Understanding Artificial Intelligence

AI 101 “Under the hood”
Applications
Emerging Trends in Law Enforcement

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Key AI Concepts and Technologies
Embedded AI
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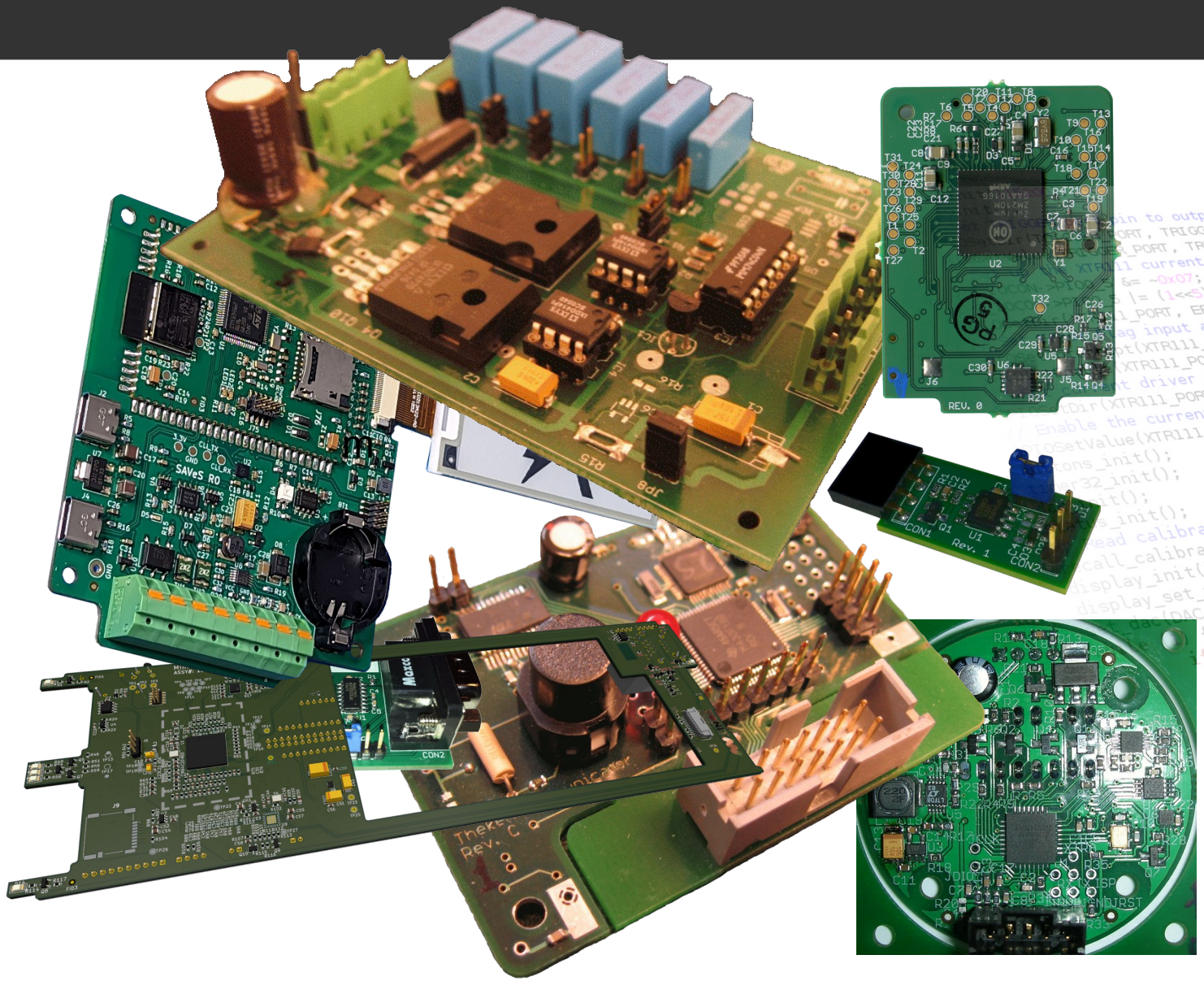
Introduction

COLE
DESIGN & DEVELOPMENT, LLC

Cole Design and Development, LLC

We’re an embedded systems consultancy in Hudson, Ohio that specializes in firmware development, microelectronic design, and wireless telemetry for medical and industrial applications.

Introduction



SynthInt

Embedded Machine Learning for Intelligent Devices

SynthInt Technologies, LLC was started in 2023 for our AI design work.

Introduction

AI has been transformative across multiple Industries:

Healthcare
AI helps in diagnostics, personalized treatment, and drug discovery.

Finance
It powers fraud detection, risk management, and algorithmic trading.

Retail
AI enhances customer experiences through personalized recommendations and inventory management.

Manufacturing
It drives automation, predictive maintenance, and quality control.

Transportation & Automotive
AI drives advancements in autonomous vehicles, smart traffic management, and route optimization.

Agriculture
AI supports precision farming with crop monitoring, yield prediction, and automation in tasks like harvesting.

Education
Adaptive learning platforms and intelligent tutoring systems personalize education, making learning more effective.

Security
AI enhances threat detection, facial recognition, and cybersecurity efforts across various sectors.

Why is an understanding of AI important in today's world?

Navigating a Technological World:
A basic understanding helps us *use technologies* with integrated AI *more effectively*

Career and Skills Development:
AI is reshaping job markets and creating *new opportunities* that did not exist before

Knowledge of AI opens doors to *innovation and problem-solving*

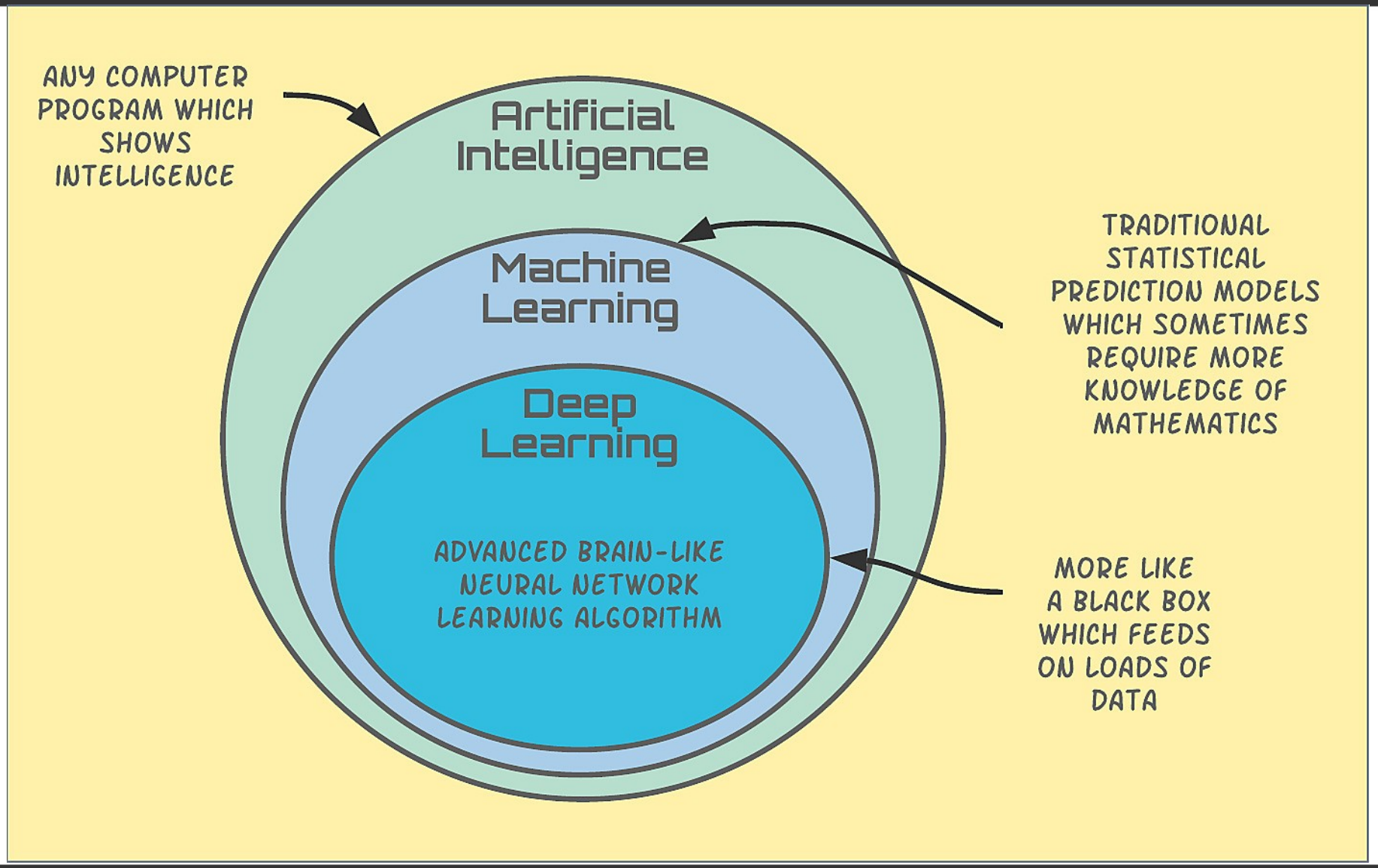
Understanding Artificial Intelligence

Definition of AI:

Artificial Intelligence (AI) is the branch of computer science dedicated to creating systems that can *perform tasks that typically require human intelligence*.

This includes learning from data, reasoning, problem-solving, perception, and understanding natural language, enabling machines to *mimic cognitive functions* such as decision-making and pattern recognition.

Understanding Artificial Intelligence



Understanding Artificial Intelligence

Artificial Intelligence (AI):

A broad field focused on creating systems that can mimic human intelligence and perform tasks such as reasoning, decision-making, and problem-solving.

Machine Learning (ML):

A subset of AI that trains algorithms to learn patterns from data and improve over time without being explicitly programmed for every scenario.

