

Probabilistic Artificial Intelligence

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Topics

1. Probabilistic Computing
2. Third wave of AI
3. Ex: Driving a car
4. Role in Explainable AI (XAI)
5. Role of probability in machine learning

Role of Probability in AI

- Probabilistic computing allows us to
 1. Deal with uncertainty in natural data around us
 2. Predict events in the world with an understanding of data and model uncertainty
- Predicting what will happen next in a scenario, as well as effects of our actions, can only be done if we know how to model the world around us with probability distributions

Role with XAI

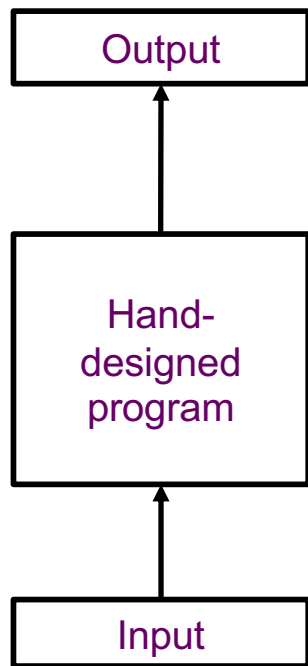
- Augmenting deep learning with probabilistic methods opens door to understanding why AI systems make the decisions they make,
- Will help with issues like tackling bias in AI systems.

Next wave of AI

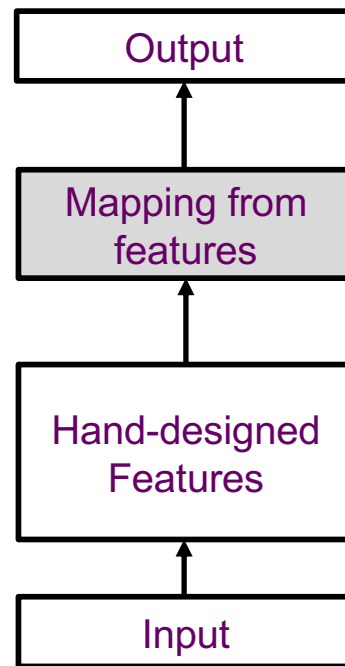
- Research into probabilistic computing is really about establishing a new way to evaluate the performance of the next wave of AI—one that requires real-time assessment of “noisy” data.

Current AI Models

Rule-based System: Pre-programmed Logic

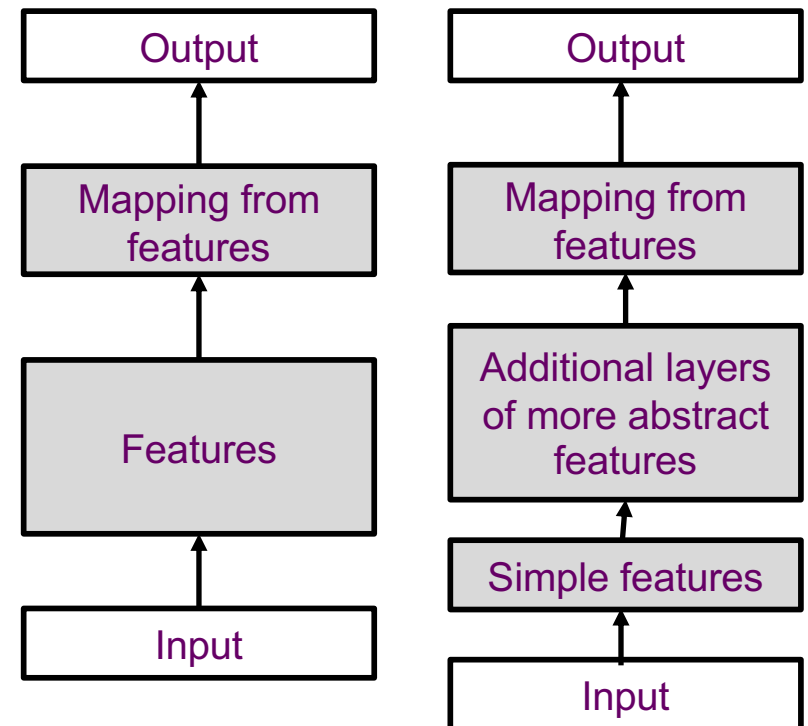


Classic Machine learning



Representation Learning: Sense and Perceive

Deep Learning



 Shaded boxes indicate components that can learn from data

Next step for AI

- First AI systems focused on logic:
 - Pre-programmed rules.
- Second wave of AI concerns ability to sense and perceive information
 - Leveraging neural networks to learn over time.
- But, neither solution can do things that human beings do naturally as we navigate the world.
 - They can't think through multiple potential scenarios based on data that you have on-hand while conscious of potential data that you don't have.

