IoT Sensor Data Analytics and Smart Health Systems

Omar Boursalie, Ph.D.

Mock Lecture

Lecture Slides, Code, and Data:
https://github.com/OBoursalie/McMaster_Lecture

Land Acknowledgement

I take this time to recognize that McMaster University is currently on the traditional territory shared between the Haudenosaunee (Hoh-de-noh-show-knee) confederacy and the Anishinabe (Ann-neesh-in-na-beg) nations, which was acknowledged in the Dish with One Spoon Wampum belt

That wampum uses the symbolism of a **dish to represent the territory**, and **one spoon to represent that the people** are to **share the resources** of the land and only take what they need

https://www.torontomu.ca/aec/land-acknowledgment/

https://healthsci.mcmaster.ca/docs/librariesprovider59/resources/mcmaster-university-land-acknowledgment-guide.pdf?sfvrsn=7318d517_2

My Teaching Journey

Omar Boursalie, B.Eng, M.A.Sc., Ph.D.

1991: Born (at McMaster Hospital!)

2006: Starting learning to play the clarinet

2009-2014: Undergraduate Electrical, Computer, and Biomedical Engineering (McMaster)

- 2012-2013: 12-Month co-op Instructional Assistant Intern (IAI) for 1C03 (McMaster)

2014-2016: M.A.Sc. Biomedical Engineering (McMaster)

2016-2021: Ph.D. Biomedical Engineering (McMaster)

- Artificial intelligence in healthcare

2022-2023: Postdoctoral Fellow (Toronto Metropolitan University)

- Sessional Instructor (Winter 2022): Electrical and Computer Engineering (McMaster)

2023-now: Assistant Professor in Mechanical Engineering and the iBioMed Program (McMaster)

You Are Here

My Goal: Teaching Professor Position

Lessons Learned

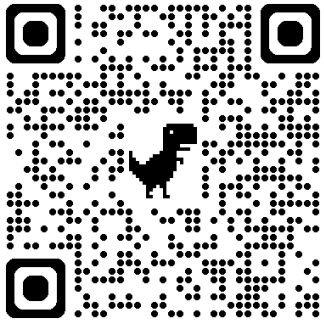
(Or what I wished I knew before I started)

- Co-op
  - Start looking early!
- Extracurricular projects
  - Usually, what you discuss in interviews
  - Your undergraduate courses are a starting point
  - Pick your favorite courses and use them as a launching board for your side projects (e.g., Raspberry Pi)
- Writing (especially if you are interested in doing graduate school)
  - Academic writing is an important skill
  - University has lots of free resources you can take advantage of on your own
  - Classes may not require it, but you can take courses and apply it to your labs on your own
- Mental Health
  - Importance of weekends and breaks

“IoT Sensor Data Analytics and Smart Health Systems”

Lecture Objectives

1. **Motivation**
2. What is the Internet of Things (IoT)?
3. IoT Data Collection
4. IoT Data Transmission
5. IoT Data Processing
6. Activity: IoT Device to Measure Temperature



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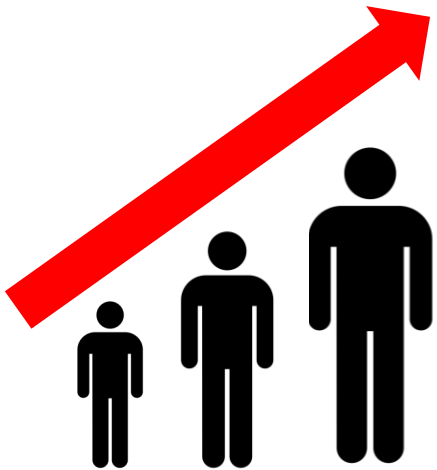
Textbook: m-Health: Fundamentals and Applications

Challenges in Healthcare

Growing Population

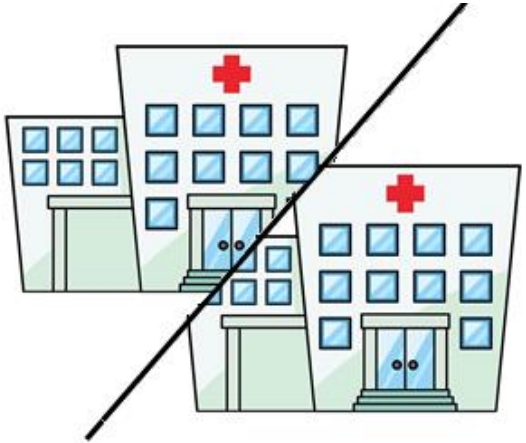


51 million by 2063
(Stats Canada, 2014)

