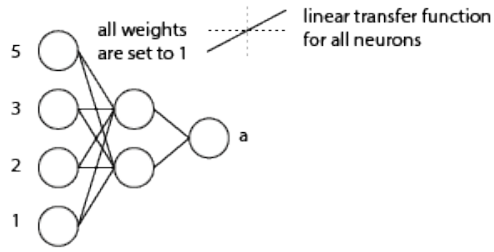
Q1. Neural Networks

(a) Name the largest European project on brain research that is currently active.

(1 mark)

(b) Calculate the value of a.



(2 marks)

(c) Could this neural network serve as an accurate predictor for a problem that is not linearly separable? If not, say why. Give an example of a transfer function that would make this possible.

(2 marks)

(d) The expected output for these inputs was 12. Adapt the two weights connected to the output neuron, after one iteration of error backpropagation, given a learning rate of 0.1.

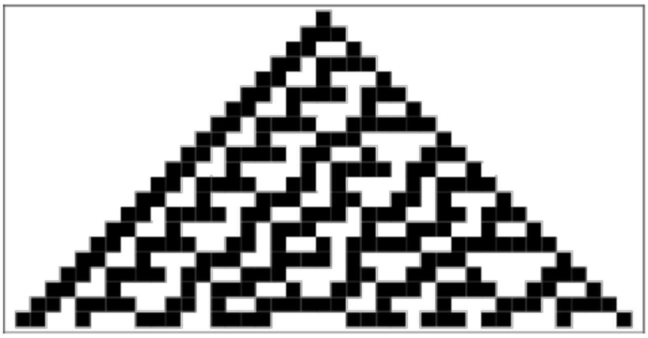
(2 marks)

(e) Imagine two people playing blackjack, the goal is for each to get points as high as possible, while avoiding going over 21. Number cards have their face value, jacks, kings and queens are worth 10. Ace can be either 1 or 11. Create a neural network architecture that could be used to predict whether a player should draw a card, or not, based on the current two cards of both players. Describe how you would train the neural network (data used, testing).

(3 marks)

Q2. Cellular Automata

(a) Draw rules for the cellular automaton pictured below.

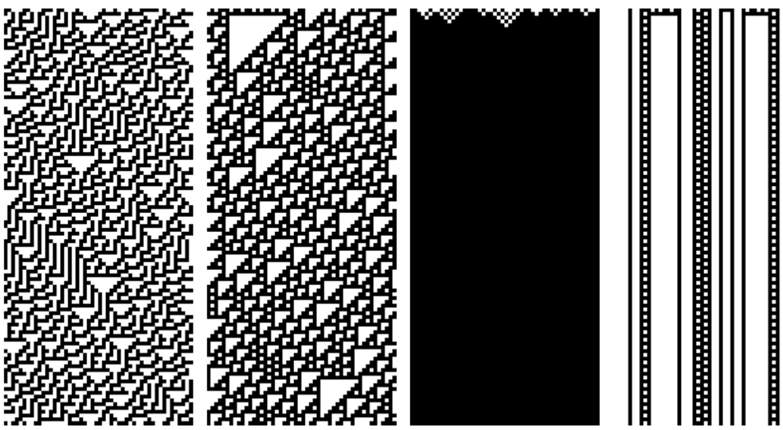


Rules

(2 marks)

(b) For each cellular automaton below, select the correct description:

1. Uniform final state
2. Simple stable or periodic final state
3. Chaotic, random, nonperiodic patterns
4. Complex, localized, propagating structures



(4 marks)

(c) The "Game of Life" rules have been shown to support Universal Computation. What can they theoretically compute? Are all 2D cellular automata rules capable of Universal Computation?

(2 marks)

Q3. Artificial Evolution

(a) Design an evolutionary algorithm that allows a team of 10 robots to aggregate in a common arbitrary location. Each robot is identical and has two sensors to detect other robots in front of it, to its right, and left. Robots can control the speed of both their wheels.

In a couple of words, describe how you would set the following elements of the algorithm:

1) genotype
2) phenotype
3) fitness
4) initial population
5) selection operator

(5 marks)

(b) How would you adapt the fitness to minimize energy usage? Provide a formula for the fitness. Does your evolutionary approach favour cooperative or competitive behaviour?

(2 marks)

Q4. Biomimetic Robotics

(a) What is a CPG and where can they be found?

(1 mark)

(b) What types of CPG are typically implemented in a robot?

(1 mark)

(c) Design a reactive controller using a subsumption architecture to control a small robot toy that reacts to people pressing a button on its head by whizzing around while avoiding obstacles. The robot stops if it hears a clap.

(2 marks)

(d) What is the "philosophy" behind behaviour-based robotics? Name one advantage and one disadvantage.

(3 marks)

(e) Imagine you're designing an underwater robot. What could you use from nature to design 1) the body of the robot, 2) the control of the robot.

(2 marks)

(f) What could biologists learn from your underwater robot?

(1 mark)

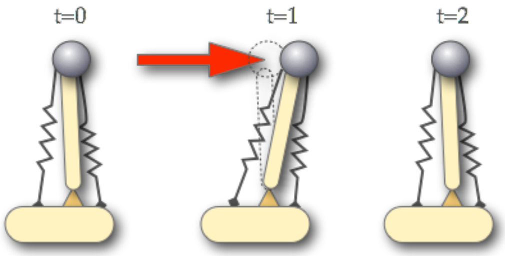
turn over/...

Q5. Morphological Computation

(a) Provide two advantages and two disadvantages of making robots soft.

(4 marks)

(b) Explain what type of computation is implemented in the following morphology. The red arrow represents a disturbance force that vanishes after some time. What is computed?



(2 marks)

Q6. Micro-nano bots

(a) Given the chemical species X_1, X_2, Y (fluorescent red), and N (fluorescent green), what reaction networks (there can be more than one) give you the following functions?

1) $f(x_1)$: parity of x_1 - initial state: $x_1 X_1$, $1N$
2) $f(x_1, x_2)$: $x_1 > x_2$ - initial state: $x_1 X_1$, $x_2 X_2$, $1N$
3) $f(x_1, x_2) = x_1 + x_2$ - initial state: $x_1 X_1$, $x_2 X_2$
4) $f(x_1, x_2) = \min(x_1, x_2)$ - initial state: $x_1 X_1$, $x_2 X_2$

(4 marks)

(b) Name one limitation to making large programmes with chemical computing.

(2 marks)

Q7. Swarm Robotics

(a) What is the main challenge in designing individual rules that give rise to a desired swarm behaviour?

(1 mark)

(b) Name two techniques to design swarm controller for robots, other than trial-and-error.

(2 marks)

(c) Describe the individual rules needed for each one of these swarm behaviours:
1) Reynolds flocking
2) Object collection
3) Ant-like trail formation

(6 marks)