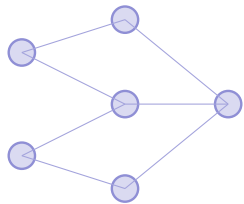
Artificial Intelligence

A-Level Computer Science ▪ Topic 18

A-Level Computer Science



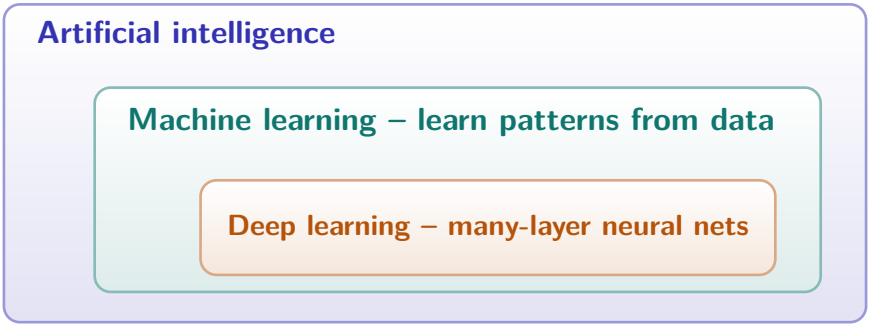
What we will cover

1. What AI is
2. Graphs in AI
3. Neural networks
4. ML, DL, RL, regression
5. Recap

1 What AI is

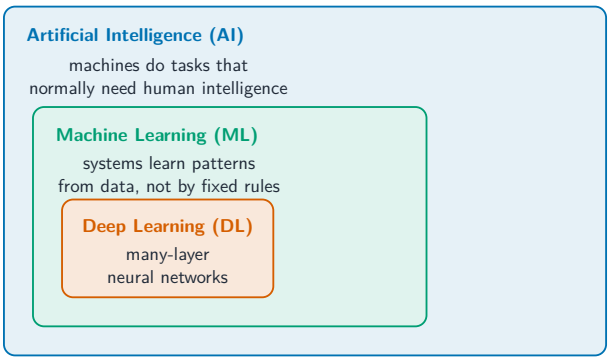
Three nested ideas

Artificial intelligence 人工智能 builds systems that do tasks normally needing human intelligence – speech, images, translation, games, driving, generating text.



AI, machine learning, deep learning

Each is a subset of the one before – deep learning is one way of doing machine learning, which is one way of doing AI.



2 Graphs

Many AI problems sit on a graph

Nodes 节点 are states or places; **edges** 边 are moves or relationships.

pathfinding

roads; shortest route – Dijkstra, A*

game playing

board positions; **mini-max** 极小化极大 with alpha-beta

state space

apply operators until you reach a goal

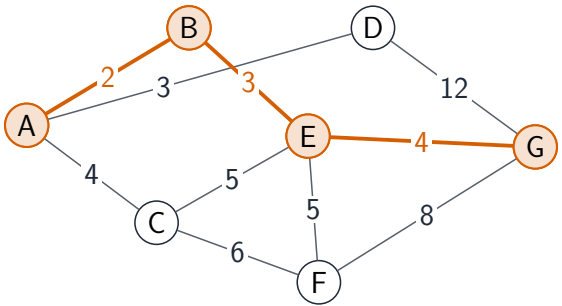
knowledge

a **semantic network** 语义网络: dog IS-A animal

Standard tools: **BFS** 广度优先搜索 and **DFS** 深度优先搜索.

Shortest path on a graph

Weights are costs; Dijkstra keeps the cheapest known route to each node and improves it.



shortest path A → G (length 9)

Searching a graph, and when to reach for ML

breadth-first search 广度优先搜索	explores level by level – finds the fewest-edge path first
depth-first search 深度优先搜索	follows one branch to the end before backtracking – less memory, no shortest guarantee
Dijkstra's algorithm	the shortest path when edges carry weights
A*	Dijkstra plus a heuristic estimate of the remaining distance, so it explores fewer nodes
machine learning	the umbrella term: any algorithm that learns from data rather than following written rules
when to use it	where explicit rules would be impractical – spam filters, recommendations, fraud detection

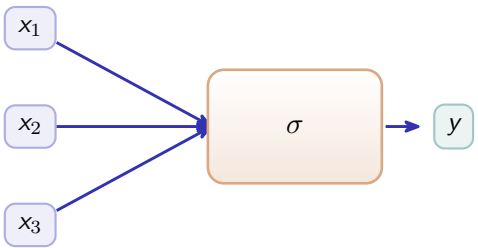
Three paradigms: supervised (labelled examples), unsupervised (structure found in unlabelled data), reinforcement (learning from reward).