Aging Population

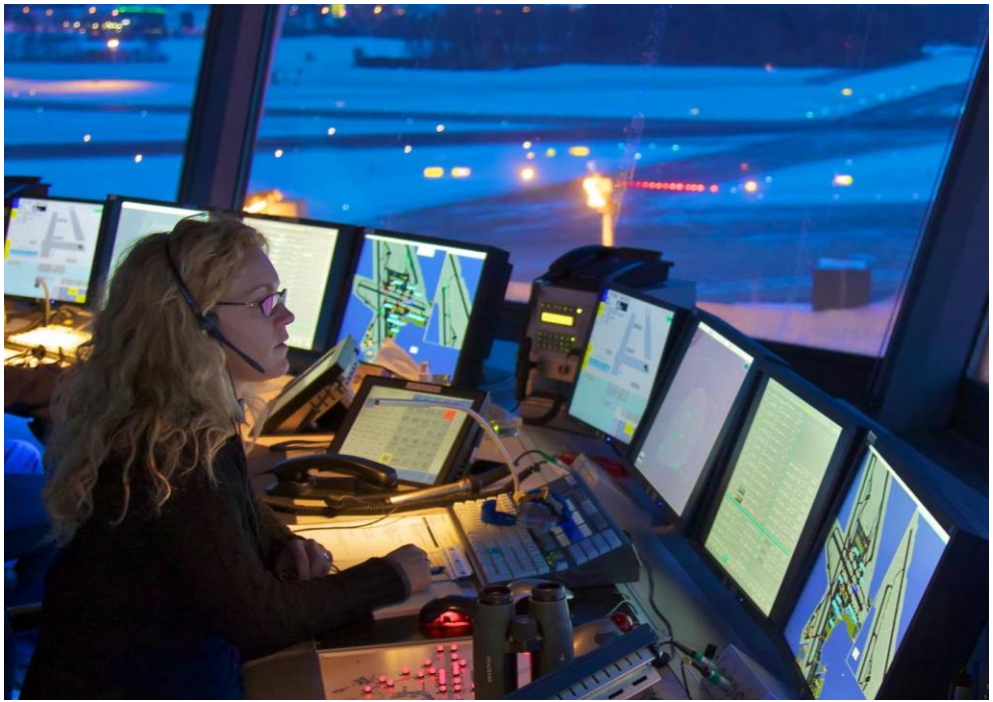
25% of Population by 2036
(Stats Canada, 2016)

Medical resources not increasing fast enough



Length of stay for admitted patients was up 11% in 2018 (CIHI, 2018)

Imagine the Future … Personalized Predictive Monitoring

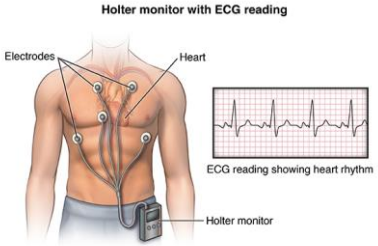


- Remote intensive-care units (ICUs)
  - “Air traffic control” for hospitals
  - Treat patients who are thousands of miles away
  - Decentralize hospitals
- Move treatments into the home
- Use artificial intelligence (machine learning) to assist in remote clinical decision-making
- The Internet of Things (IoT) is essential to make this future a reality

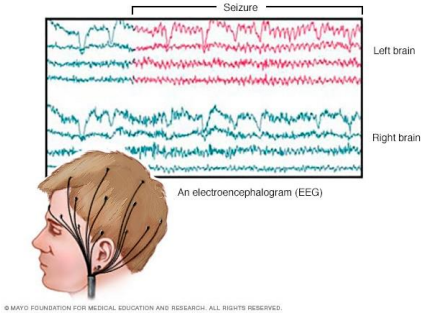
https://img.jobs.ch/www/img/organisation/background_image_27857.jpg

IoT Sensor Data Analytics and Smart Health Systems

Screening
(e.g., Depression Voice Analysis)



Diagnosis
(e.g., ECG Holter Monitor)
https://www.hopkinsmedicine.org/health



Treatment
(e.g., EEG Brain Control Interface)
https://www.mayoclinic.org/tests-procedures/eeg/about/pac-20393875

Monitoring
(e.g., Apple Watch)
https://www.apple.com/ca/shop/buy-watch

Disease Management
(e.g., Blood Glucose)
https://www.cbc.ca/news/canada/edmonton/glucose-monitoring

Motivation

IoT Sensor Data Analytics

- Undergraduate Studies
  - PROCTECH 4TR1/3 - Capstone Design Project I/II
  - SMRTTECH 4AI3 – Artificial Intelligence and Machine Learning
  - PROCTECH 4MH3 – Machine Health and Remote Monitoring
  - SMRTTECH 4SC3 – Smart Cities and Communities
  - SMRTTECH 4ID3 – IoT Devices and Networks
  - GENTECH 4EP3 - Entrepreneurial Thinking and Innovation
- Graduate Studies
  - https://www.eng.uwo.ca/electrical/faculty/fang_f/index.html
  - https://www.eng.mcmaster.ca/research-innovation/research-clusters/digital-smart-systems/
  - SEP 769 – Cyber-Physical Systems
- Careers
  - Data Analytics, Network, Security, IoT Architect/ Developer, Cloud Computing
  - Cloud Solutions Architect – Internet of Things (IoT)
  - Connexall - Business and Data Analyst
- Start-ups
  - https://www.incorahealth.com/ (IoT Earrings)

