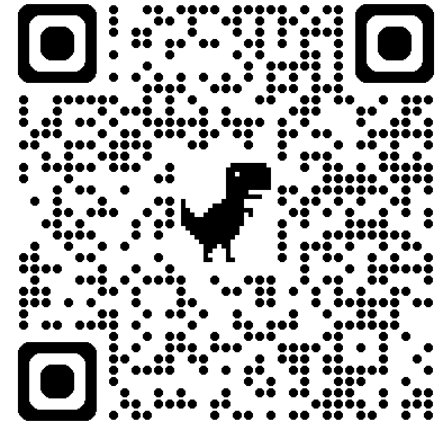


IoT Sensor Data Analytics and Smart Health Systems

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)

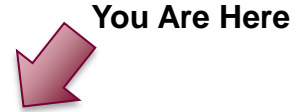
Artificial intelligence in healthcare

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)

My Goal: Teaching Professor Position



Lessons Learned

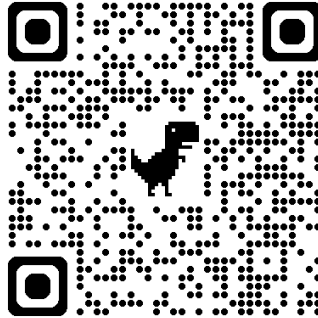
(Or what I wished I knew before I started)

- 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



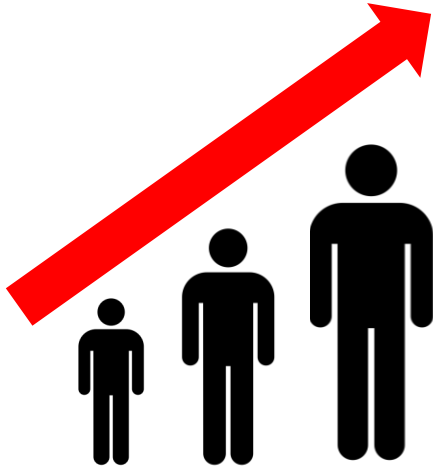
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Textbook: m-Health: Fundamentals and Applications

Challenges in Healthcare

Growing Population



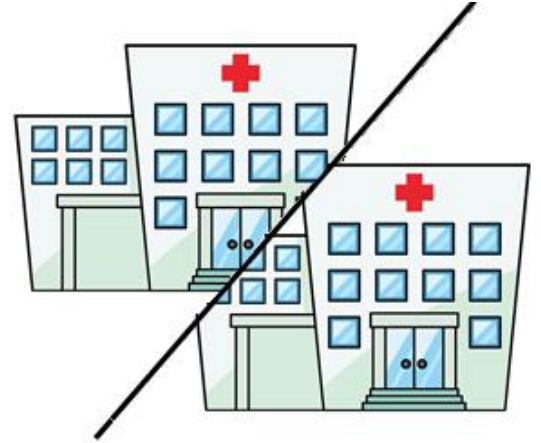
51 million by 2063
(Stats Canada, 2014)

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



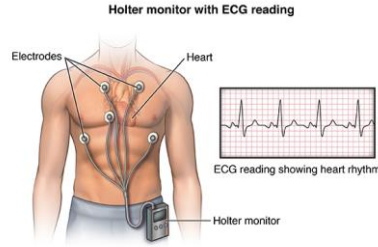
- Remote intensive-care units (ICUs)
 - “Air traffic control” for hospitals
 - Treat patients who are thousands of miles away
 - Decentralize hospitals
- Move treatments into the home
- Use artificial intelligence (machine learning) to assist in remote clinical decision-making
- The Internet of Things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

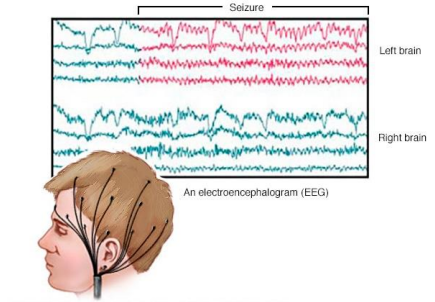


Screening
(e.g., Depression Voice Analysis)



Diagnosis
(e.g., ECG Holter Monitor)

<https://www.hopkinsmedicine.org/health>



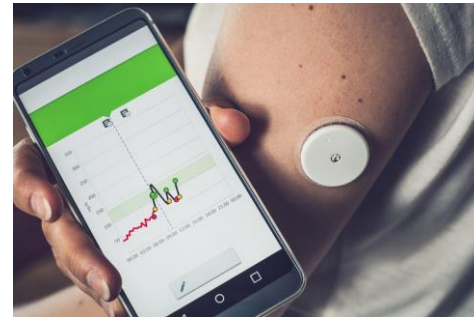
Treatment
(e.g., EEG Brain Control Interface)

