



National University of Computer and Emerging Sciences

Fundamentals of Generative AI

AI-4009 Generative AI

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What is AI?

Artificial Intelligence

- The capability of machines to perform tasks that typically require human intelligence, such as learning, reasoning, problem-solving, and decision-making.
- “It is basically trying to simulate with a computer something that would match or exceed human intelligence”

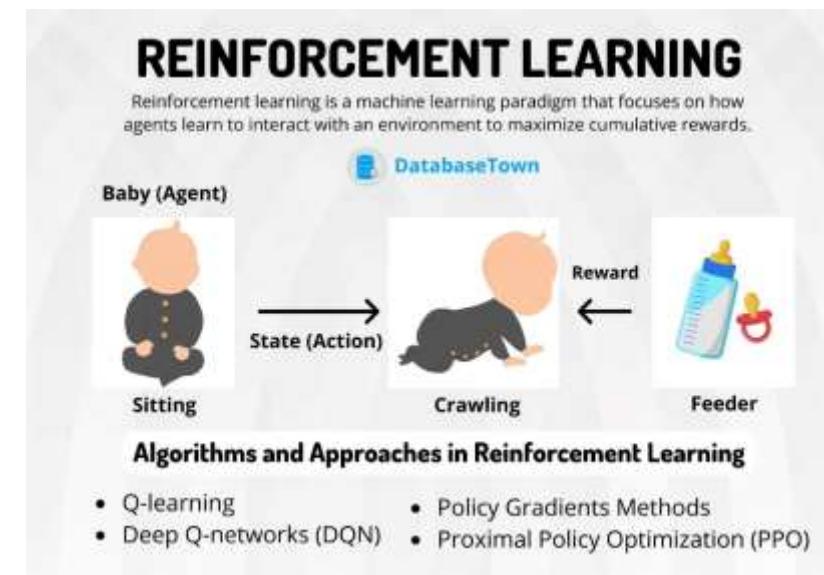
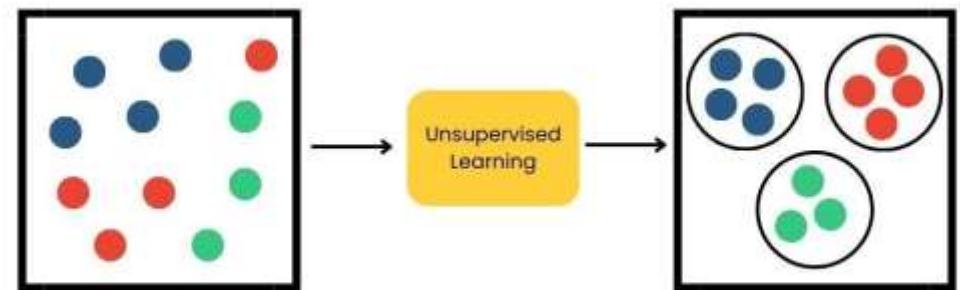
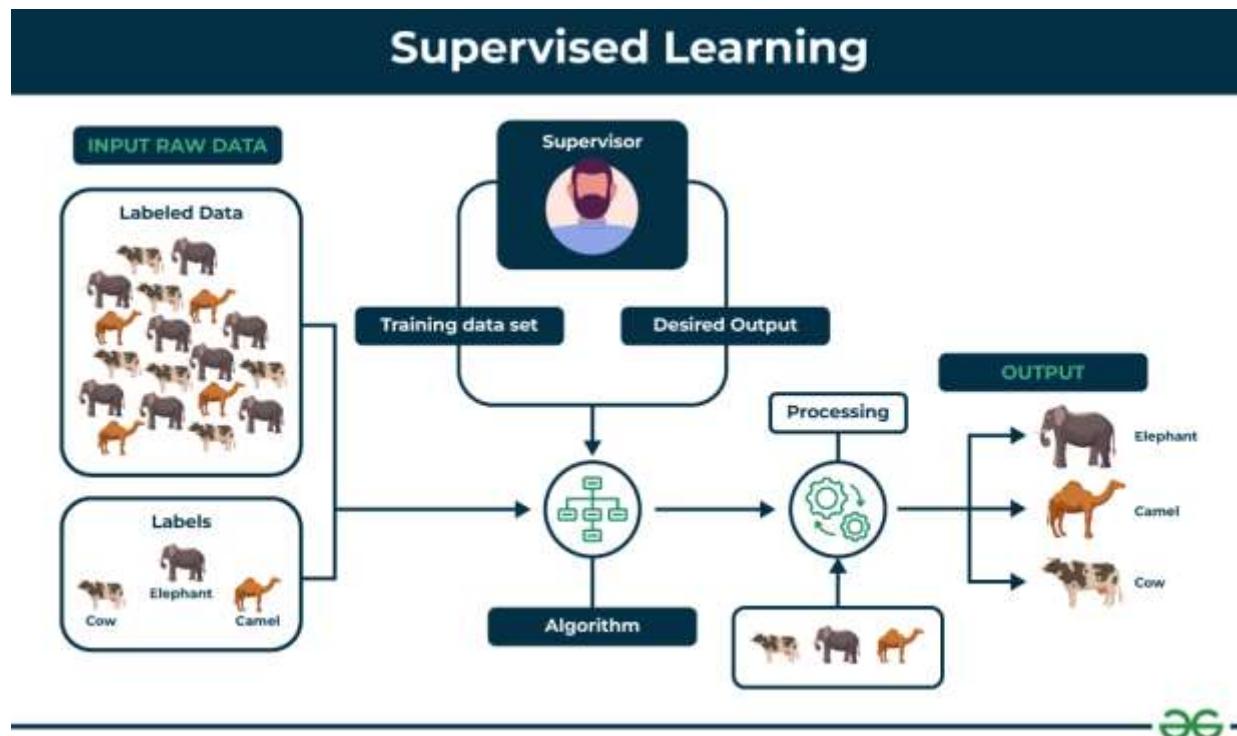
What is Machine Learning?

