Exam Topics (Dec. 11, 2024)

2024. december 15., vasárnap 13:25

- [x] 1. Tests for AGI
- [x] 2. Techniques for generative AI
- [x] 3. Text to Image models
- [x] 4. The computational model for Foraging Ants and the details of it's workings
- [x] 5. The Schelling model and it's working on examples
- [x] 6. Basic ethical frameworks for technology
- [x] 7. Different approaches to machine learning (i.e.: supervised, unsupervised, reinforced learning) and their premises, data requirements and limitations
- [x] 8. The basic concept of supervised learning
- [x] 9. Supervised learning by decision trees
- [x] 10. The basic concept of unsupervised learning
- [x] 11. The working mechanism of k-means algorithm
- [x] 12. The mechanism of reinforced learning
- [x] 13. The Q-learning method
- [x] 14. Deep-Learning methods, value learning and policy learning
- [x] 15. The policy gradient algorithm
- [x] 16. The basic concept of evolutionary algorithms
- [x] 17. Optimization by genetic algorithm
- [x] 18. The basic concept of genetic programming, differences compared to genetic algorithms
- [x] 19. The basic concept of swarm intelligence
- [x] 20. Optimization by Particle Swarm Optimization
- [x] 21. More recent swarm intelligence techniques, the firefly algorithm
- [x] 22. The basics of neural networks
- [x] 23. Perception, perception training
- [x] 24. The basic concept of CRISP-DM

1. Tests for Artificial General Intelligence

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Artifical General Intelligence: AGI	↔	Narrow AI
• Can match human performance • Good for any intellectual task		• Can match human performance • In a narrow, specific domain

Tests:::

- **Turing Test:**
    - Both a machine and a human converse with an another, unseen human
    - The evaluator outrules the one it thinks is the machine
    - Test is passed when the evaluator is fooled a significant fraction of time
- **Robot College Student Test (Goertzel):**
    - A machine takes and passes the same classes that humans would
    - It gets a degree
    - Some LLMs (Large Language Model) can pass degree-level exams without even attending a single class
- **Employment Test (Nilsson):**
    - A machine performs an economically important job atleast as well as humans would
- **Ikea Test (Marcus):**
    - Aka Flat Pack Furniture Test
    - An AI studies the parts and instructions of a product, then controls a machine to assemble it correctly
- **Coffee Test (Wozniak):**
    - A machine enters a regular home, and figures out how to make coffee
    - Find machine, coffee, add water/milk etc.
    - Not yet comleted

2. Techniques for generative AI

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Generative Adversarial Network (GAN):

- First widely used generative solution

Bandit-Cop game:

- In every iteration, both learn / optimise their output
- After a few rounds, the bandit's output is a new creation

3. Text to Image models

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Text to Image models:

- They take in human text input / prompts, and they create an image that represents said input's content
- There are many widely used models nowadays: Dall-E, Stable-Diffusion, Midjourney

4. The CM for Foraging Ants and the details of its workings

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Shortest path problem (Observation):

- Ants pick the closest food source first
- Between the nest and said source a *direct line is the shortest path*
- For navigation, they lay 2 types of *pheromones*:
  - The first is when they are searching for food (A)
  - The second is when they are carrying the food back to the nest (B)
- They follow these pheromones *stochastically*:
  - When heading out for food: (B)
  - When bringing food back: (A)
- These pheromone-trails *fade* after some time
- *Time and effort* to reinforce is proportional to the *length*

