Better Buildings
U.S. DEPARTMENT OF ENERGY

De-Mystifying How Artificial Intelligence and Machine Learning Can Be Used to Improve Building Performance

Jessica Granderson, Hannah Kramer, Yimin Chen
Lawrence Berkeley National Laboratory
September 16, 2020

Welcome! We'll be starting shortly…

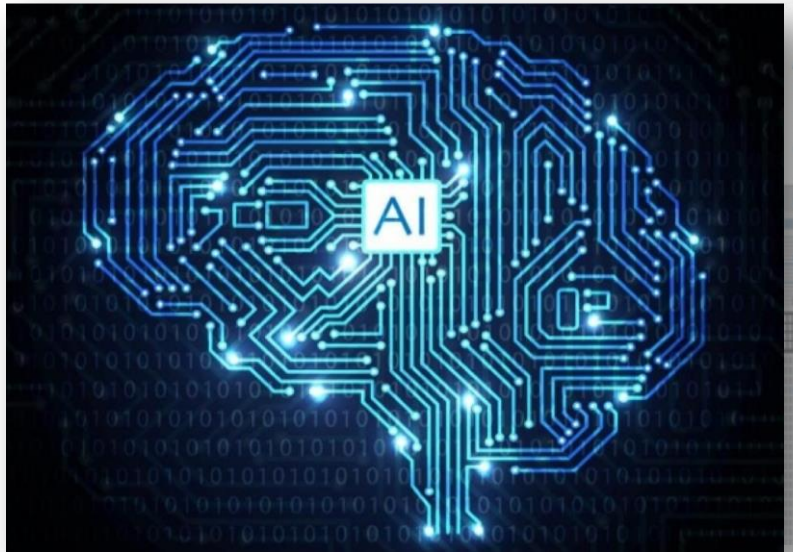
Outline

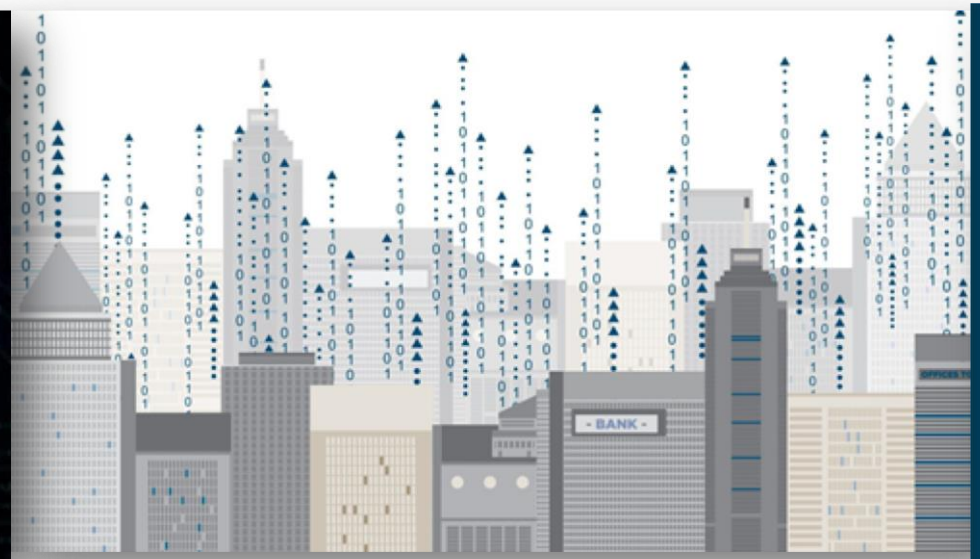
- Introduction
- Review of Artificial Intelligence and Machine Learning
- Major Machine Learning Methods
- Applications in Commercial Products
- Discussion and Conclusion

