Artificial Intelligence

MACHINE LEARNING, DEEP LEARNING, IDEAS AND APPLICATIONS

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Outline

Introduction

- What exactly is Machine Learning?
- What is Deep Learning?
- How does a machine learn?
- Visual Example of Deep Learning
- Machine Learning in Industry
- Machine Learning in Defense

Applications of Deep Learning

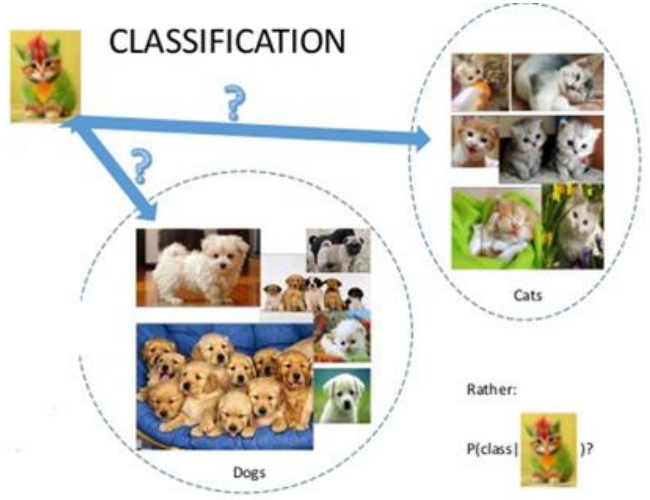
- Data Mining & Feature Extraction
- Anomaly Detection / Cyber Security
- Computer Vision
- Language Analysis
- Time Series/Sensor Data Modeling

Capability Survey Questions

Conclusions

Introduction: What is Machine Learning?

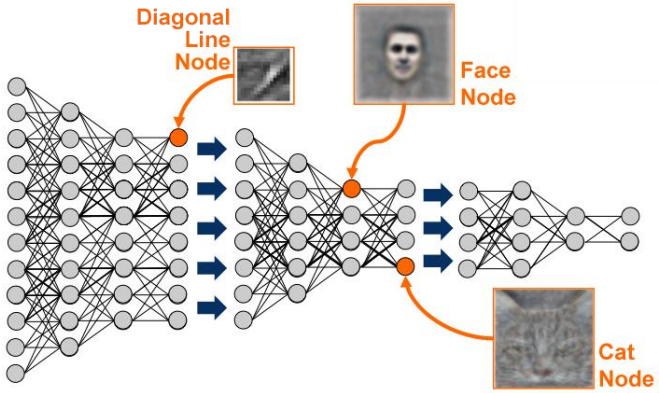
- Machine Learning is a sub-field of computer science aimed at giving computers the ability to learn without being explicitly programmed.
- Simply put, machine learning attempts to let computers learn to translate all the 1s and 0s into concepts that are meaningful to humans.
- Machine Learning has traditionally been applied in data science to perform classification, clustering, pattern recognition, and regression across data that is otherwise difficult to understand.



http://www.tothenew.com/blog/introduction-to-machine-learning-a-brief-concept-overview/

Introduction:
What exactly is deep learning?

- **Deep Learning is machine learning techniques combined in sequential layers resulting in "deep" architectures.**
- This is made possible by advanced computing capabilities that are now industry standards.
- The term "deep learning" gained popularity in 2007 after Geoffrey Hinton showed how a deep architecture can combine unsupervised techniques (automatic feature extraction) and supervised techniques (classification).



http://theanalyticsstore.ie/wp-content/uploads/2013/03/DeepNetwork.png

Google's deep network that automatically created image filters for recognizing faces and cats.