- A branch of artificial intelligence that **enables systems to learn and improve from experience** without being explicitly programmed.
- Key Components:
 - Data: **Essential for training models**.
 - Algorithms: **Learn from data** to make predictions or decisions.

Types of Machine Learning

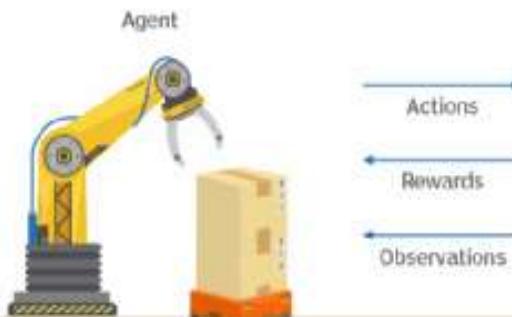
- **Supervised Learning:** Learning with labeled data. You have the output/result for each input attached to confirm if your prediction is correct.
- **Unsupervised Learning:** Learning from unlabeled data to find patterns. You just have raw data points, it's upto the model to learn how to categorize the data.
- **Reinforcement Learning:** Learning by trial and error to achieve a goal. Reward the model if it's doing something right, punish if it does wrong.

What is Machine Learning?

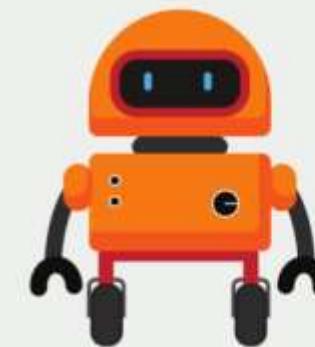


What is Machine Learning?

Training a logistics robot



Agent



Actions
Rewards
Observations

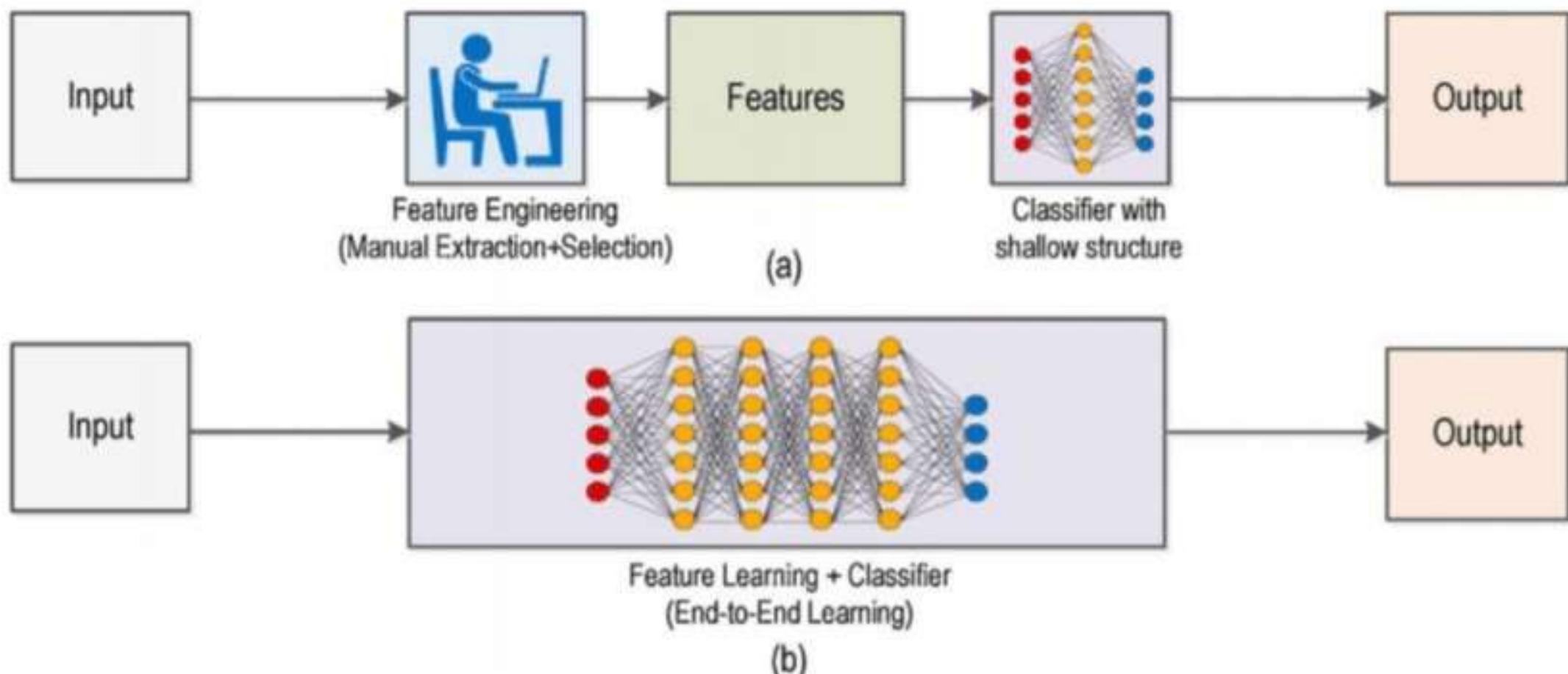
Environment



Deep Learning

- Uses **complex neural networks** with many layers (deep neural networks).
- These networks are capable **of automatically discovering and learning patterns** in data
 - Superior performance on tasks like image and speech recognition.
- Deep learning models can **automatically extract and learn features from raw data**, reducing the need for manual feature extraction.