“IoT Sensor Data Analytics and Smart Health Systems”

Lecture Objectives

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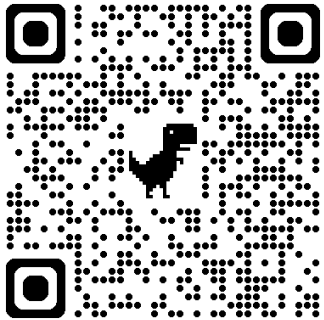
2. **What is the Internet of Things (IoT)?**
3. IoT Data Collection
4. IoT Data Transmission
5. IoT Data Processing
6. Activity: IoT Device to Record Temperature



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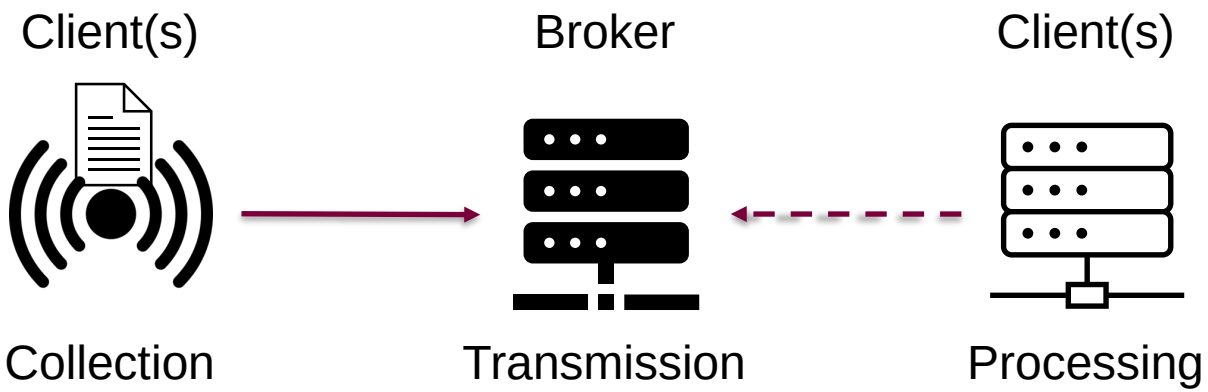
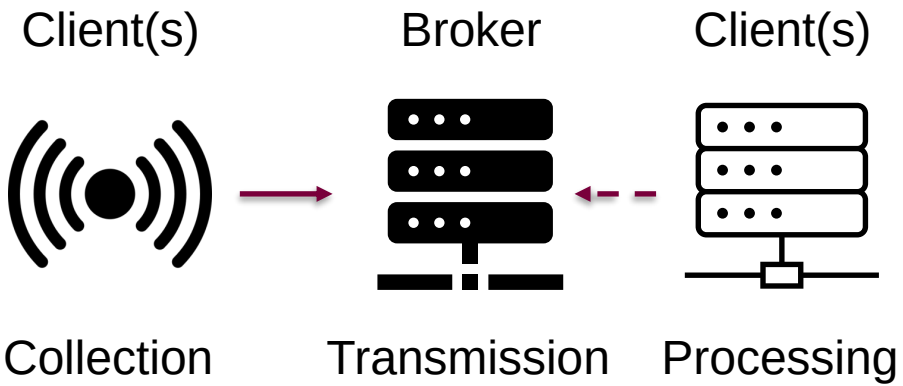
Textbook: m-Health: Fundamentals and Applications

What is the Internet of Things (IoT)?

The Internet of Things (IoT) is a network of physically embedded sensors (“things”) that can connect and exchange data over the Internet or other communications networks



IoT Advantages



- Efficient
- Scalable
- Bidirectional
- Decoupled
  - Designed for reliable communication over unreliable channels
- Secure

“IoT Sensor Data Analytics and Smart Health Systems”

