

Introduction to Deep Learning

Sargur N. Srihari
srihari@cedar.buffalo.edu

This is part of lecture slides on [Deep Learning](#):
<http://www.cedar.buffalo.edu/~srihari/CSE676>

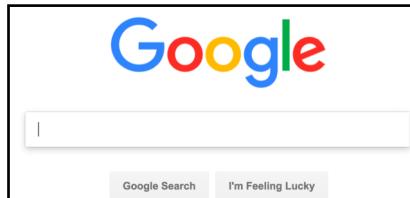
Topics

- Artificial Intelligence Paradigm shifts
- Definition of Deep Learning
- Representation Learning
- Software 1.0 vs Software 2.0

AI is ubiquitous

- Automate routine labor

- Search

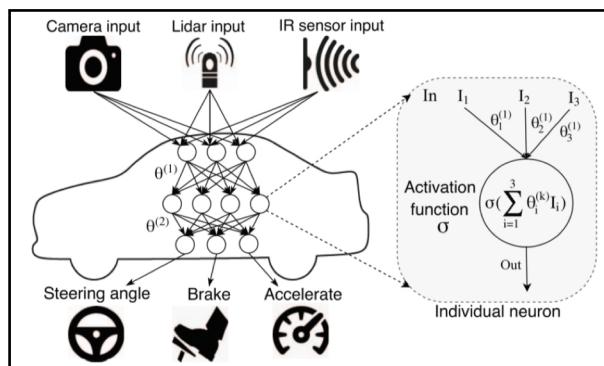


- Understand speech

- SIRI, Alexa



- Autonomous Vehicles



AI is based on Machine Learning

- ML powers many aspects of modern society
 - Web searches
 - Content filtering on social networks
 - Recommendations on e-commerce websites
 - Consumer products:
 - cameras, smartphones
- ML used to:
 - Identify objects in images
 - Transcribe speech to text
 - Match news items, posts or products with user interests
 - Select relevant results of search
- Increasingly these use deep learning techniques

Challenge of AI

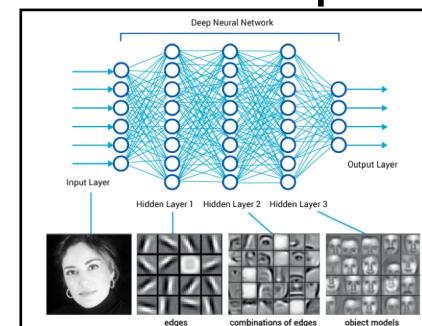
- Early successes of AI:
 - Solved problems intellectually difficult for humans
 - Problems described by small set of rules
 - Sterile formal environment
 - Little knowledge about the world
- True challenge of AI
 - Solve tasks easy for people but hard to describe formally
 - solved intuitively, that feel automatic
 - e,g recognize spoken words, or faces in images
- Today's AI:
 - It is about solving these more intuitive problems

Everyday life needs knowledge

- A person's everyday life requires immense amount of knowledge of the world
 - Much of this knowledge is intuitive and subjective
 - Difficult to articulate in a formal way
- Computers need to capture same knowledge to behave intelligently
- Key challenge of AI is how to get this informal knowledge into a computer

Solution to Intuitive Problems

1. Allow computers to learn from experience
 - By gathering knowledge from experience
 - Avoids need for human operators to specify knowledge that the computer needs
2. Understand the world as hierarchy of concepts
 - Thereby learn complicated concepts by building them out of simpler ones
 - A graph of how these concepts are built on top of each other is deep, with many layers

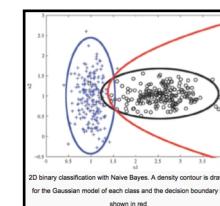
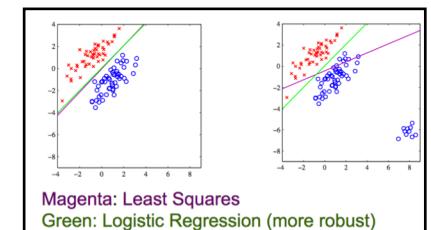