Driving a Car and Soccer Ball

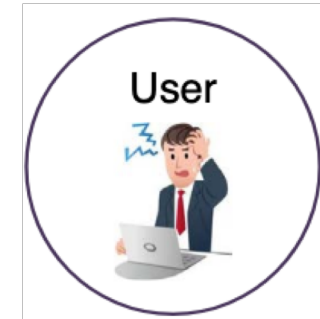
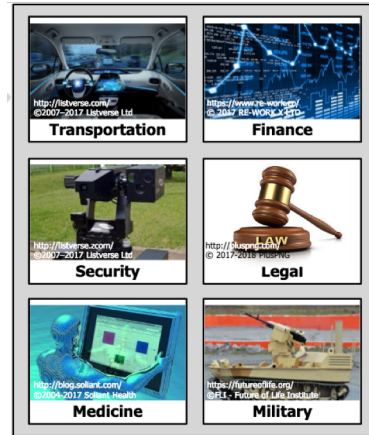
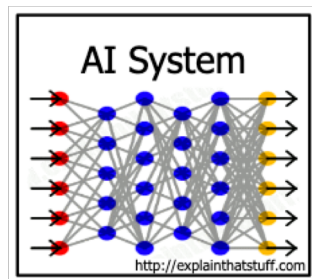


- If you are driving a car and see a soccer ball roll into the street,
- Your immediate and natural reaction is to stop the car since we can assume a child is running after the ball and isn't far behind.

Role of Probabilistic System

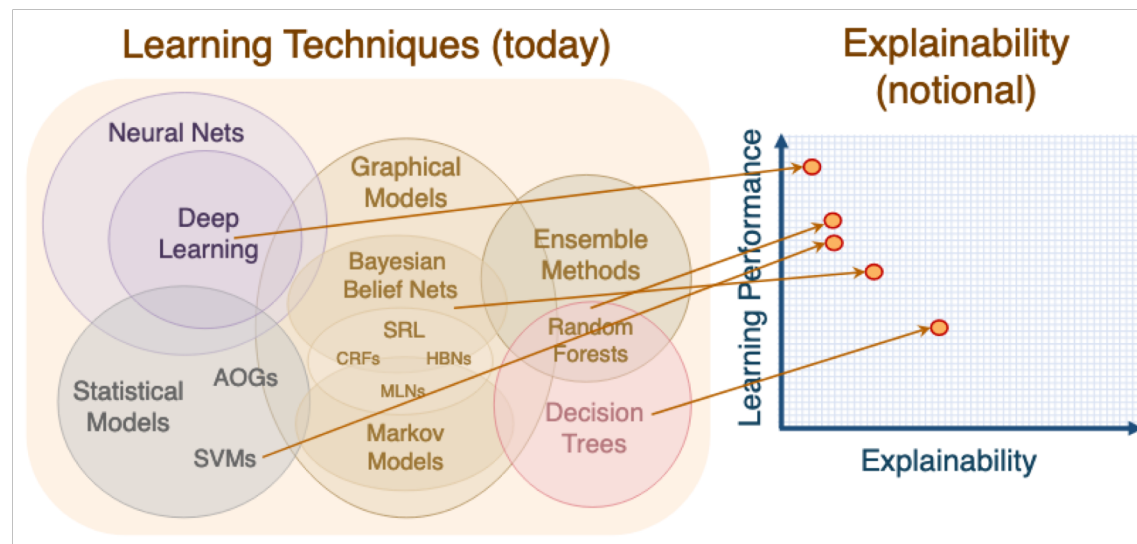
- Driver reaches the decision to stop the car based on experience of natural data and assumptions about human behavior.
 - But, a traditional computer likely wouldn't reach the same conclusion in real-time, because today's systems are not programmed to mine noisy data efficiently and to make decisions based on environmental awareness.
 - You would want a probabilistic system calling the shots—one that could quickly assess the situation and act (stop the car) immediately.

PGMs in Explainable AI



Anecdote: Medical AI
Decisions can be worse with AI
e.g., Patient discharge to a nursing home

Why did you do that?
Why not something else?
When do you succeed?
When do you fail?
When can I trust you?
How do I correct an error?

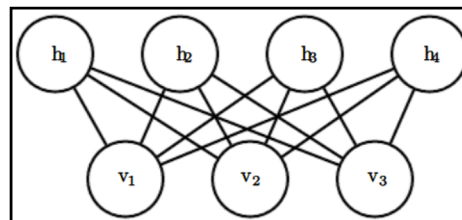


Role of Probability in ML

- In neural networks (discriminative models)
 1. Output is a probability distribution over y
 2. Instead of error as loss function we use a surrogate loss function, viz., log-likelihood, so that it is differentiable (which is necessary for gradient descent)
- In probabilistic AI (generative models)
 - We learn a distribution over observed and latent variables whose parameters are determined by gradient descent as well

$$p(\mathbf{x}; \boldsymbol{\theta}) = \frac{1}{Z(\boldsymbol{\theta})} \tilde{p}(\mathbf{x}, \boldsymbol{\theta})$$

$$Z(\boldsymbol{\theta}) = \sum_x \tilde{p}(\mathbf{x}, \boldsymbol{\theta})$$



Importance of Probabilistic AI

- Intel's new architectures for 2019*
- With end of Moore's law, focus is on
 1. Quantum computing
 - Manufactured 49-qubit supercomputing chip
 2. Neuromorphic computing
 - Implement aspects of biological neural networks as analog or digital copies on electronic circuits
 3. Probabilistic computing
 - Extend AI solutions to include novel and efficient implementations that enable calculations with probability distributions

*<https://spectrum.ieee.org/tech-talk/computing/hardware/intel-labs-director-talks-quantum-probabilistic-and-neuromorphic-computing> 2