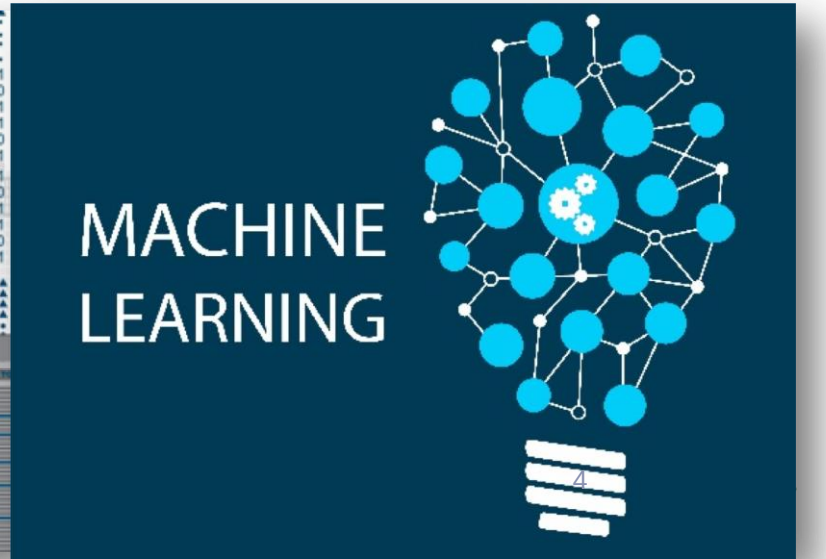
Introduction

Objectives

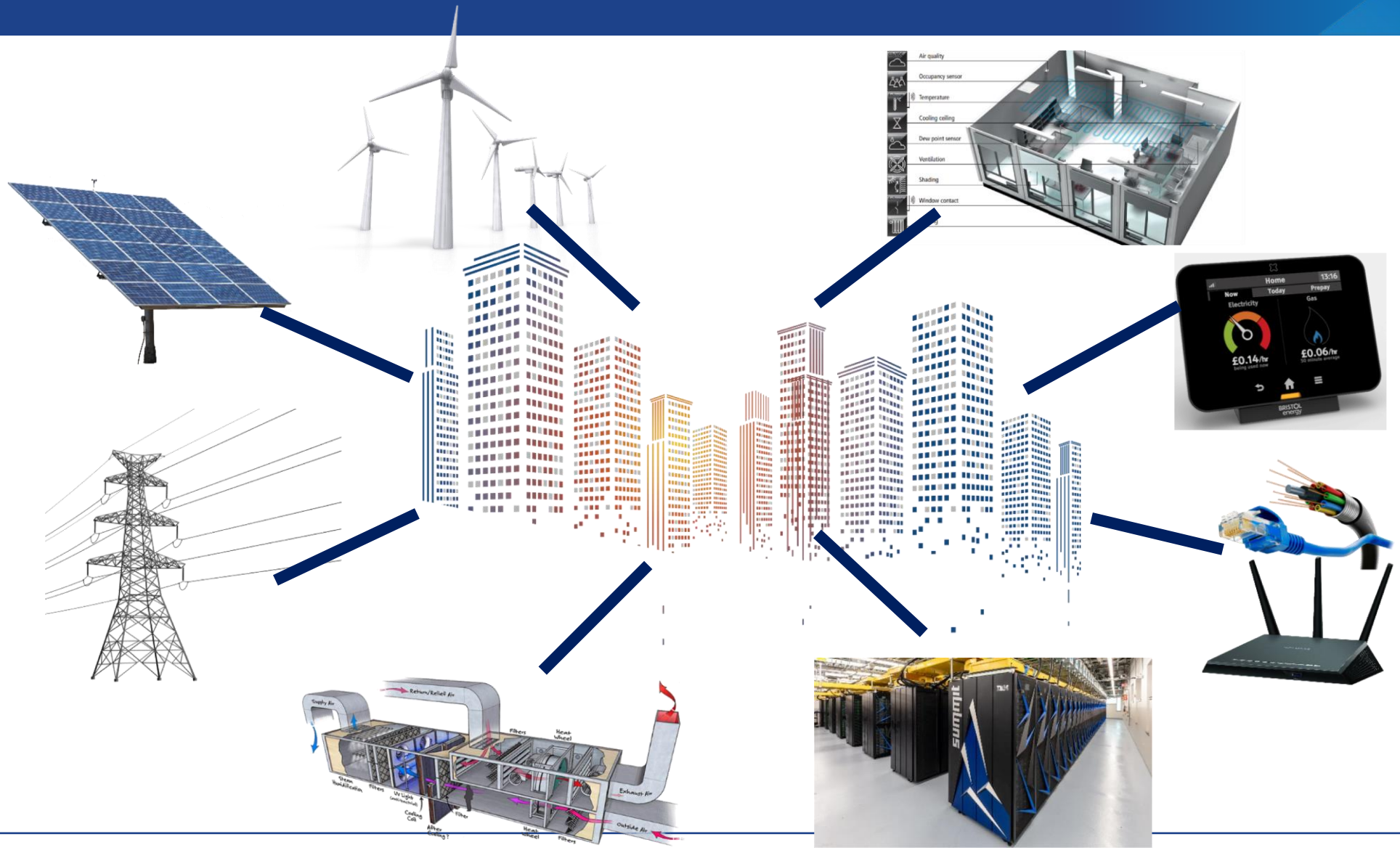
- Identify latest Machine Learning (ML) and Artificial Intelligence (AI) techniques used in market-deployed EMIS (FDD and adv. control)
- Raise awareness about emerging AI/ML techniques and their roles in building operations
- Uncover potential and challenges