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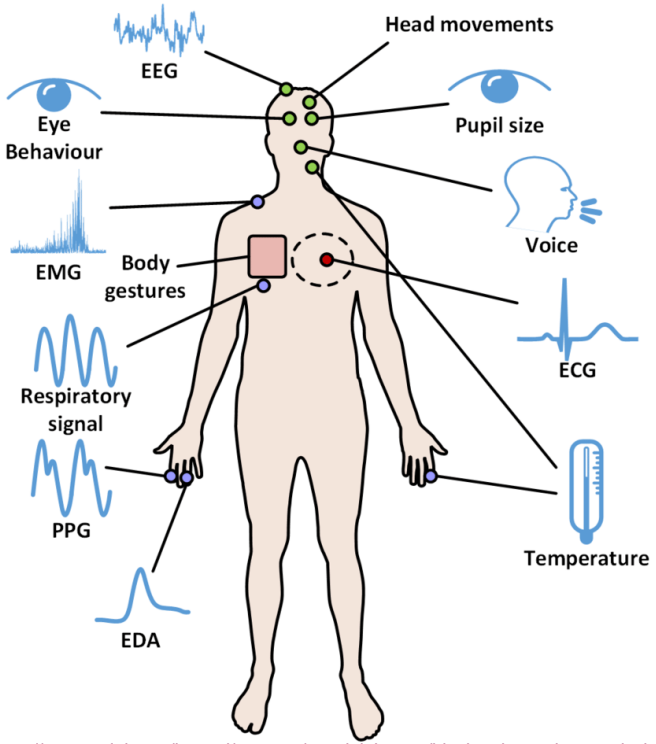
Textbook: m-Health: Fundamentals and Applications

Acquiring Real-World Data

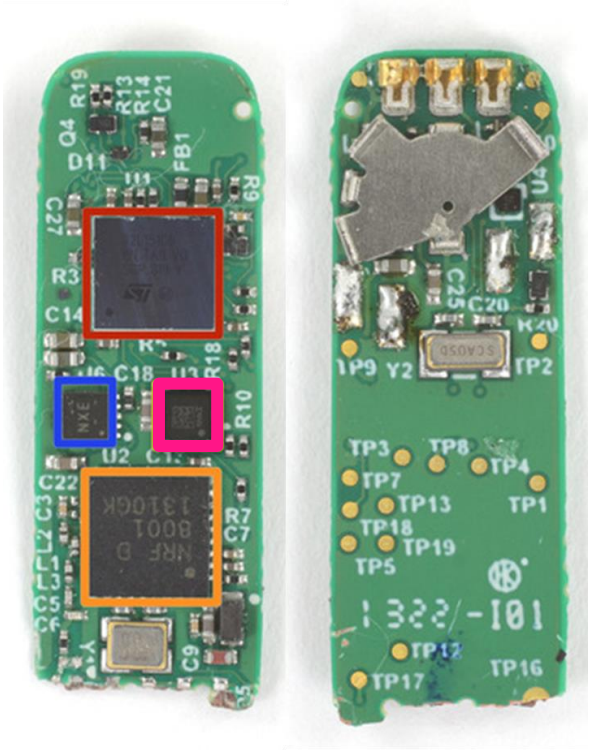
Biomedical signals can be captured (mostly) non-invasively and used as indicators of health



https://www.mdpi.com/journal/sensors/special_issues/biosignal_sensing_analysis

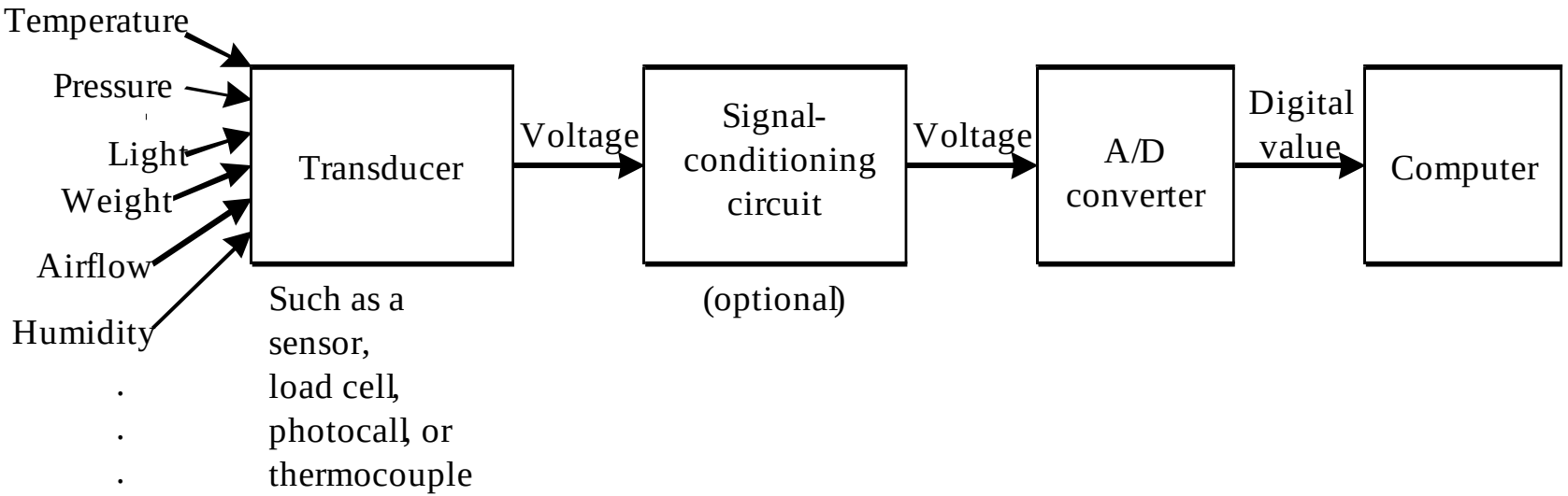
- Temperature
- Electroencephalogram (EEG)
- Electrooculogram (EOG)
- Electrocardiogram (ECG)
- Electromyogram (EMG)
- Photoplethysmogram (PPG)
- Electrodermal activity (EDA)
- Humidity
- Pressure
- Activity

What Makes the Fitbit Tick?



