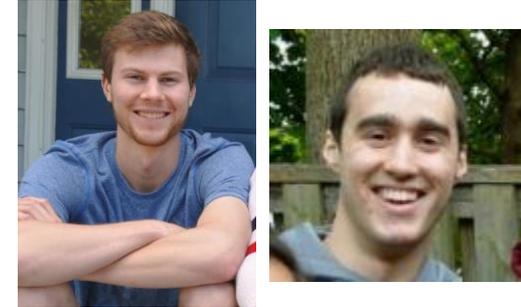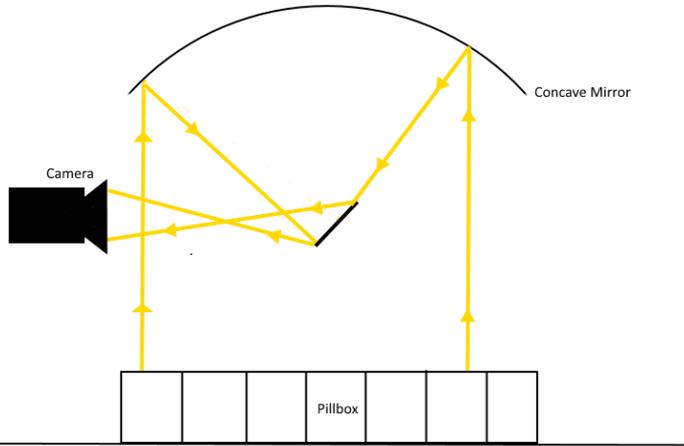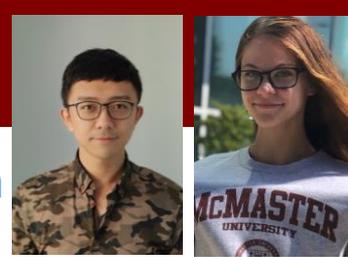
Smart Toilets: Doctors in Your Bathroom

BY AARON SAENZ ON MAY 12, 2009 | LONGEVITY

Diode Laser (450 nm)

Objective Lens

θ

Optical Detector

Emission Filter

L

Emission Light (650 nm)

PDMS Water Channel Cap

O_2 O_2 O_2 O_2 O_2 O_2 O_2

d_P

d

d_G

Water Cha

Fluorophore

Glass Slide

4-layer Structure of DO Sensor

Spatially Incoherent Light

Aperture

$z_1 \sim 50\text{-}100mm$

Microfluidic Channel

Flow

$z_2 \sim 1mm$

CMOS Sensor Array
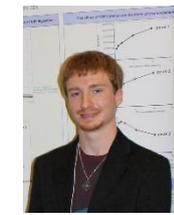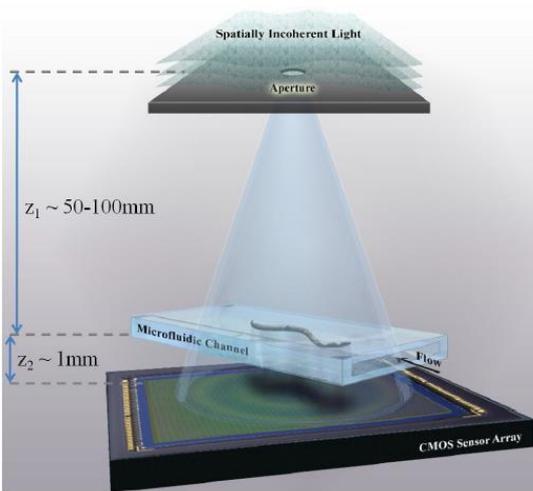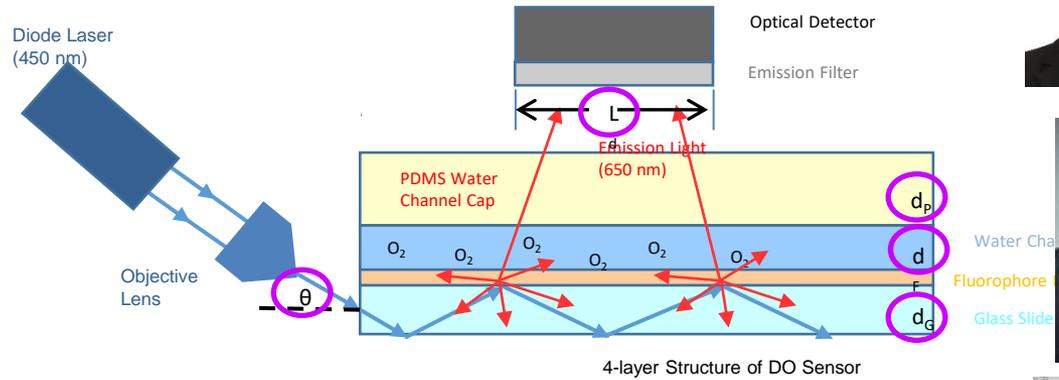
Holographic opto-fluidic microscopy

Waheb Bishara,[1,*] Hongying Zhu,[1] and Aydogan Ozcan[1,2,3]

[1]Electrical Engineering Department, University of California, Los Angeles, CA 90095, USA
[2]California NanoSystems Institute, University of California, Los Angeles, CA 90095, USA
[3]ozcan@ucla.edu
*bishara@ucla.edu
http://innovate.ee.ucla.edu