<https://www.mayoclinic.org/tests-procedures/eeeg/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

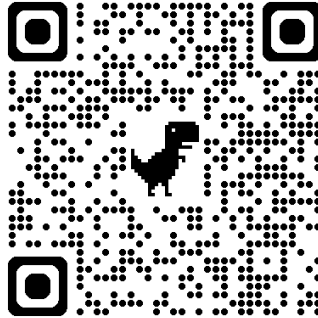
IoT Sensor Data Analytics

- 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

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 Record Temperature



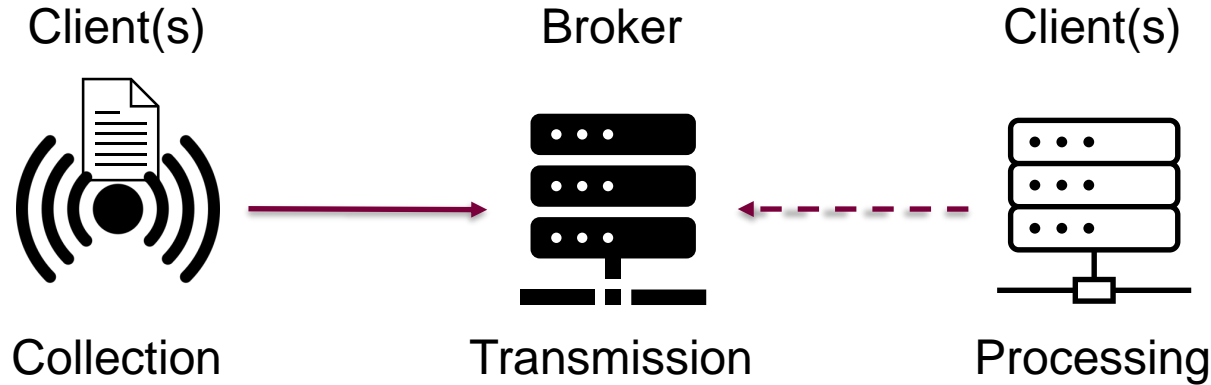
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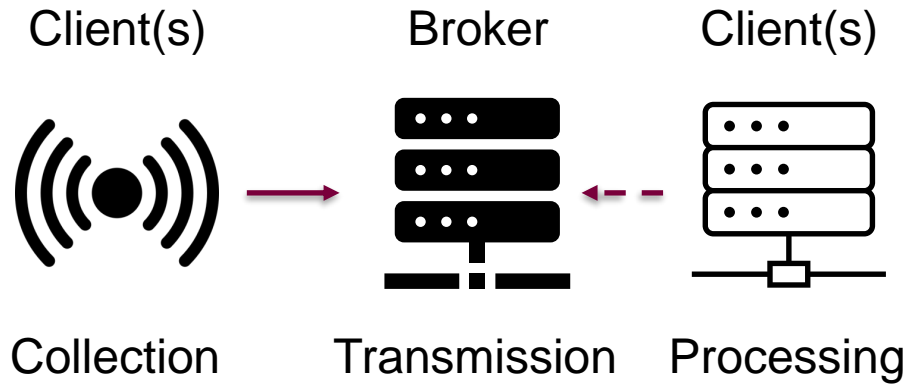
Textbook: m-Health: Fundamentals and Applications

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



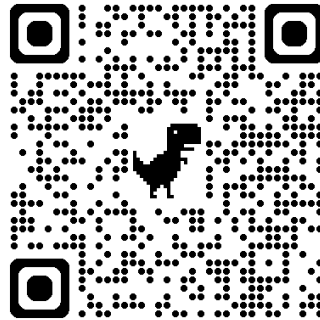
- Efficient
- Scalable
- Bidirectional
- Decoupled
 - Designed for reliable communication over unreliable channels
- Secure

“IoT Sensor Data Analytics and Smart Health Systems”

Lecture Objectives



1. Motivation
2. What is the Internet of Things (IoT)?
3. **IoT Data Collection**
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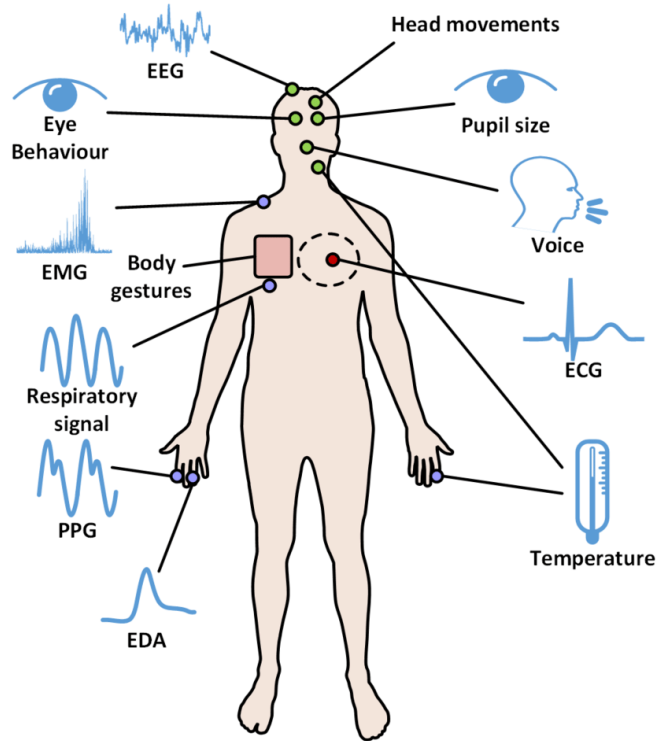
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Textbook: m-Health: Fundamentals and Applications