- Accelerometer
- Thermometer
- Microcontroller
- WiFi
- Battery

Acquiring Real-World Data



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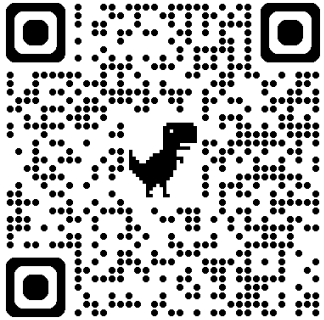

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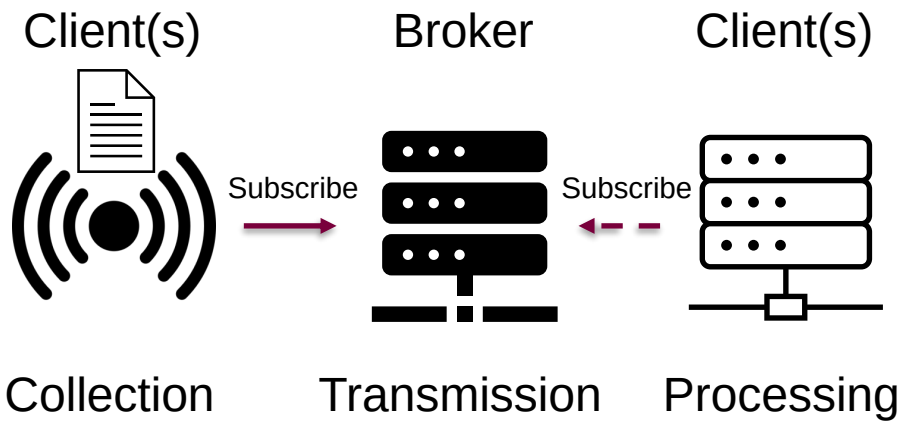
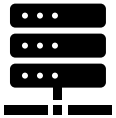
Textbook: m-Health: Fundamentals and Applications

IoT Messaging

Data Transmission Using MQTT Protocol



- Clients
  - Sensors, software, and other technologies that want to exchange data
- Broker
  - Handles data transaction
- Subscribe
  - Client(s) wants to receive data from a broker
- Publish
  - Client(s) wants to send data to a broker
- Distribute
  - Broker sends data to the subscribed client(s)



Broker

Responsible for

- Determining if client(s) are allowed to connect to the broker (and what permissions they have)
- Receiving messages
- Determining who subscribed to client(s)
- Sending the message to the subscribed client(s)

Managed broker services that let you use their hosted brokers for your IoT ecosystem (Today's Activity)

- Azure IoT Hub
- AWS IoT Core
- HiveMQ

“IoT Sensor Data Analytics and Smart Health Systems”

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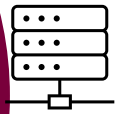

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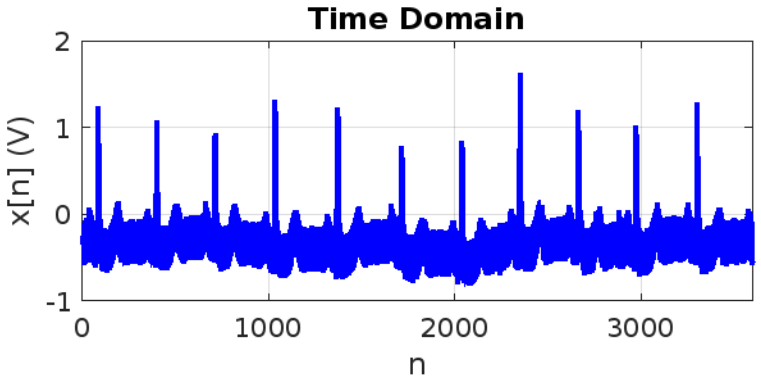
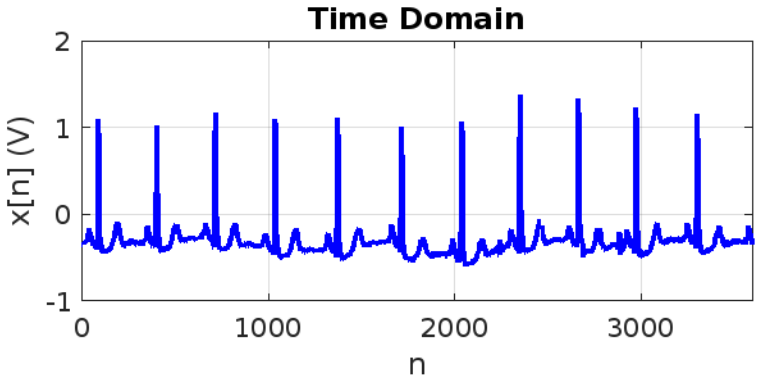
Textbook: m-Health: Fundamentals and Applications