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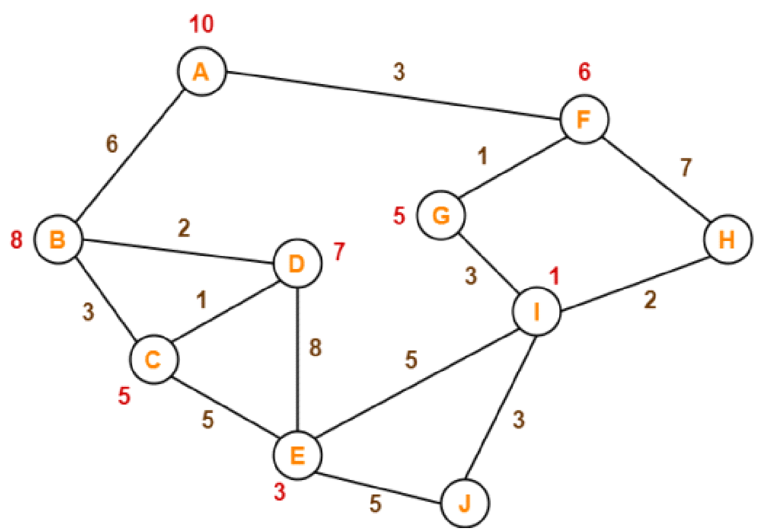
Application:

- Many types, starting from the generic "shortest path" problem
  - Routing, scheduling, "Travelling Salesman" etc.
- Ant Colony Optimisation (ACO):
  - Graph, instead of 2D grid (pheromone accumulates on edges)
  - Random starting node
    - Next is selected probabilistically
  - Stopping when most ants select the same route

Shortest path problem (Model):

- Ants wander around on a *2D grid* starting from the **nest**
- They avoid obstacles
- They **follow pheromones** if possible (*probabilistically*)
- **Pick up food** if not carrying
- **Place food** if at nest + if carrying
- Meanwhile they constantly **lay pheromones**
- Pheromone **evaporates at a constant rate of time**



5. The Schelling model, and it's workings on examples

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A model of housing segregation (Thomas Schelling, 1978):

- 2D environment
- Two types of household: **Oranges** and **Blues**
- Each has a tolerance level (TL, max % of different households next to them, ignore empty)
  - If segregation lvl. < avg. Tolerance lvl.: random population configuration
  - If segregation lvl. ≥ avg. Tolerance lvl.: segregated population
- If below the TL, the household moves to an empty location
- Variants:
  - Move to random empty,
  - Move to closest empty,
  - Move if happy there, etc

What does the simulation show?

- Groups of same-coloured households emerge
- This grouping would happen "naturally" over time
- Even with an avarage TL of 70%

6. The basic ethical frameworks for technology

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Ethics in technology and AI fields, now probably more than ever, is a very hot topic. More and more people fear that AI is going to - or at least is going to try - to **take their jobs**, which certainly can be a real threat, but it is not that simple. For example, many people view **AI as a tool** to enhance our abilities, to **help with simple, repetative tasks**. Moreover there are **fields** whose goal is to **bridge that gap** between humans and AI, for example Ethorobotics.

Ethorobotics:

- Give the technology a body to connect more easily with humans
- Integrate robots into everyday life
- Process:
    - Study the behaviour of animals (deep learning)
    - Design a robot thats able to perform the taskss
    - Implement the learned patterns into robots
- Be aware: uncanny valley

7/8/10. Different approaches to Machine Learning

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Supervised learning:

- The input is **labeled data**
- The objective: **generalize knowledge** to be able to label new, unlabeled data

- *Learn a function that maps inputs to outputs*

- Performance is measured on training sets and test sets
- Generalization:
  - Generalizes well if accuratly performs on test set
- Bias-Variance tradeoff:
  - Bias: tendency to deviate from expected value on training sets
  - Variance: change in hypothesis due to fluctuation in training data

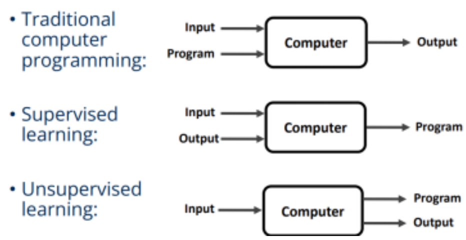
Low-bias	Low-Variance
• More complex • Fits training data more	• Simpler • Generalize better

- **Underfitting**: fail to find a pattern (too simple model)
- **Overfitting**: fits too much to the particular training set, performes poorly on unseen data

Unsupervised learning:

- The input is **unlabeled data** en masse
- The objective: **learn the hidden structure** of data, in order to later categorize it (broadly)