Acquiring Real-World Data

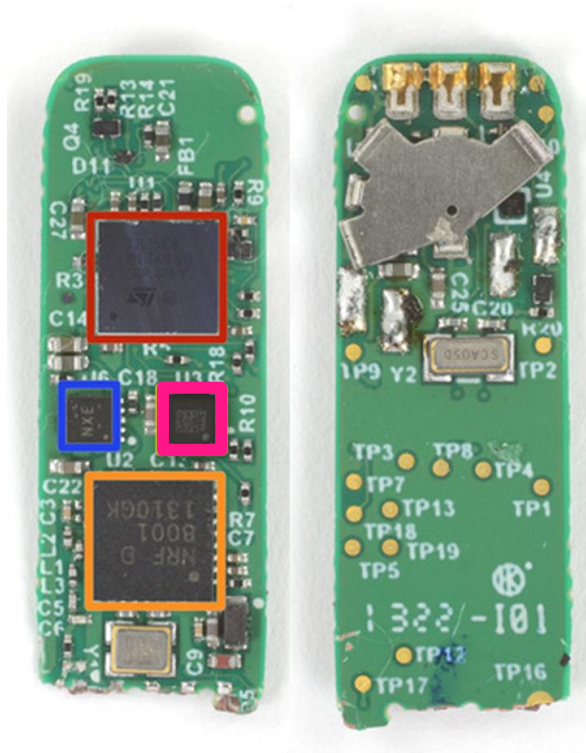
Biomedical signals can be captured (mostly) non-invasively and used as indicators of health



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

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

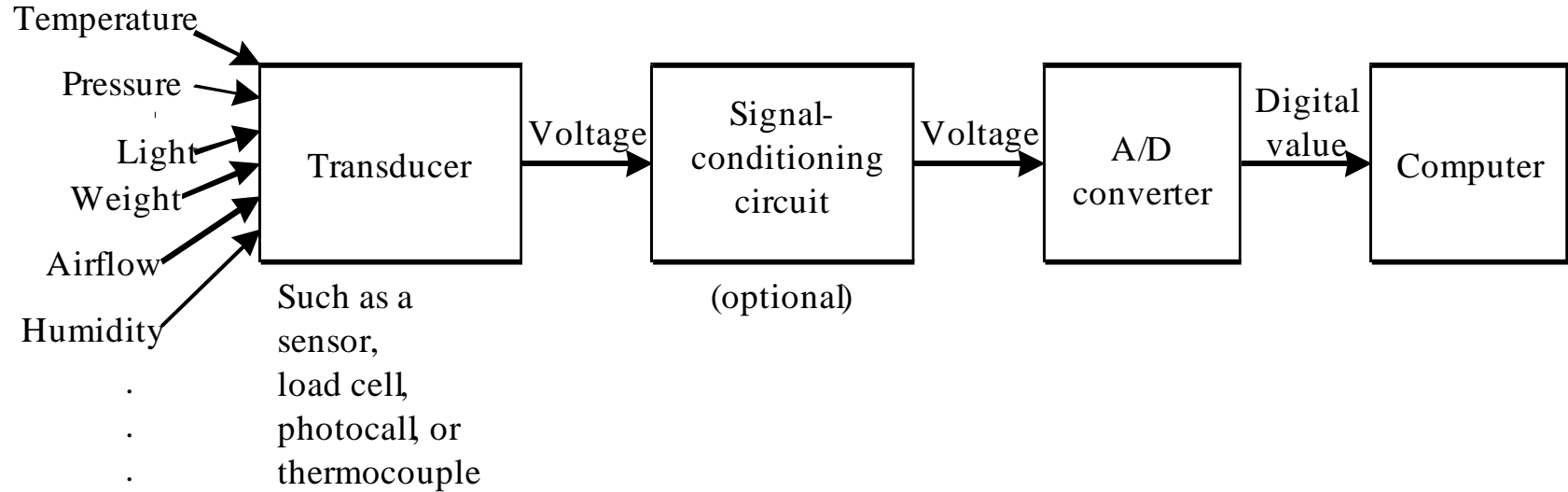
What Makes the Fitbit Tick?