DETOUR D-1

Detour: Signal Processing

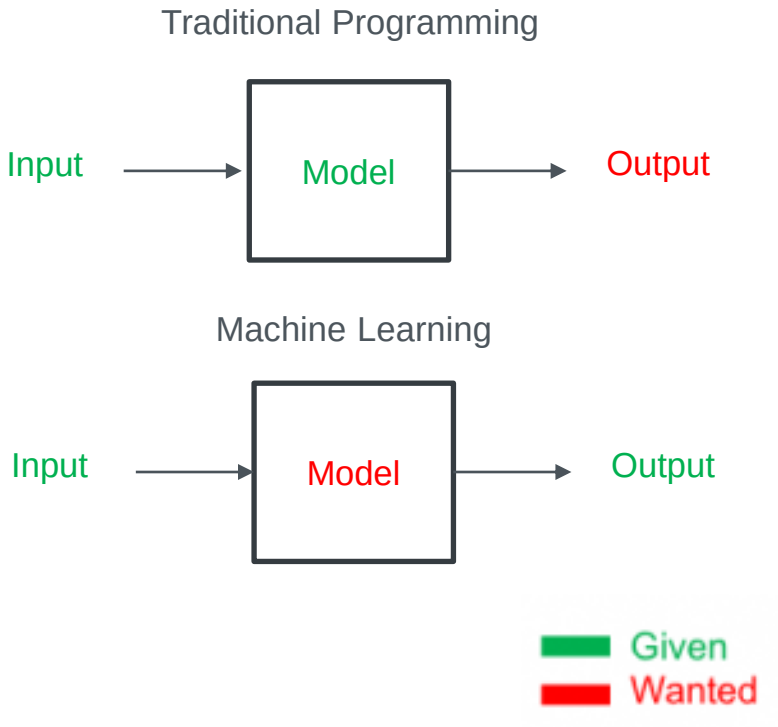
Biomedical Signals are Noisy





- These are real ECG signals
  - Sample 101 from the MIT-BIH Arrhythmia Database
  - https://archive.physionet.org/physiobank/database/mitdb/
- Biomedical signals contain
  - Noise of different types, e.g., movement, electricity interference)
  - Aggregated information from different concurrent sources (e.g., EOG, EEG, and EMG)
- Signal processing techniques are needed to extract clinically meaningful information from the biomedical signals
- We will discuss signal processing later this term

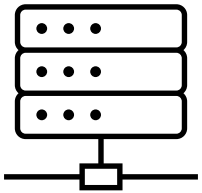
What is an Algorithm? What is Machine Learning?



- An algorithm is a sequence of instructions that tells a computer what to do
  - E.g., Algorithm for playing tic-tac-toe
- Normally, humans write the algorithms that turn input into outputs
  - We have to **hand-craft our algorithm for every possible outcome**
- With machine learning, **computers write their algorithms**
  - Machine learning **generates the algorithm that turns inputs into outputs**!