Machine Learning vs Deep Learning



Machine Learning vs Deep Learning



Machine learning

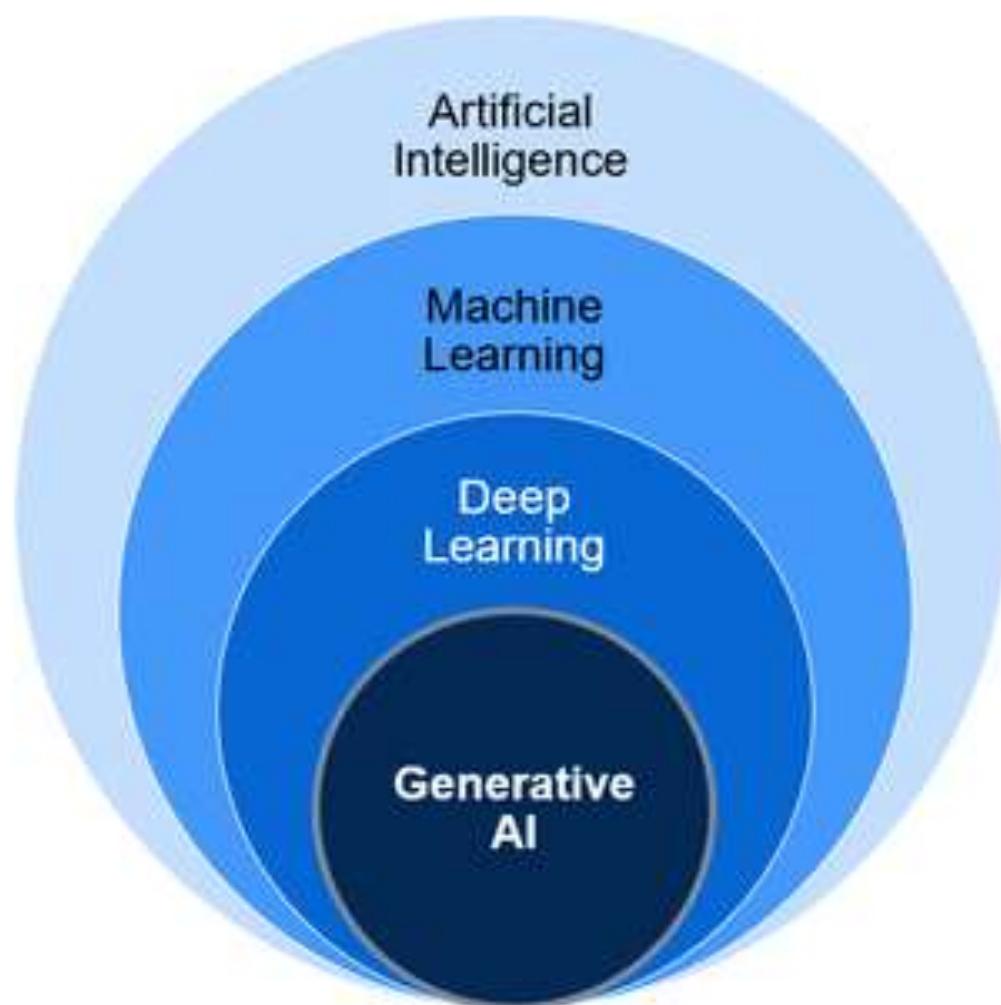
Uses algorithms and learns on its own but may need human intervention to correct errors



Deep learning

Uses advanced computing, its own neural network, to adapt with little to no human intervention

The AI Landscape



What are Generative Models?

- Generative models are a class of **statistical models** used in machine learning that focus on the **generation of new data instances**.
- Generative models used in **unsupervised machine learning**.
- They try understanding and replicating the complex **probability distributions** of training data.
- Capture the essence of data - its **patterns, variations, and structure** - and can produce new data that follows the same statistical properties.
- They contrast with **discriminative models**, which are designed to distinguish between different kinds of data instances.

Discriminative Vs Generative Model

- **Generative Models**
- Generative learn the **joint probability distribution** $P(X, Y)$, where X is the input data and Y is the output label.
- They understand how the data is generated in terms of a **probabilistic model**.
- These models can generate new data points that is **similar to the training data**.
- e.g. Gaussian Mixture Models, Hidden Markov Models, Naive Bayes, Variational Autoencoders (VAEs), and Generative Adversarial Networks (GANs).

Discriminative Vs Generative Model

- **Discriminative Models**
- Discriminative models learn the **conditional probability** $P(Y | X)$, which is the probability of the output label Y given the input data X .
- They focus on the **boundary between classes**.
- These models are used to **distinguish between different types of data points**.
- They **do not inherently generate new data points** but classify input data into predefined categories.
- **Examples include** Logistic Regression, Support Vector Machines, Decision Trees, and most of the Neural Networks used for classification tasks.

History of Deep Learning

- Specialized DL (Before BERT in 2018)
 - Design specialized model architectures.
 - Leveraging **task-specific features**.
 - Train the specialized models with limited data.
- Transfer DL (Between 2018 - 2021)
 - Train a model with large amount of training data.
 - Use the features of the trained model to initialize part of the architecture
 - Design specialized modules on top of the trained features.
 - Train the **partially specialized model with limited data**.
- Foundation Model (After 2021)
 - Train a single **huge model on astronomical amount of data**
 - **Prompt the single model for everything**
 - Autonomous Agents

What are Generative Models?