- *Learn patterns in data without explicit feedback*

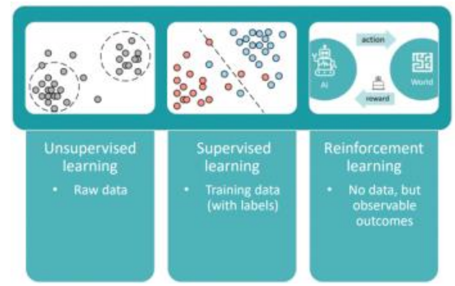


- Clustering:
  - Cluster: group of data very similar/close to eachother
  - Usage: reducing number of data, labels not always known
  - Market/Data analysis
- Different types of clustering:
  - Agglomerative, SAHN, k-means etc.

Reinforcement learning:

- **No prior knowledge** of system
- Gathers **feedback** to learn and maximize an objective
- The agent (it) can move/execute different actions, and it gets feedback for those actions
- At first it has to gather insights, and later it must exploit the learned knowledge to adjust its behaviour in order to achieve its goal faster, more precisely etc.

- *Learn beneficial actions based on rewards / punishments*



9. Supervised Learning with Decision tees

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What is a decision tree?

- Maps a **vector of values** to a **single output** ("decision")
- Starts from **Root Node**
- Explores **branches** based on the input
- Eventually reaches a **Leaf Node**
    - (*Node: test of input value*)

- *Find the most important feature, then solve sub-problems sequentially*

Generalization:

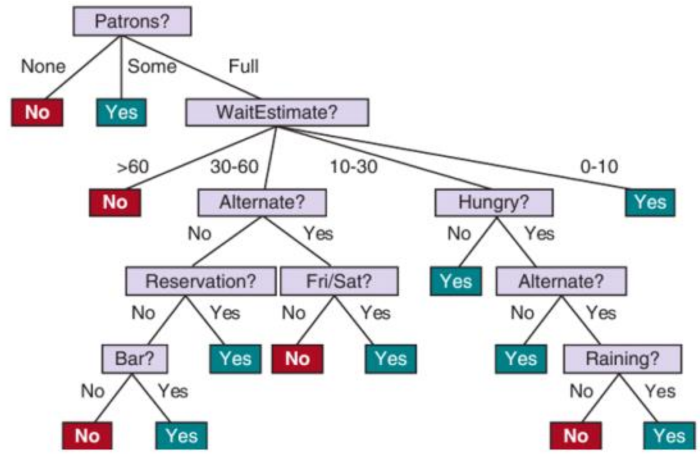
- More attributes => overfitting is more likely
- More training sets => overfitting is less likely

Pruning:

- Eliminate **not-relevant** nodes
    - Take a node that has **only Leafs as childre**n
    - If the test is irrelevant: **replace itself** with a Leaf
    - (*Use **significance tests** to determine if irrelevant*)

Pros	Cons
Easy to understand Scalable Perform classification and regression	If the tree is **deep**, getting a prediction can be **expensive** Unstable *(adding a node can change the whole tree)*

Example: Waiting in restaurant



11. k-means algorithms

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What is k-means?

- Iterative process for clustering
- It's **input**:
  - $\{x_1, \ldots, x_n\} \subseteq R^p$ data set
  - K, the predefined number of clusters
  - t_{max} is the maximum number of iterations
  - $\|.\|_v$ (v-norm) is a distance measure
  - ε tolerance
- The **output**:
  - The partition matrix (U)
  - The cluster centers (V)

The process:

- At the start, we **initialize the clusters** and **centers** randomly
- We assign every point to a cluster based on the **nearest center** point
- **Recalculate** the centerpoints, move **K to the mean** of the cluster
- Repeat until **no more points** can change their membership

Pros	Cons
• Easy to implement • Relatively efficient	• Unable to handle noisy data and outliers • Often only finds the local minimum

```
for t in [0, t_max]:
    # Determine the partition matrix U[t]
    #   according to the previous iteration's cluster centers V[t-1]
    U[t] = Determine_Partition_Matrix(V[t - 1])

    # Determine the cluster centers
    #   now according to the new partition matrix
    V[t] = Determine_Cluster_Centroids(U[t])

    # If the distance between two centroids is smaller than the tolerance
    #   then end the loop
    if Distance_With_V_Norm(V[t], V[t - 1]) <= epsilon:
        break
```

