

## **Convolutional Neural Networks (CNNs)**

**Operation:** Use convolution operations with filters/kernels that slide across input data, detecting local patterns and features. Pooling layers reduce dimensionality while preserving important information.

### **Real-world Applications:**

- Medical imaging (detecting tumors in MRIs, X-rays)
- Autonomous vehicle vision systems
- Facial recognition in security systems
- Quality control in manufacturing (defect detection)
- U-Net evolution > Diffusion + image simultaneous vs LLM token sequencing (DALL-E, Midjourney, Stable Diffusion)

## **Recurrent Neural Networks (RNNs)**

**Operation:** Maintain internal memory through feedback connections, allowing information to persist across time steps. Can process sequences of varying length.

### **Real-world Applications:**

- Language translation services (Google Translate)
- Speech recognition systems (Siri, Alexa)
- Stock market trend analysis
- Weather forecasting models

## **Long Short-Term Memory Networks (LSTMs)**

**Operation:** Enhanced RNNs with gating mechanisms that control information flow, solving the vanishing gradient problem. Can remember information over longer sequences.

### **Real-world Applications:**

- Sentiment analysis of customer reviews
- Predictive text on smartphones
- Fraud detection in financial transactions
- Music composition algorithms (Sonu)

## **Transformer Networks**

**Operation:** Use self-attention mechanisms to process entire sequences simultaneously, allowing each element to attend to all other elements. Highly parallelizable architecture.

### **Real-world Applications:**

- Large language models (ChatGPT, Claude)
- Document summarization systems
- Code generation tools (GitHub Copilot)
- Scientific paper analysis and research assistance

## **Generative Adversarial Networks (GANs)**

**Operation:** Two networks compete—a generator creates fake data while a discriminator tries to detect fakes. Through adversarial training, the generator improves until it produces realistic outputs.

### **Real-world Applications:**

- Deepfake detection and creation
- Art generation and style transfer
- Data augmentation for training datasets
- Drug discovery molecular generation

## **Graph Neural Networks (GNNs)**

**Operation:** Process data structured as graphs, where entities are nodes and relationships are edges. Message passing allows nodes to aggregate information from neighbors.

### **Real-world Applications:**

- Social network analysis and friend recommendations
- Drug interaction prediction in pharmaceuticals
- Traffic flow optimization in smart cities
- Protein structure prediction in biology