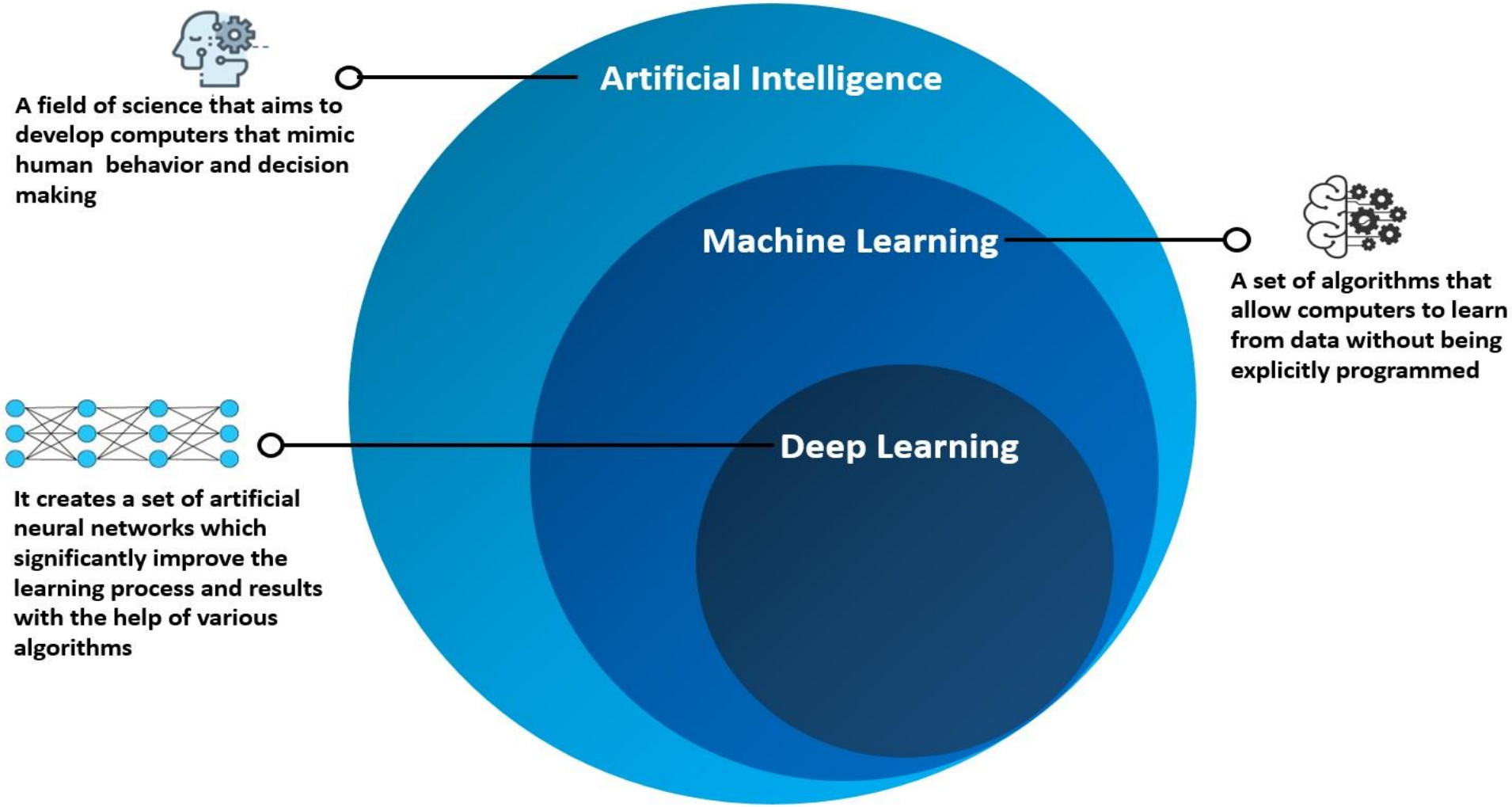


Context, Motivation

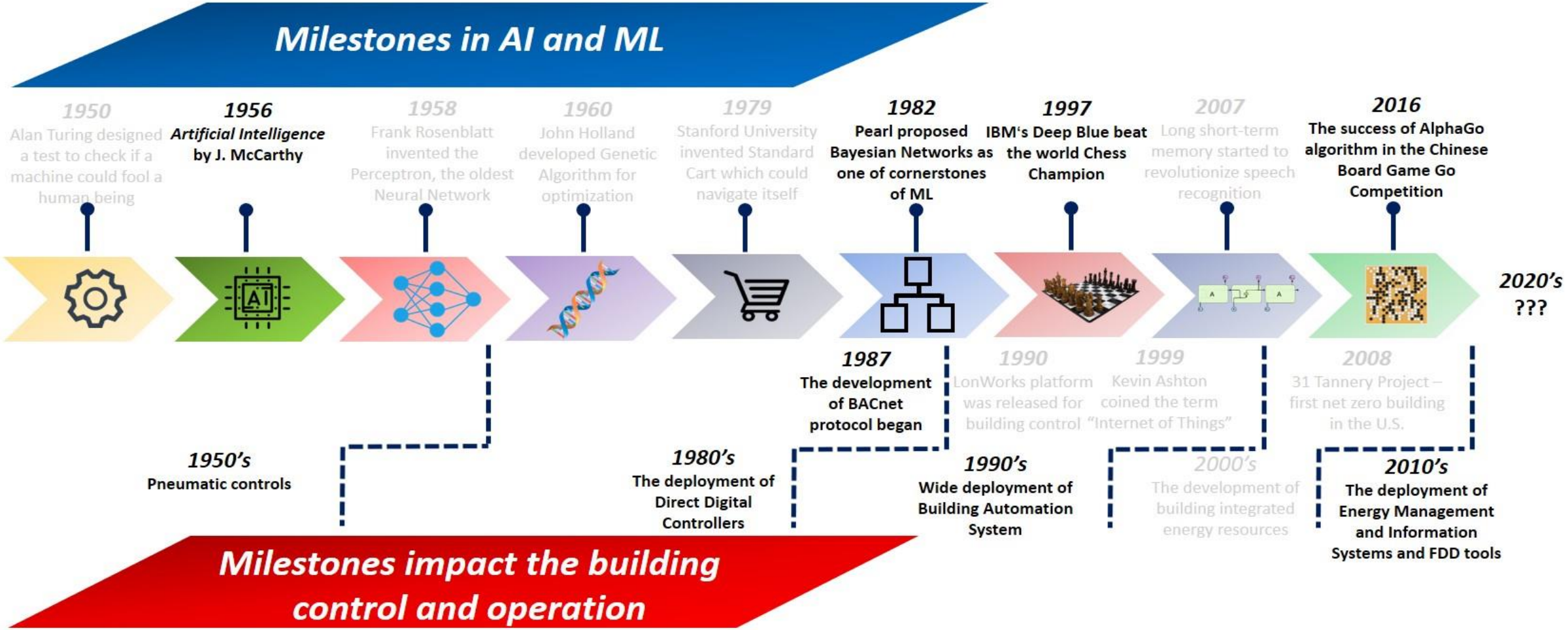


Review of Artificial Intelligence and Machine Learning

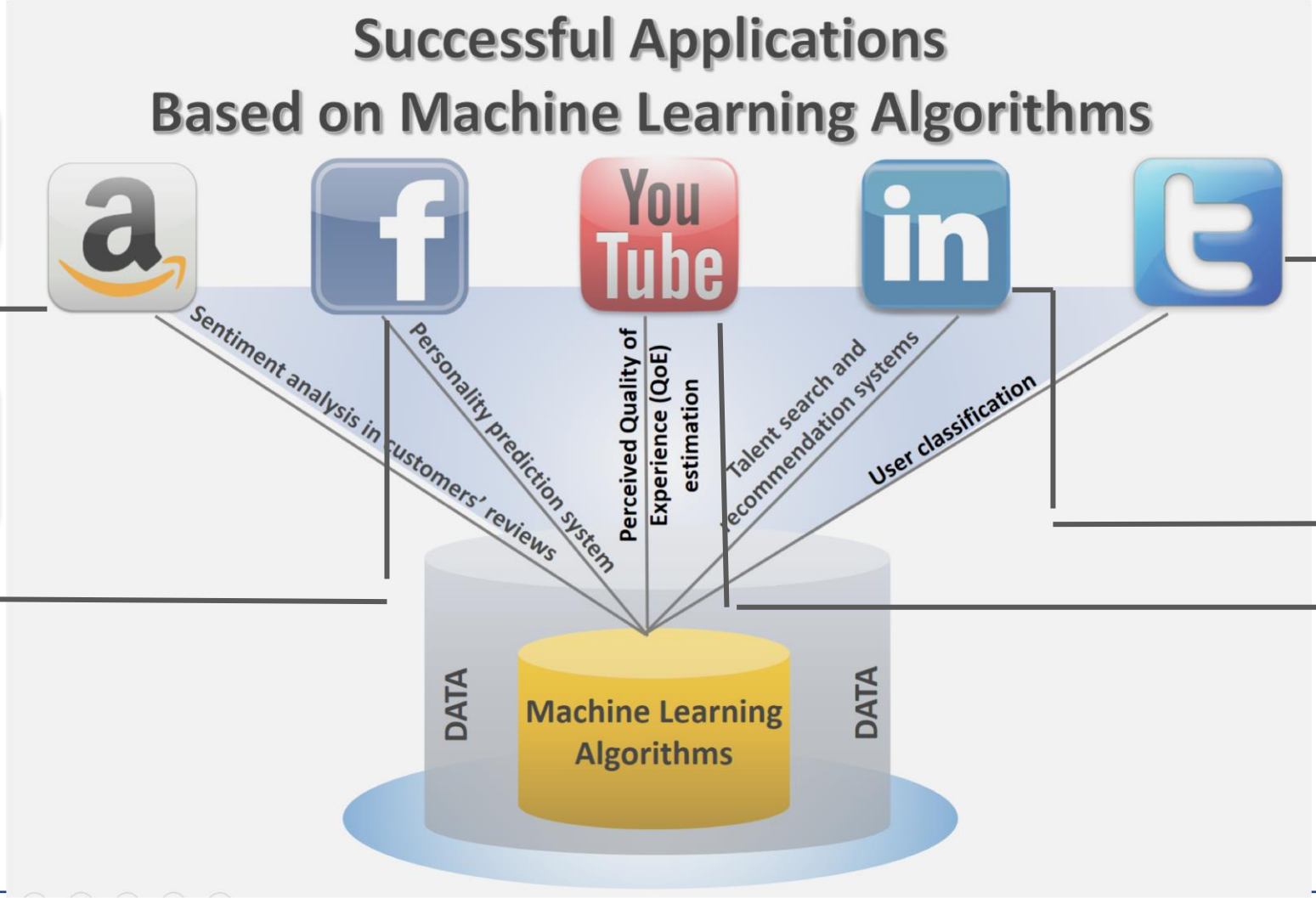
Definitions



Highlighted milestones



Successful applications in other industries



Naive Bayes and Decision List Classifiers

Scale Invariant Feature Transform (SIFT)

Latent Dirichlet Allocation

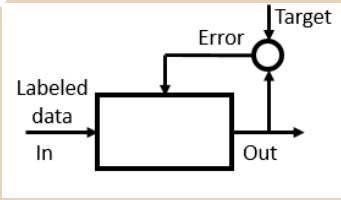
Alternating Direction Method of Multipliers (ADMM)

Bayesian classification

Major Machine Learning Methods

Overview

Supervised Learning



Knowledge of output
Goal: predict class or value

Data

Annotations
These are bananas

Model

?