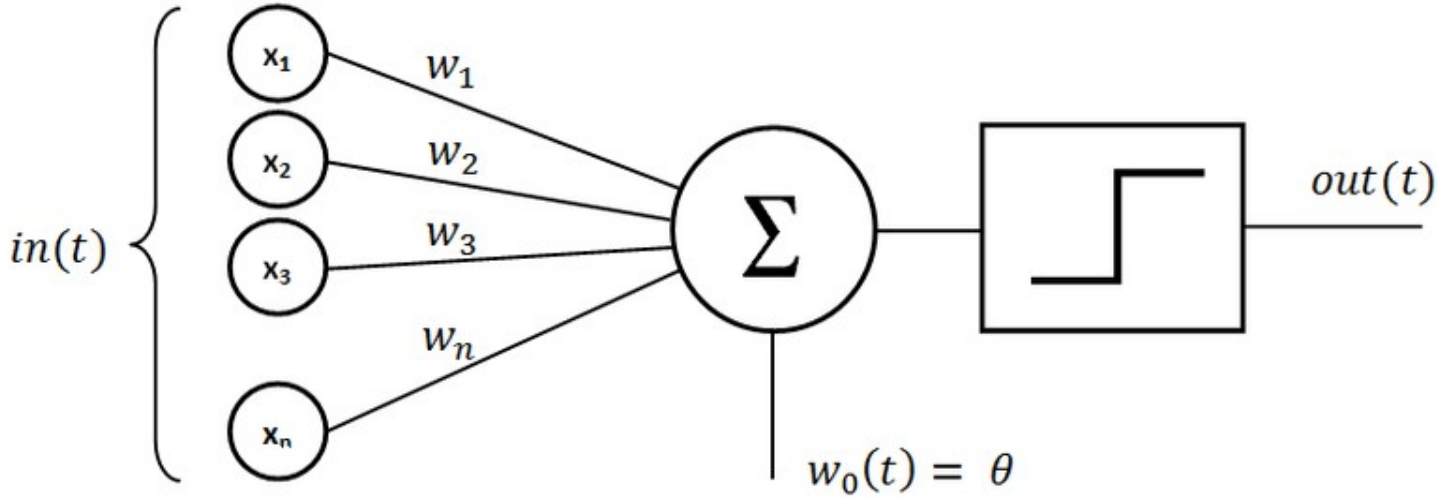
Deep Learning (DL):

A specialized subset of machine learning that uses layered neural networks to model complex patterns and representations in data.

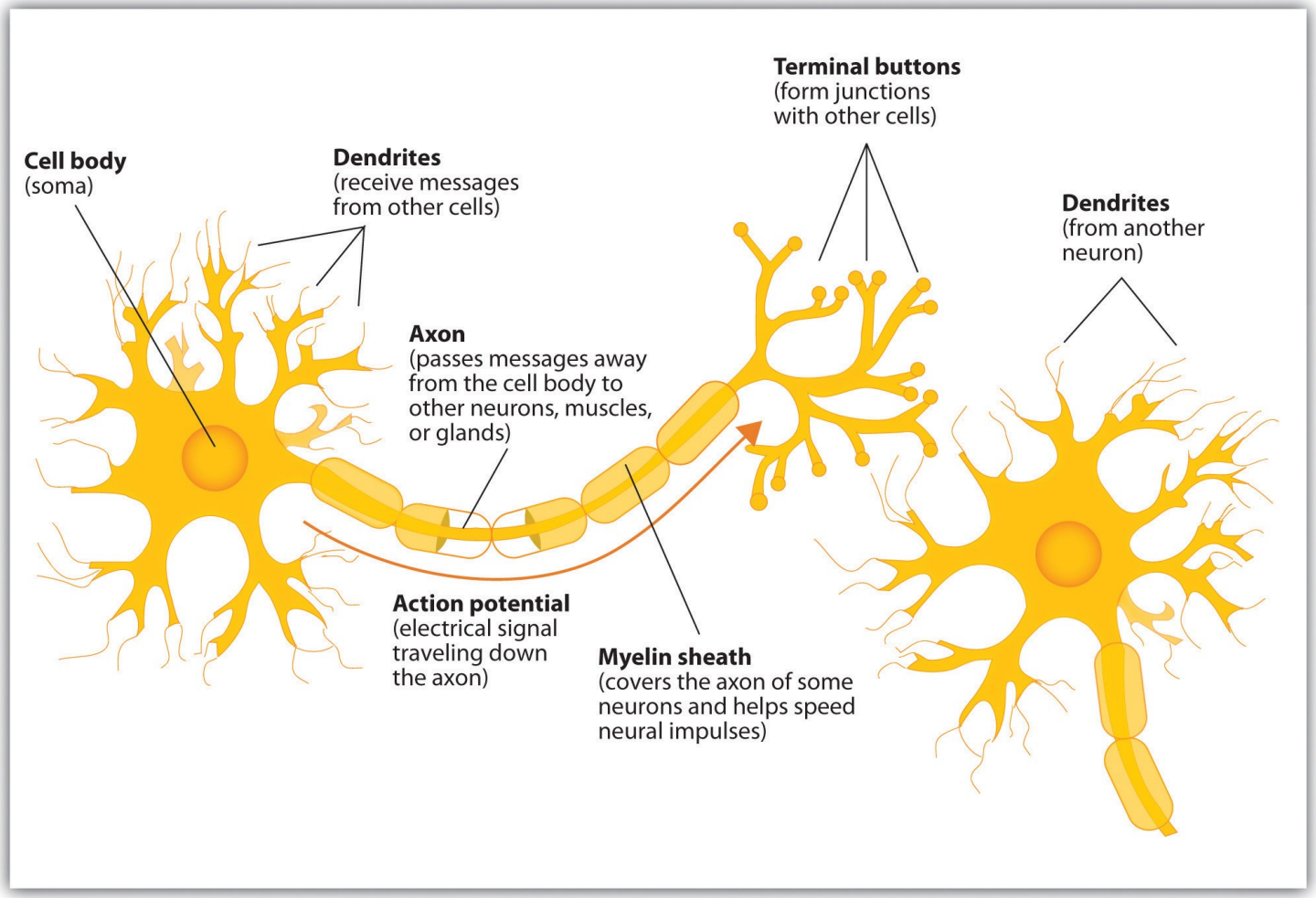
A Brief History of AI

1950: The concept of machines emulating human reasoning using hard-coded rules and logic (Alan Turing's 'Turing Test', which determines if a machine can think by mimicking human communication)

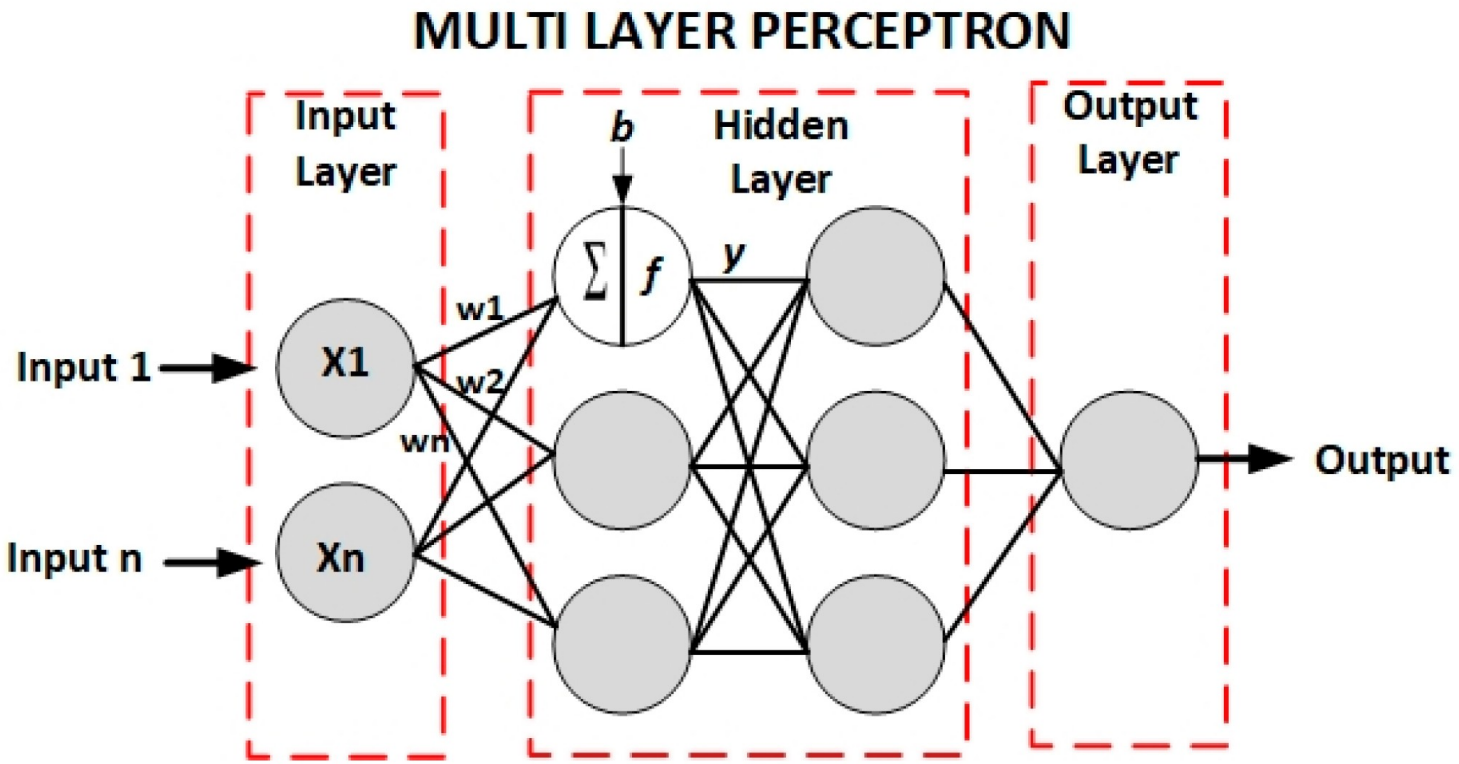
1957: Frank Rosenblatt invented the perceptron, which was used for pattern recognition and image processing



The perceptron mimics the biological neuron:



1958: Frank Rosenblatt extended the idea to the multi layer perceptron



A Brief History of AI

1966: ELIZA invented at MIT (first program using NLP)

1990’s: Emergence of data-driven approaches using statistical methods and probabilistic models

2000’s: Early neural networks

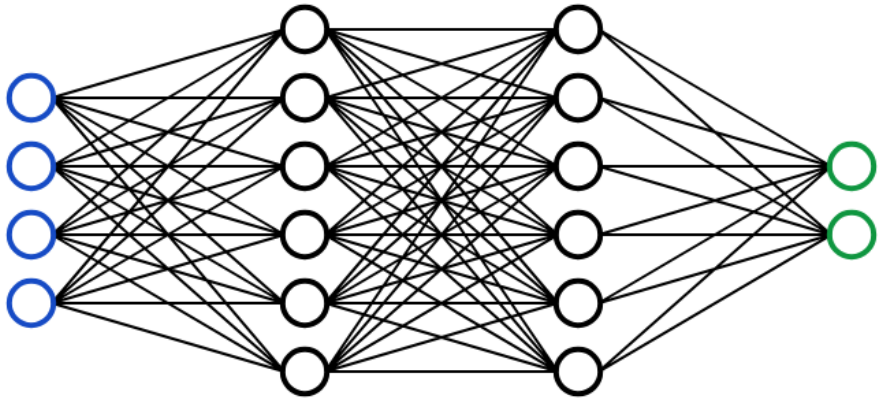
2010’s: Deep learning

2017: LLMs became available thanks to the attention mechanism (and more compute horsepower and storage)

How does a Neural Network work?