13. Q-learning method

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The Q-function:

- Captures the **expected total reward** an agent, who's in the **state $\boldsymbol{s_t}$**, can get by executing the **action $\boldsymbol{a_t}$**
- $\mathrm{E}[\ldots]$ stands for "expected
- R_t is the total reward from time t

$$Q(s_t, a_t) = \mathbb{E}[R_t | s_t, a_t]$$

Policy $\pi(s)$:

- Chooses the best action to take in state s
- Should choose an action that **maximizes future reward**

$$\pi^*(s) = \arg\max_a Q(s, a)$$

- For **humans**, it can be **very difficult** to find / accurately estimate Q values
- Use **(Deep) NNs** to learn the Q function, then use Q to **infer the optimal policy**

Downsides:

- Complexity
  - Can't handle continious action spaces
  - The smaller and the more discrete, the better
- Flexibility
  - Cannot learn stochastic policies

14. Deep Learning: Value and Policy learning

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Value learning:
- We use NNs to find the Q-function
- Use the Q-function to infer the optimal policy

Policy learning:
- Approximate the Q-function
- Use the Q-function to infer the optimal policy
- **Policy Gradient**:
  - Optimizing the policy
  - Enables the modeling of **continious action spaces**

15. Policy Learning: Policy Gradient algorithm

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The training algorithm:

- Initialize the agent and **run a policy** until termination
- **Record all** used states, actions and the rewards
- **Decrease/Increase** the **probability** (w and w') of the action that resulted in **low/high reward**
  - The amount is determined by the **Policy Gradient**

$$\mathrm{PG} = \log\left(P(a_t|s_t)\right) * R_t \qquad \mathrm{w}' = \mathrm{w} \pm \mathrm{PG}$$

16. Basic concept of EAs

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Basic principle:

- Search on the population of solutions, guided by the laws known from biology
- **Individuals** in the population are the solutions of a **given problem**
- Population is evolving, meaning we obtain better individuals

The idea of using simulated evolution to solve design and engineering problems has been around since the 50's

3 forms of EAs:

- Evolutionary programming (*solving prediction problems*)
- Genetic algorithms (*solving parameter optimization problems*)
- Evolution strategies (*develop robust, adaptive systems*)

17. Optimization by genetic algorithm

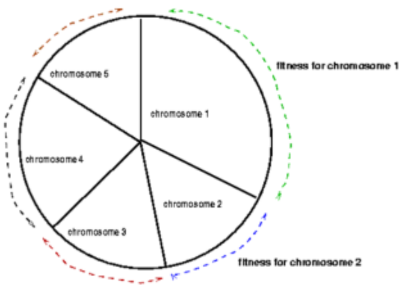
2024. december 16., hétfő 12:55

Genetic algorithm:

- Population based optimization
- Stochastic
- Bio-inspired **operators**: *selection*, crossover, *mutation*

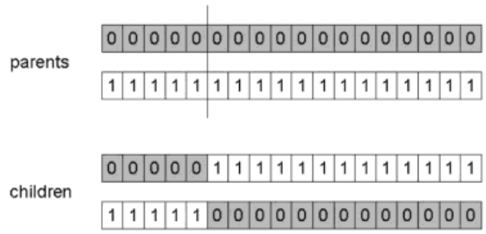
Selection methods:

- There are many ways to select chromosomes to survive to the next generation
- For example: Roulette wheel
    - The **better the chromosome**, the **higher chance** it has to survive



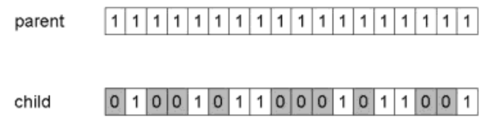
Crossover method:

- Divide the parents along one or more **random separation** point(s)
- **Create children** whose traits are their parents' **exchanged "DNA"**