Prediction

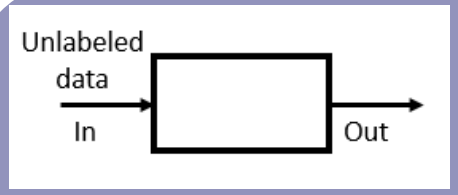
It is a banana

Regression

Classification

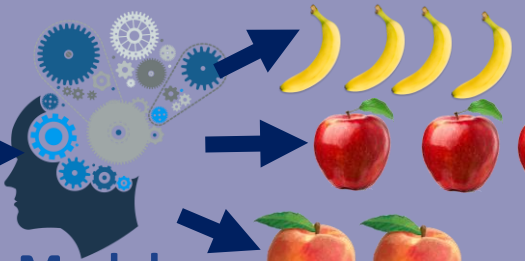
Artificial neural network

Unsupervised Learning



No knowledge of output
Goal: determine data patterns/groups

Data



Model

Output

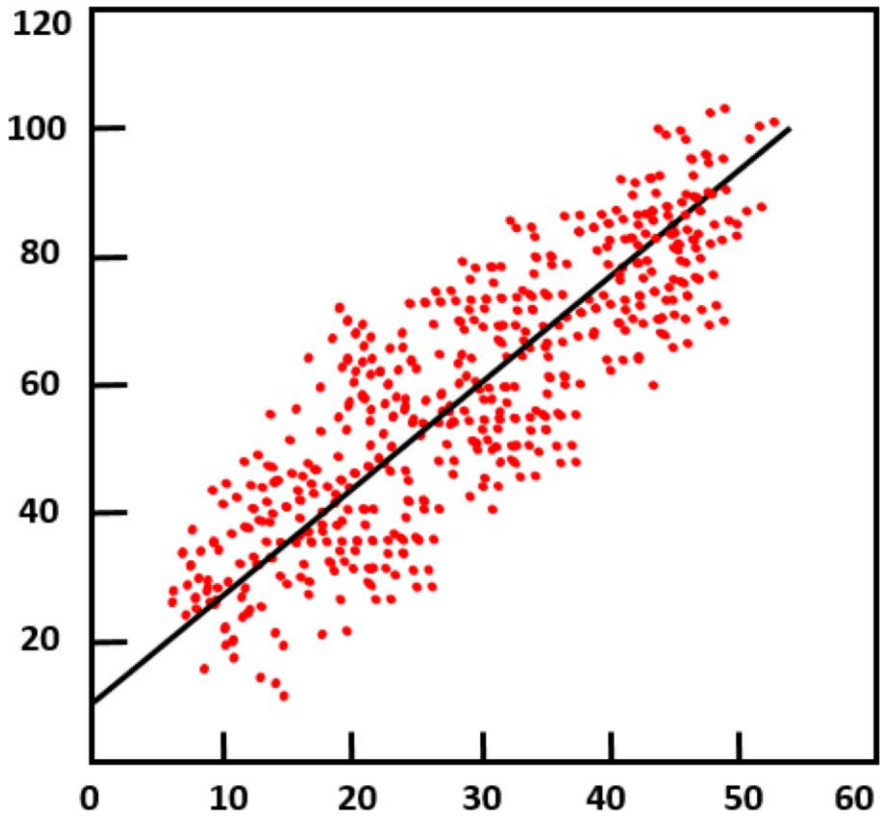
Dimension Reduction

Clustering

***In addition to supervised and unsupervised learning, two other categories include semi-supervised and reinforcement learning**

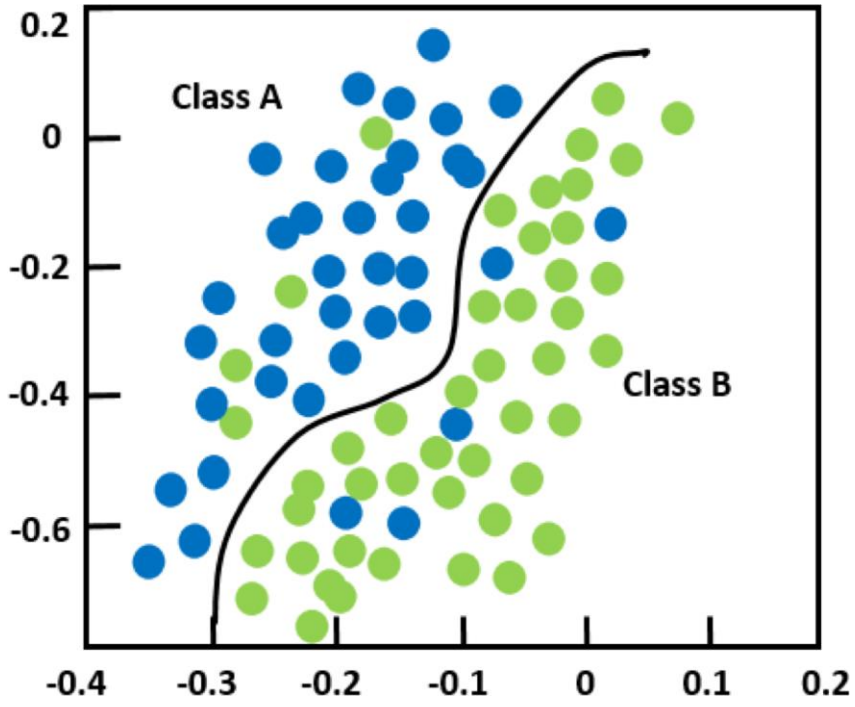
Supervised Learning - Regression

- Concept
  - a set of statistical processes for estimating the relationships between a dependent variable and one or more independent
- Common methods
  - Linear regression
  - Non linear regression
  - Multi variate regression
  - Logistic regression
- Applications in building analytics
  - Prediction and modeling of load, energy use
  - Anomaly detection, M&V
  - Model predictive control
  - Data cleaning