The Knowledge-based Approach

- Hard-code knowledge in a formal language
 - Computer can reason about statements in these languages using inference rules
 - Ex: Cyc is an inference engine and database of statements in CycL
- Unwieldy process
 - Staff of human supervisors
 - People struggle to formalize rules with enough complexity to describe the world

The ML approach

- Difficulties of hard-coded approach suggests:
 - AI systems need ability to acquire knowledge
 - By extracting patterns from raw data
- This approach is known as machine learning
 - It allowed tackling problems requiring knowledge of real world and make decisions that seem subjective
 - Simple ML algorithms are:
 - Logistic Regression
 - Caeserian delivery using uterine scar feature
 - Naive Bayes
 - Decide whether email is spam



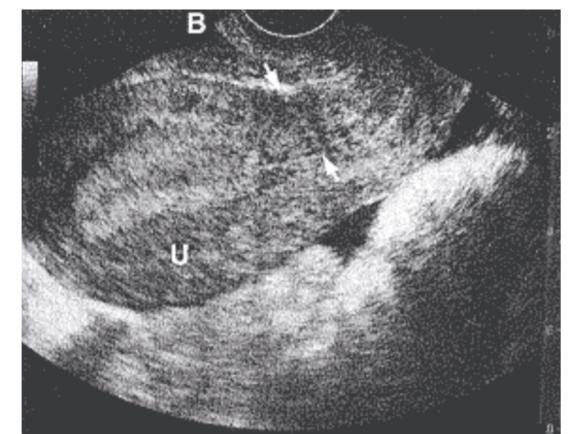
Limitations of Conventional ML

- Limited in ability to process natural data in raw form
- PR and ML systems require
 - careful engineering and domain expertise to transform raw data, e.g., pixel values, into a feature vector for a classifier

Simple ML depends on representation

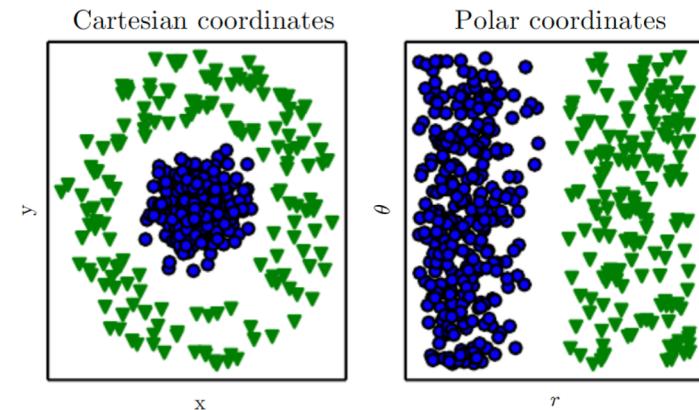
- Simple ML algorithms depend heavily on *representation* of given data
- Ex: Logistic regression to recommend delivery does not examine patient directly
 - Instead doctor provides information such presence of uterine scar (called a feature)
 - If Logistic regression was provided with MRI scan, it could not make useful predictions

Individual pixels have negligible correlation with complications in delivery



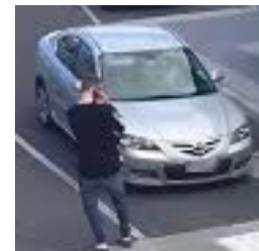
Dependence on Representation

- This dependence appears in computer science and daily life
 - In CS: search is exponentially faster if data is structured and indexed intelligently 
 - People: arithmetic on Arabic numerals 1,2,...9,10, easier than using Roman numerals I, II,...IX, X,
 - Choice of representation has enormous effect on ML algorithm performance
 - Ex: straight line separation
 - Impossible in Cartesian
 - Simple straight line in polar



Designing right set of features

- Difficult to know what set of features are good for detecting a car in photographs
 - Presence of wheel as a feature
 - Has a simple geometric shape but difficult to describe in terms of pixel values
 - Shadows, glare from metal parts, fender or object in front obscures



