

Introduction to Machine Learning

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Overview

- 1 Quick Review
- 2 Artificial Intelligence and Machine Learning
- 3 Machine Learning Capabilities
- 4 Taxonomy of Machine Learning Problems
- 5 Types of Machine Learning Systems
- 6 Urban Applications
- 7 Recent Research at PEER and UMD

Part 05

Opportunities for Machine Learning

Machine Learning Opportunities:

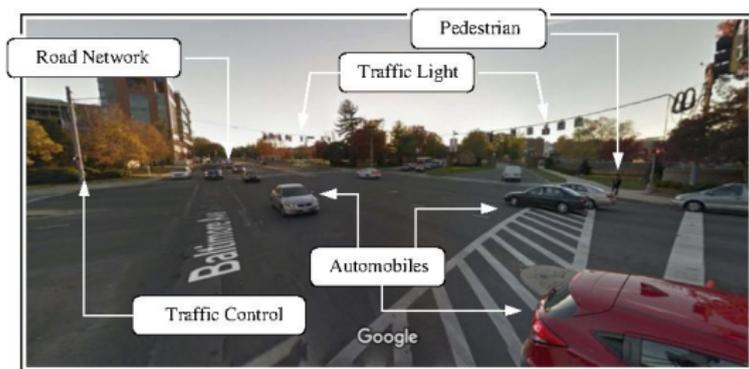
- Predicting system response and performance.
- Interpreting data and formulating models to predict component and subsystem-level properties.
- Information retrieval from images and text.
- Recognizing patterns in streams of sensed data.

Economic Considerations:

- Urban infrastructure is permanent/semi-permanent and very expensive to build and maintain.
- Prioritize improvements to efficiency by identifying and removing bottlenecks in performance.
- Use AI-ML for design of actions that enhance behavior/system performance.

Small Scale: Traffic Intersection at UMD

Goal. How to traverse a traffic intersection safely and without causing an accident?

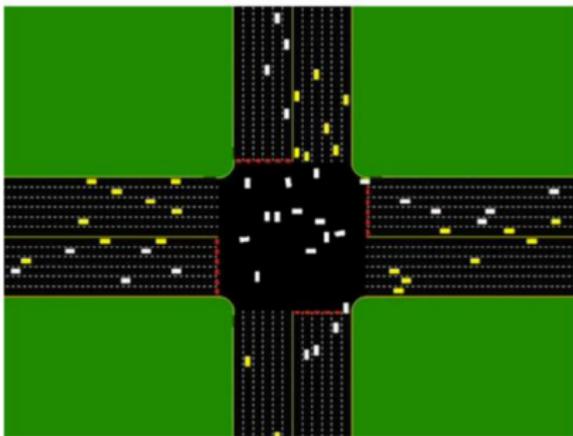


Required Capability. Observe, evaluate, reason, take actions.

Challenges. Multiple types of data, event-driven behavior, dynamic, time critical. Too much traffic congestion.

Self-Driving Cars

Goal. Improve performance by removing bottlenecks → no human driver; no traffic lights.



Remark: 95% of the requirements are for the system software.

Source: ISR visitor from GM Research.

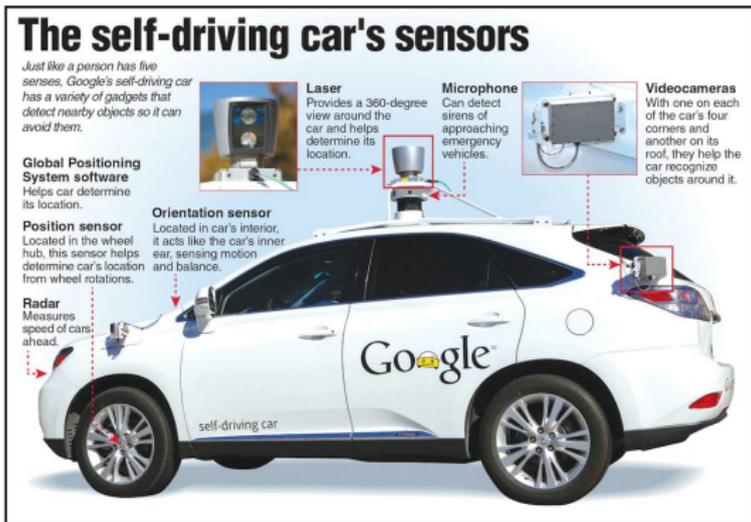
Remark: Tesla will produce self-driving cars by 2016.