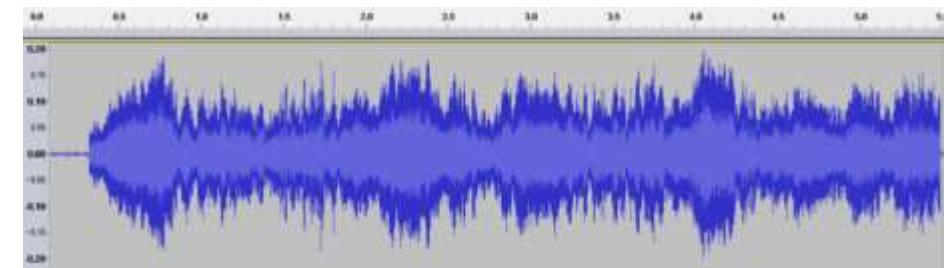
Generative machine learning algorithms model complex, **high-dimensional** objects.



High-Resolution Images

Once upon a time, we knew that our ancestors were on the verge of extinction. The great explorers and poets of the Old World, from Alexander the Great to Chaucer, are dead and gone. A good many of our ancient explorers and poets have

Paragraphs of Text



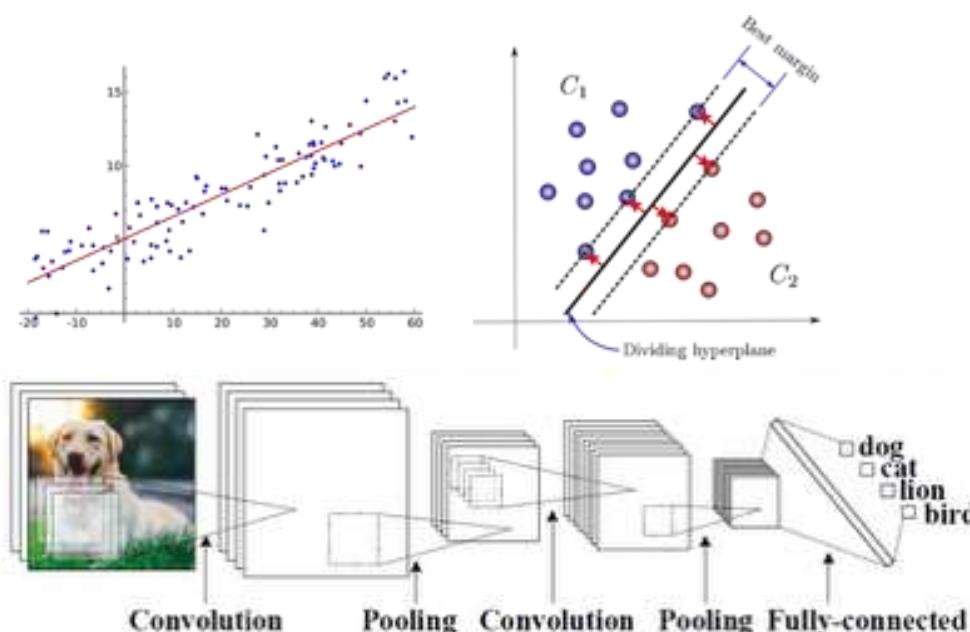
Human Speech

**AI in Anomaly Detection:
Uncovering Hidden Threats in Data in Real Time**

What are Generative Models?

Generative machine learning algorithms model complex, **high-dimensional** objects.