DL is Representation Learning

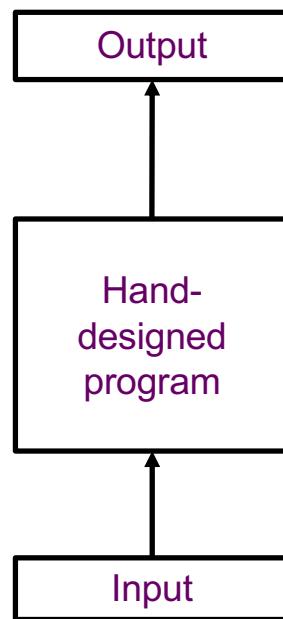
- Use ML to not only learn mapping from representation to output but representation itself
 - Better results than hand-coded representations
 - Allows AI systems to rapidly adapt to new tasks
 - Designing features can take great human effort
 - Can take decades for a community of researchers
- Deep Learning methods are Representation Learning Methods
 - Methods allow a machine to be fed with raw data to automatically discover representations needed for detection or classification

Advantage of multiple levels

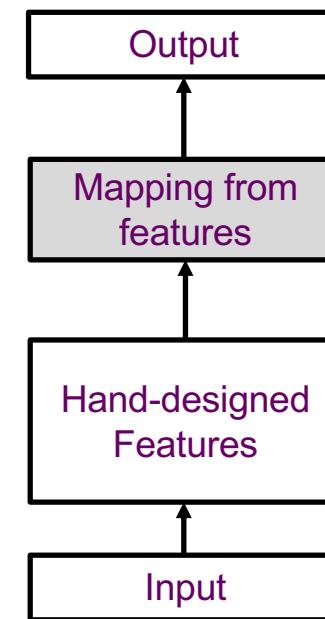
- Compose simple but non-linear modules that transform representation at one level (starting with raw input) into a representation at a higher slightly more abstract level
- Complex functions can be learned
 - Higher layers of representation amplify aspects of input important for discrimination and suppress irrelevant variations