https://developer.nvidia.com/cuda-zone

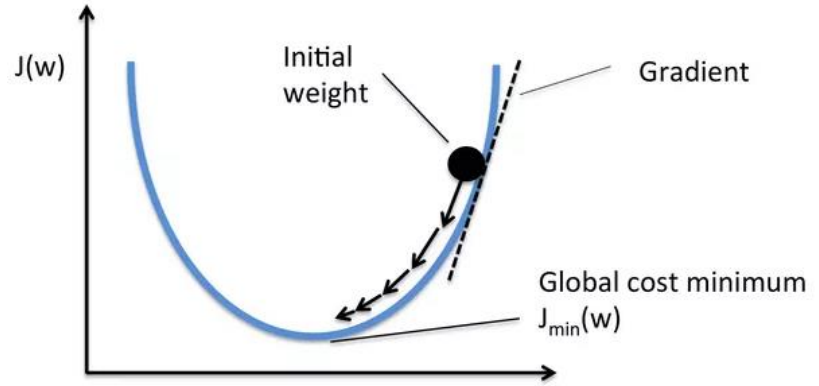
http://spark.apache.org/

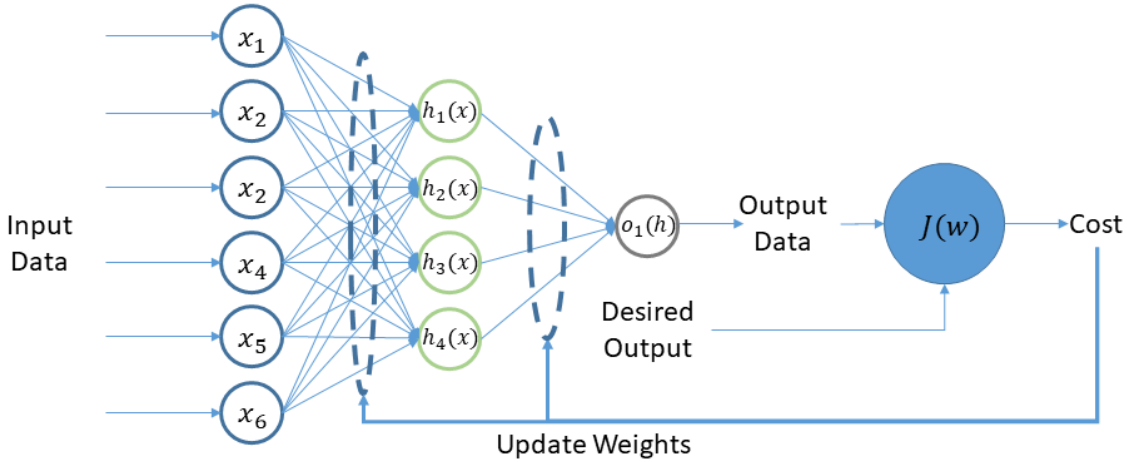
http://hadoop.apache.org/

How does a machine learn?

The key lies in iterative optimization:

- First, a model architecture is established.
  - Neural Network, Support Vector Machine, etc.
- Then a cost function is defined.
  - Classification error, distance between neurons, etc.
- Finally, network parameters are optimized using an iterative optimization process called, training.

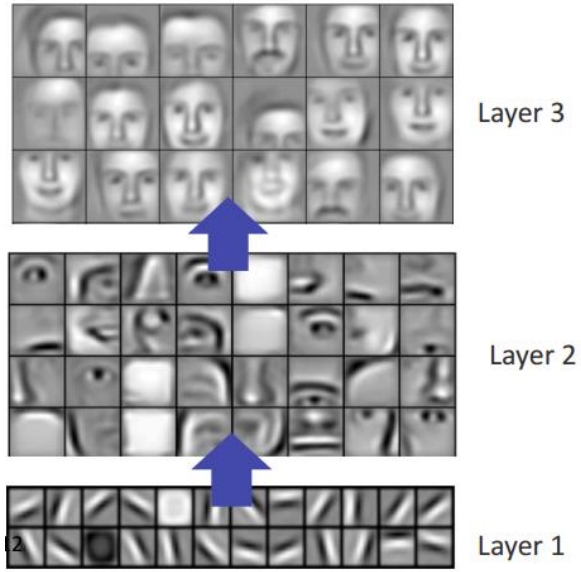




Introduction:
A Visual Example of Deep Learning

Facial Recognition

- Facial Recognition is one of the most popular applications of deep learning architectures.
- Features extracted by the neural networks actually correspond to facial features.
- Deeper layers contain features that are more complex.



Lee, Honglak, Roger Grosse, Rajesh Ranganath, and Andrew Y. Ng. 2009. "Convolutional Deep Belief Networks for Scalable Unsupervised Learning of Hierarchical Representations." In *Proceedings of the 26th Annual International Conference on Machine Learning*, 609–16.