3 Neural networks

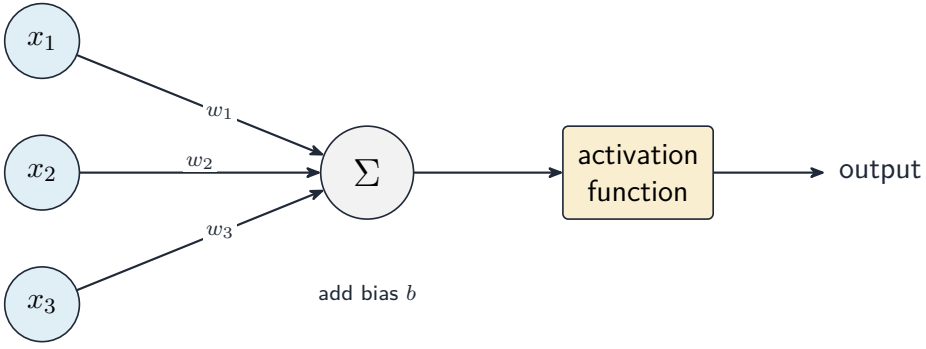
One artificial neuron

An **artificial neuron** 人工神经元:

1. multiply each input by a **weight** 权重
2. add them up with a **bias** 偏置项
3. apply an **activation function** 激活函数 (e.g. ReLU)
4. the output feeds the next layer



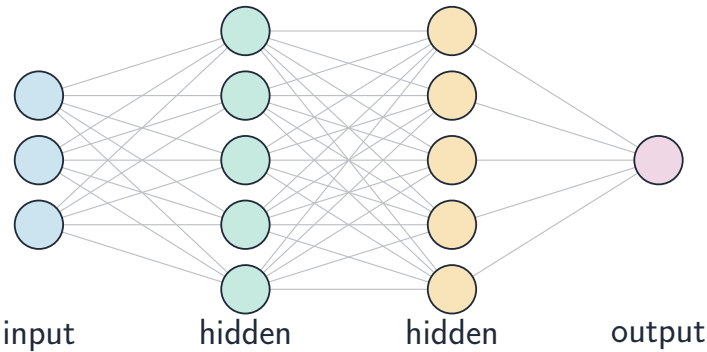
A single neuron



A single neuron: each input times its weight, summed with a bias, then an activation function

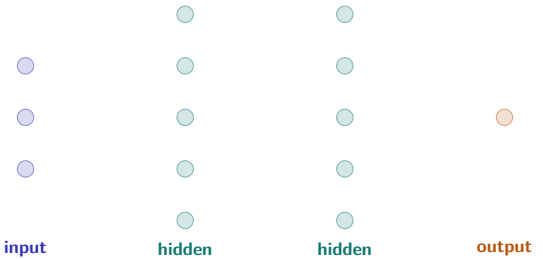
A layered network

Inputs feed hidden layers feed outputs; “deep” just means more than one hidden layer.



Layers: input, hidden, output

Neurons sit in layers. With many **hidden layers** 隐藏层 it is a **deep neural network** 深度神经网络.



ANNs learn patterns straight from raw data – pixels, audio, text – without hand-designed features.

Three kinds of learning

supervised

监督学习

data has **labels** 标签. Learns input → label. Classification or regression.

unsupervised

无监督学习

no labels. Finds structure – e.g. a **cluster** 聚类 of similar customers.

reinforcement

强化学习

an **agent** 智能体 acts, gets a **reward** 奖励, learns a **policy** 策略 by trial and error.