How Does A Machine Learn? Training

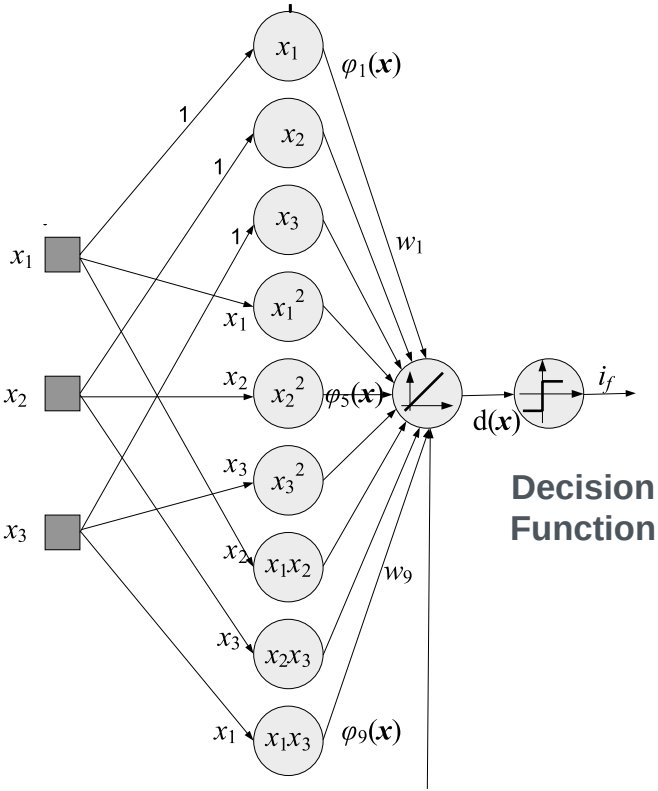
Data Mapping and Decision Function



Preprocess → Age

Preprocess → Temp

Preprocess → Activity



Heart Attack Risk
1 = High
0 = Low

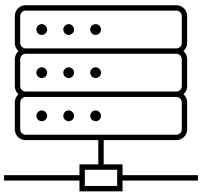
Decision Function

Each attribute must be preprocessed

Data Mapping Applied

How Does A Machine Learn? Training

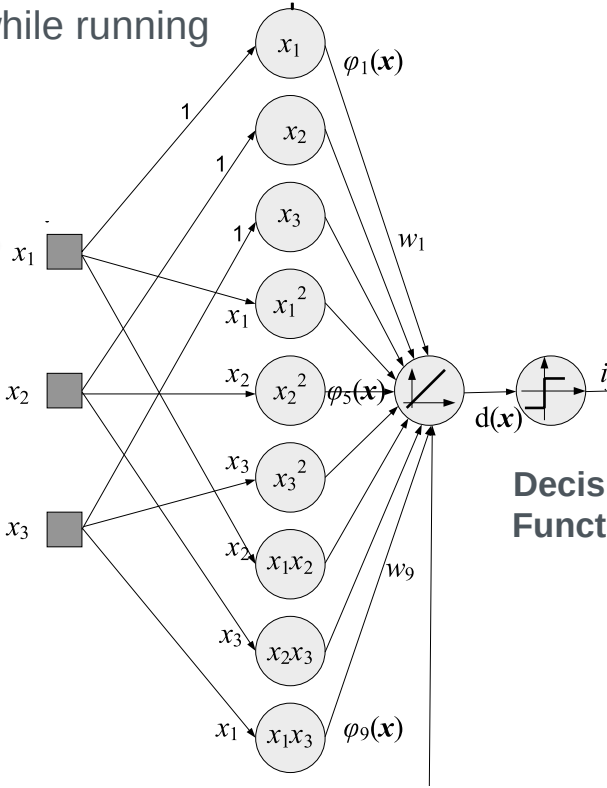
Risk of 27 years old with high temperature while running



Preprocess → Age 27

Preprocess → Temp High

Preprocess → Activity Running



Predict High Risk

INCORRECT

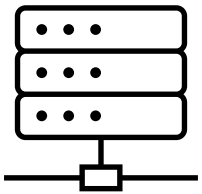
Decision Function

Each attribute must be preprocessed

Data Mapping Applied

How Does A Machine Learn? Training

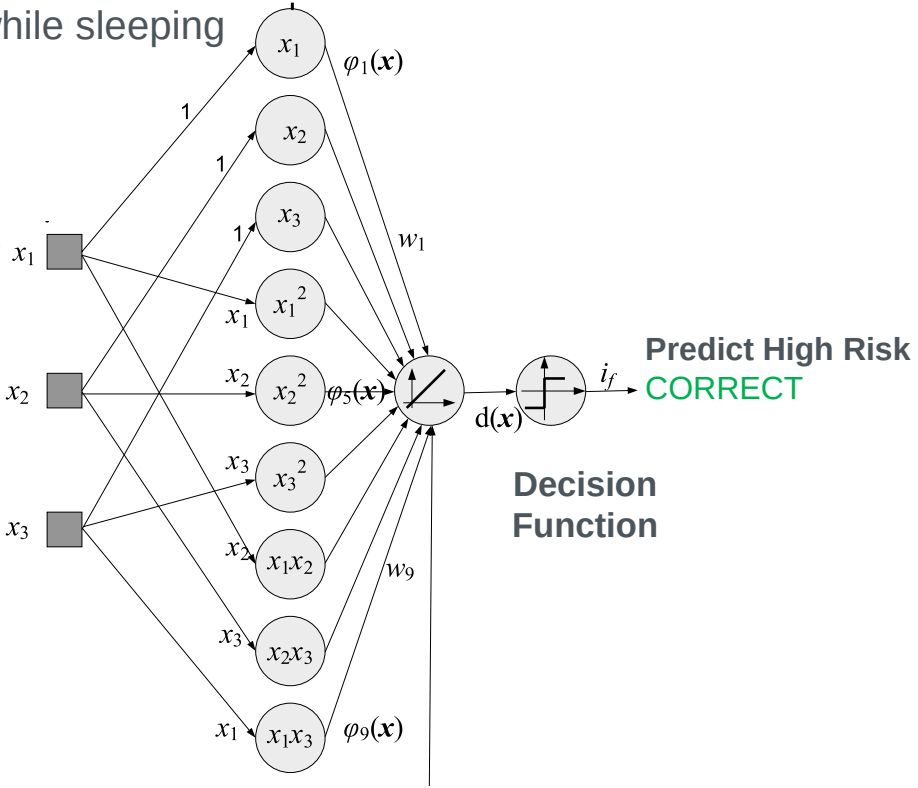
Risk of 27 years old with high temperature while sleeping