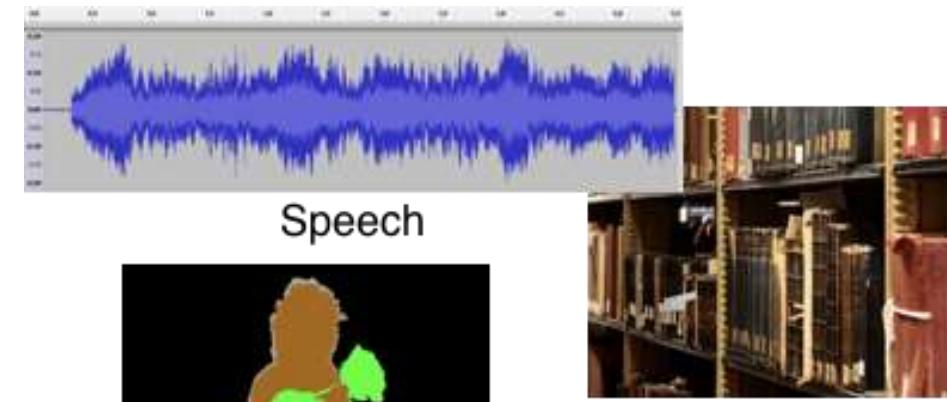
Discriminative Models



Input: Complex Image

Output: Simple Label

Generative Models



Speech



Images

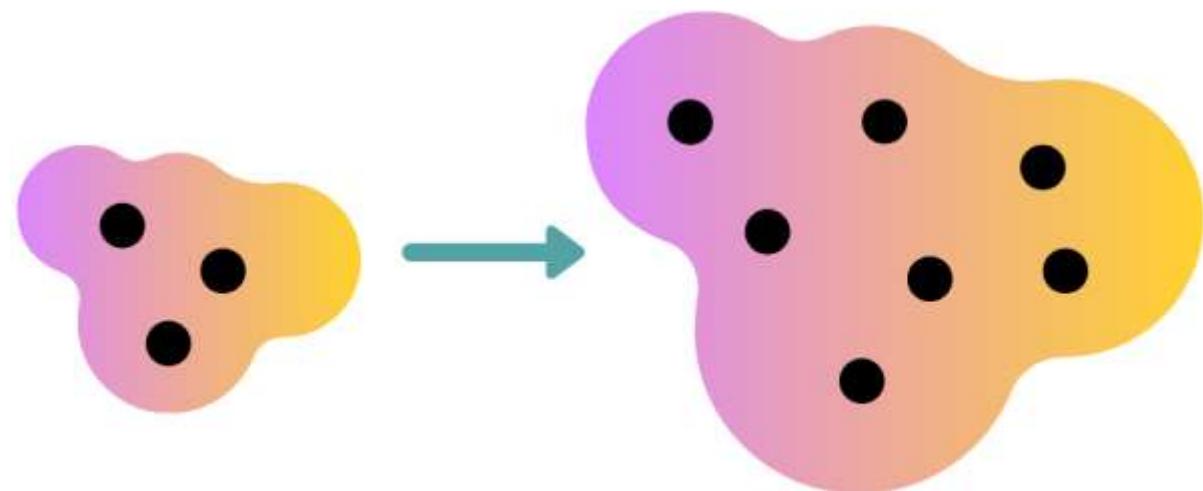
Language

Input: Simple Label

Output: Complex Image, Text, Speech

Discriminative vs. Generative Models

- Generative models can do **everything that discriminative models can do**: e.g., prediction (can get conditional $p(y|x)$ from $p(x,y)$ via Bayes' rule).
- But generative models can also do much more!
 - Generating new x 's
 - Conditional generation of $p(x|y)$
 - Handling missing inputs in x



Generating new data using past data

Discriminative vs. Generative Models

“generate an image of a person with seven cars”



Generative Model



ChatGPT



Generative Art



“generate an art containing mountains and a small house”

ChatGPT-4



Generative Art

“Generate an art where a professor explains a hard topic and students are enjoying”

ChatGPT-4

Image Enhancement and Super-Resolution

Uses a conditional generative model **P(high res image | low res image)**



Ledig et al., 2017

Representation Learning

X



smiling
woman



neutral
woman



neutral
man

Here, the generative models learns high-level concepts from data (smiling, man, woman, etc.). We can use these to perform complex semantic manipulations over images.