- Accelerometer
- Thermometer
- Microcontroller
- WiFi
- Battery



Acquiring Real-World Data

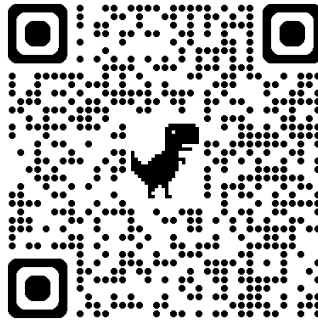


“IoT Sensor Data Analytics and Smart Health Systems”

Lecture Objectives



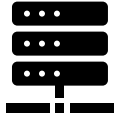
1. Motivation
2. What is the Internet of Things (IoT)?
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Lecture Slides, Code, and Data:

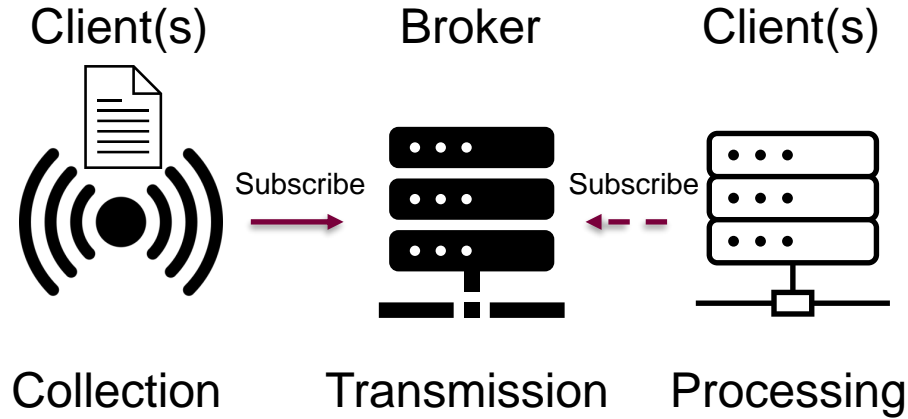
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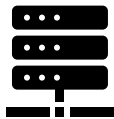


IoT Messaging

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)

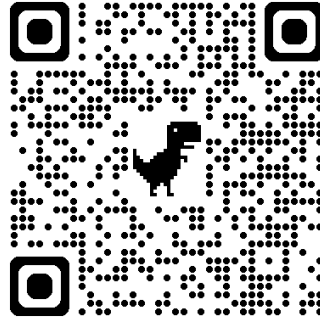
- Azure IoT Hub
- AWS IoT Core
- HiveMQ

“IoT Sensor Data Analytics and Smart Health Systems”

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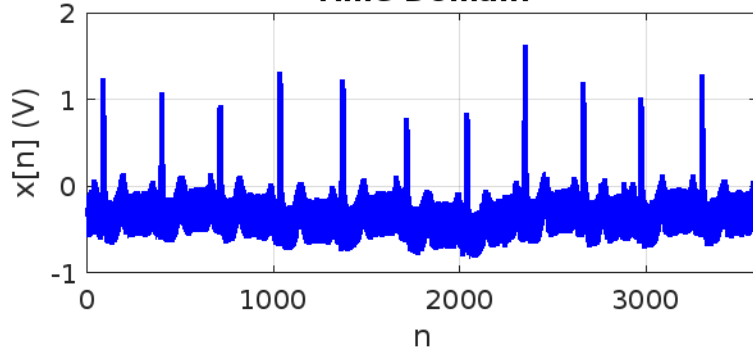
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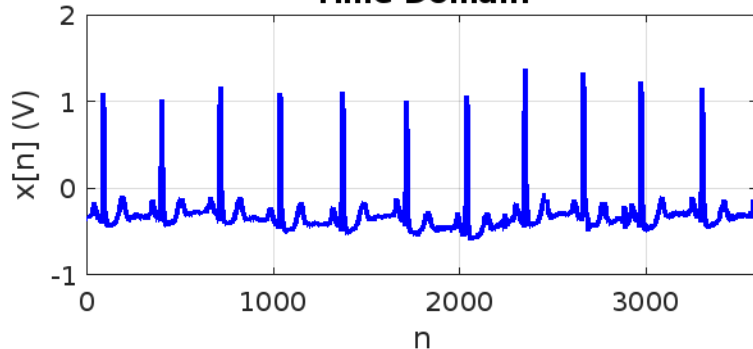
Detour: Signal Processing

Biomedical Signals are Noisy

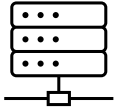
Time Domain



Time Domain

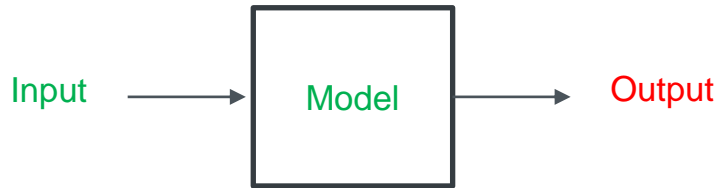


- These are real ECG signals
 - Sample 101 from the MIT-BIH Arrhythmia Database
 - <https://archive.physionet.org/physiobank/database/mitdb/>
- Biomedical signals contain
 - Noise of different types, e.g., movement, electricity interference)
 - Aggregated information from different concurrent sources (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?