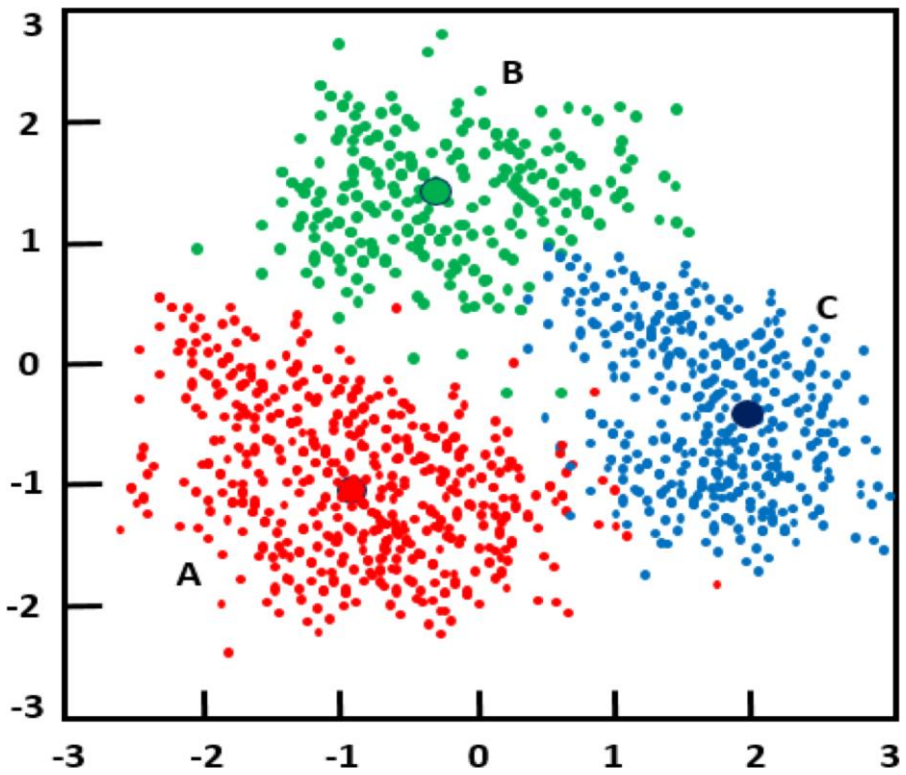
Supervised Learning - Classification

- Concept
  - Identifying which set of categories (sub-populations) a new observation belongs to, based on a training set of data containing observations (or instances) whose category membership is known
- Common methods
  - Linear classifier
  - Support vector machines
  - Decision trees
  - Bayes method (e.g., Bayesian Network)
  - Neural networks
- Application in building analytics
  - Fault detection and diagnostics
  - Characterizing operational regimes
  - Data cleaning



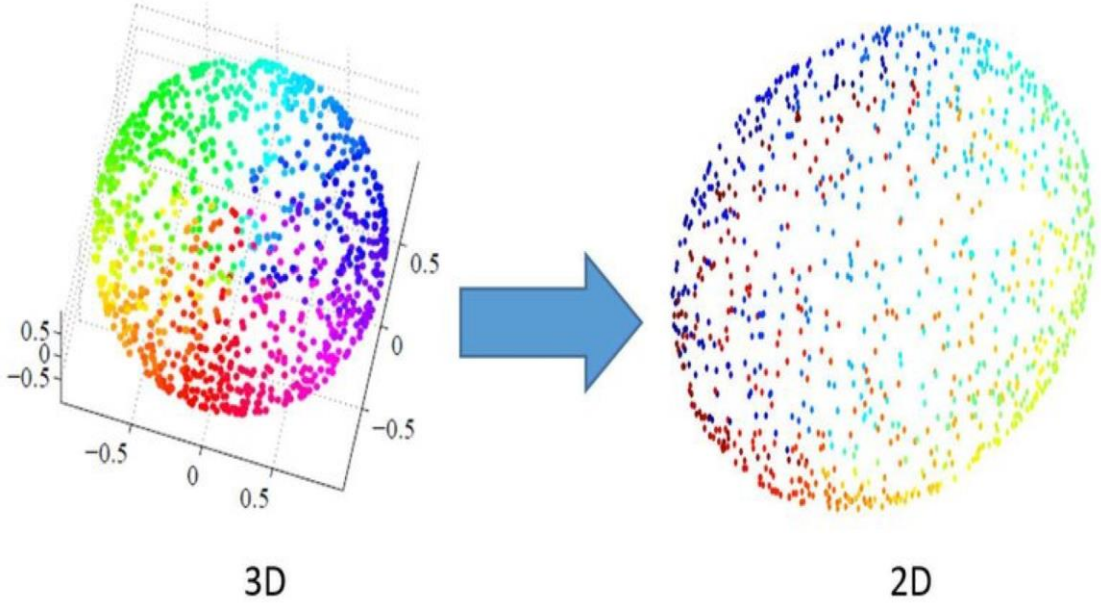
Unsupervised Learning - Clustering

- Concept
  - Group data points that are similar to each other
- Common methods
  - Artificial neural network
  - K-means clustering
  - Expectation-Maximization (EM) clustering
- Applications in building analytics
  - Tag BAS data
  - Fault diagnostics
  - Characterizing load profiles
  - Optimal control
  - Human <> computer language processing (?)
  - Data cleaning



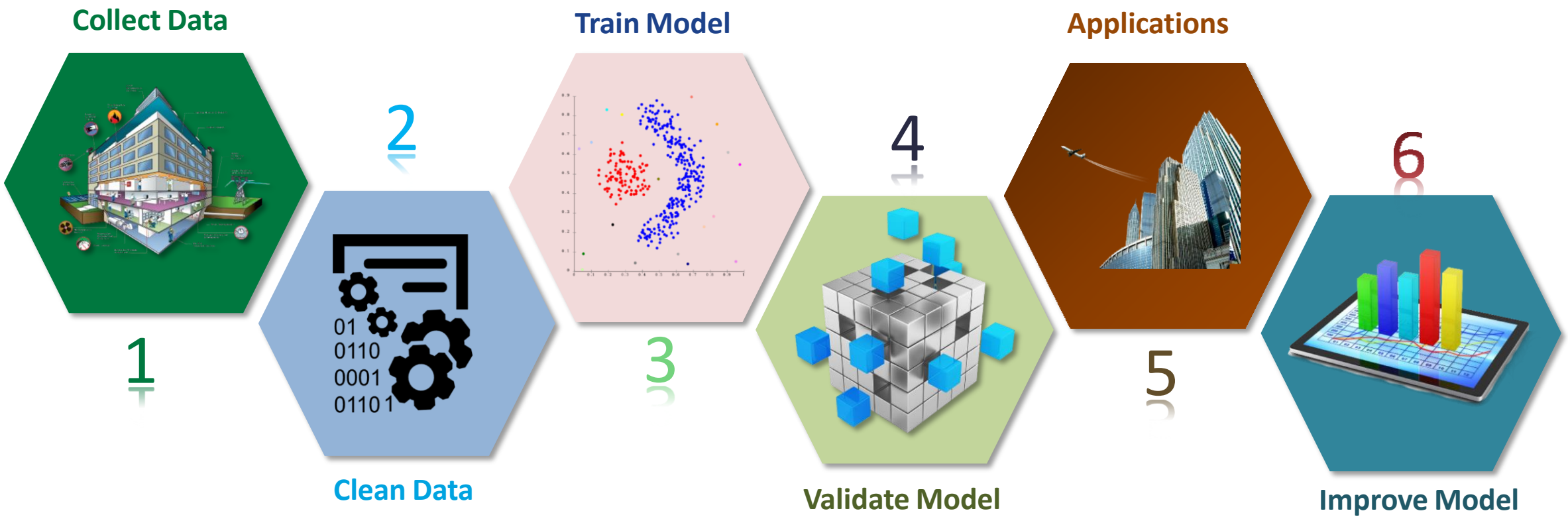
Unsupervised Learning - Dimensionality reduction