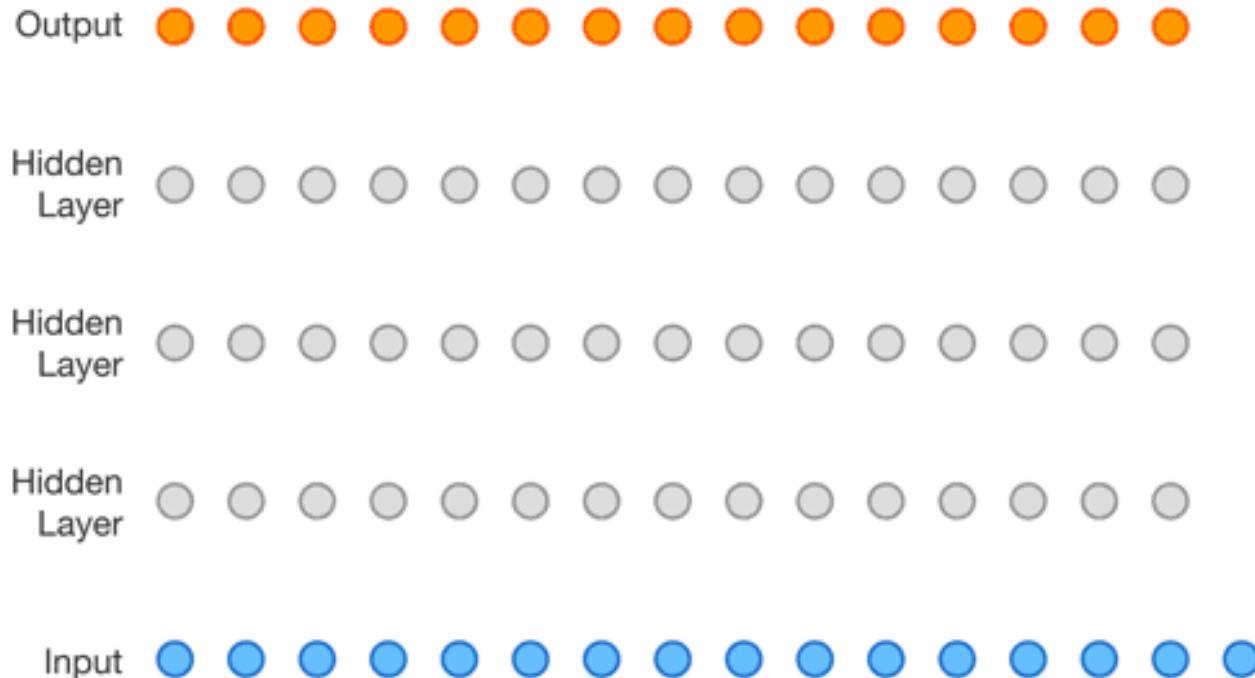


smiling man

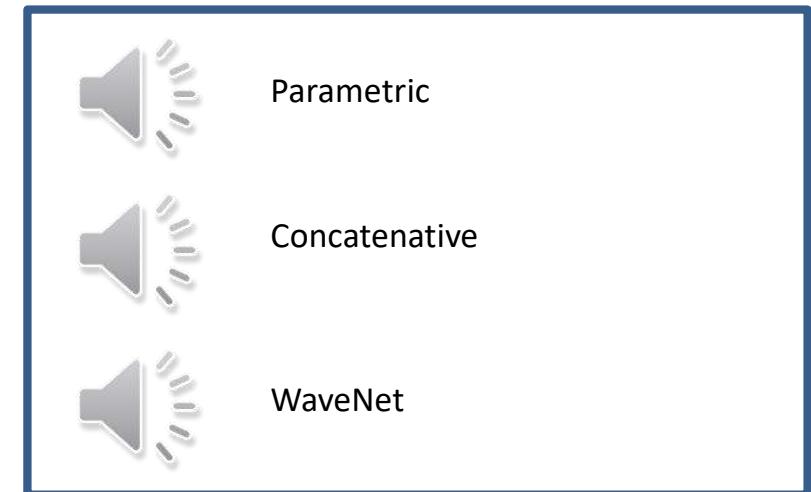
Radford et al.

Generating Realistic Human Speech

Generative model of speech signals



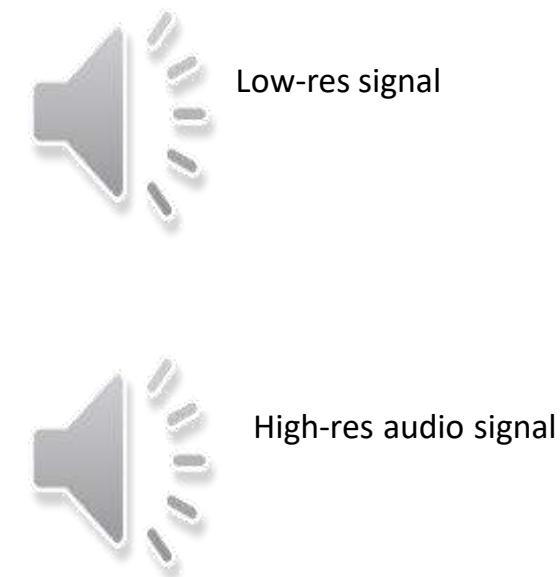
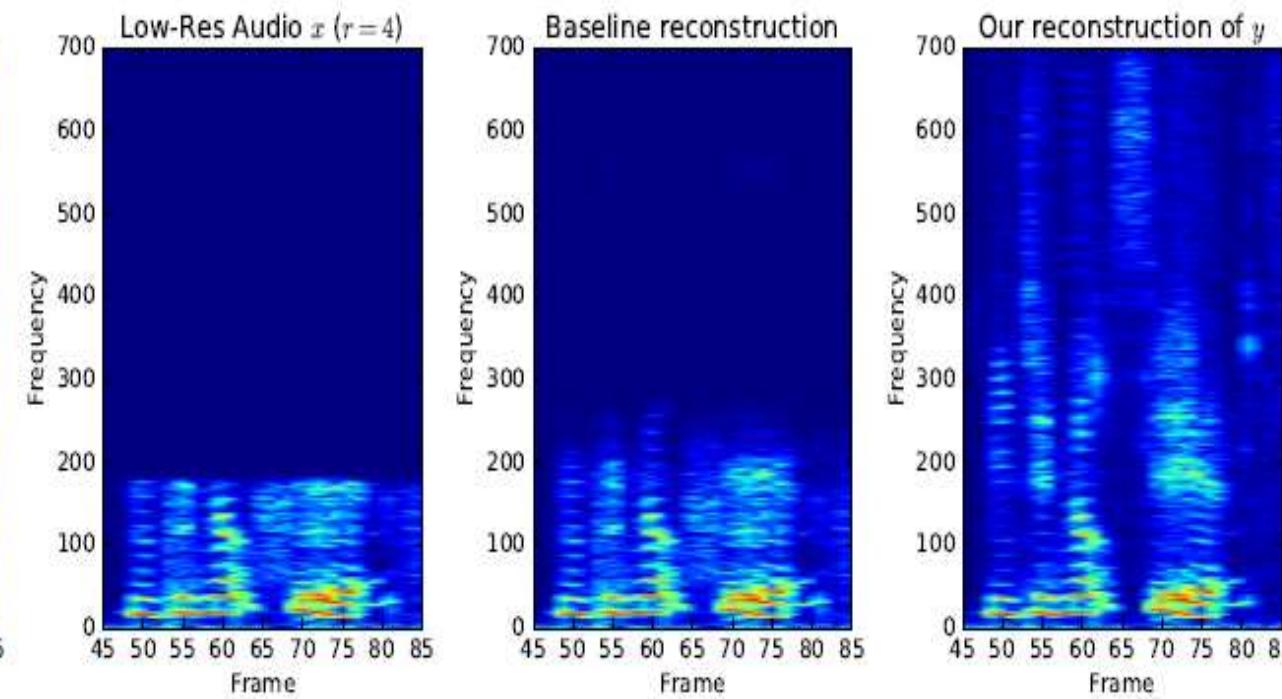
Text to Speech



van den Oord et al. 2016c

Signal Processing and Signal Enhancement

Audio super-resolution using a conditional model $P(\text{high-res} \mid \text{low-res audio signal})$.