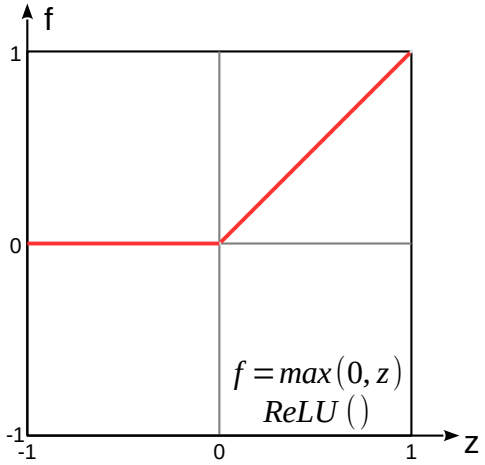
Layers: Input, hidden, output

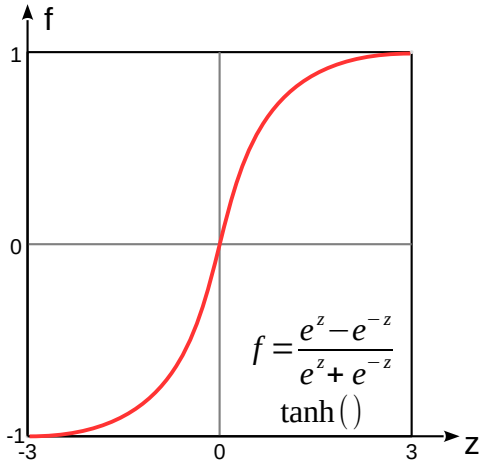
Inferencing = forward propagation
Learning = back propagation



Activation Functions:

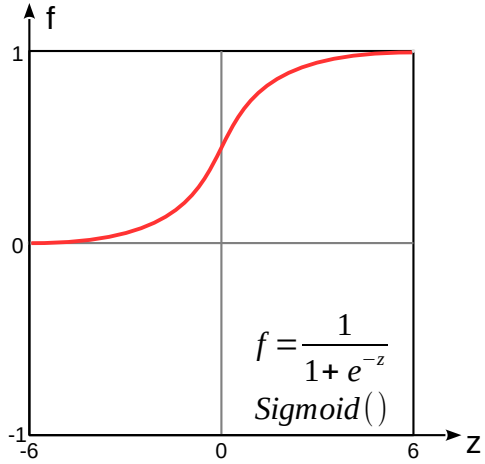
ReLU

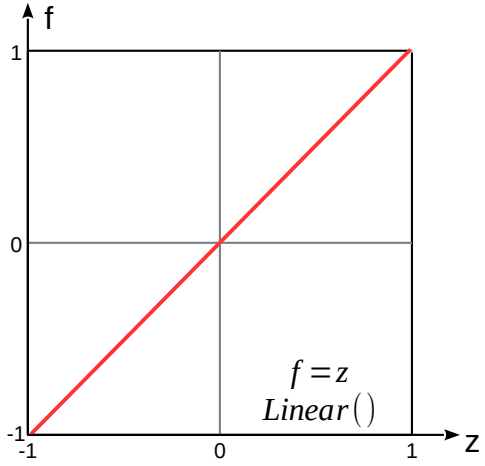




Hyperbolic Tangent

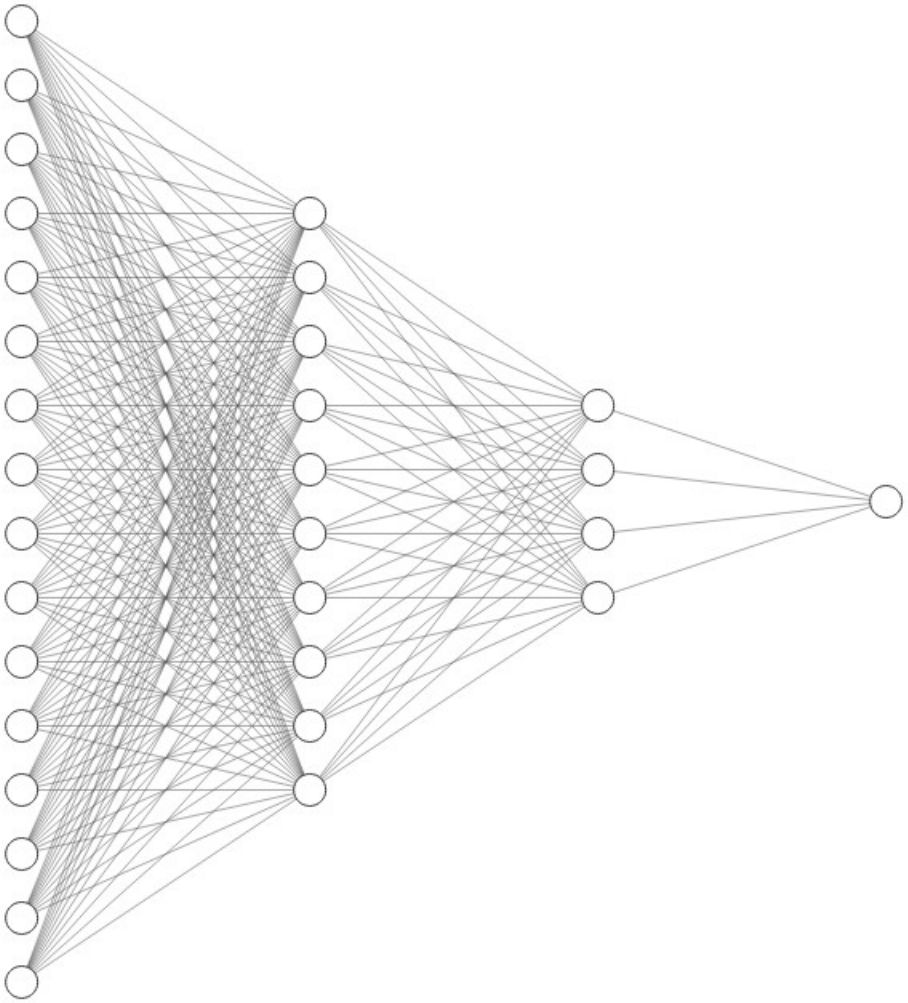
Sigmoid



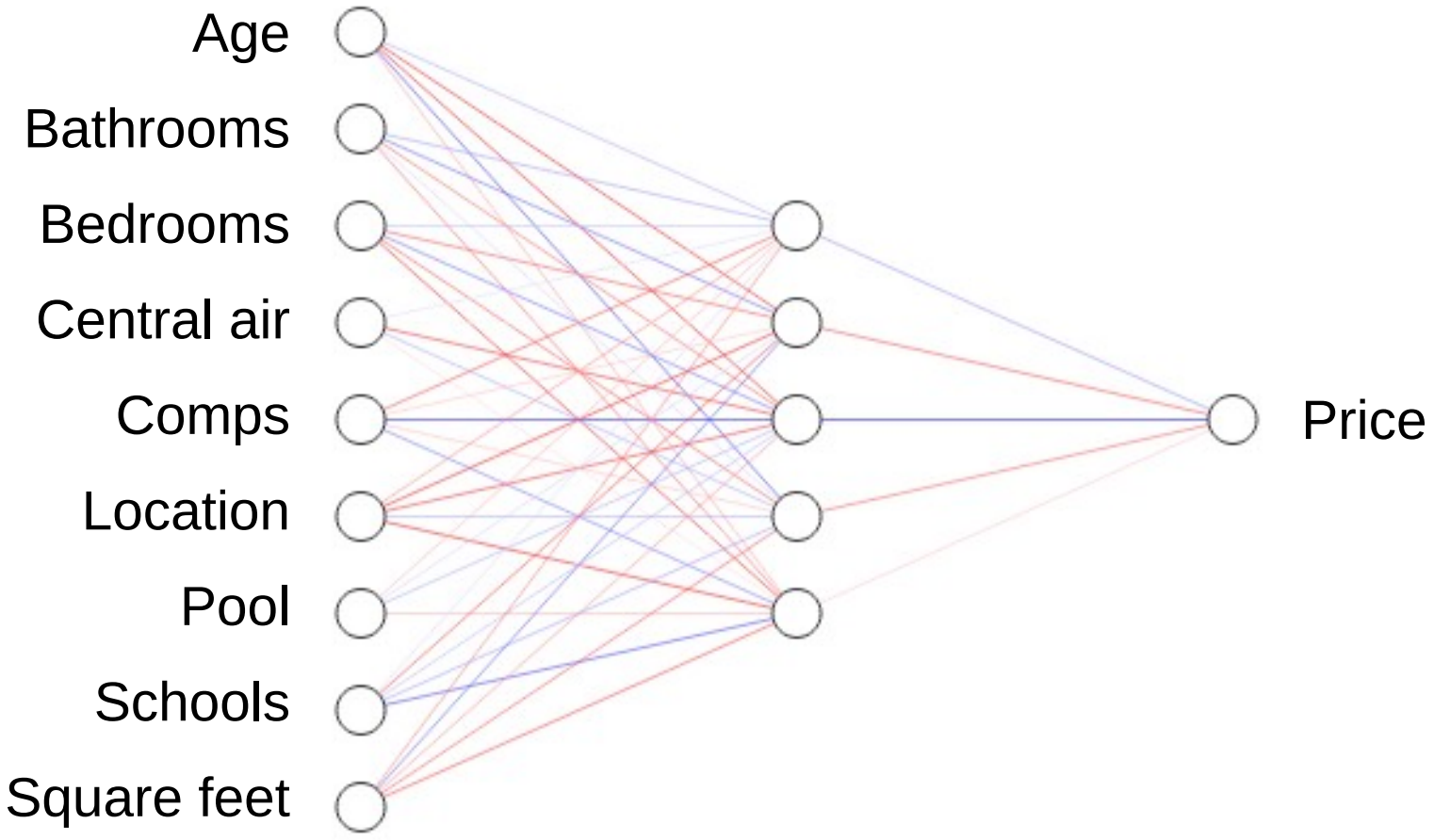


Linear

Fully Connected Feed-Forward Neural Network for Classification



Neural Network to Estimate Home Prices:



Input data to train the Home Prices model:

Property ID	Age	Bathrooms	Bedrooms	Central air	Comps	Location	Pool	Schools	Square feet	Price	Affordability
1	10	3	4	Y	320,000	44112	Y	5	4,000	335,000	L
2	12	2	3	N	180,000	44107	N	6	2,500	175,000	H
3	6	1	3	N	190,000	44115	N	8	3,200	170,000	H
4	7	4	5	Y	335,000	44143	Y	10	4,500	305,000	L
5	1	3	4	Y	270,000	44143	N	10	3,500	275,000	M

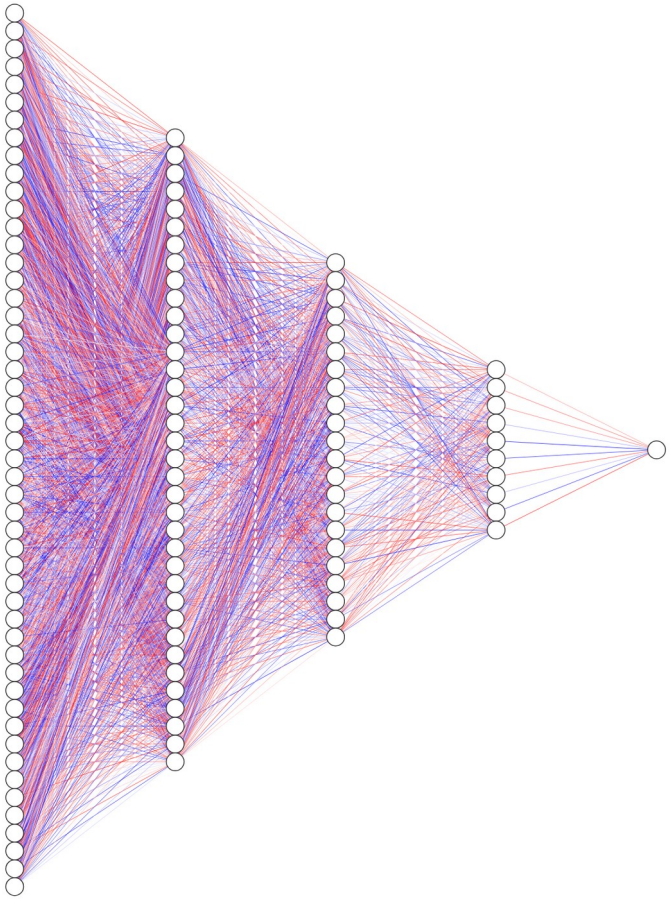
Each line is an *observation* (yellow) – we have 5 observations

Each feature is an *attribute* (green) – 9 attributes

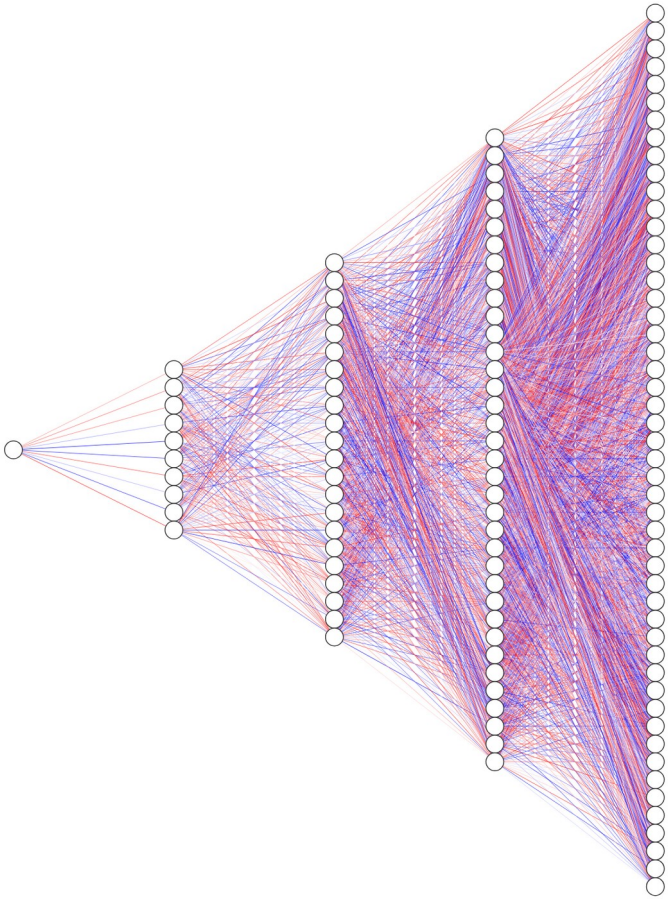
Each classification is called a *label* (red) – There are 2 labels