Three paradigms of AI

Rule-based System

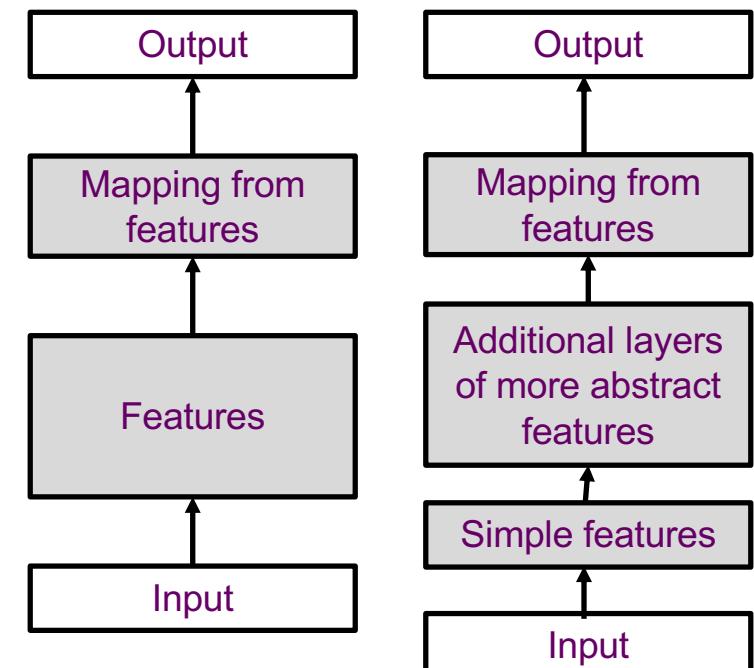


Classic Machine learning



Representation Learning

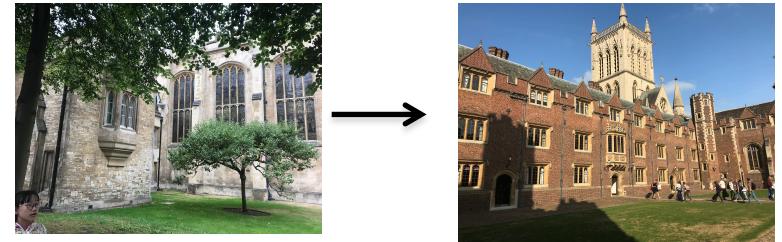
Deep Learning



- Shaded boxes indicate components that can learn from data

Physics and AI Paradigm Shifts

- Physics paradigm shift
 - Newtonian Physics
 - Cannot explain black-body radiation
 - Quantum Mechanics
- AI paradigm shift
 - Knowledge-based systems
 - Cannot perform simple recognition tasks
 - Simple machine learning methods
 - Cannot perform complex recognition tasks
 - Deep Learning methods
- Coexisting paradigms



Definition of Deep Learning

- Deep learning is inspired by neural networks of the brain to build learning machines which discover rich and useful internal representations, computed as a composition of learned features and functions
- This definition is a goal and does not say much about HOW we achieve that
 - E.g., by adding priors to learn better high-level representations
 - The term deep learning is indeed aspirational, like 'AI' or 'machine learning'

Characteristics of Deep Learning

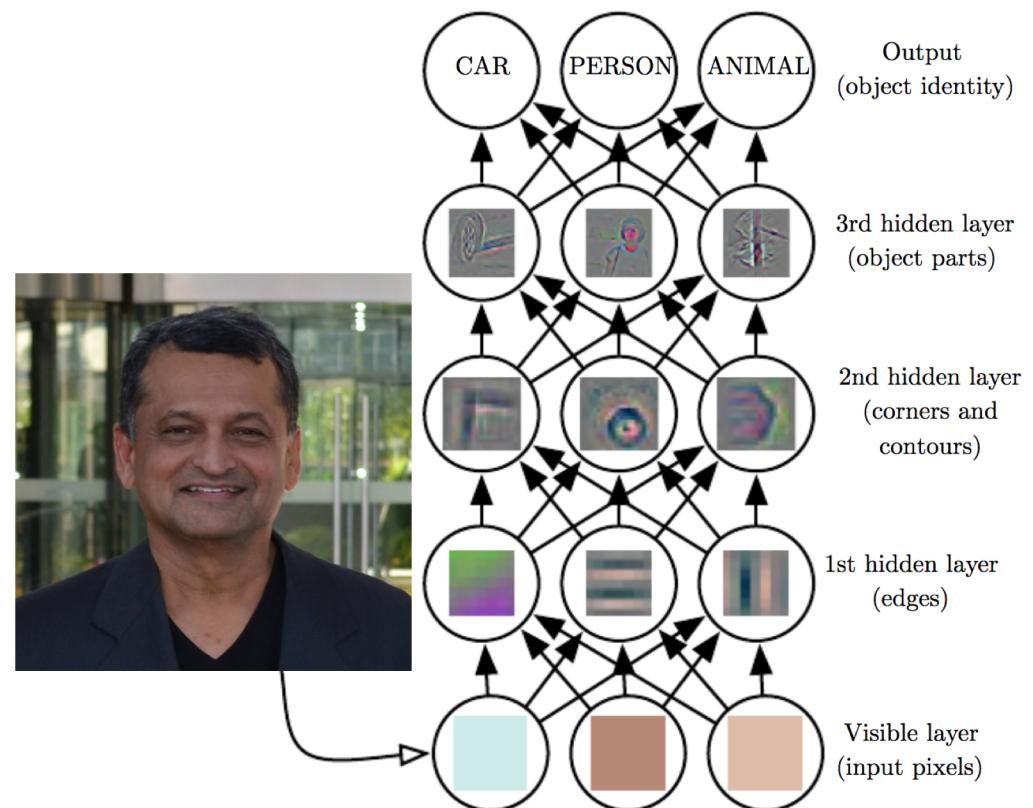
1. A type of Machine Learning that improves with experience and data
2. Only viable approach to building AI systems in real-world environments
3. Obtains its power by a nested hierarchy of concepts
 - each concept defined by relationship to simpler concepts
 - More abstract representations computed in terms of less abstract ones