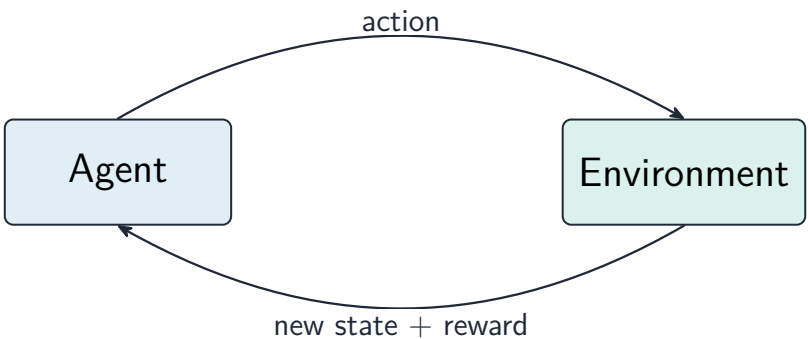
How a model learns, and where it is used

Supervised learning	**Supervised learning** 监督学习: labelled examples, so the error against the known answer drives the training.
Unsupervised learning	**Unsupervised learning** 无监督学习: no labels – the model finds clusters and structure by itself.
The bias term	Each neuron computes $\sum w_i x_i + b$: the weights scale the inputs, and the **bias term** 偏置项 shifts the threshold at which it fires.
Where it shows up	**Speech recognition** 语音识别 and **text-to-speech** 语音合成 are the two directions of the same problem; a **knowledge graph** 知识图谱 stores facts as entities and relations for a system to reason over.

Ask what the training signal is. Labels, no labels, or a reward – that single question separates the three kinds.

Reinforcement learning

The agent acts, the environment returns a state and a reward, and the policy is updated to earn more reward.



Industrial robot arms on a production line

Industrial robot arms on a production line: reinforcement learning can teach a robot to control its movements

Deep learning vs reinforcement learning

Deep learning is ML with deep nets. Lower layers learn edges and phonemes; higher layers combine them. Needs lots of data and lots of compute (GPUs). For small datasets, simpler ML often wins.

Reinforcement learning: the agent sends an action; the environment returns a new state and a reward. Used for games, robot control, driving – sequential decisions, no labels up front.

Where it ends up

Perception, planning and control – each a learned model, all running together.

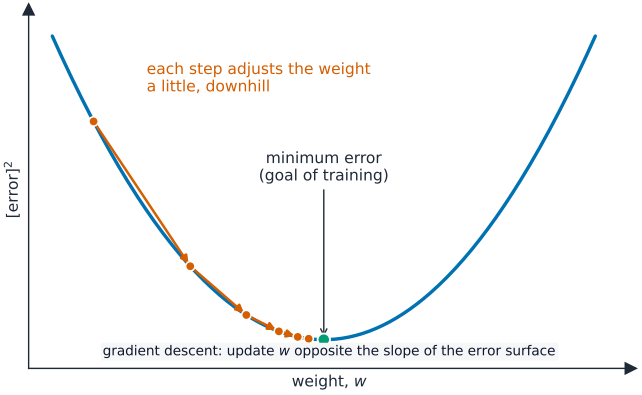
Training: backpropagation

Training adjusts the weights so outputs match the targets – **backpropagation** 反向传播 with **gradient descent** 梯度下降.

1. forward pass – input through to the output
2. compute the error with a **loss function** 损失函数
3. backward pass – each weight's gradient, via the chain rule
4. update the weights by a small **learning rate** 学习率

> Repeat over many examples and many **epochs** 训练轮次. After training, a new input needs only one forward pass.

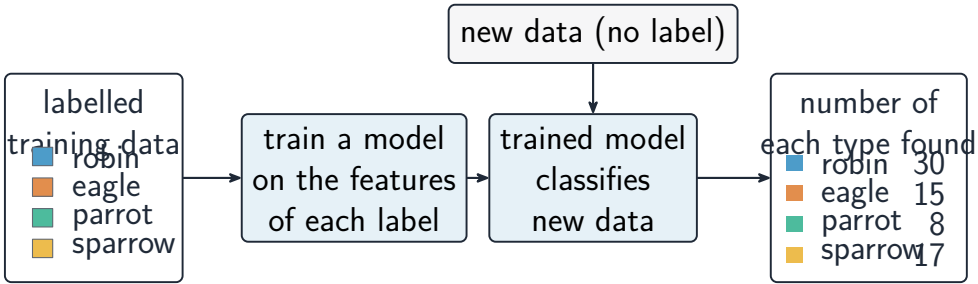
Training an ANN: backpropagation



Training adjusts the weights to reach the minimum error

The training loop

Forward pass, compare with the label, propagate the error back, adjust the weights – repeated over the whole training set.