Illustration of how a deep learning system learns features from images of faces

Introduction:
Deep Learning in Industry

Data savvy companies are putting a huge amount of money and effort into deep learning capabilities. Baidu, Facebook, Google, Twitter, and Yahoo are all among companies that have made hires and started research labs focused on deep learning. **What has got the data science community so excited about deep learning techniques?**

State of the art performance:

Computer vision.

- Facial Recognition
- Object Detection and location tracking

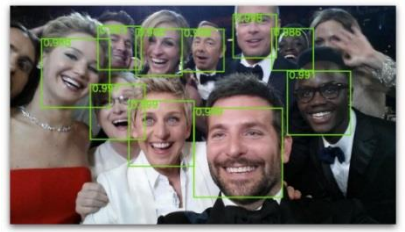
Language modeling.

- Speech Recognition
- Natural Language Generation
- Machine Translation

Modeling time-series data such as sensor or cyber data.

- Fraud Detection
- Medical Data (EEG, MEG, ECG)

http://dataconomy.com/wp-content/uploads/2015/03/Apical-ART-Image-Recognition-IoT-Internet-Things-e1425396522415.jpg



http://arxiv.org/abs/1502.02766

Introduction:
Deep Learning Defense

The DoD and the ARMY have many use cases similar to private industry for which AI is useful.

- DOD AI strategy calls out RAM related topics for AI.
- ARMY AL&T Magazine Summer 2019 discusses the use of AI to generate actionable insights from massive amounts of data.

"Implementing predictive maintenance and supply. We will use AI to predict the failure of critical parts, automate diagnostics, and plan maintenance based on data and equipment condition. Similar technology will be used to guide provisioning of spare parts and optimize inventory levels. These advances will ensure appropriate inventory levels, assist in troubleshooting, and enable more rapidly deployable and adaptable forces at reduced cost."

– Summary of DOD AI Strategy 2018

"If we use all the resources at our disposal, such as artificial intelligence and industry's example of effective data management, we can ensure a future acquisition enterprise in which business processes are truly streamlined, with programs and products practically always guaranteed to be delivered on time and on budget. In the end, our Soldiers will be the beneficiaries."
– Dr. Bruce D. Jette
Assistant Secretary of the Army for Acquisition, Logistics and Technology (ASA/ALT)

Applications of AI

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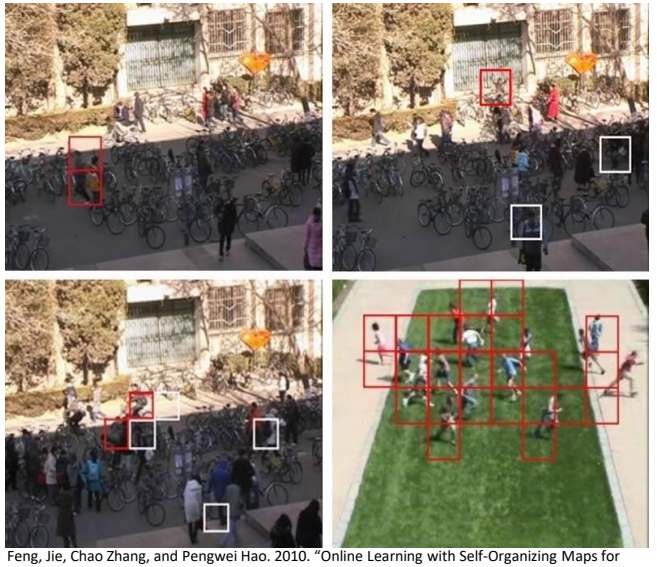
Cybersecurity / Anomaly Detection

- Cyber attacks are often associated with a significant change in some measurable metric over a short period of time.
- The key to detecting suspicious or anomalous activity is understanding the ground truth.
- Deep learning provides an effective framework for modeling what is normal, what is the ground truth.
- Companies such as PayPal and AirBnB use deep learning to perform fraud detection on network transactions.



Feng, Jie, Chao Zhang, and Pengwei Hao. 2010. "Online Learning with Self-Organizing Maps for Anomaly Detection in Crowd Scenes." In *ICPR*, 3599–3602.