Image Example

- Input is an array of pixel values
 - First Layer: presence or absence of edges at particular locations and orientations of image
 - Second layer: detect *motifs* by spotting arrangements of edges, regardless of small variations in edge positions
 - Third layer: assemble motifs into larger combinations that corresponds to *parts* of familiar objects
 - Subsequent layers: detect *objects* as combinations of these parts
- Key aspect of deep learning:
 - Layers not designed by human engineers
 - Learned from data using a general purpose learning procedure

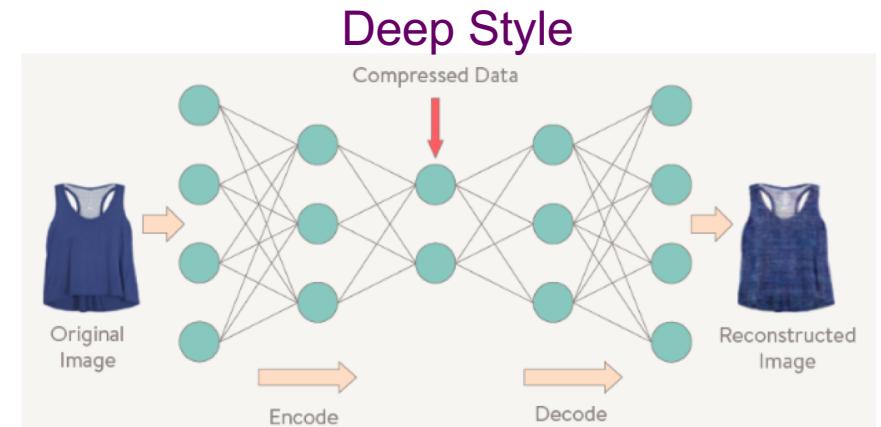
Example of Image Deep Learning

- Function to map pixels to object identity is complicated
- Series of hidden layers extract increasingly abstract features
- Final decision made by a simple classifier



Unsupervised Representation Learning

- Autoencoder:
 - Quintessential example of representation learning
 - Encoder:
 - Converts input into a representation with nice properties
 - Decoder:
 - Converts the representation back to input

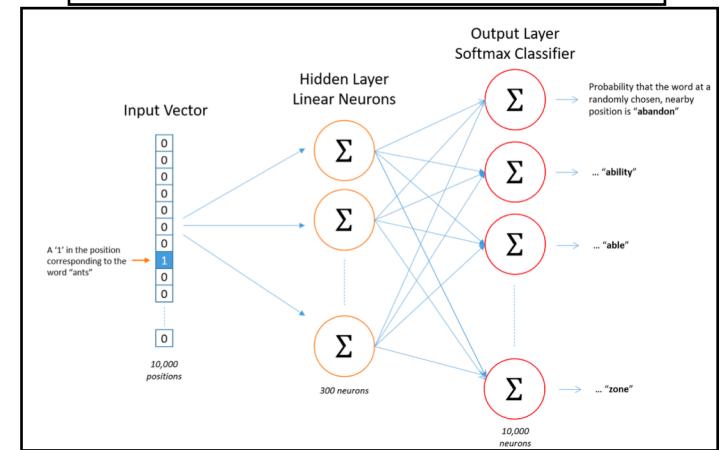
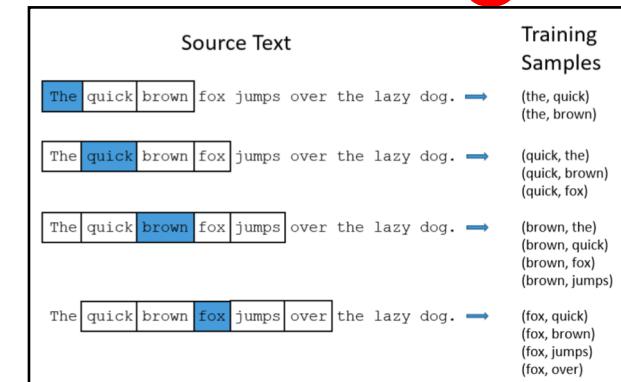