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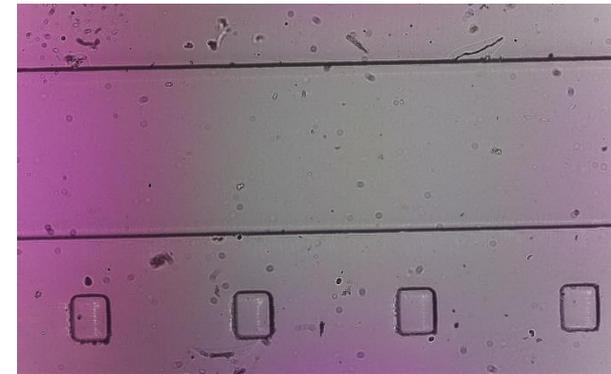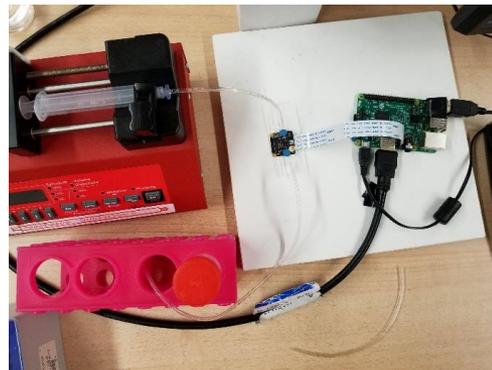
Lessons Learned

- Sensing modalities and clinical relevance:
  - Motions are easy to measure
  - Activities are hard to determine
  - Glucose, sweat, saliva, pressure/weight
  - Feeling, pain
- Analytics
  - Edge computing, battery issues
  - Longitudinal data
  - Personalized Machine Learning
- Data security and privacy
  - Patient owned data
  - How about processed data?
- **Cost?**
  - **Equipment purchase, Installation, Operation**
- **Equity, Diversity, and Inclusive**
- **Regulatory Issues: Health Canada, FDA, EMA**
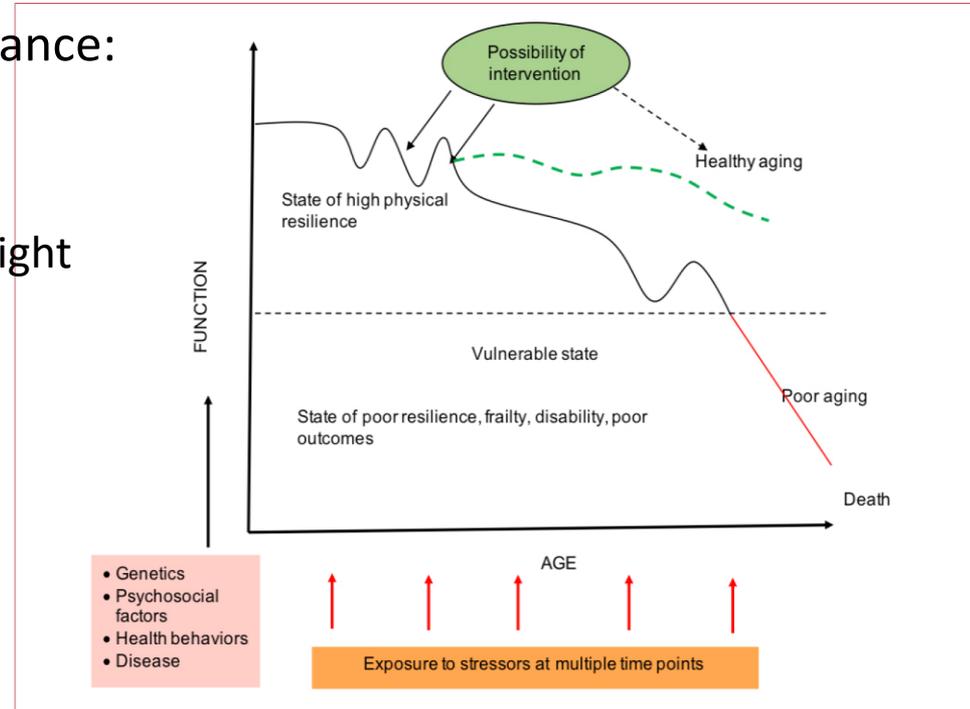
Physical Resilience: A novel approach for healthy aging, Chan et al., 2021, Journal of Frailty Sarcopenia and Falls 07(01) http://dx.doi.org/10.22540/JFSF-07-029

Additional thoughts

- What is "Smart" or "intelligent"?
  - Smart means capability of decision making beyond a static decision tree;
  - Ideally, in new situations
  - We are only at the sensing level
  - Will AI/ML take us there?
  - Regulatory approval is far
- Design for 60+yr old
 - Not limited to rehab scenarios
  - Workplaces

Acknowledgement

- Engineering
  - Prof. Jamal Deen
  - Prof. Ravi Selvagapathy

- Clinical
  - Dr. David Chan
  - Dr. Joseph E. Hayward
  - Dr. Brian Misiaszek
  - Dr. Pierre Major
  - Dr. Raymond Wong
  - Dr. Henry Siu