Feng et al. used deep learning to detect anomalous behavior in videos.

Computer Vision

- Computer Vision is one of the most popular areas of application of deep learning research.
- Some of the first deep network architectures (convolutional neural networks) were designed to solve computer vision problems.
- Deep learning techniques have been used to detect and classify objects in images.
- Google and Facebook both use deep learning to provide automatic image tagging services.

http://safety.trw.com/wp-content/uploads/2013/08/photo-sae-Data-Fusion-jpg.jpg

Google's self driving cars use deep learning for some of their computer vision needs.

Computer Vision

Image Classification

- Recognizing what is in an image is one of the most studied applications of deep learning.
- Currently, a system built by Google can perform classifications on the ImageNet database with near human level accuracy.

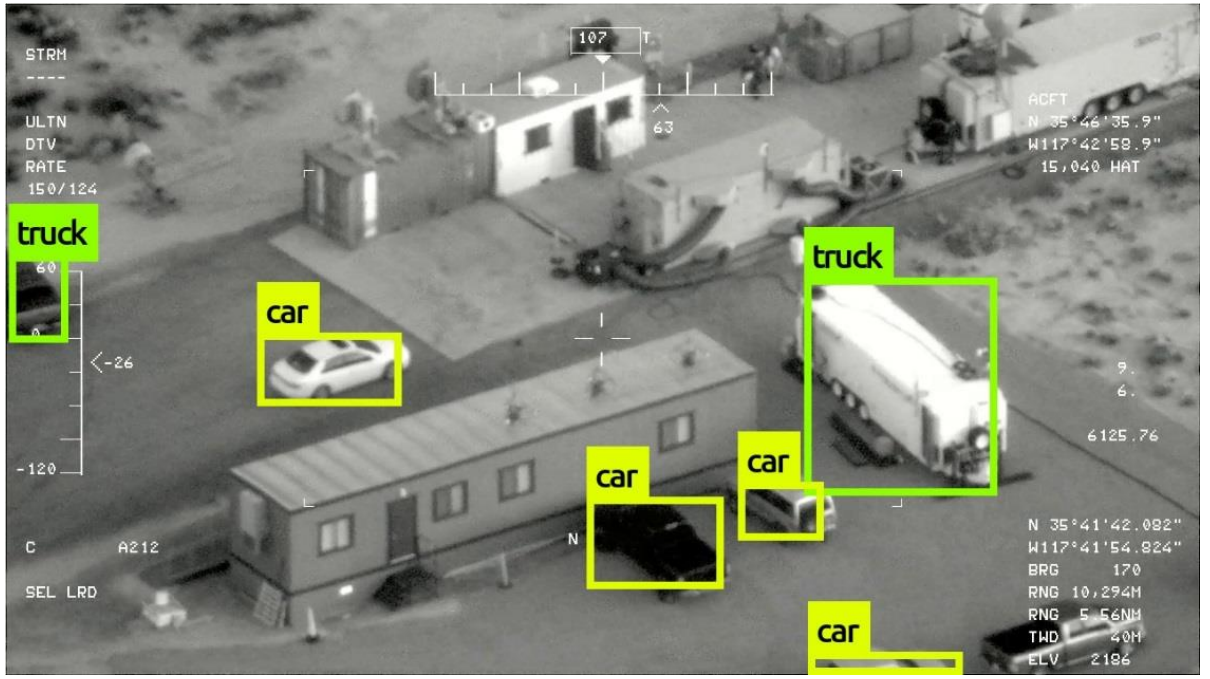
Krizhevsky, Alex, Ilya Sutskever, and Geoffrey E. Hinton. n.d. "Imagenet Classification with Deep Convolutional Neural Networks." In *Advances in Neural Information Processing Systems*, 2012.