Traditional Programming

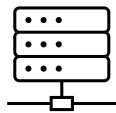


Machine Learning



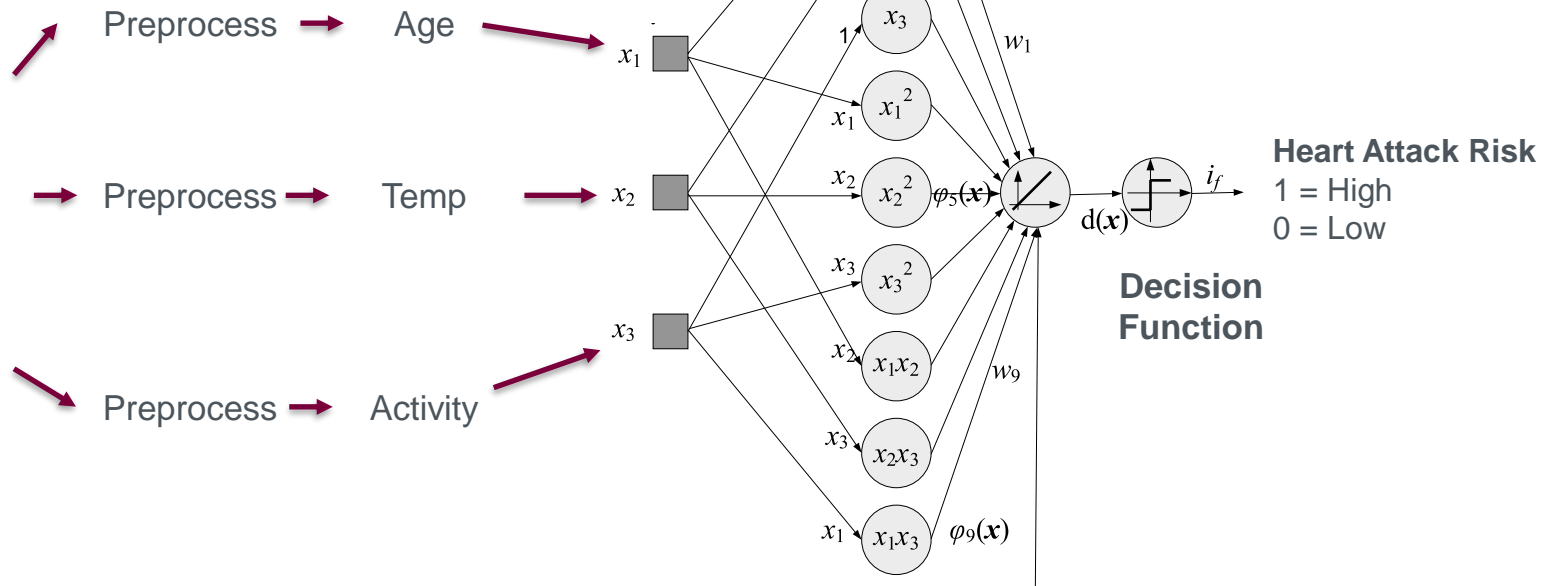
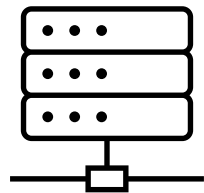
 Given
 Wanted