Key Concepts and Technologies

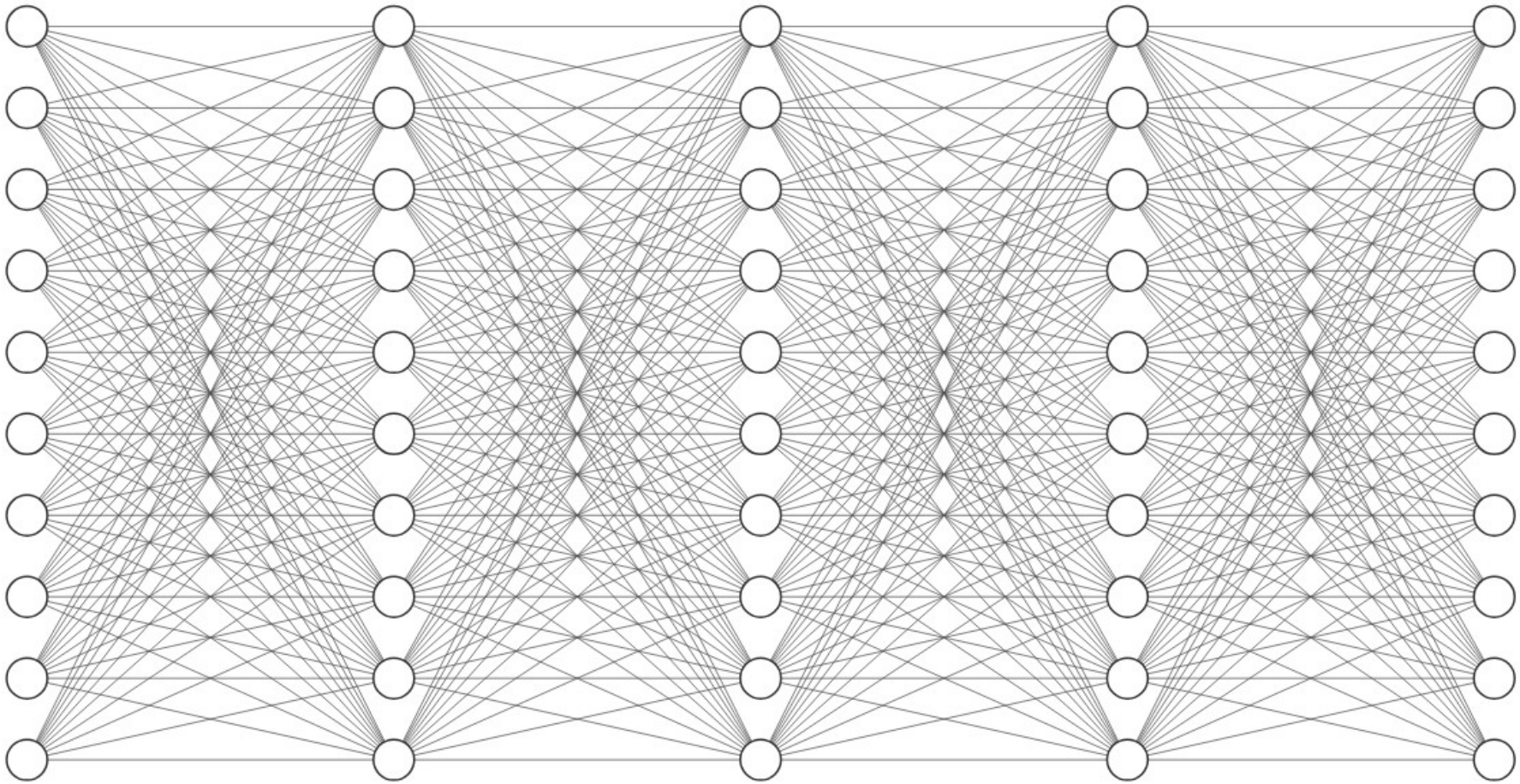
Classification Model



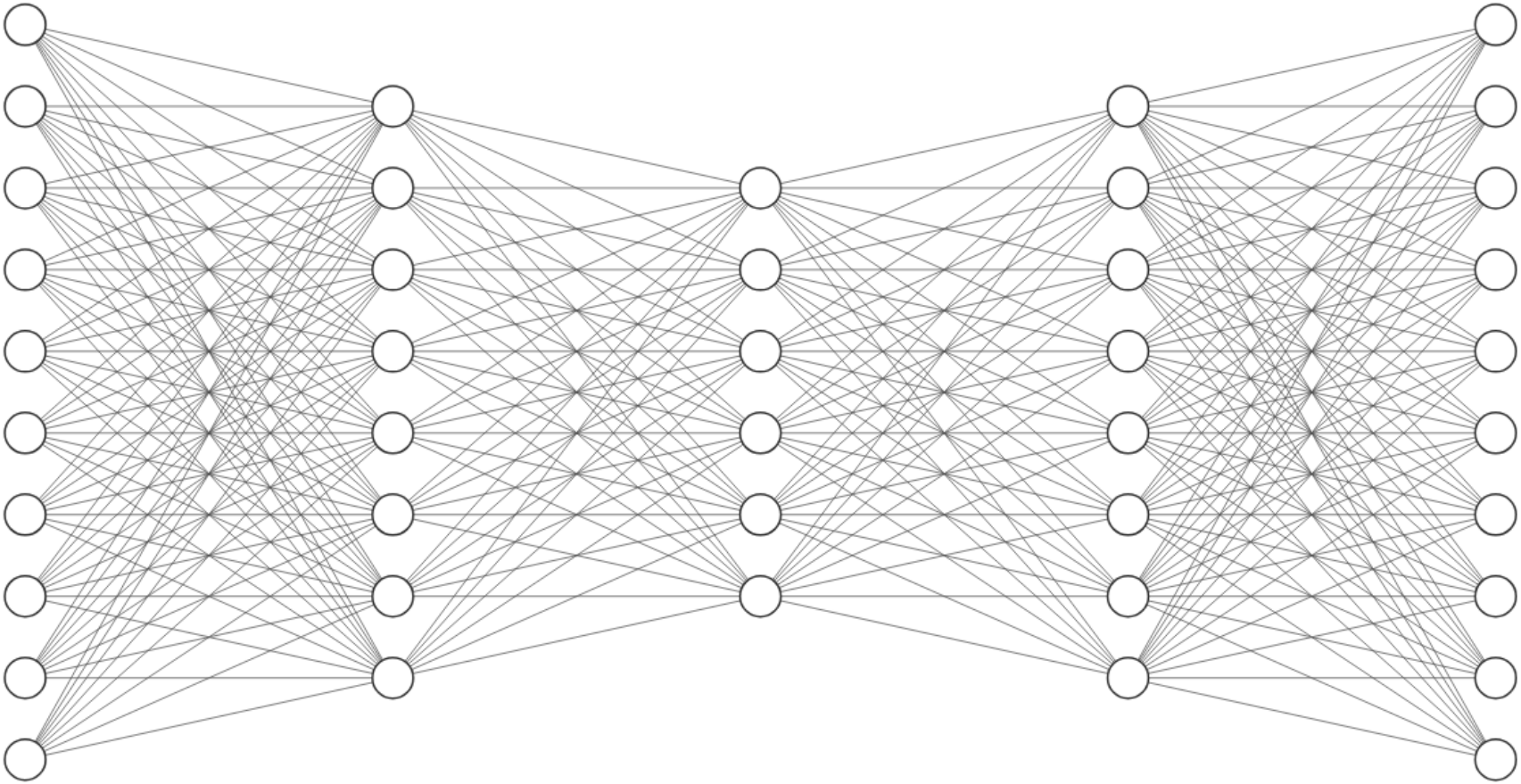
Generative Model



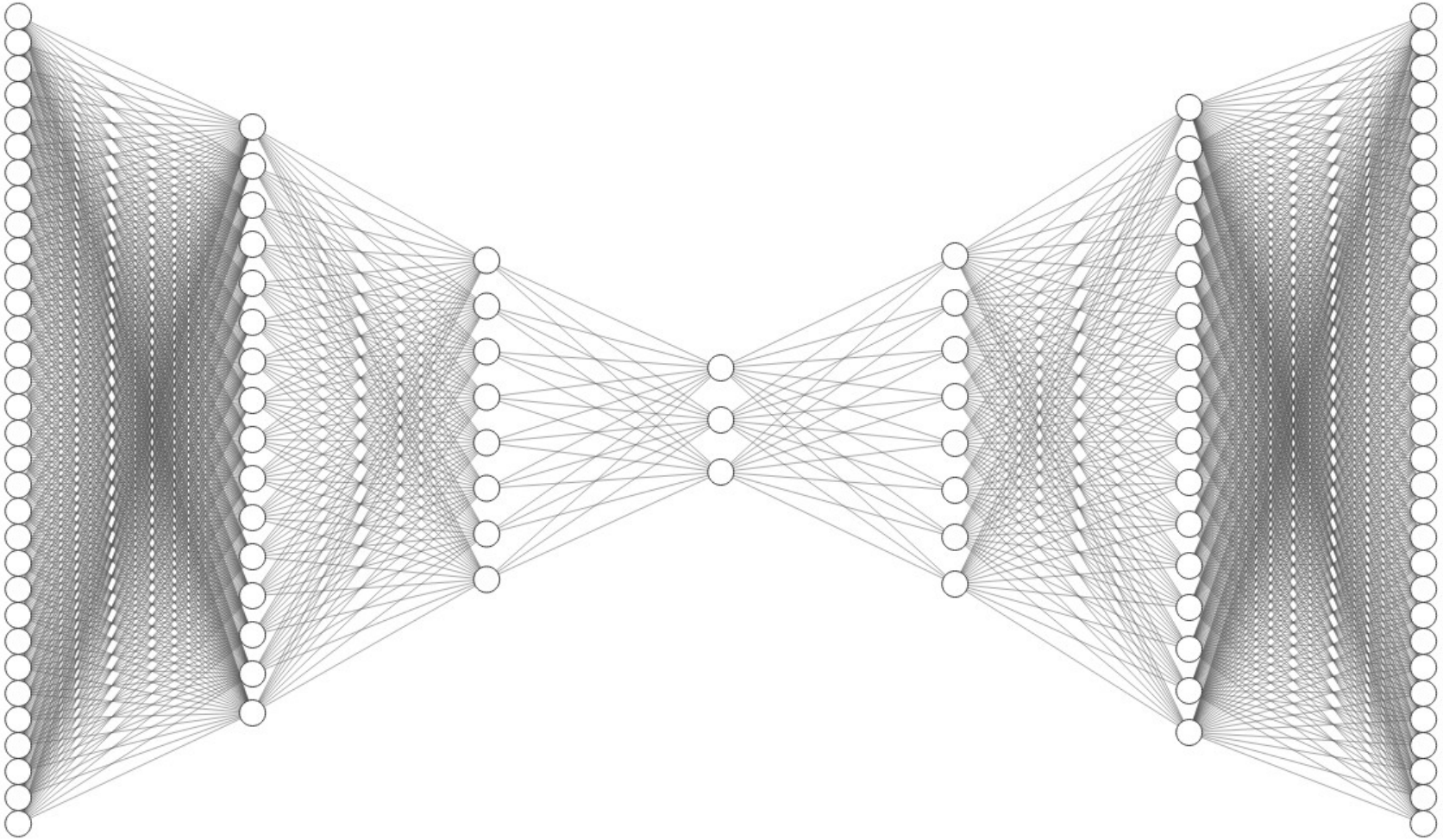
Autoencoder



Autoencoder



Autoencoder



Large Language Models (LLM)

- Generative machine learning model that can comprehend and generate human language text

How Does an LLM Work?

- Sentences are split up into smaller units called **tokens**
- **Embeddings** turn the tokens into vectors of numbers
- Embeddings enrich tokenized data with meaning, allowing LLMs to comprehend **context** and **patterns**
- They are numerical representations of contextual similarities between words, and can be manipulated mathematically (king - man + woman = queen)

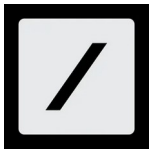
Key Concepts and Technologies

OpenAI ChatGPT

DeepSeek

Anthropic Claude

Google Gemini



xAI Grok

Key AI Concepts and Technologies

Types of AI

- Narrow AI vs. General AI
- Supervised vs. unsupervised learning

Tools and Frameworks

- Popular AI platforms (TensorFlow, PyTorch)
- Cloud-based AI services (OpenAI, AWS, Google, Microsoft)

Local LLMs

LLMs can be very large

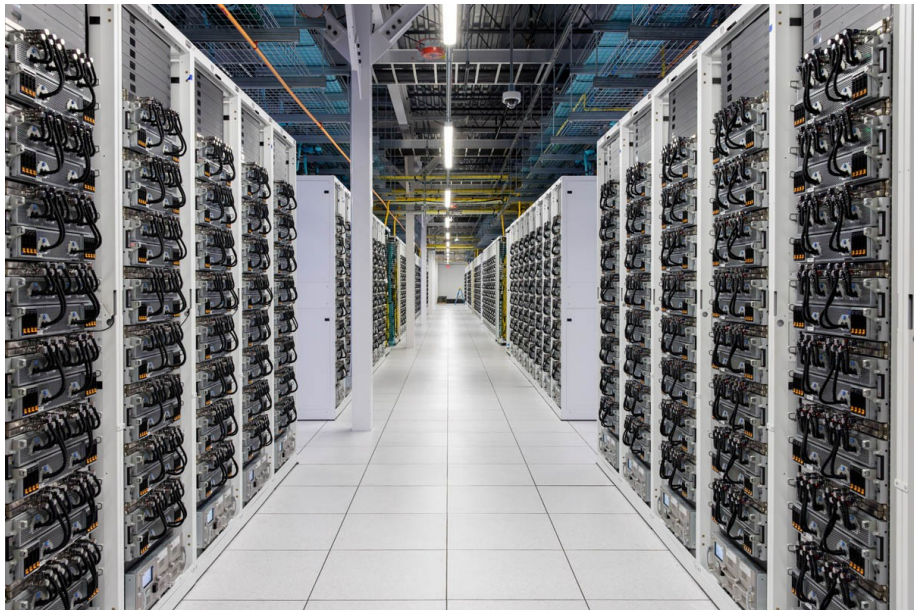
Smaller models are available that may be run on a desktop

Model size reduction through quantization

llama3.1:8b	4.7 GB
llama3.1:70b	39 GB
llama3.1:405b	228 GB

AI Requires a Lot of Compute. Right?

- xAI’s Colossus Cluster
- 100,000 Nvidia H100 GPUs
- Requires 150 MW of power
- Used to train Grok



El Capitan: Fastest Supercomputer

Lawrence Livermore National Laboratory in California

87 computer racks weighing 1.3 million pounds

2.79 quintillion calculations / sec.

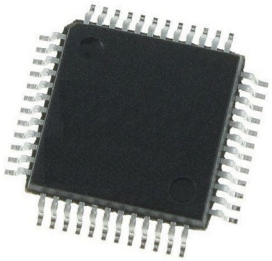
30 megawatts of power

$600 million

Runs Linux

Use is classified

How does embedded AI work?