- Concept
  - A process of reducing the number of random variables under consideration by obtaining a set of principal variables
- Common methods
  - Principal component analysis
  - Independent component analysis
  - Linear discriminant analysis
- Major applications in building analytics
  - Feature selection for BAS data processing, data point tagging, and fault diagnostics, optimal control



Source: Paul Rosero et al., Interactive Data Visualization Using Dimensionality Reduction and Similarity-Based Representations. *21st Iberoamerican Congress, CIARP 2016*

Common working flow of ML



Applications in Commercial Products

Interview objectives

- Explore emerging AI based or ML based applications in EMIS
- Obtain vendors' first-hand perspectives on AI/ML progress
- Identify benefits and possible barriers in applying AL/ML technique in the EMIS sector

How do you define AI and ML

How do you apply AI/ML techniques into your products

Is the ML implemented in product/buildings; what are technical challenges

What's your vision on AI/ML in the building industry in the future

Interview overview

- A total of 88 product vendors and corresponding products* reviewed
- 11 vendors note ML/AL or techniques used in their products
- Four interviews were conducted

*Source: https://smart-energy-analytics.org/product-service

Applications

Load prediction

Fault diagnostics

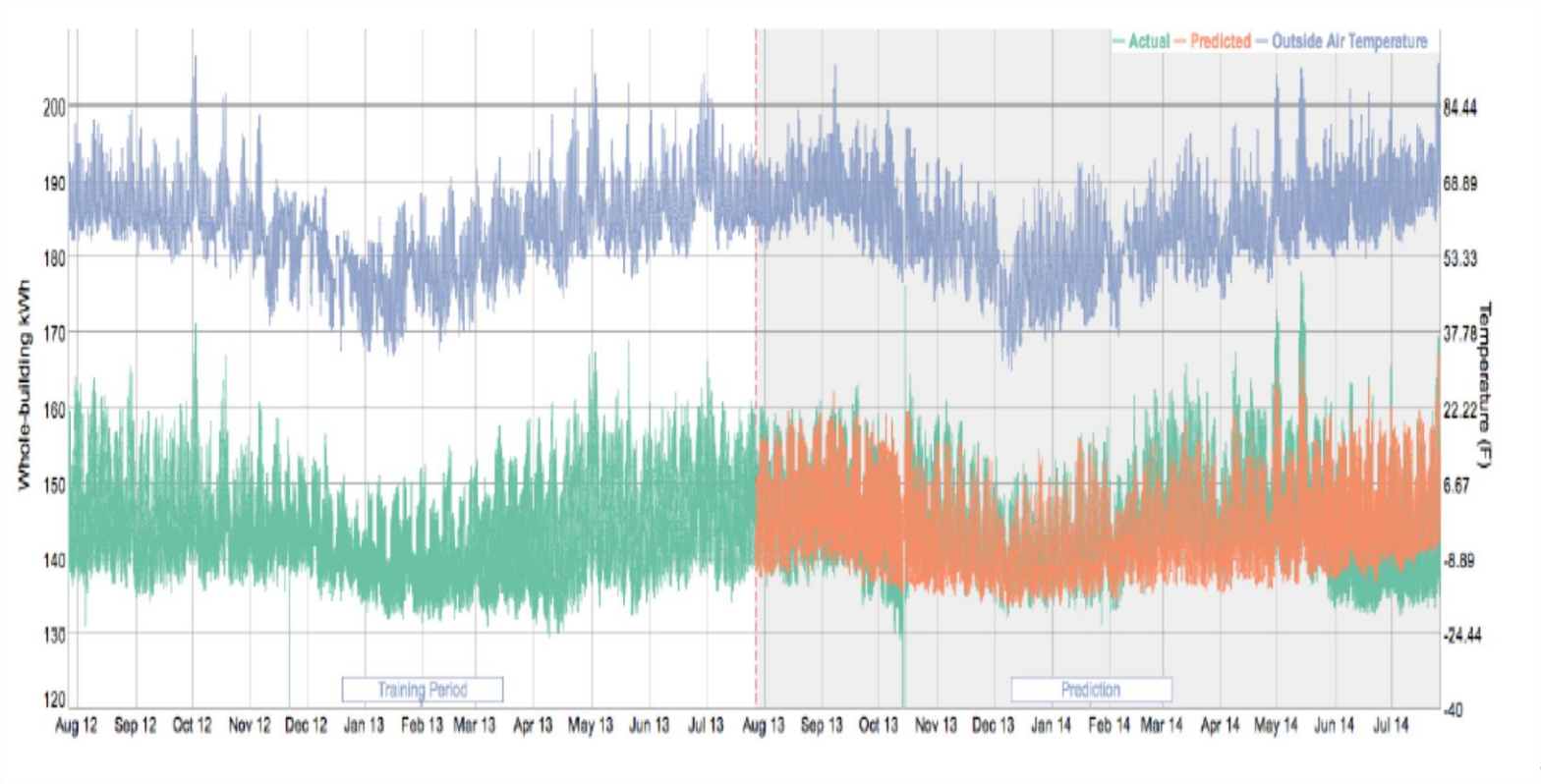
Automated data tagging

Control optimization

Data cleaning

Load prediction

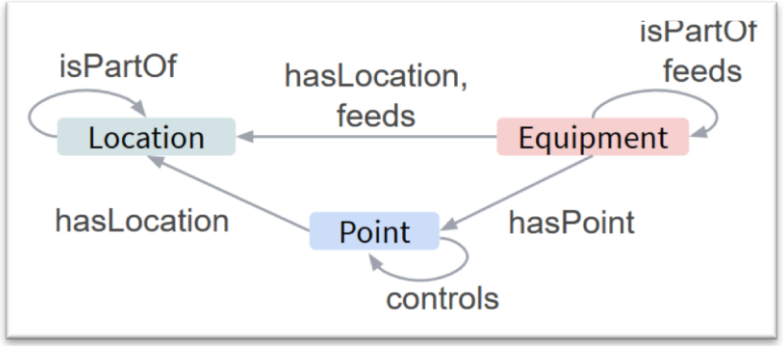
- Use BAS/meter historical data to develop a building energy consumption model for energy anomaly detection, control optimization, or savings estimation
- Various regression-based approaches are commonly employed