- 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!**



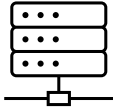
How Does A Machine Learn? Training

Data Mapping and Decision Function



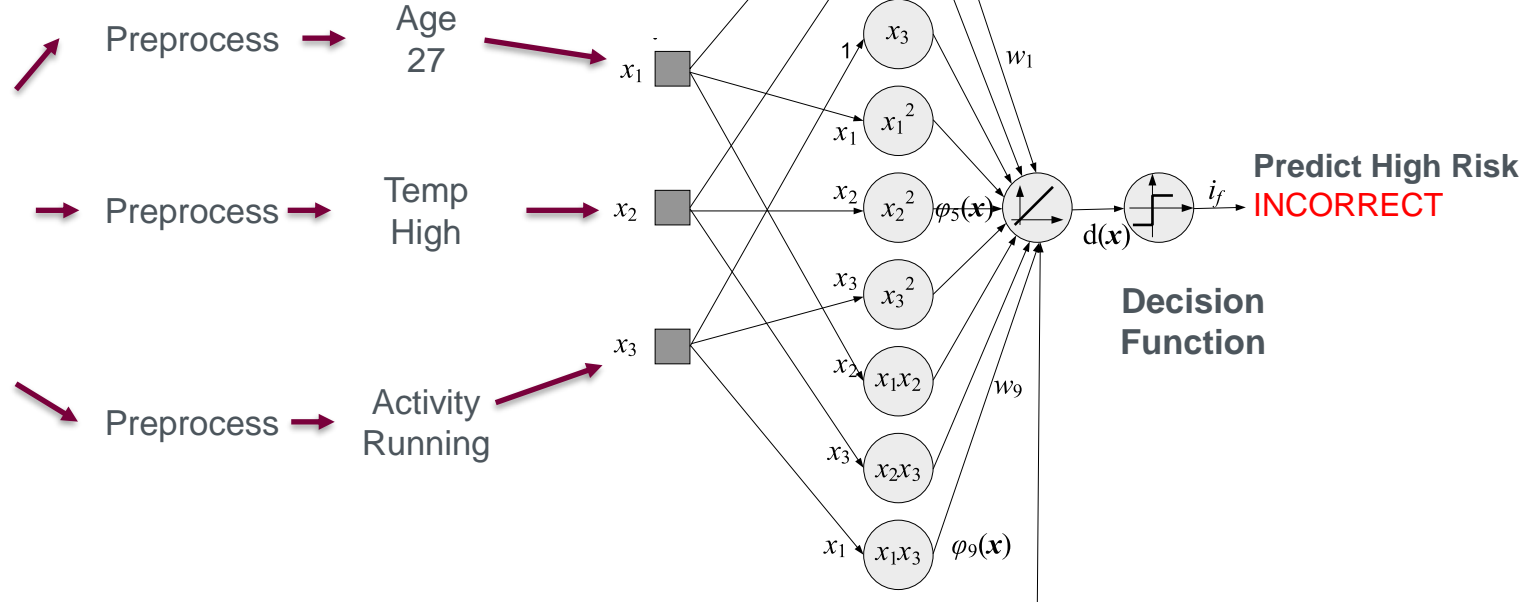
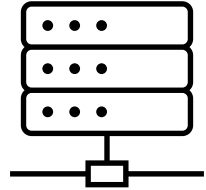
Each attribute must be preprocessed

Data Mapping Applied



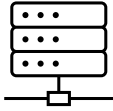
How Does A Machine Learn? Training

Risk of 27 years old with high temperature while running



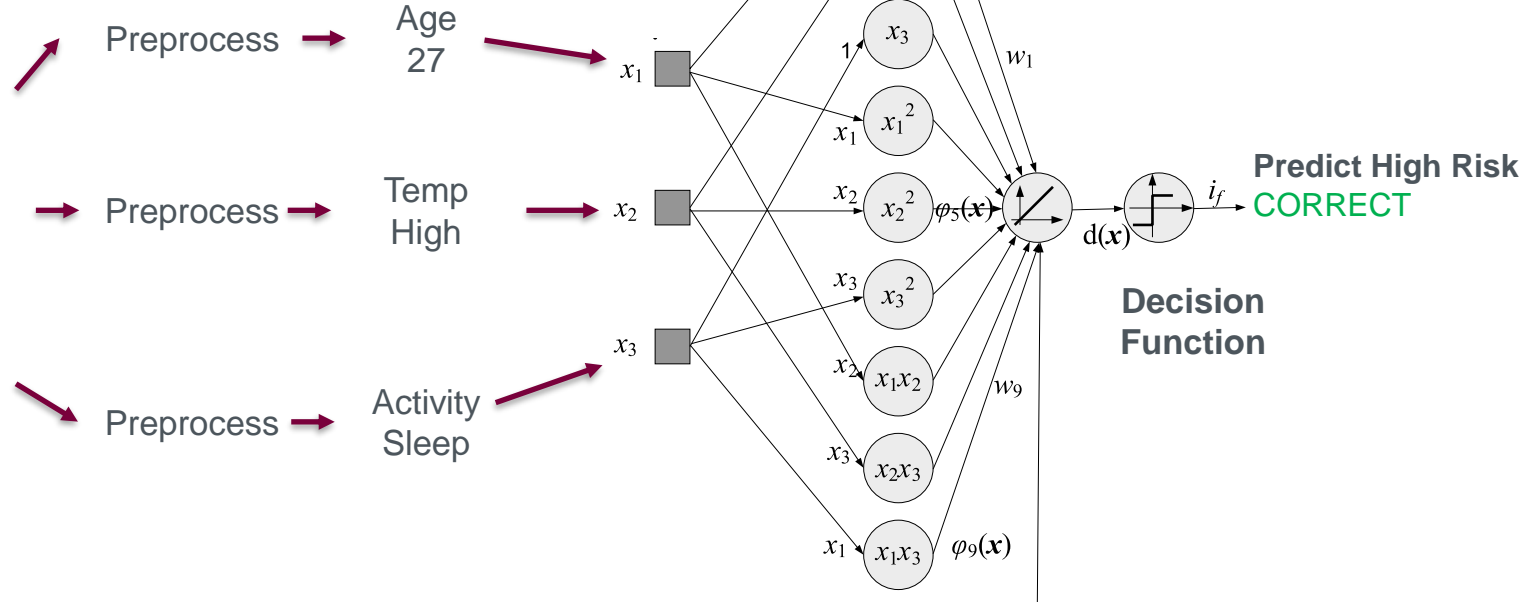
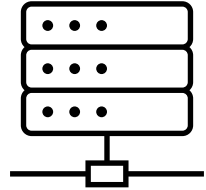
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Data Mapping Applied