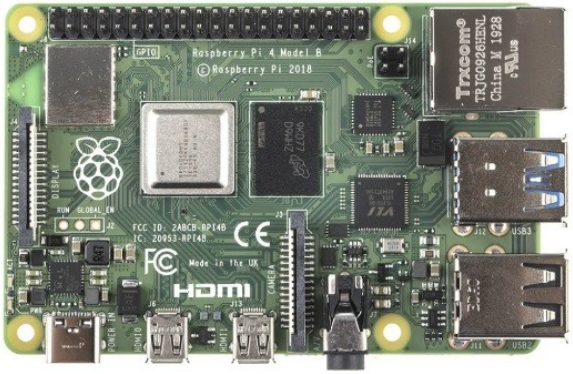


Reduce scope of problem trying to solve

Reduce model size and hence amount of training data

Use specific, highly efficient code
TensorFlow Lite, MS ELL, SynthInt NN

Run on a low power, embedded system

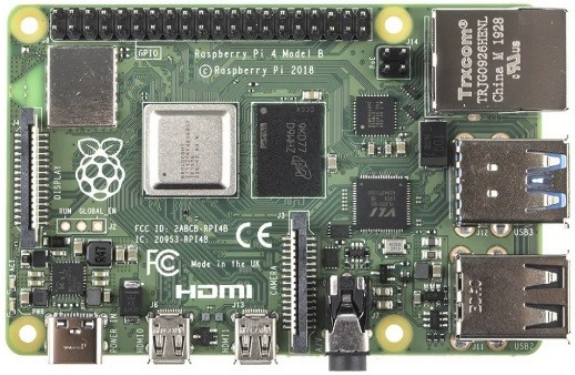


AI at the Edge

Reduced latency
Move computation as close to the data as possible

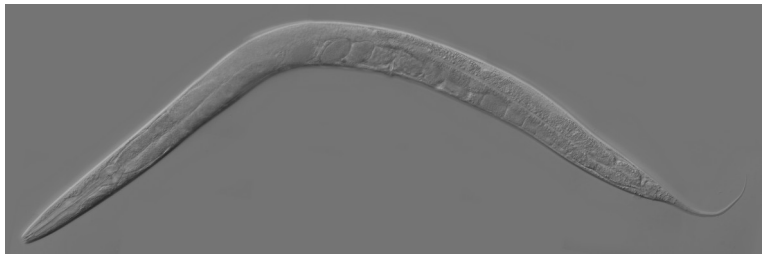
Minimize network bandwidth requirements
Ability to process this data offline

Enhance privacy
No need to upload data to the cloud



Neural Network Sizes

Sperm whale: 500 billion neurons
African elephant: 257 billion neurons
Human brain: 86 billion neurons
Fruit Fly: 135 thousand neurons
Roundworm: 302 neurons



State of the art ANNs:
2020: 16 million neurons
2023: 1.8 trillion neurons in GPT4
2025: 12 trillion neurons in GPT4.5

Typically, my ANN applications to date: < 200 neurons

Training vs. Inference

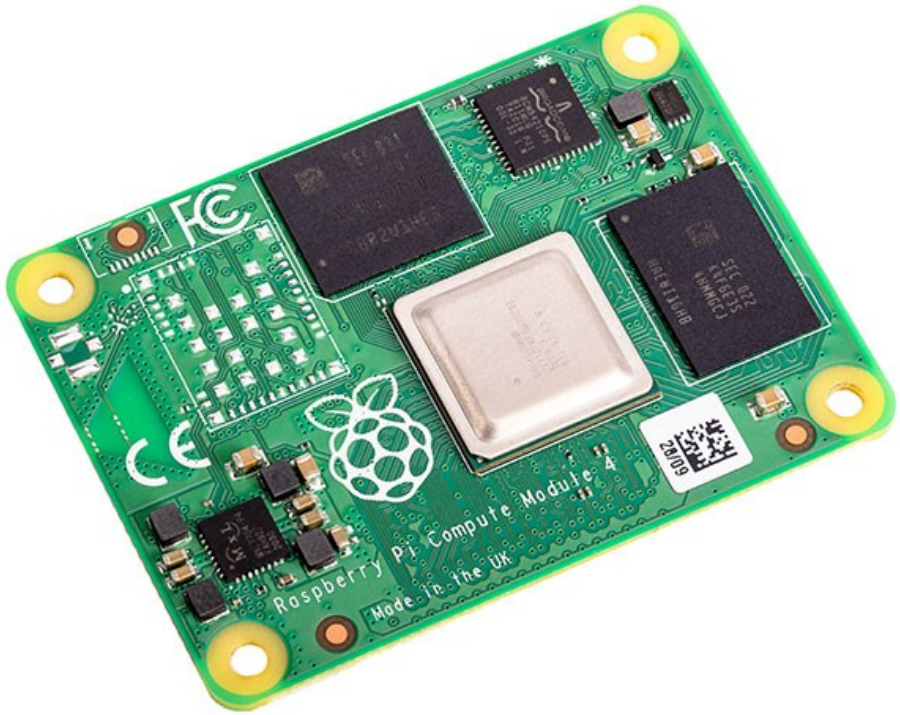
- Inference is much faster than training
- Example
  - May take about 20 minutes to train a 200 KB model (using a powerful desktop PC)
  - An MCU can inference this model in under 1 ms

Embedded Platforms: Jetson Nano

- Quad-core Cortex-A57 @ 1.43 GHz
- 128-core Nvidia Maxwell GPU
- 4 GB LPDDR4
- 16 GB eMMC
- LAN, USB, HDMI

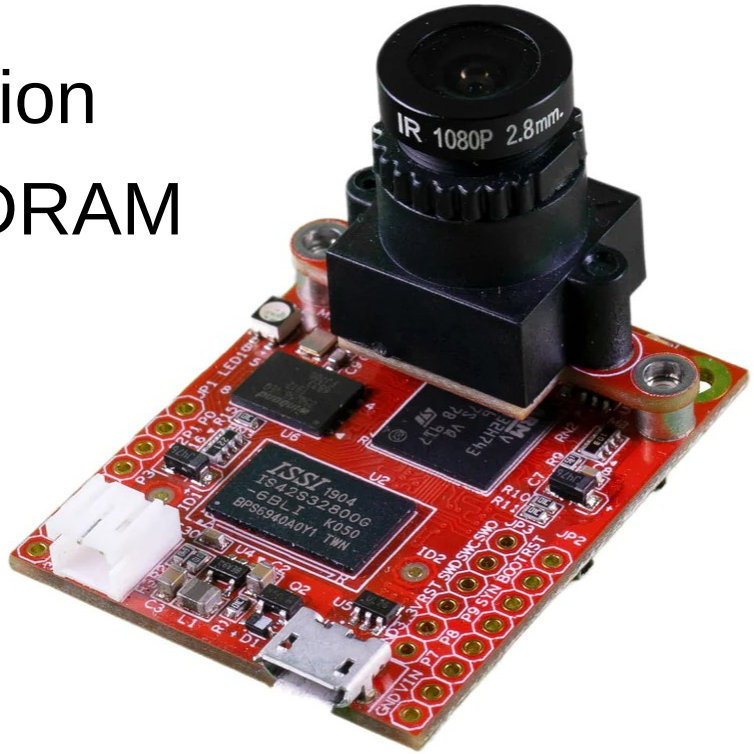
Embedded Platforms: Raspberry Pi CM4

- Quad-core Cortex-A72 @ 1.5 GHz
- 8 GB SDRAM
- 32 GB eMMC
- LAN, USB, HDMI



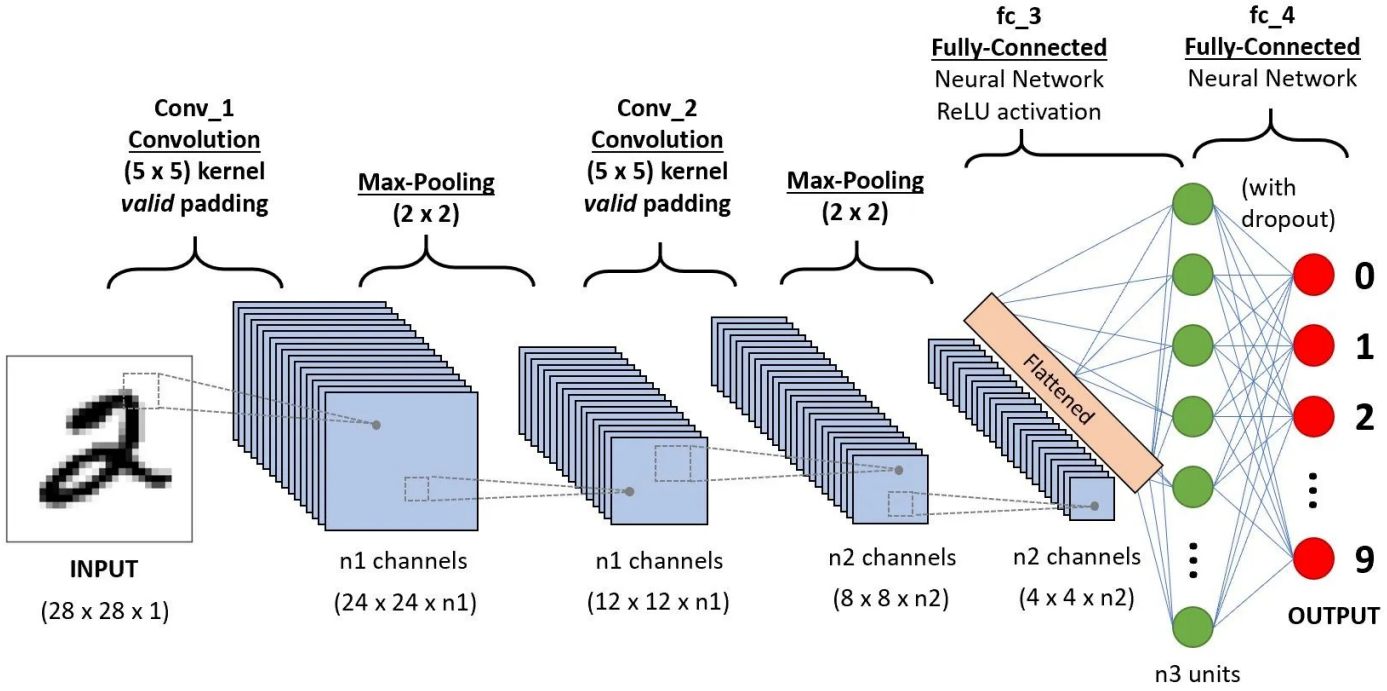
Embedded Platforms: OpenMV H7

- 480 MHz Cortex-M7 MCU
- 5 MP camera (2592 x 1944), IR option
- 2 MB flash, 1 MB SRAM, 32 MB SDRAM
- SD Card to store model and data