Kuleshov et al., 2017

Language Generation



You

find error in this code and fix it:

```
for (int i = 0; i >= 0; i++) {  
    std::cout << "i = " << i << std::endl;  
}
```



ChatGPT

The code you've provided is a `for` loop in C++ that, as written, will result in an infinite loop. This is because the loop's termination condition, `i >= 0`, will always be true as `i` is initialized to 0 and only increases with each iteration (`i++`).

cpp

```
#include <iostream>  
  
int main() {  
    for (int i = 0; i < 10; i++) {  
        std::cout << "i = " << i << std::endl;  
    }  
  
    return 0;  
}
```



You



Twitter_Streaming_Data_Analytics_for_...
PDF

Generate a technical summary of this paper



ChatGPT

The paper "Twitter Streaming Data Analytics for Disaster Alerts" presents a novel approach to disaster management by leveraging real-time Twitter data. Here's a technical summary of the paper:

Abstract

- The paper discusses the use of Big Data Analytics (BDA) to harness information from Twitter for generating real-time alerts about ongoing disasters.
- It proposes the "Twitter Alert Generation System" (TAGS), a solution that collects and analyzes social media streaming data in real-time to issue warnings related to ongoing disasters.
- The system employs a combination of Hadoop and Spark frameworks.
- It was tested and evaluated using Twitter data from the 2018 earthquake in Palu City, Sulawesi, Indonesia, demonstrating the ability to issue alert messages and identify critical information efficiently.

Introduction

- The paper emphasizes the increasing role of social media, particularly Twitter, in real-time information dissemination.
- It underlines the concept of "Human as a sensor," where individuals can provide instant information about their surroundings.

Proposed Architecture (TAGS)

- TAGS architecture collects data from Twitter streams using various APIs, supporting both real-time and historical data streams aggregation.
- It extracts features using Spark Streaming and stores classified datasets on HBase, an open-source NoSQL database that operates with the Hadoop platform.
- Apache Spark is used for interactive querying over massive real-time data streams, operating on Resilient Distributed Datasets (RDDs).

Conclusion

- The paper illustrates the integration of real-time Twitter streams into the disaster management process.
- TAGS, utilizing Spark, HBase, and Hadoop, allows for scalable and fault-tolerant analytics.
- The system's efficacy was demonstrated in the context of the 2018 Palu City earthquake and tsunami, highlighting its potential in disaster management and event detection.

Keywords

- Data Analytics, Disaster Management, Disaster Alert Generation, Twitter, Hadoop, Spark, Geo-social Media Analytics

This summary encapsulates the core aspects of the paper, outlining its objectives, methodology, and the significance of its findings in the context of using social media

Language Generation



You

To get an A+ in Generative AI



ChatGPT

Achieving an A+ in a course on Generative AI involves a combination of theoretical understanding, practical application, and staying updated with the latest advancements in the field. Here are some steps to help you excel:

1. Understand the Fundamentals:

- Gain a solid understanding of machine learning basics, especially neural networks.
- Study the principles behind generative models like GANs (Generative Adversarial Networks), VAEs (Variational Autoencoders), and autoregressive models like the Transformer.

2. Deep Dive into Key Models:

- Thoroughly understand the architecture, training process, and applications of key generative models.

3. Practical Application:

- Implement generative models using programming languages like Python and frameworks like TensorFlow or PyTorch.
- Experiment with different datasets and tasks (e.g., image generation, text generation, style transfer).

4. Stay Current with Research:

- Regularly read research papers and articles to stay updated with the latest developments in generative AI.
- Attend webinars, conferences, or online courses focused on the latest trends and techniques.

5. Participate in Projects and Competitions:

- Engage in hands-on projects or contribute to open-source projects to apply your knowledge practically.

Machine Translation

Uses a conditional generative model $P(\text{English text} \mid \text{Urdu text})$.