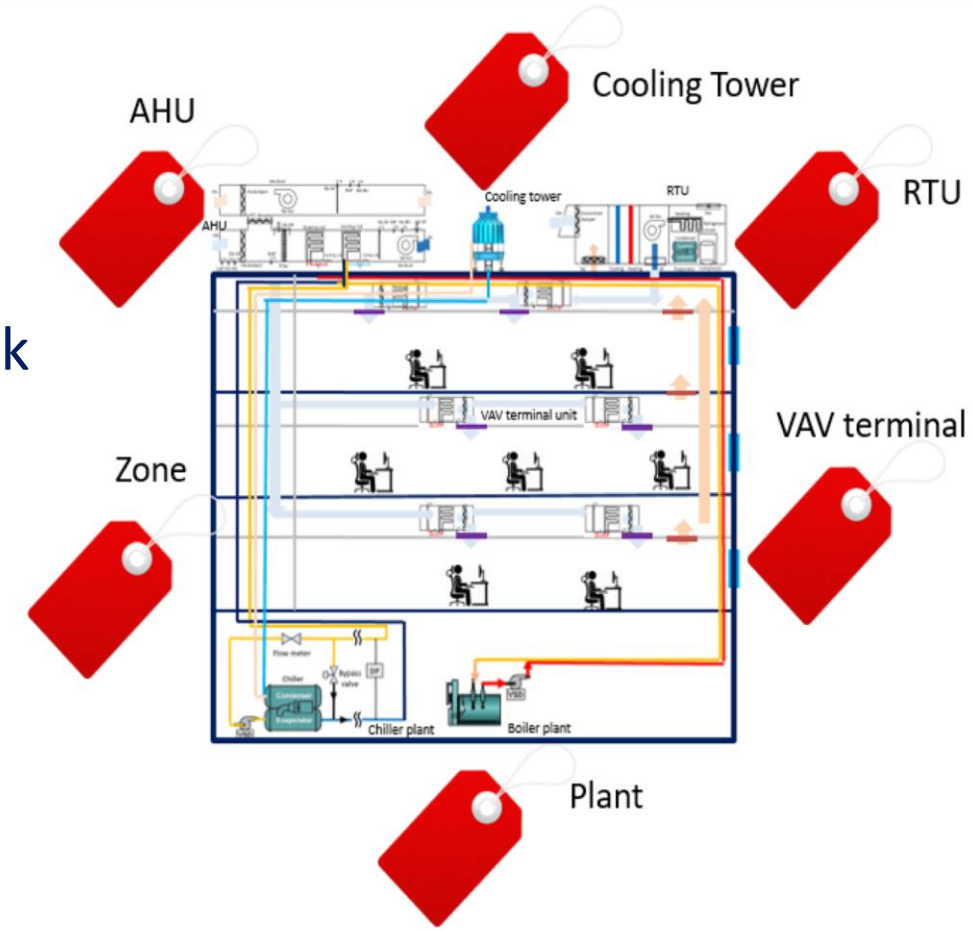
J. Granderson et al., Accuracy of Automated Measurement and Verification (M&V) Techniques for Energy Savings in Commercial Buildings

Automated data point tagging

- One vendor noted: 70% efforts used in tagging data, 30% efforts used in the energy modeling
- Accelerate data integration for application configuration
- One vendor noted use of Bayesian networks for classification of tags, and use of
- Supervised labeling using time series data the Brick semantic model

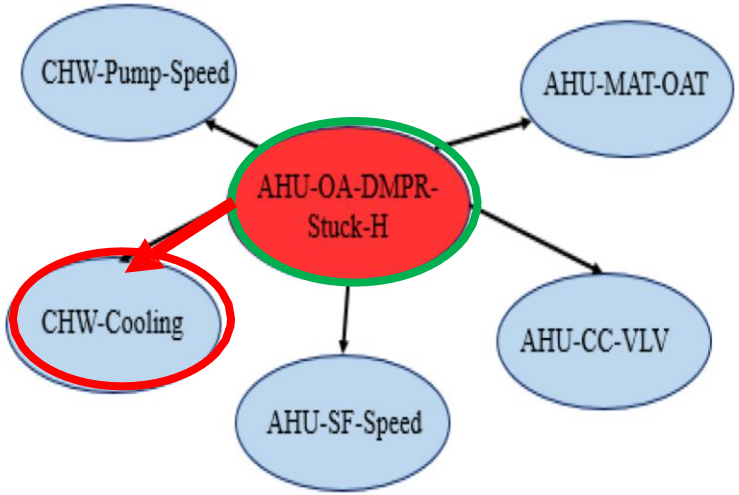


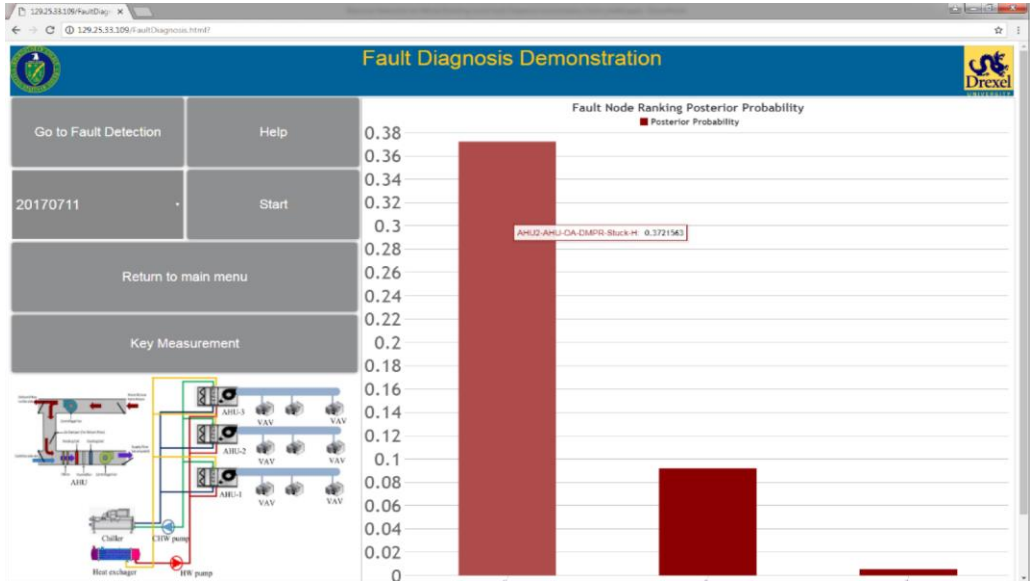
Graphic source: Jason Koh, Brick tutorial, available at https://goo.gl/bhRdeF