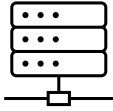
How Does A Machine Learn? Training

Risk of 27 years old with high temperature while sleeping



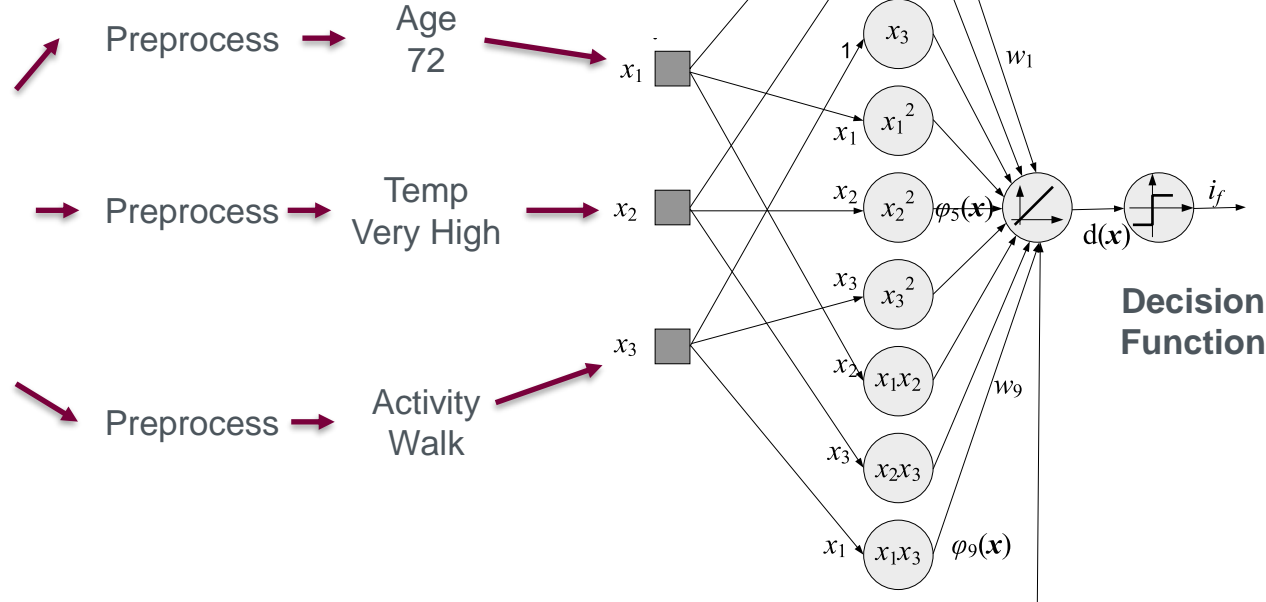
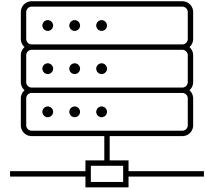
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Data Mapping Applied