Regression predicts a number

Regression 回归 predicts a number (a house price, tomorrow's temperature).
Classification 分类 predicts a category.
Linear regression 线性回归 fits a line that minimises the sum of squared errors:

$$y = m_1 x_1 + \cdots + m_n x_n + c$$

Temperature or spam?

(a) tomorrow's temperature – a number ⇒ **regression**, one output neuron.

(b) spam or not – a category ⇒ **classification**, one probability per class.

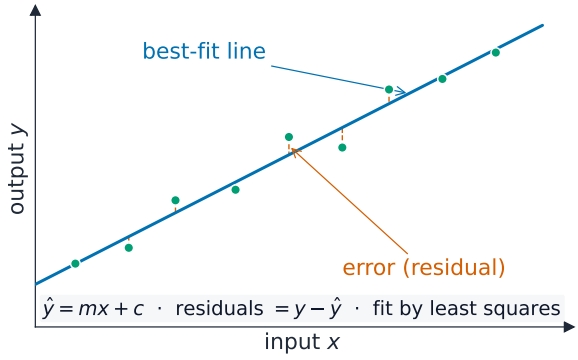
Both are supervised.

Reinforcement learning, and regression

reinforcement learning	an agent acts, receives a reward or penalty, and adjusts to maximise reward over time
a real example	a **self-driving car** 自动驾驶汽车: **lidar** 激光雷达 and camera sensors feed the model, which learns which actions are rewarded
the difference	no labelled right answer is supplied – only a signal about how well the action turned out
regression	predicts a number rather than a class
fitting it	choose the coefficients to minimise the sum of squared errors against the training data
when to use it	where the relationship looks roughly linear and you need a quantity, not a label

Classification answers *which*; regression answers *how much*. Choosing the wrong one is a modelling error no amount of data will fix.

Regression



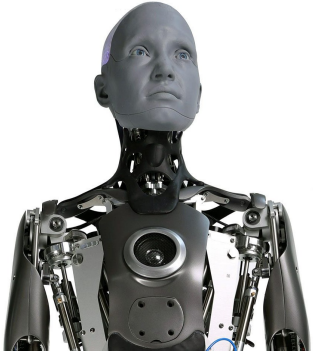
Linear regression fits the line that makes the total squared error (the dashed gaps) as small as possible

How AI is used in a real scenario

Many exam scenarios use the same pattern – a **deep-learning model trained on labelled data**, often several combined into a pipeline:

- **customer identification** at an automated shop: the system is trained on labelled face images; a camera captures a face; image recognition extracts a representation.
- **reading text from images**: image recognition finds text regions; **optical character recognition 光学字符识别** extracts the characters; machine translation converts them.
- **checkout item-detection**: object-detection AI, trained on labelled product images, sees which items go into a basket and charges the account.

A humanoid robot uses AI to see



Every one of those is a separate trained model – vision, speech, planning – stitched together. Nothing here understands the room the way a person does.

Exam tips

- Distinguish **machine learning, deep learning and reinforcement learning** with an example of each.
- Describe an **ANN** (input, hidden and output layers; weighted connections) and how **backpropagation** adjusts weights to cut error.
- Distinguish **supervised vs unsupervised** learning; regression predicts a continuous value.

4 Recap

Topic 18 – key takeaways

1 Nesting

DL $\subset$ ML $\subset$ AI

2 Neuron

weighted sum + bias + activation

3 Learning

supervised, unsupervised, reinforcement

4 Train

backprop adjusts weights to cut the loss

Check yourself

1. Is deep learning a kind of machine learning, or the other way round?
2. What does an activation function do?
3. An agent learns from reward, with no labels – which paradigm?
4. Predicting a house price: regression or classification?

Answers **1.** DL is a kind of ML **2.** adds non-linearity after the weighted sum **3.** reinforcement learning **4.** regression