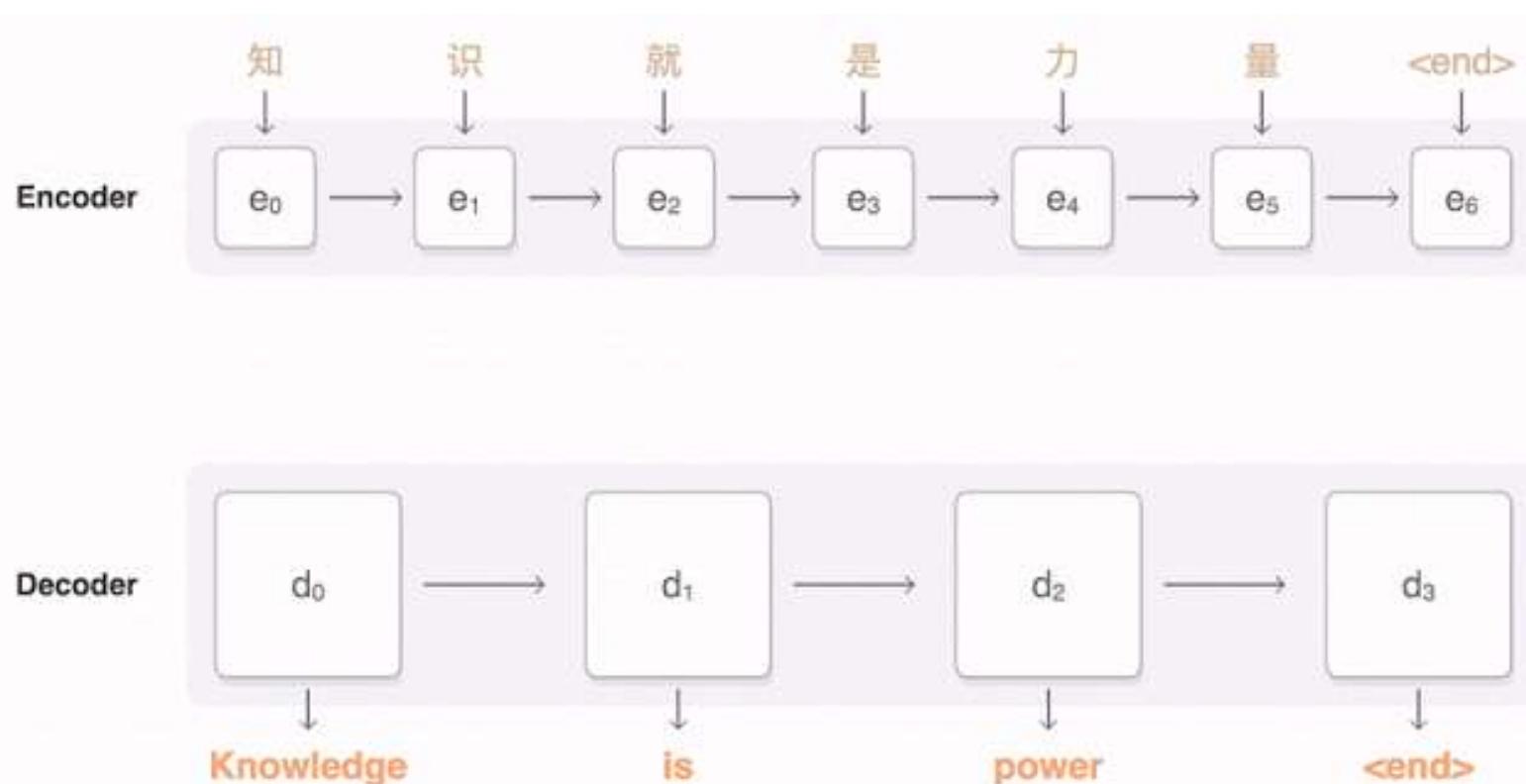


Figure from Google AI research blog.

Deep Fakes & Face Swapping



Do you recognize anyone you know in these pictures?

Image Translation

Horse-to-zebra translation using a model $P(\text{zebra images} \mid \text{horse images})$.



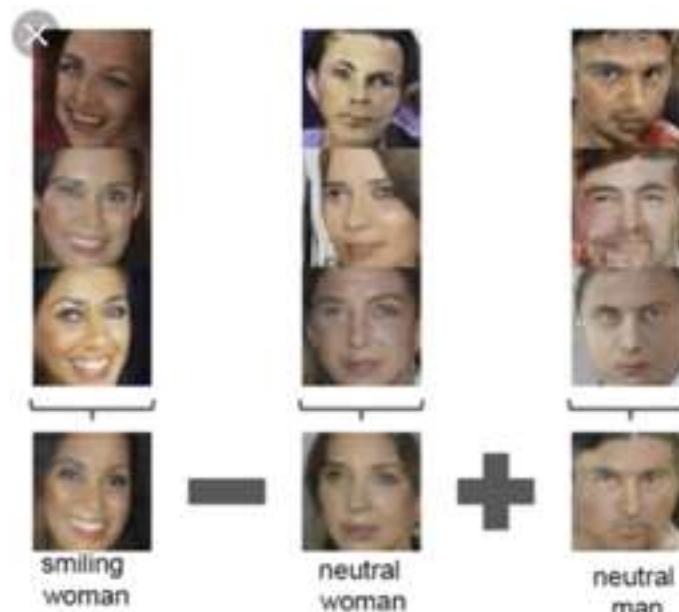
Zhu et al., 2017

Image Translation

Dog-to-cat image translation using a model $P(\text{cat images} \mid \text{dog images})$



What Are Generative Models Useful For?

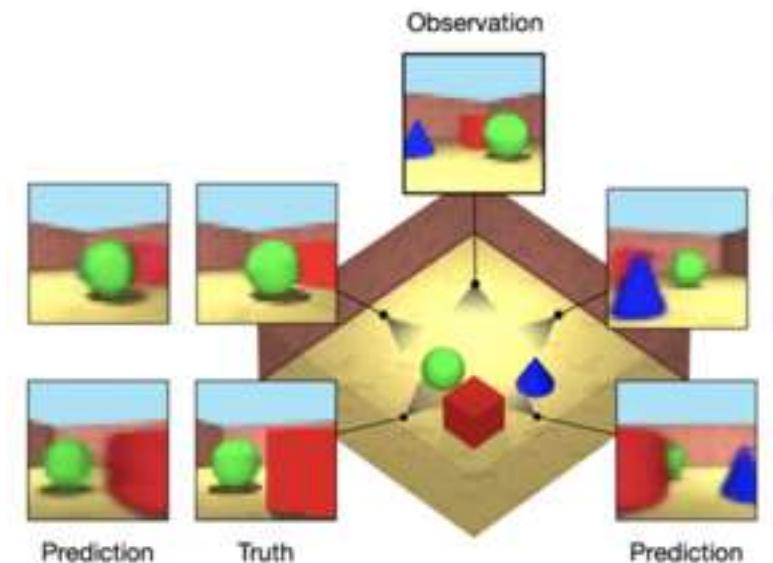


Generation and Manipulation

Super Resolution
Signal Processing
Signal Enhancement

Representation Learning

Style Transfer
Image Translation
Controlled generation



Decision-Making

Planning
Imitation Learning

References

- Chapter 20, Deep Learning, MIT Press, Ian Goodfellow, Yoshua Bengio, Aaron Courville
- Lecture slides of <https://www.cs.cornell.edu/~kuleshov/>

Thank You 😊