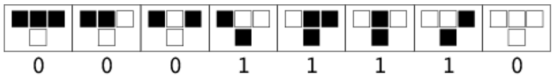
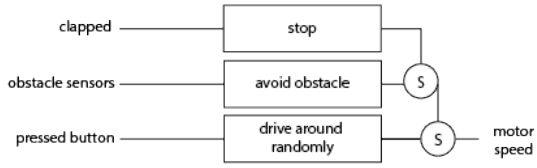
ENGINEERING MATHS EXAM SOLUTIONS 2030

Q No.	PAPER NAME Advanced Sprockets	Q.SETTER INITIALS PJN	Marks
1a	The Human Brain Project		1
1b	22		2
1c	Linear transfer functions would not be suitable for a non-linearly separable predictor. A sigmoid function could be used instead.		2
1d	Both weights will need to be adapted by -11*(22-12)*0.1=-11, the resulting weights are therefore -10.		2
1e	The network takes 4 inputs, one for each card displayed. Hidden neurons are needed to account for non-linearities caused by the Ace value changing from 1 to 11. Training data should be generated from winning games only. Each game data should show if a draw was used or not based on the four input cards. A proportion of the game data should be kept as test data to avoid overfitting.		3
2a			2
2b	3,4,1,2		4
2c	Universal Computing Machines can theoretically compute anything that can be computed. Many cellular automaton rules are not capable of Universal Computation.		2
3a	There are many correct answers to this question. One example would be to have a minimal neural controller for the robots with two inputs for sensors, two outputs for the motor speeds. The swarm is homogenous so the robots all have the same controller. This means the genotype is simply the 4 weights between 0 and 1 of the neural controller. The phenotype is the behaviour of the robots moving in their environment. The swarm-level fitness aims to minimise the distance between all robots over time. Roulette wheel selection is used with elitism for selection. 100 individuals from the initial population are initialised with random weights and at random locations in the test environment.		5
3b	I would include the total cost associated with the movement of all robots to the swarm-level fitness. This will favour cooperation as the swarm is homogeneous, and team-level selection is used. This avoids incentives for individuals to maximise their score at the detriment of their team members.		2
4a	Central pattern generators (CPGs) are biological neural networks that produce rhythmic patterned outputs without sensory feedback. They can be found in the spinal cord and the brainstem of vertebrates, and the ganglia in invertebrates.		1
4b	Globally stable limit cycles are used.		1
4c			2
4d	The philosophy of behaviour-based robotics is "the world is its own best model". One advantage is the controllers are very simple and make very few assumptions. This tends to make them robust. One disadvantage is that they may be limited in the complexity of the tasks they can achieve. It would be difficult to make a fully reactive autonomous car for example.		3
4e	There are many possible answers. You could take inspiration from their morphology, soft bodies, shoaling, lateral-lines.		2
4f	Robots can be helpful to understand swarm dynamics, individual fish control, how the morphology was evolved for specific purposes, etc.		1
5a	Advantages: compliance, safety, potentially biodegradable, implicit control. Disadvantage: less precise control, difficult to model and predict.		4
5b	This is a position controller (more specifically a PD controller). Based on the angle the morphology calculates the appropriate response force to bring the system back in its desired position (i.e. vertical).		2
6a	$N+X_1> Y$,$Y+X_1> N$; $N+X_1> Y$,$Y+X_2> N$;$X_1>Y$,$X_2>Y$; $X_1+X_2> Y$		4
6b	Noise in the system, and the complexity of "debugging" chemical computing makes it difficult to build programmes that use many logic blocks.		2
7a	There is often no obvious relation between the individual rules and the emergent swarm behaviour.		1
7b	Bio-inspiration, machine-learning, artificial evolution, crowd-sourcing.		2
7c	Reynolds flocking: robots are attracted to center of mass of their neighbours, repulsed from their neighbours, and align their heading. Object collection: Robots move randomly, pick up objects that are alone, and deposit them when they encounter piles with more than one object. Ant-like trail formation: robots follow paths with a probability proportional to the amount of pheromone on that path. They deposit pheromone as they move, more so when returning to the nest with food.		6

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