Preprocess → Age 27

Preprocess → Temp High

Preprocess → Activity Sleep

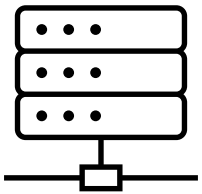


Each attribute must be preprocessed

Data Mapping Applied

How Does A Machine Learn? Training

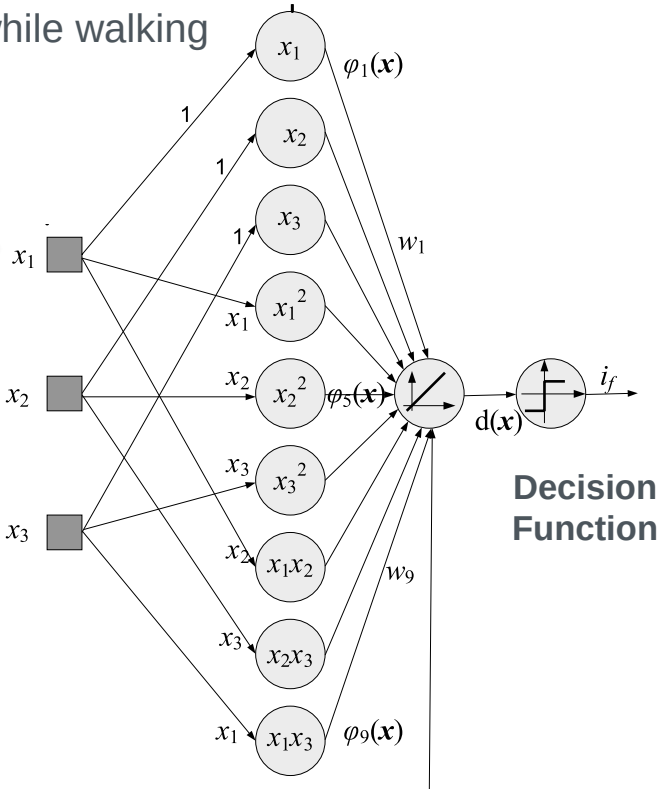
Risk of 72 years old with high temperature while walking



Preprocess → Age 72

Preprocess → Temp Very High

Preprocess → Activity Walk



Predict High Risk
CORRECT

Decision Function

Each attribute must be preprocessed

Data Mapping Applied

Training Machine Learning Algorithm

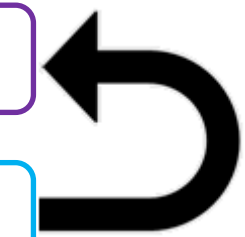
LABEL — Label data (e.g., healthy and not healthy)

SPLIT — Split data into **training** and **testing set**

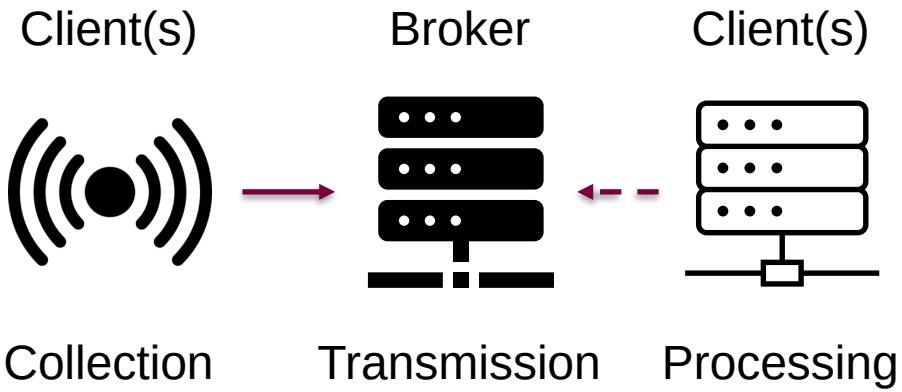
LEARN — Algorithm **learns** from **training set**

TEST — Algorithm is **tested** on **test set**

DEPLOY — Deploy to **classify new data**



Summary



- Internet of Things (IoT) is a network of embedded sensors that can connect and exchange data over communications networks
  - IoT architecture contains data collection, transmission, and processing

- Working with IoT requires knowledge of electronics, programming, networking, security, signal processing, and data analysis (such as machine learning)

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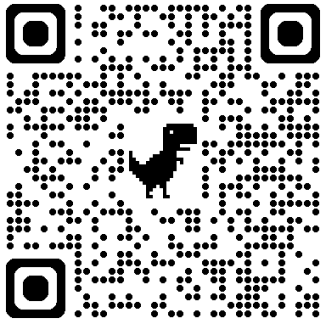

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