Mutation method:

- Alter each of the children's gene independently
- The chance of altering is the "Mutation rate" (p_m)



18. Concept of genetic programming

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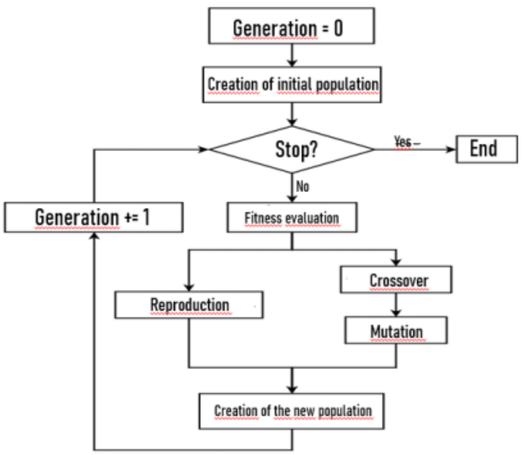
Genetic Programming:

- Applies the approach of genetic algorithm to computer programs
- Individuals here are described by an **expression tree**



Differences compared to EAs: **Evolutionary operators**

- **Reproduction:**
  - Select an individual based on chromosomes
  - Copy it into the next generation
- **Mutation:**
  - Select a parent and pick a point in it's expression tree
  - Delete the subtree from the selected point, and generate a new subtree the same way as the initial population was generated
  - Put the offspring (the complete, new tree) into the next generation
- **Crossover:**
  - Select 2 parents, and pick randomly one-one point in their tree
  - Exchange the subtrees starting from these points
  - Put the results into the new generation

19. Swarm Intelligence

2024. december 16., hétfő 13:20

Basic concept:

- Collective system capable of **performing complex tasks** in **dynamic, changing environments** without external control or coordination
- Collective performance **cannot be achieved by a single organism** alone
- Models based on this are suitable for **distributed problem** solving

20. Optimization by Particle Swarm Optimization

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PSO:

- Applies the concept of social interaction to problem solving
- Uses particles that move in swarms in the search space, searching for the best solution
- Particles adjust their "flight" based on their and their comrades' experiences
- Solutions:
  - Gbest : best solution achieved by the whole swarm
  - Pbest : best solution by a lone particle
- Particles accelerate toward the two points, each time with randomly weighted acceleration

21. Recent swarm intelligence techniques: Firefly algorithm

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Firefly:

- Purpose:
    - Attract partners
    - Attract prey
    - Protective warning mechanism
- They have limited light intensity

The algorithm:

- Inspired by the behaviour of real world fireflies
- Similar to the PSO
- We assume that:
    - The fireflies are unisex
    - Attractiveness is based on brightness, effected by distance
    - Brightness is determined by an objective function
- Light intensity of fireflies is proportional to the quality of solution
- Each firefly will move towards the brighter fireflies

22. Basics of Neural Networks

2024. december 16., hétfő 17:49

Neural Networks:

- The building block of a network is a neutron
- Neutron:
    - Information processing unit
    - Mimicks real neutrons
    - Can perform only simple tasks, but connect them into layers and BOOM, they can collectively achieve more complex solutions of more complex problems
- Each neuron has an input, and a weight ssociated with it
- These inputs can be many types, starting from binary values all the way to functions

23. Perception, Percetion training

2024. december 17., kedd 8:34

The algorithm:

- Has 4 steps:
    - Initialization
        - We set the initial weight values to a random threshold value
        - Set the learning rate to a positive number, that is less than 1
    - Activation
        - Calculate the output values with the chosen activation function
    - Weight learning
        - Update weight values based on the calculated error
    - Iteration
        - Repeat 2 and 3 until convergence

24. CRISP-DM

2024. december 17., kedd 8:45

- The most popular framework for executing data science projects
- 6 phases:
    - Business understanding
        - What the business needs
    - Data understanding
        - What data do we need
        - Is that data clean?
    - Data preparation
        - How should we organize the data for modelling
    - Modelling
        - What model we should use
    - Evaluation
        - Did we achieve our goals?
    - Deployment