Fault diagnostics

- Use historical data to implement pattern recognition and pattern matching
- Label abnormal data by using ML classification or clustering algorithms (fault detection)
- Locate fault root cause by using ML inference algorithms (fault diagnosis)

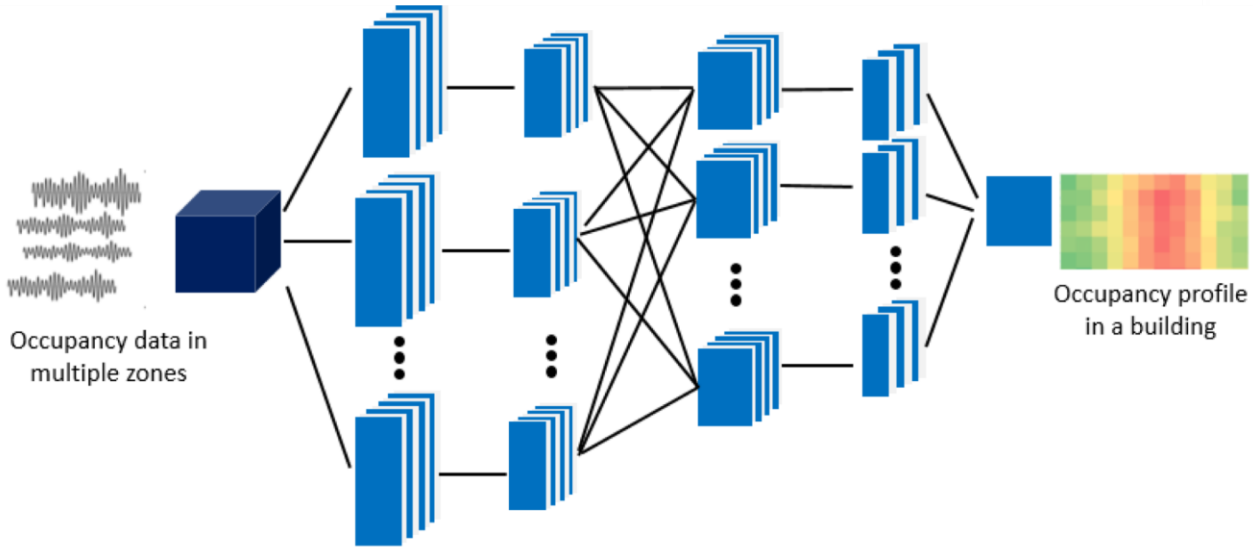




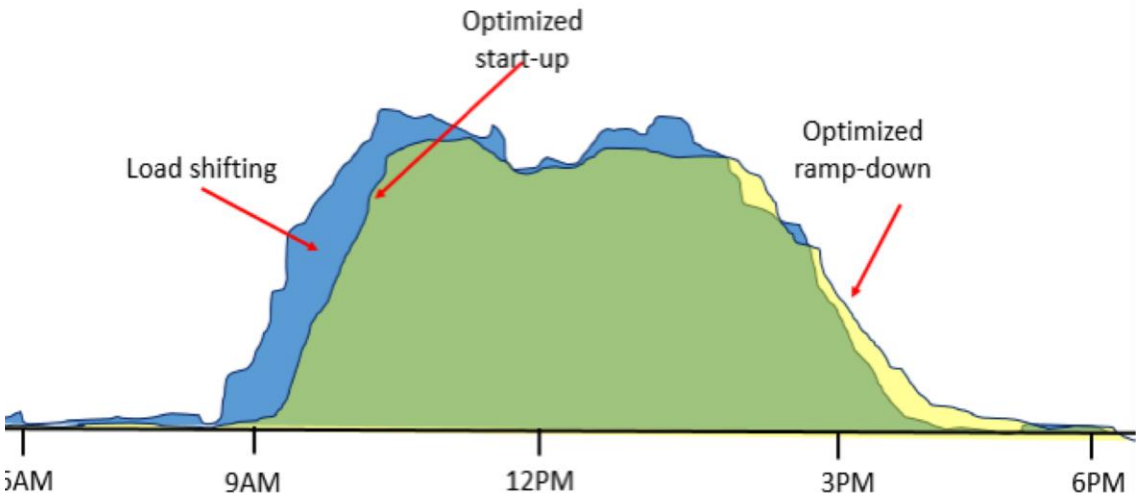
Y Chen et al., Bayesian Networks for Whole Building Level Fault Diagnosis and Isolation

Control optimization

- Use advanced occupancy sensor network to determine building occupancy profile
- Use energy consumption model and building occupancy profile to optimize system operation schedule



Building occupancy profile model



Optimized system start-up and ramp-down operation to enable energy saving

Modified from C Feng et al., Deep Learning-based Real-time Building Occupancy Detection Using AMI Data

Discussion and Conclusion

Identified challenges and barriers

- Data quality
  - Lack of high-quality data from BAS
- Model selection and parameter tuning
  - Experts needed to select best model and implement complicated parameter tuning

Identified challenges and barriers (con't.)

- Result visualization
  - Present results to help the user evaluate and understand the results
- Significant human intervention
  - Currently, expert knowledge is widely used to supplement ML, often for verification and authorization (e.g., in control)

Conclusions

- Vendors interviewed have different opinions as to how much will be ultimately be gained through AI/ML
- In order to make product more intelligent, both ML and conventional techniques (e.g., rules, classical optimization) are likely to be paired
- AI/ML just beginning to be incorporated into EMIS products, with exception of regression
- There is clearly great potential, and this will be validated, further understood through ongoing industry and research efforts

Questions

Thank you

Next Steps: Register for upcoming webinars

BUILDING PERFORMANCE RESULTS FROM NEW YORK STATE'S REAL-TIME ENERGY MANAGEMENT PROGRAM

Webinar

Thursday, October 8, 2020 2:00-3:00 pm ET

Register Now

FINAL RESULTS ON ENERGY SAVINGS, COSTS, AND BENEFITS FROM THE SMART ENERGY ANALYTICS CAMPAIGN

Webinar

Wednesday, October 28, 2020 1:00-2:00 pm ET

Register Now

Better Buildings EMIS Technical Team

The EMIS Tech Team collaborates with researchers and industry experts to promote awareness and energy reduction through new technologies. Contact the Better Buildings Alliance to learn how you can get involved.