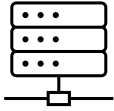
How Does A Machine Learn? Training

Risk of 72 years old with high temperature while walking

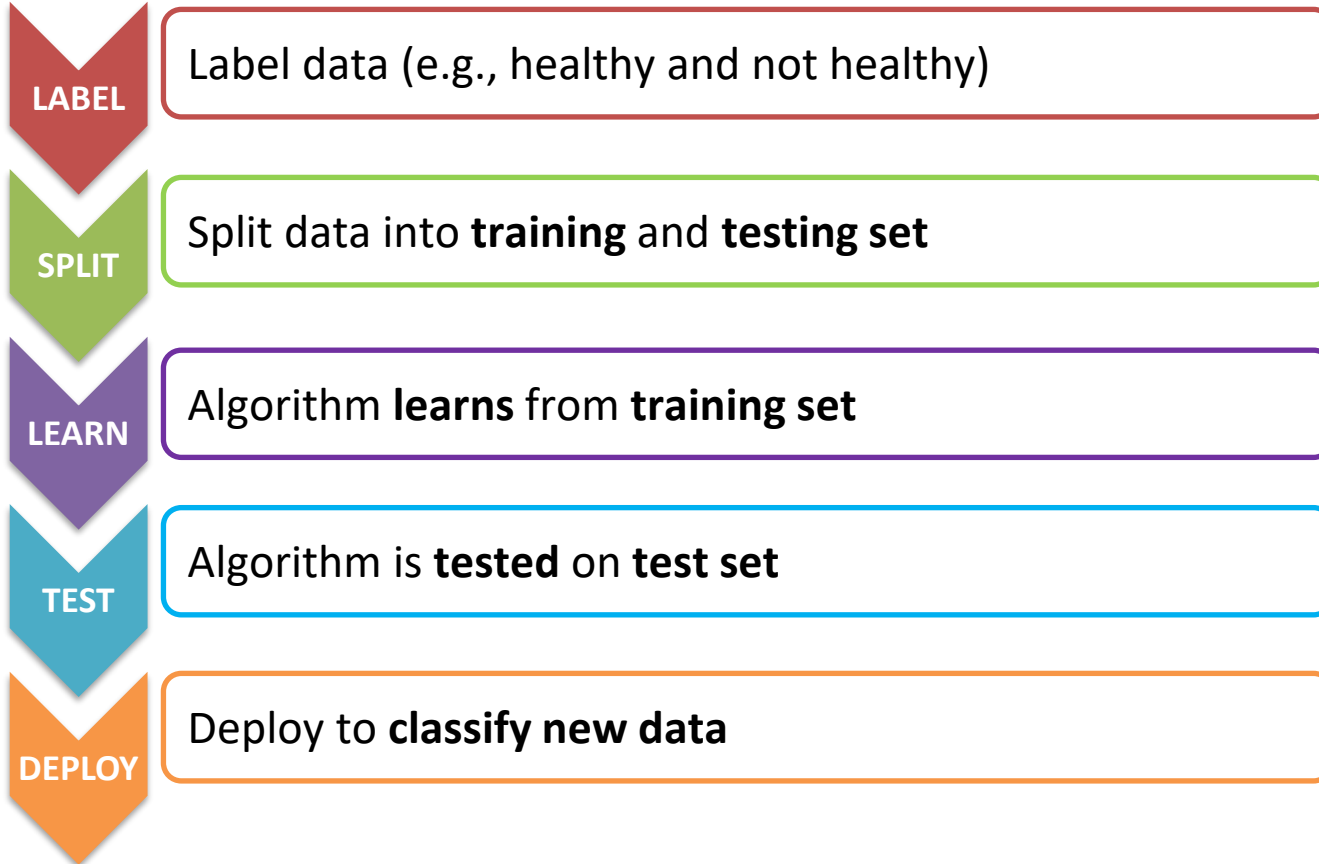


Each attribute must be preprocessed

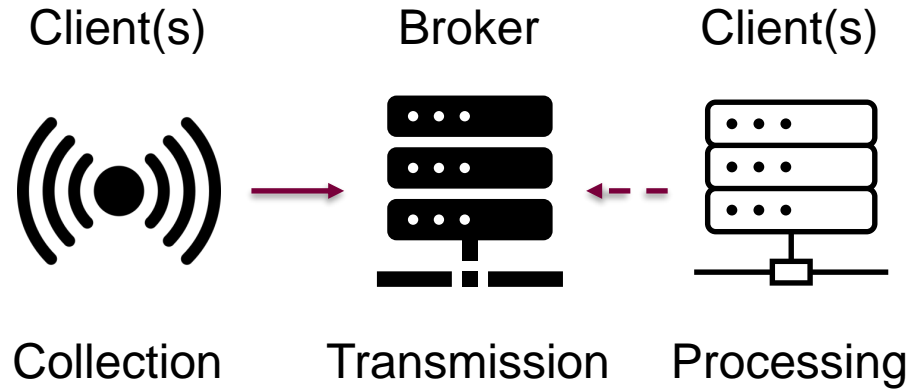
Data Mapping Applied



Training Machine Learning Algorithm



Summary

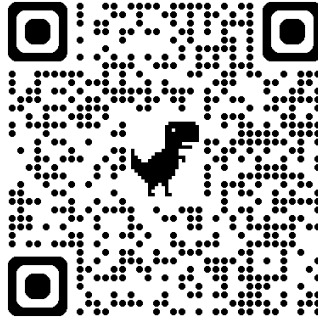


- Internet of Things (IoT) is a network of embedded sensors that can connect and exchange data over communications networks
 - IoT architecture contains data collection, transmission, and processing
- Working with IoT requires knowledge of electronics, programming, networking, security, signal processing, and data analysis (such as machine learning)

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