New designs from representation



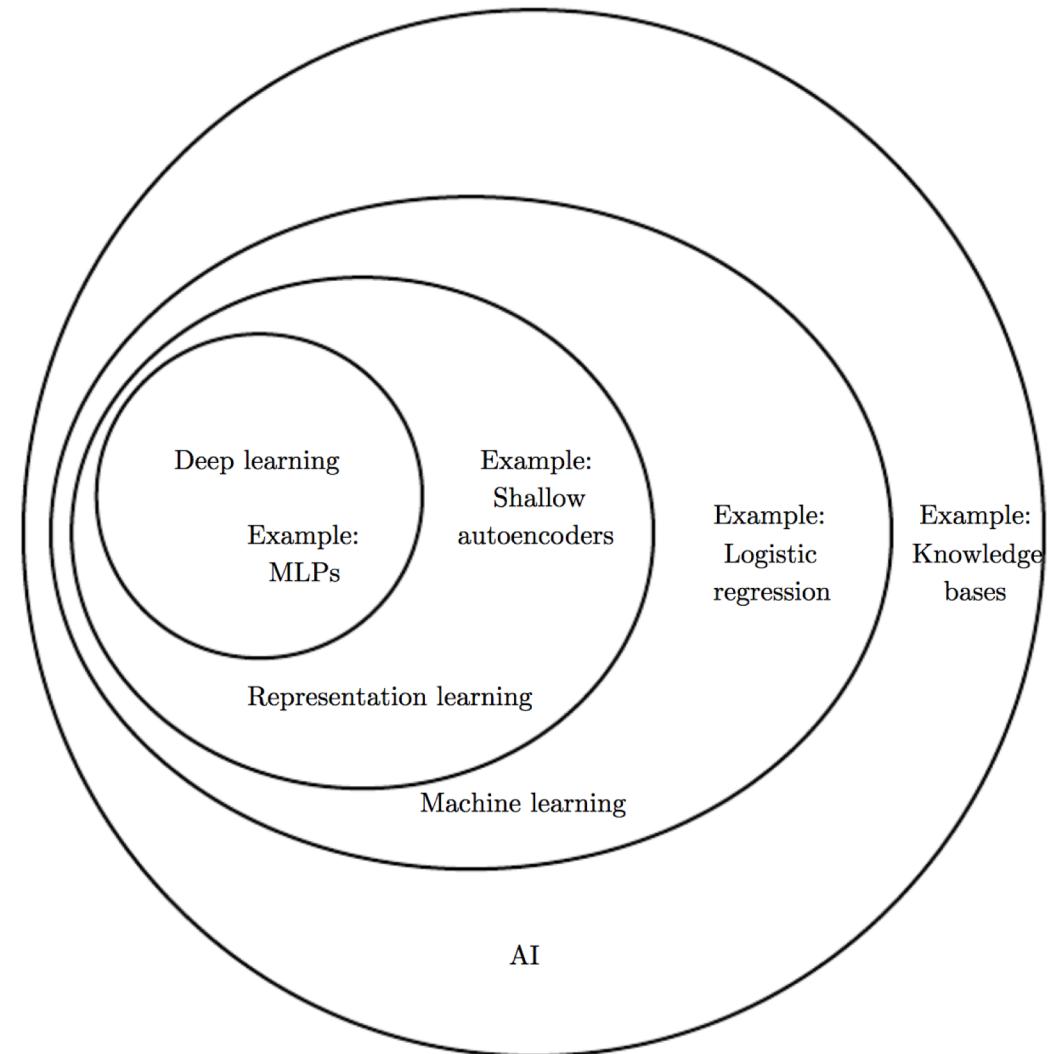
Natural Language Processing

- Training Data
- Word-to-vec
 - One-hot vector mapped to vector of 300
- Word embedding
 - Similar words are close together