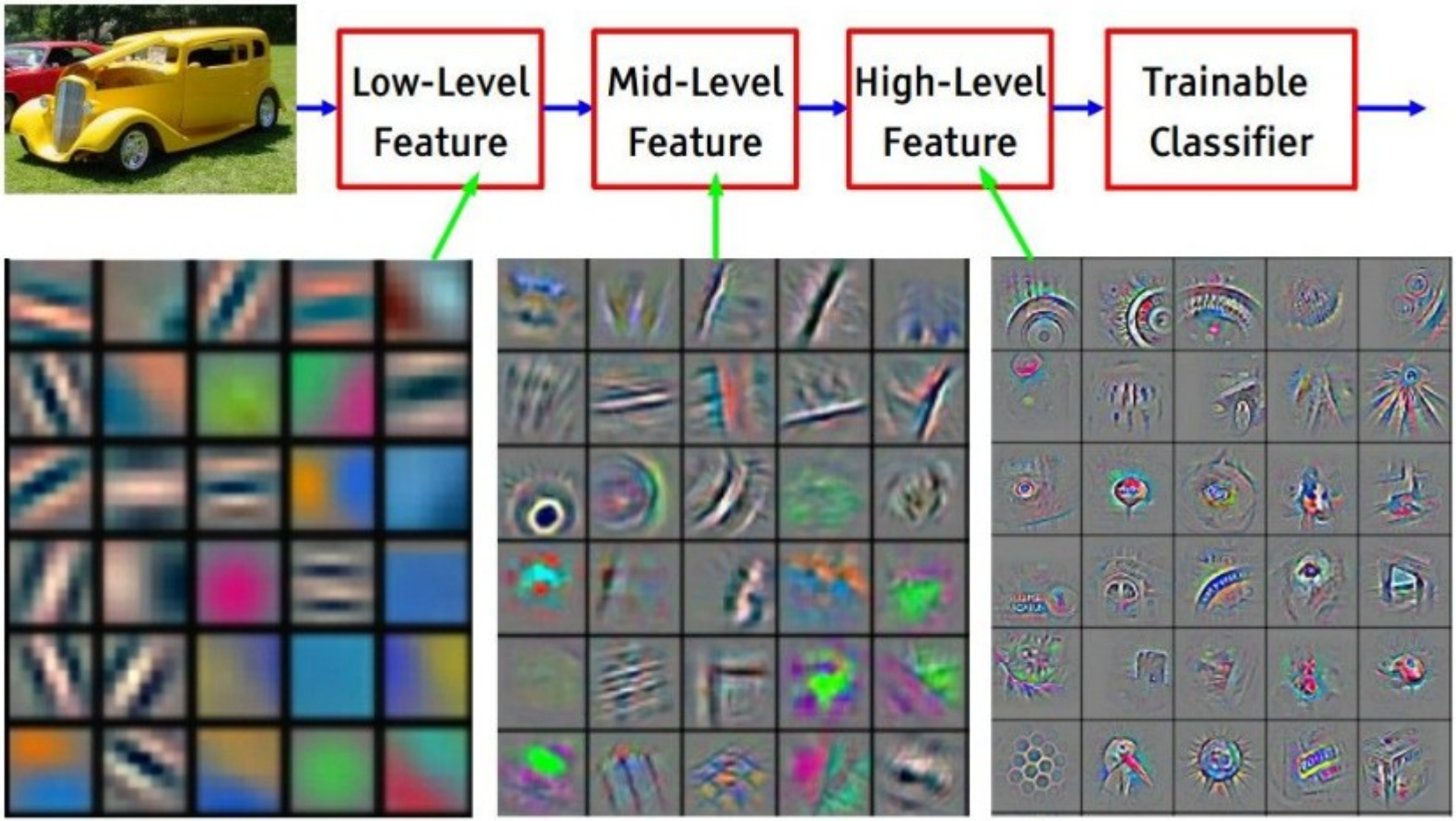


Object Detection Theory

Utilize a convolutional neural network (CNN) to classify objects within a field of view



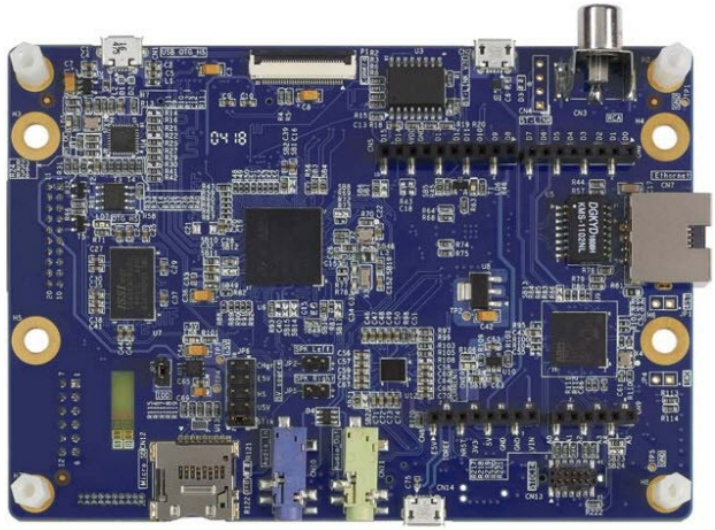
CNN Feature extraction



Embedded LLMs (SLMs)

- An LLM running in an STM32H7 MCU

  480 MHz Cortex-M7, 2 MB flash, 1 MB SRAM, 32 MB DRAM
- Dynamically generates a random TinyStory
- Output via serial port
- MCU consumes 75 mA to run the demo



Embedded LLM-generated story

```
One day, a boy named Tim went to the park with his mom. Tim was a very
popular boy, always happy and modest. His mom told him, "Tim, you must behave
when you play with your friends."While playing, Tim found a big box. He
opened the box and saw a pretty jewel. He picked it up and showed it to his
mom. "Look, mom! I found a pretty jewel!" he said. His mom smiled and said,
"Wow, Tim! That's amazing! You did a great job!"Then, Tim's friend Sue came
to the park. She saw the pretty jewel and asked, "Where did you get this?"
Tim showed her the pretty jewel. Sue was excited and said, "I found it! I am
so excited!" They played with the jewel all day, and Tim knew he did a great
job.

Once upon a time, there was a little boy named Timmy. Timmy loved to play
outside in the mud. One day, he got very dirty and needed to bathe. His mom
said, "Timmy, it's time to take a bath!" Timmy didn't want to stop playing,
but he knew he had to listen to his mom.After his bath, Timmy's mom gave him
a bottle of milk. Timmy drank the milk and smiled. He realized that he had a
good time playing in the mud. When he got out of the bath, he showed his mom
his clean milk and said, "I love you mommy!" His mom hugged him and said, "I
love you too, Timmy."
```

Applications of Embedded AI

Examples of how AI can enhance functionality:

- Predictive analytics
- Anomaly detection
- Natural Language Processing
- Computer Vision
- Robotic Process Automation
- Recommendation Engines
- Decision Support Systems
- Voice and Speech Recognition