Some classification results from a system developed at the University of Toronto

Computer Vision

Object recognition and Localization

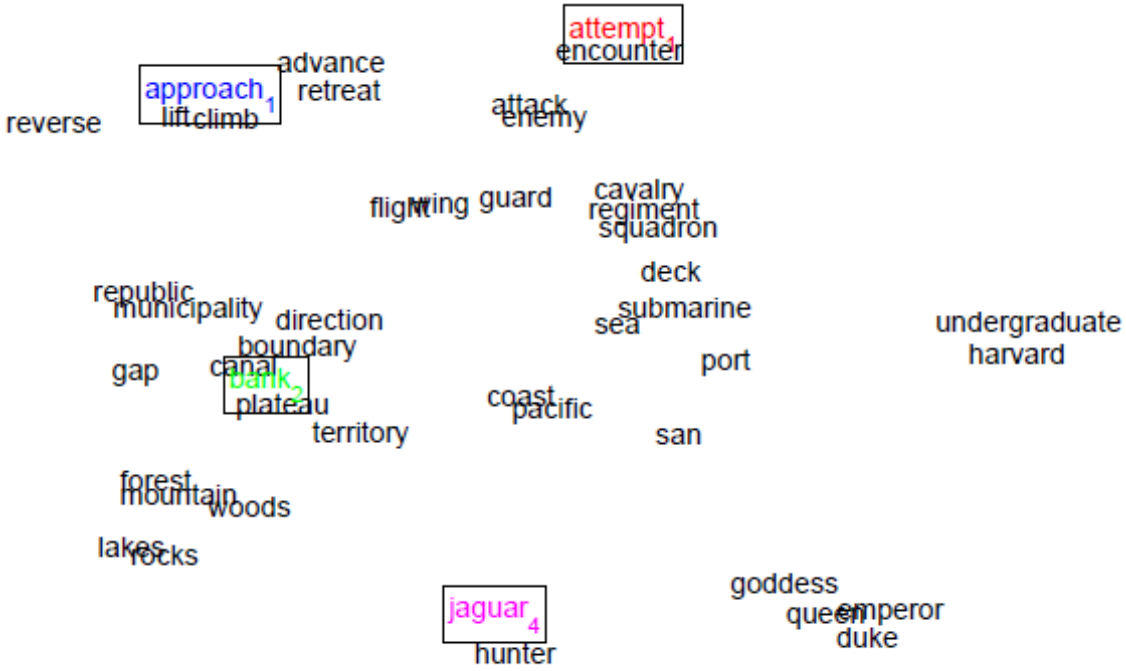
- Recognizing objects in a scene is another challenging task that is being done by deep learning systems.
- Deep learning systems have also demonstrated the ability to pinpoint the locations of objects in a scene.



UAV footage with cars and trucks recognized and highlighted.

Natural Language Processing

- Machine Learning is commonly used in Natural Language Processing applications, topic clustering, and parts-of-speech analysis.
- Microsoft's interest in this application led to revived interest in the field of machine learning.
- Speech recognition products at Apple (Siri) and Google, Amazon (Alexa) successfully use deep learning methods to model and recognize speech.



Word vector groupings learned by deep learning techniques at Stanford.