Source: Elon Musk.

Stop signs and traffic lights are replaced by mechanisms for vehicle-to-vehicle communication (Adapted from <http://citylab.com>).

Google Self-Driving Car

Essentially: A network of sensors and computers on wheels.



Today: Modern automobiles → 100 million lines of code.

Tomorrow: Self-driving automobiles → 300 million lines of code.

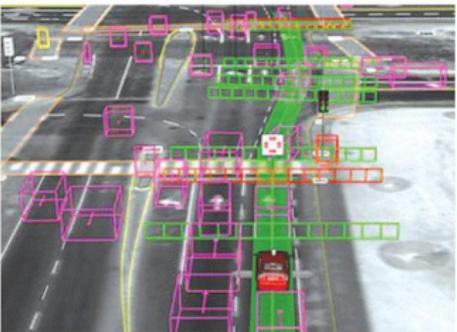
Navigating a Busy Traffic Intersection

Step-by-Step Procedure:

How the car operates

- 1 Any object the vehicle's sensors spot is interpreted by software to determine if it's a pedestrian, cyclist, vehicle or something else.
- 2 Using what it's learned from previous driving, the software makes predictions about what objects will do next.
- 3 The software analyzes the information to decide whether it is safe to accelerate, turn or hit the brakes.

Source: Google
Graphic: Tribune News Service



How the car sees the world

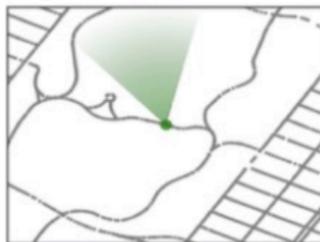
This computerized image is what Google researchers monitoring sensor data see as they ride in the vehicle.

-  Other vehicle
-  Pedestrian
-  Cyclist
-  Objects that warrant caution
-  A crosswalk, indicating the car needs to stop
-  A traffic signal, warning of upcoming railroad tracks
-  Path where Google's car intends to go

- Identify various kinds of objects (e.g., vehicles, crosswalk).
- Predict what objects will do next.
- Conduct safety assessment.
- Take action.

Google DeepMind (2018-2020)

Teach Self-Driving Cars to Navigate a City without a Map



Test Cities: London, Paris, New York.

ML Research at PEER

PEER Hub ImageNet (2018): Classification of Structural Engineering images:

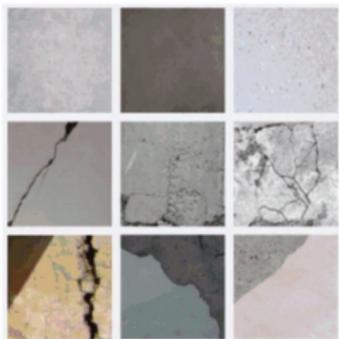


Fig 1a Pixel Level Samples



Fig 1b Object level Samples



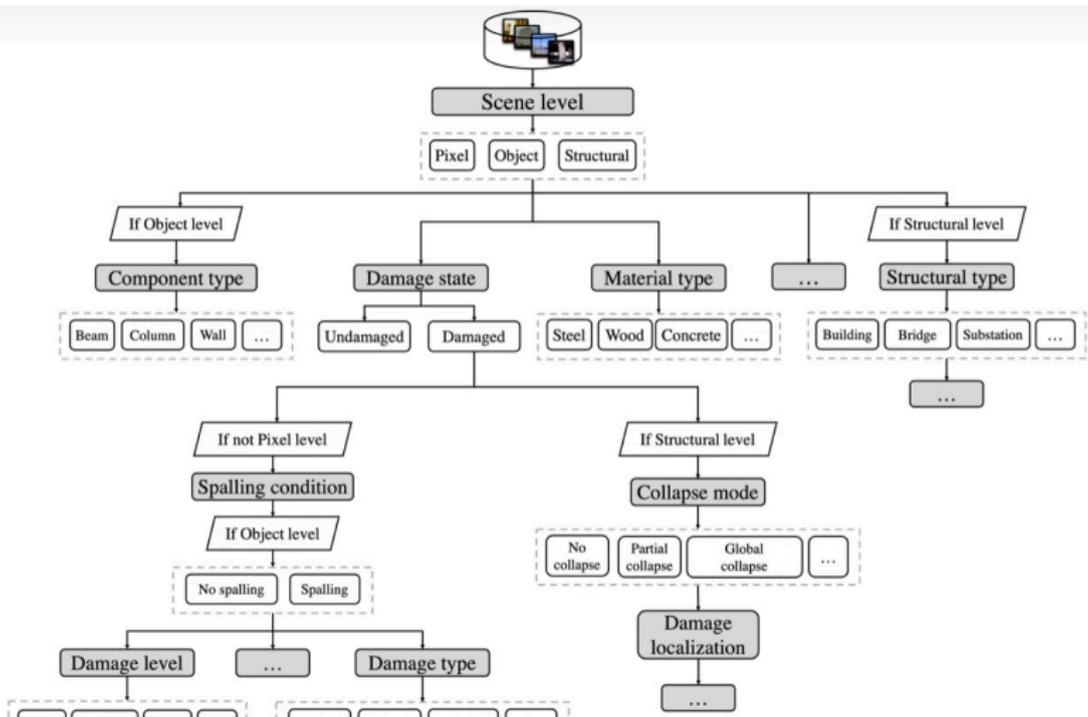
Fig 1c Structure Level Samples

Source:

<https://apps.peer.berkeley.edu/phichallenge/detection-tasks/>

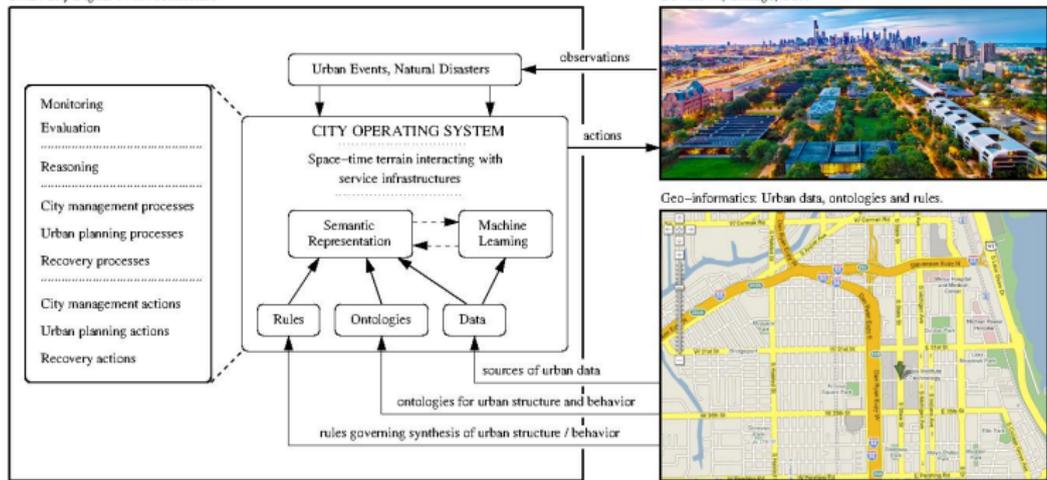
ML Research at PEER

Future Work: Create pathway from image classification to decision making:



Large Scale: Management of City Operations

Smart City Digital Twin Architecture

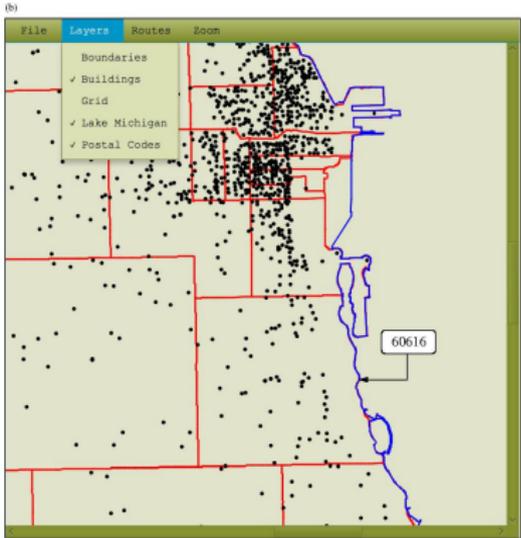
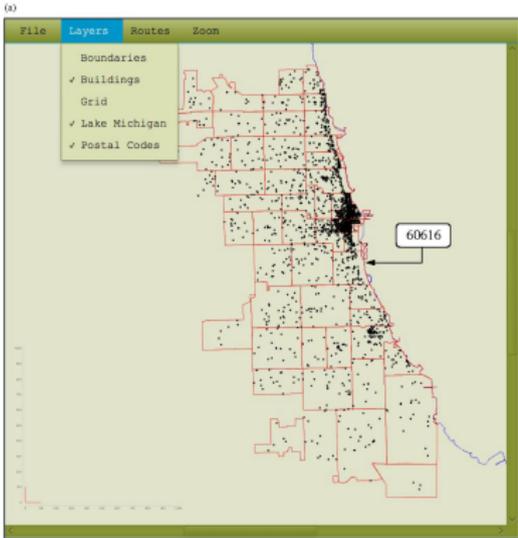


Required Capability. Modeling and Control of Urban Processes.

Challenges. Distributed system behavior/control. Decision making covers a wide range of temporal and spatial scales.

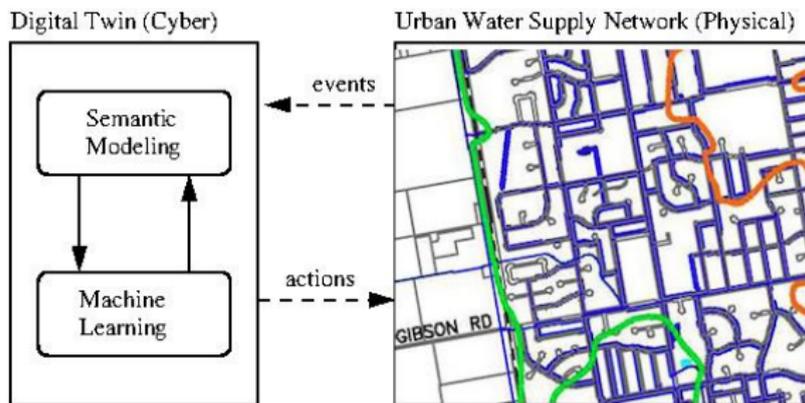
Large Scale: Management of City Operations

Case Study A (2019): Mine publically available data to understand Energy Consumption in 2,500 Buildings in Chicago.



Large Scale: Management of City Operations

Case Study B (2020): Can we teach a machine to understand the structure and behavior of water supply networks?



Reference: Coelho M., et al., Teaching Machines to Understand Urban Networks, ICONS 2020.

References

- Austin M.A., Delgoshaei P., Coelho M. and Heidarinejad M. , Architecting Smart City Digital Twins: Combined Semantic Model and Machine Learning Approach, Journal of Management in Engineering, ASCE, Volume 36, Issue 4, July, 2020.
- Coelho M., and Austin M.A. , Teaching Machines to Understand Urban Networks, The Fifteenth International Conference on Systems (ICONS 2020), Lisbon, Portugal, February 23-27, 2020, pp. 37-42.
- Bhiksha R., Introduction to Neural Networks, Lisbon Machine Learning School, June, 2018.
- Lu T., Fundamental Limitations of Semi-Supervised Learning, MS Thesis in Mathematics in Computer Science, University of Waterloo, Canada, 2009.
- Van Engelen J.E., and Hoos H.H., A Survey on Semi-Supervised Learning, Machine Learning, Vol. 109, 2020, pp. 373-440.