Medical Device Locator

- Neural Network to interpret X,Y,Z location of a magnet
- Sensor readings: 4x4 array of 3-axis magnetometers
- ANN: 48/50(ReLU)/50(ReLU)/3(Linear)

```
-18.44,-14.87,50.15,-22.34,-18.93,
-18.53,-14.87,50.35,-22.52,-18.76,
-18.55,-14.94,50.1,-22.42,-18.71,3
-18.7,-15.02,50.13,-22.52,-18.54,3
-18.75,-15.22,50.15,-22.45,-18.73,
-18.72,-15.04,50.22,-22.57,-18.62,
-18.7,-14.89,50.21,-22.73,-18.69,3
-18.64,-14.96,50.12,-22.72,-18.76,
-18.7,-14.91,50.22,-22.65,-18.75,3
-18.67,-14.77,50.36,-22.68,-18.53,
-18.65,-14.88,50.37,-22.8,-18.36,3
-18.65,-14.81,50.27,-22.77,-18.14,
-18.7,-14.84,50.24,-22.82,-18.27,3
-18.64,-14.8,50.11,-22.68,-18.4,36
-18.61,-14.72,49.79,-22.66,-18.28,
-18.58,-14.84,49.93,-22.64,-18.31,
-18.58,-14.92,50.04,-22.56,-18.33,
-18.5,-14.88,49.75,-22.63,-18.23,3
-18.48,-14.91,49.61,-22.71,-18.54,
-18.56,-14.99,49.49,-22.68,-18.51,
-18.77,-15.02,49.59,-22.45,-18.5,3
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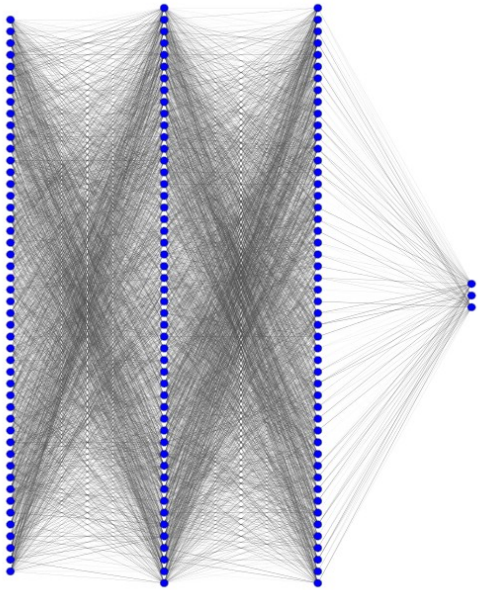
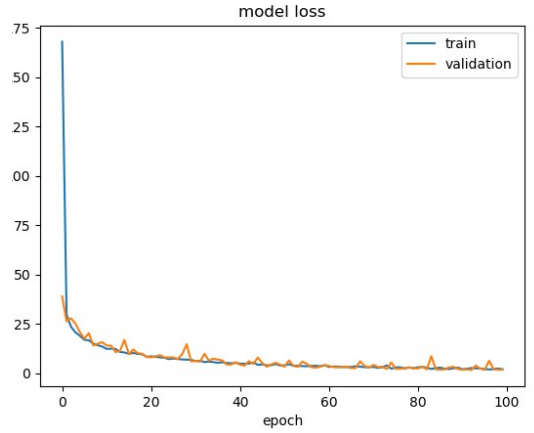
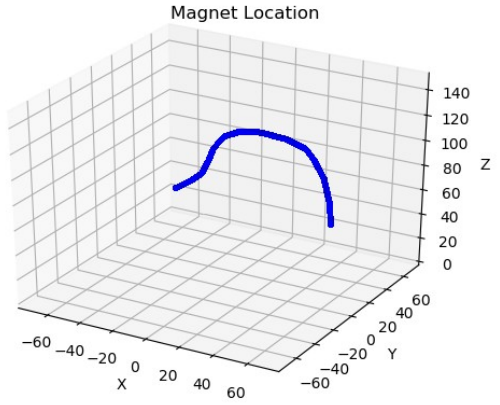
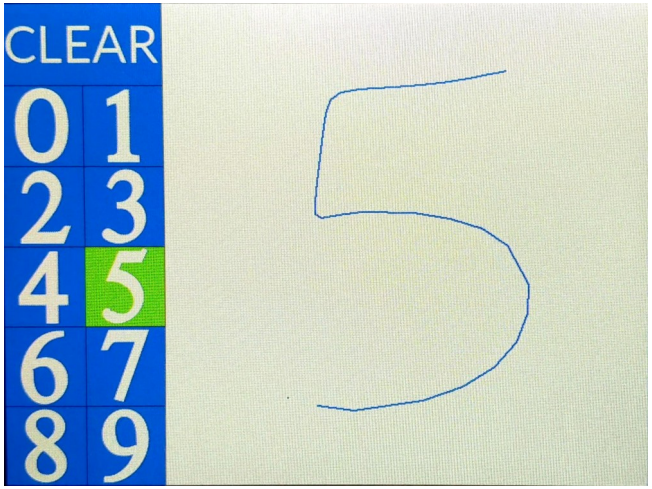


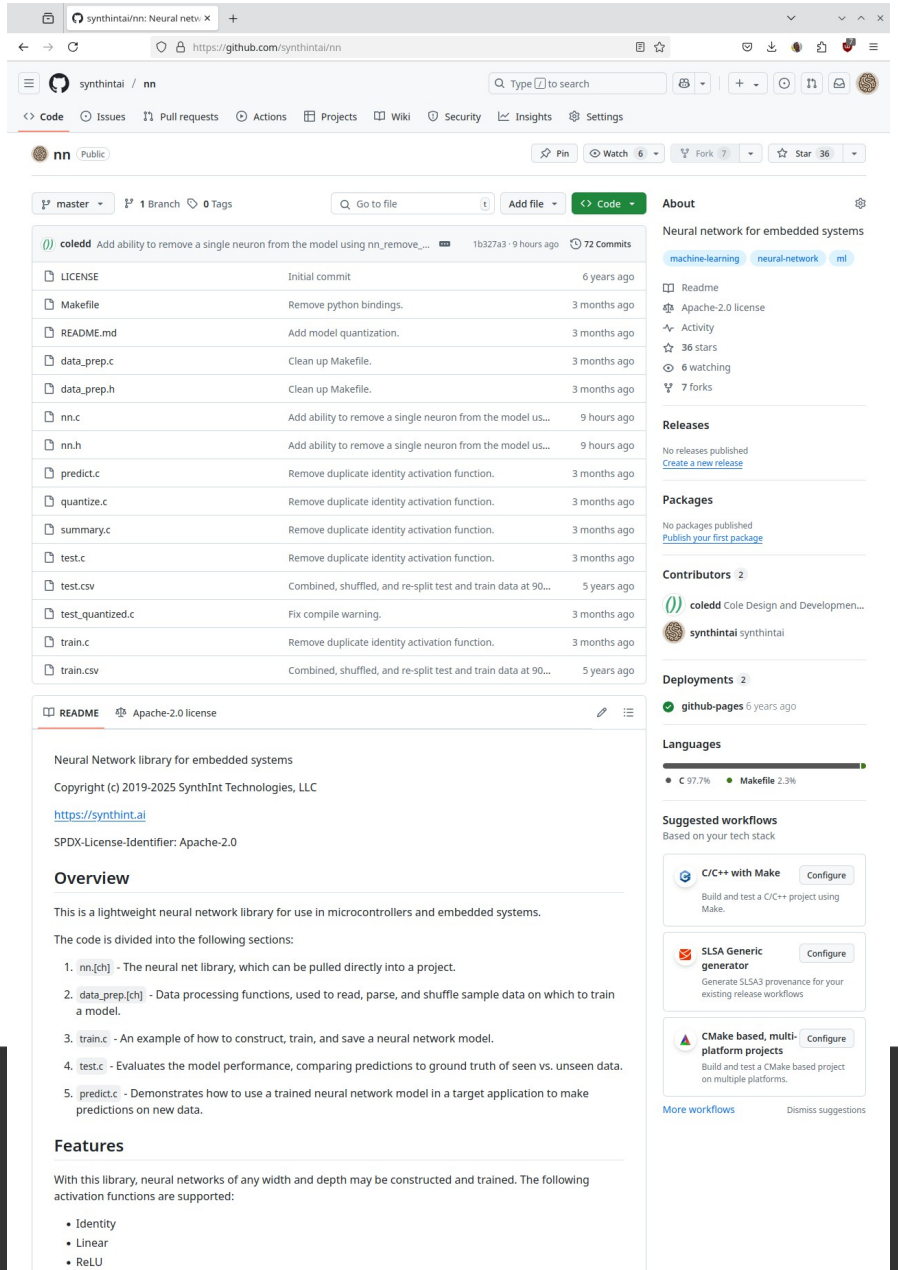




Handwritten character recognition

- ANN: 256/110(ReLU)/10(Sigmoid)
- Open sourced NN code at:
- https://github.com/synthintai/nn
- https://youtu.be/cqjwSkrGtww
- STM32H7 MCU



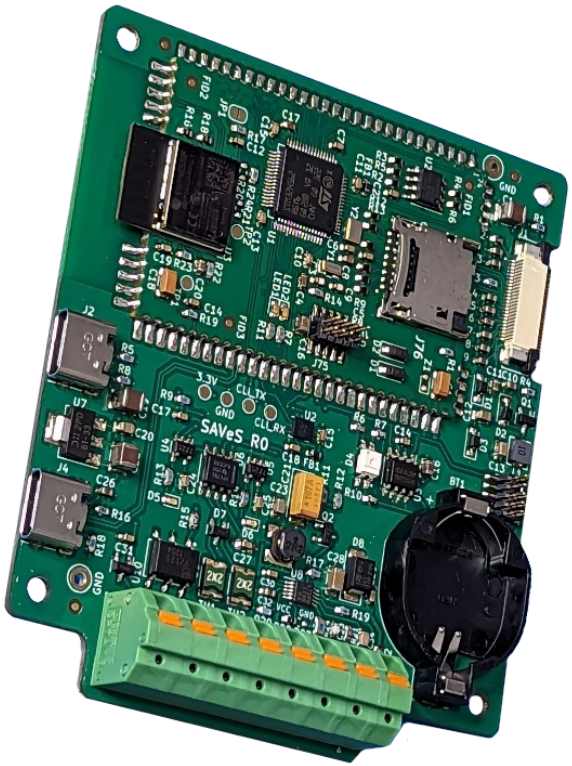


Vibration Monitor

Monitor engines and compressors for safe operation.

Predictive analytics using Machine Learning.

Circuit design, PCB layout, firmware, app.



Limitations of AI

- As models get smaller or overquantized, they lose quality
- “Hallucinations” generate incorrect output at high confidence
- Training bias
- Explainability

Ethical, Legal, and Social Considerations

Ethical Challenges in AI
- Bias and the importance of fairness
- Transparency and explainability in AI decision-making

Regulatory and Legal Perspectives
- Emerging laws and standards governing AI: TBD
- IP ownership of training data ans results

Data Privacy and Security
- Addressing privacy concerns with AI data usage
- Regulatory considerations impacting AI development and deployment

Social Impact
- How AI is reshaping society: How we work, learn, and interact

Deep Fakes and Synthetic Media

Impersonation: AI can generate realistic deepfake videos, images, and audio to impersonate individuals, including executives, family members, or public figures.

Fraud & Scams: These deepfakes can be used in scams like Business Email Compromise (BEC), romance scams, or extortion schemes, making it harder to verify authenticity.

Disinformation: Deepfakes can be used to create and spread false or misleading content, impacting public opinion or even influencing elections.

Enhanced Cyberattacks

Automated Phishing: AI can create highly personalized and convincing phishing emails at scale, increasing the likelihood of victims falling for scams.

Malware Evolution: AI can help malware adapt to evade detection, making it more difficult for cybersecurity systems to identify and block threats.

Vulnerability Exploitation: AI can scan for vulnerabilities in systems more efficiently, accelerating the reconnaissance phase of cyberattacks.

Ransomware Attacks: AI can be used to identify and encrypt critical data, maximizing the impact of ransomware attacks and potentially increasing ransom payments.

Fraud and Financial Crime

Synthetic Identity Generation: AI can be used to generate fake identities for financial fraud, including opening fraudulent bank accounts or applying for credit.

Money Laundering: AI could automate aspects of money laundering, making it faster and more difficult to trace illicit funds.

Market Manipulation: AI could be used to analyze market data and potentially execute trades for market manipulation schemes.

Social Engineering Attacks

Personalized Scams: AI enables the creation of highly targeted social engineering attacks by leveraging information gathered from social media and other sources.

Automated Impersonation: AI-powered chatbots can be used to impersonate customer support or service agents, extracting sensitive information from unsuspecting individuals.

Production of Illegal Content

AI-Generated CSAM: AI can generate realistic child sexual abuse material (CSAM), posing a serious threat to children and increasing the challenges of detection and law enforcement.

Facilitating Illegal Activities: AI could be used to generate content promoting illegal activities, such as drug trafficking or terrorism.

Emerging Trends in Law Enforcement

Cutting-edge developments in AI:

Crime prediction tools
Deepfake detection
Facial recognition
Geolocate photos
License plate readers
Analyze phone calls
Tattoo identification
Object detection
Digital evidence analysis
Automated report writing
Speech recognition and translation
Automated metadata tagging
Crime scene analysis
Gunshot detection
AI-driven drones

Interactive Q&A and Discussion

Open Floor for questions and discussion

- Ask questions and share your thoughts on AI
- Examples from the audience’s own experiences with AI
- Brainstorm other ways AI could assist law enforcement

Thank You!

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