Natural Language Processing

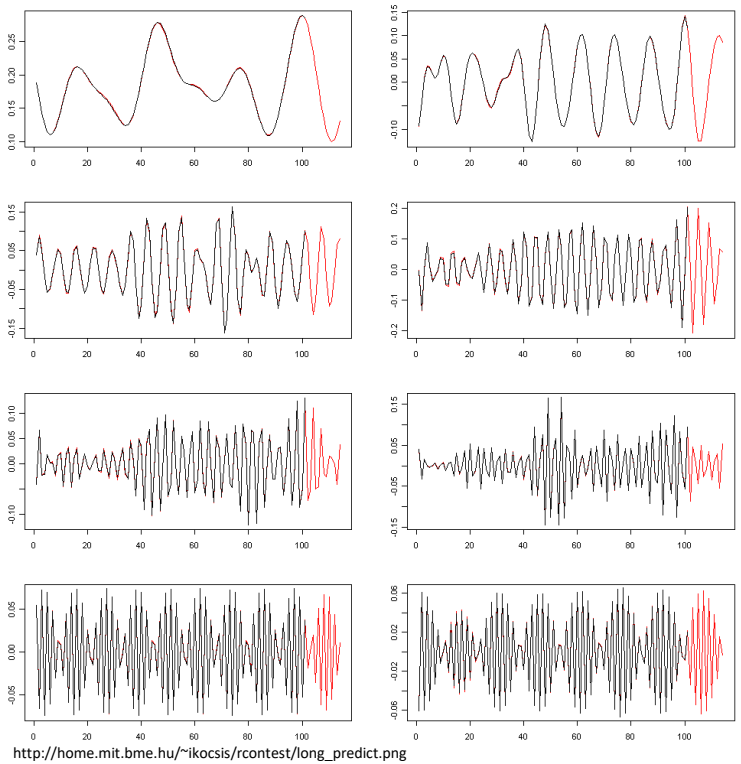
Natural Language Generation

- Microsoft has been using deep learning techniques to recognize speech, translate it into another language, and **generate speech from the translation**.
- Microsoft did a demo of this capability where a skype conversation was had between two people speaking different languages.
- https://www.youtube.com/watch?v=3aSgLYgLnSY

http://microsoft-news.com/wp-content/uploads/2014/12/Skype-Translator-Preview.jpg

Time-Series Data Modeling

- Most real-world data has a temporal component.
- Traditional approaches for modeling time-series data require an assumed model.
- Assuming a model is often insufficient due to noisy, complex, and high dimensional data.
- Deep learning has been successfully applied to model and predict time-series data in applications such as: machine olfaction, motion capture (as in the Xbox Kinect), music recognition, video analysis, and stock market prediction.
- The time-series modeling abilities of Deep Learning are well suited for using sensor data to determine when it is necessary to perform predictive maintenance.

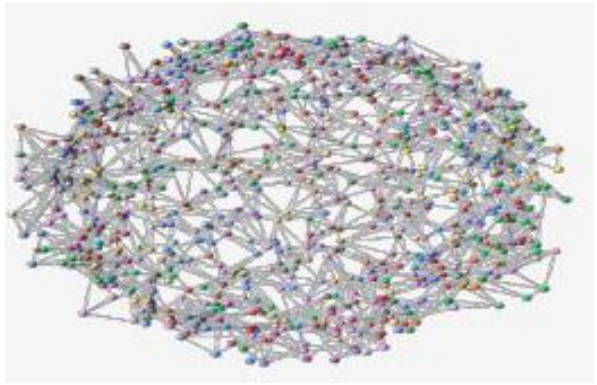


http://home.mit.bme.hu/~ikocsis/rcontest/long_predict.png

Some time series data predictions.

System of Systems, Internet of Things, and Connected Assets

- IOT and SOS are all about time series data, with many devices communicating sensor data between each other.
- Deep learning provides a framework for automatically learning normal individual sensor behavior, including both short and long term cyclic behavior.
- Deep learning also provides state machine modeling capabilities that are applicable to SOS problems such as load forecasting, spares forecasting, etc.



http://simularity.com/wp-content/uploads/2015/03/IOT_overview_March2015_v2.pdf

Capability Survey Questions

What operational needs could be addressed with Deep Learning?

Computer Vision Objectives?

- Object Recognition
- Image Classification
- Analysis of Full Motion Video

Data Mining Objectives?

- Automatic Feature Extraction
- Organizing Unstructured Data

Time-Series Modeling Objectives?

- Sensor Data
- Network Traffic Data
- Predictive Maintenance

System of Systems Objectives?

- Load forecasting
- Spares Demand Forecasting
- State Modeling

Language Processing Objectives?

- Semantic Analysis
- Text classification
- Translation

Conclusions

- Machine Learning/Deep learning have been around for over ten years, but now these capabilities are exploding in digital businesses.
- Recent advances in distributed storage and distributed computing allow for deep learning techniques to be applied to today's problems.
- Deep learning delivers technical capability in fields such as Time-series data Analytics, Computer Vision, Language Processing, Speech Translation, Data mining, and Data modeling.
- The foremost tech companies are buying research personnel and resources in this area.
- Deep Learning can address needs in Intel (OSINT), State (sentiment), Health (sensor analytics), and Defense (sensor networks); additionally pervasive IT areas such as Cyber and Infrastructure performance.
- **Deep Learning has applications to RAM in simulation state modeling, optimization of sparing, predictive maintenance, and even text analysis.**

Thank You

Questions?

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