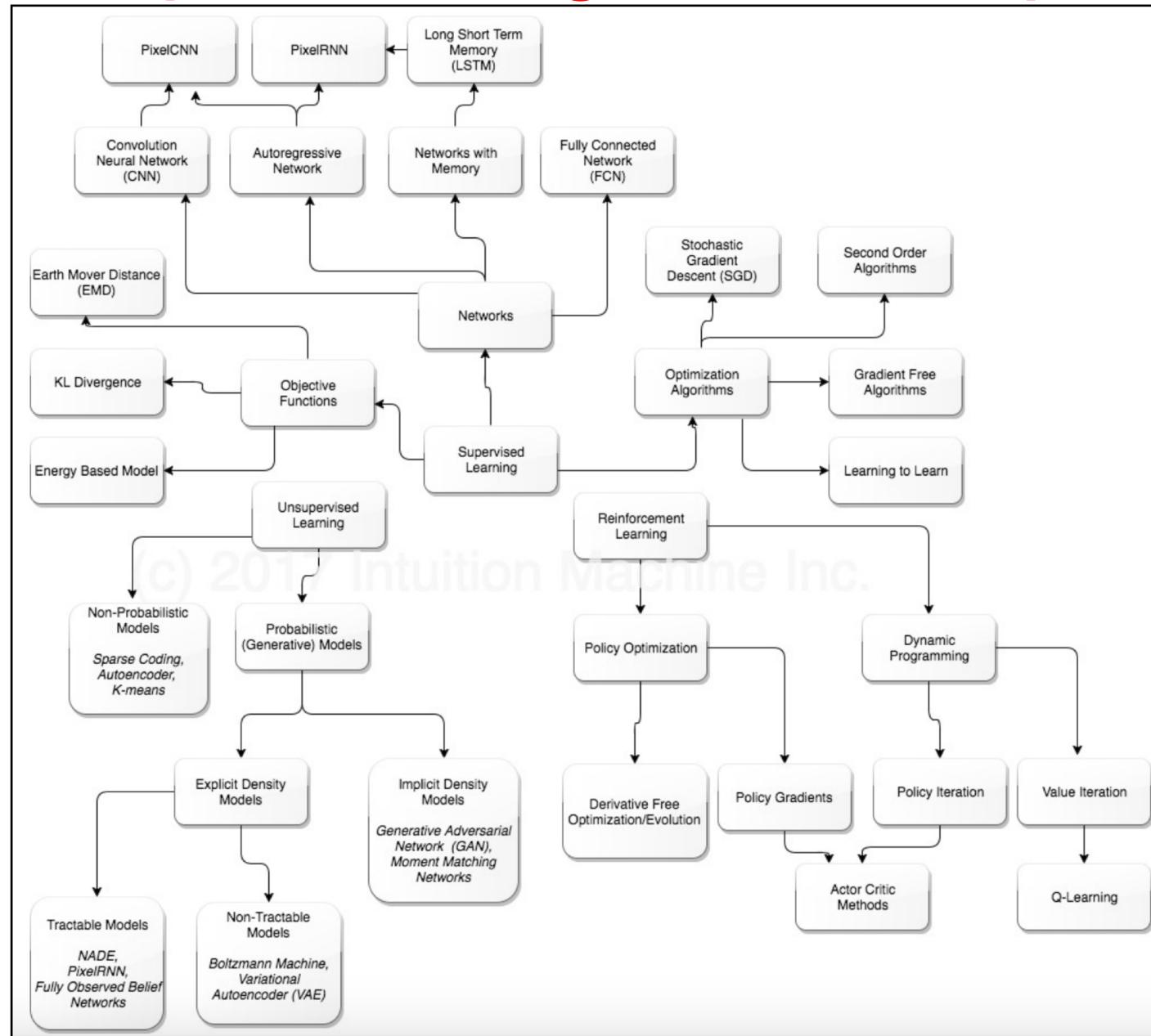
Approaches to AI: Venn Diagram

- AI methods
- Deep Learning is a type of representation learning
- An example AI technology is included in each
- Also see



<https://blogsinsider.blogspot.com/2018/10/relationship-between-ai-ml-dl.html>

Deep Learning Road Map



Study of Deep Learning

